Building skills for conserving seventeenth- and eighteenth-century Scottish built heritage: the initial assessment of timber roof structures

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TABLE OF CONTENTS

VOLUME 1 ..... **1**

LIST OF FIGURES **2**

LIST OF TABLES **16**

GLOSSARY **17**

LIST OF ABBREVIATIONS **28**

ACKNOWLEDGEMENTS **30**

ABSTRACT **32**

1 Introduction **33**
1.1 Context and Background 33
1.2 Aims and Objectives 36
1.3 Methodology 37
1.4 Research Limitations 41
1.5 Structure of the thesis 42

2 Investigating seventeenth- and eighteenth-century timber roof structures in Scotland: methodology **44**
2.1 Review of the available tools, methods and standards in Europe for the assessment of historic timber roof structures 44
2.1.1 Visual Inspection 46
2.1.2 Visual Strength Grading 47
2.1.3 Non-destructive and semi-destructive testing 48
2.1.4 Structural Analysis 72
2.1.5 Standards 74
2.2 A novel database of seventeenth- and eighteenth-century buildings in Scotland 76
2.2.1 Data acquisition 77
2.2.2 Selection of reference buildings 78
2.3 Preliminary surveys carried out in 53 buildings 82
2.3.1 Data collection 82
2.3.2 Identification and dating of different types of roof structures 84
2.3.3 Selection of case studies 89
2.4 Condition surveys and material Investigations carried out in the case studies 91
2.4.1 Selection of assessment techniques 91
2.4.2 Assessment methodology 93
2.4.3 Tests procedure and interpretation of results 99
2.5 A novel structured digital form to support the survey and data analysis 107
2.5.1 Approach 107
2.5.2 Content 108
2.5.3 Users interface 120
2.6 Conclusions 121

3 The historic development of seventeenth- and eighteenth-century timber roof structures in Scotland within the European context 122
3.1 The architectural context 122
3.1.1 Tower Houses, laird houses and villas: the increasing use of timber 122
3.1.2 Country houses: shallower pitches and wider spans 126
3.1.3 Churches and military buildings 129
3.1.4 Urban development: grand public buildings and foreign builders 130
3.1.5 Discussion within the European context 130
3.2 Existing knowledge on timber roof structures in Scotland 133
3.2.1 Structural arrangements 133
3.2.2 Timber species and provenance 150
3.2.3 The dressing of timbers and the construction process 153
3.2.4 Wrights and carpentry treatises 155
3.3 Tracing the historic development of seventeenth- and eighteenth-century timber roof structures in Scotland based on our findings 157
3.3.1 Structural arrangements 157
3.3.2 Construction methods and details 170
3.3.3 The material 190
3.3.4 Wrights, architects and patrons 195
3.4 Conclusions 213

4 Description of the case studies investigated 214
4.1 St Andrew's & St George's church 215
4.1.1 Architecture and Construction 215
4.1.2 Current Condition 216
4.2 St Andrew's in the Square church 217
4.2.1 Architecture and Construction 217
4.2.2 Current Condition 219
4.3 Cockenzie House 221
4.3.1 Architecture and Construction 221
4.3.2 Current Condition 223
4.4 Holyrood Palace 225
4.4.1 Architecture and Construction 225
4.4.2 Current Condition 228
4.5 Newhailes House 230
4.5.1 Architecture and Construction 230
4.5.2 Current Condition 233
4.6 Pinkie House 234
4.6.1 Architecture and Construction 234
4.6.2 Current Condition 237
4.7 Stirling Castle 239
4.7.1 Architecture and Construction 239
4.7.2 Current Condition 245
4.8 Touch House 247
4.8.1 Architecture and Construction 247
4.8.2 Current Condition 252
4.9 Conclusions 253

5 The assessment of the condition of seventeenth- and eighteenth-century timber roof structures in Scotland 254
5.1 Current conservation practice of timber roof structures in Scotland 254
5.1.1 Standards, Regulations and policies 254
5.1.2 Building owners, users, managers and professionals in charge of the maintenance 256
5.1.3 Conservation professionals 259
5.1.4 Existing training in conservation 260
5.1.5 Dissemination of conservation projects 262
5.2 An overview of the typical pathologies found in the surveyed buildings 264
5.2.1 Poor initial design of the overall structural arrangements and details 268
5.2.2 Past repairs, alterations and interventions 276
5.2.3 Inadequate environmental conditions, accessibility issues and poor maintenance 277
5.3 Evaluation of the assessment techniques used 279
5.3.1 Effectiveness and reliability of the assessment techinques used 280
5.3.2 Knowledge and skills needed to implement the assessment techniques used 296
5.3.3 Costs involved and overall evaluation of the assessment techniques used 299
5.4 Proposal of specialising course for conservation professionals 303
5.5 Conclusions 306

6 Conclusions 307
6.1 Research outcomes 307
6.2 Final remarks 313
6.3 Recommendations for future research 315

REFERENCES 316

VOLUME 2 349

APPENDIX A: Information on pre-1800 Scottish timber roofs other than the reference buildings 351

APPENDIX B: Online questionnaires to building owners, users, managers, professionals in charge of the building maintenance 381

APPENDIX C: Interviews to three Scottish conservation engineers 481

APPENDIX D: List of possible sources of information on Scottish timber roof structures which have not been consulted 490

APPENDIX E: Structured forms of the reference buildings 491

APPENDIX F: Structured forms of the case studies 739

APPENDIX G: Consulted archive material 1159

APPENDIX H: Unusual carpentry marks found in the surveyed roofs 1168

APPENDIX I: Papers published by the author related to the PhD research 1187

VOLUME 1

List of Figures

Figure 1: Elements composing a simple frame and other types of frames 17
Figure 2: The difference between battens and sarking, and the elements composing the sarking 18
Figure 3: Some types of carpentry joints 19
Figure 4: Different types of side purlins 20
Figure 5: Main parts and defects of a timber log 20
Figure 6: Types of hand saws used for wood 20
Figure 7: Elements composing a king-post truss and other types of trusses 21
Figure 8: The difference between rafter roofs and purlin roofs and the elements composing them ... 21
Figure 9: Different roof geometries 22
Figure 10: The dragon tie and the dragon beam 23
Figure 11: The research methodology employed in this thesis 41
Figure 12: Methodology for the assessment of existing timber structures (Feio and Machado, 2015) 45
Figure 13: Example of graphics reporting results of visual inspection of a timber truss (Massari et al., 2010) 46
Figure 14: Failure of a rafter caused by the instability of the strut and favoured by a knot in the rafter and the notch for the joint; the efficient connection of the rafter to the post is the cause of the bending of the post (Tampone, 2007) 47
Figure 15: Knots classification according to UNI 11035 (2003): $n_1/n_3/n_5$ = single knots, $n_2/n_4/n_6$ = groups of knots 48
Figure 16: principle of photogrammetric measurement (Luhmann et al., 2014). 52
Figure 17: Schematic of time-of-flight laser scanning measurements (Bertolini Cestari et al., 2013, Park et al., 2007, Barber and Mills, 2011) 53
Figure 18: 3D laser scan model of a roof structure (Lamborghini et al., 2015) 53
Figure 19: Principle setup for active (a) and passive (b) thermography (Riggio et al., 2015b). 55
Figure 20: Thermographic image of a vault showing the timber structure behind the plaster (Cantini et al., 2013) 55
Figure 21: wood to wood connection in softwood with hardwood dowel, and the x-ray radiographies (Riggio et al., 2015b) 55
Figure 22: Example of graph resulting from the Resistance micro-drilling test (Nowak et al., 2016) .. 56
Figure 23: Example of pictures taken with an endoscope inside a borehole in a timber strut (Kloiber et al., 2015a) 57
Figure 24: Example of identification of macroscopic features in the transversal section of a sample of Alder (alnus sp.); 4=semi-porous annual ring, 17=between 6 and 20 vessels per mm^2, 24=tyloses (Crivellaro et al., 2016) 58
Figure 25: Example of identification of microscopic features in the transversal section of a sample of Douglas fir (pseudotsuga douglasii) (Nardi Berti et al., 2006); 1=resin canal, 2=epithelial cell, 3=uniseriate ray, 4=tracheid 58
Figure 26: Example of moisture meter without pins on the left and with pins on the right 59
Figure 27: Equilibrium moisture content based on the air temperature and relative humidity (Ross, 2010) 59
Figure 28: damp areas identified in thermographic imaging (Rodríguez Liñán et al., 2015) 59
Figure 29: Thermographic image showing knots in a timber roof structure (Colla and Gabrielli, 2015) 59

Figure 30: time-of-flight measurements in structural timber using different wave propoagation modes: direct longitudinal (a), indirect longitudinal (b and e), transverse (c), semi-direct (d) (Dackermann et al., 2014) 61
Figure 31: sensor chain for cross-sectional tomography (left) and 2D-tomogram of the timber post (right) (Dackermann et al., 2014) 62
Figure 32: velocity model (14x14 pixels) of a timber section, corrected for material anisotropy, obtained from 5 iterations of straight type and 6 iterations of curved type; signal velocity legend from 300 to 2200 m/s (left) - velocity model (7x7 pixels) of the same timber section after 5 straight iterations and 5 curved iterations; signal velocity legend from 300 to 2000 m/s (Colla, 2015) 63
Figure 33: Example of elements investigated with the ultrasonic echo technique: in the centre a section of the investigated element (Dackermann et al., 2014), on the left an A-scan (Dackermann et al., 2014) and on the right a B-scan (RILEM, 2010) 64
F 65
Figure 35: Pilodyn device: the penetration depth of the striker can be read directly on the scale attached on its side (Tannert et al., 2014) 66
Figure 36: The device developed for the pin pushing test (Kloiber et al., 2015b) 66
Figure 37: The output graph of the pin pushing test: the x axis is the depth to which the pin was pushed, the y axis is the force needed for pushing (Kloiber et al., 2015b) 67
Figure 38: Tensile test of a triangular bar (Kloiber et al., 2015b) 68
Figure 39: Compression device to test radial cores (Kloiber et al., 2015b) 68
Figure 40: The loading jack device (Kloiber et al., 2015c) 68
Figure 41: A rosette of three gauges placed around the drilled hole to measure bending stresses (Crespo de Antonio et al., 2016) 71
Figure 42:The test device used for the hardness test (Kloiber et al., 2015b) 71
Figure 43: The device used for screw withdrawal (Kloiber et al., 2015b) 71
Figure 44: Non-linear joints modeled by Gocal et al. (2015) 74
Figure 45: Example of stresses in a truss considering the contribution of the planking (above) and disregarding it (below); a) bending moment, b) shear force, c) axial force in a truss (Bertolini Cestari et al., 2015) 74
Figure 46: Names and locations of the 53 reference buildings surveyed - adapted from Serafini and Gonzalez Longo (2016) - with a zoom on the Edinburgh area 80
Figure 47: The selection process of the reference buildings surveyed and the results of the surveys in terms of number of original roof structures found - adapted from Serafini and Gonzalez Longo (2016) 81
Figure 48: A model of Touch House seen from North-West showing the three roof structures surveyed 81
Figure 49: Diagram of measurements taken during the preliminary surveys in a typical common rafter roof 83
Figure 50: Diagram showing the classification in structural types established for the surveyed roof structures 85
Figure 51: Timeline showing the chronological distribution of the 59 roof structures surveyed classified in different structure types: common rafter roofs, complex frames, purlin roofs, trusses (top to bottom) and composite roofs (in dark grey); the construction dates have either been estimated (white circles) or determined through dendrochronology by previous research (black circles) 86
Figure 52: Timeline showing the chronological distribution of the selected case studies amongst the 59 roof structures surveyed 90

Figure 53: Assessment phases resulting from the need to calibrate some tests with parameters obtained from other tests 94
Figure 54: The plan of the roof above Pinkie Houses' long hall with the reference frames highlighted in black 95
Figure 55: the plan of the roof of Pinkie Houses' long hall with the results of the detailed visual inspection and of the air temperature and relative humidity measurements, and the location of the sampling for the timber species identification 96
Figure 56: The results of the assessment of one of the reference frames of the roof above Pinkie Houses' long hall; the lower collars could not been assessed because they are hidden underneath insulation sheets..... 97
Figure 57: Hand lenses used for the macroscopic identification of the timber species (left) and a sample of pinus sylvestris taken from Cockenzie House (right)..... 99
Figure 58: The light transmission microscope used for the microscopic identification of the timber species (left) and the same sample as in Figure 57 (right) 99
Figure 59: The hygormeter GANN Hydromette RTU 600 used during the surveys (left) and a picture of the author while taking measurements with it (right) 100
Figure 61: The ultrasonic device Proceq Pundit PL-200 used during the surveys (left), PhD student Bowen Qiu using it during the surveys in Stirling Castle Palace (centre) while the author applys the transducers to the timber (right)..... 102
Figure 62: Signal curve of an ultrasonic measurement taken in Holyrood Palace; the last part of the graph, where only the noise remains, is highlighted in grey (only about 1/10 of the graph is here shown due to space limit). The time of flight has been calculated here to be 101 (Table 9) 103
Figure 63: The micro-drilling device IML RESI-F400 used during the surveys (left) and an example of micro-drill graph from Holyrood Palace - North range, frame 43, North strut, point b (right) 107
Figure 64: The tree like organization of the structured form, with a classification of structural typologies and damage effects identified for each level: building, system, unit, element, connection (Serafini et al., 2016) 109
Figure 65: The classification of roof geometries included in the structured form 111
Figure 66: The different types of connections with the supporting walls included in the structured form..... 111
Figure 67: First section of the structured form: information related to the building (this example shows St Andrew's in the Square church)..... 112
Figure 68: Second section of the structured form: plan and sections of the roof structure (this example shows St Andrew's in the Square church)..... 113
Figure 69: Second section of the structured form: geometrical and typological information related to the roof structure (this example shows St Andrew's in the Square church) 114
Figure 70: Second section of the structured form: use and condition of the roof structure (this example shows St Andrew's in the Square church) 116
Figure 71: Third section of the structured form: detailed information related to the elements, joints, timber species and results of the tests carried out in the roof structure (this example shows the South-West range of Stirling Castle Palace) 119
Figure 72: Neidpath Castle (late fourteenth century): section (RCAHMS DP 043860, 1959) and plan (RCAHMS DP 043862, 1964)..... 123
Figure 73: Claypotts Castle (1569-88): view from West (RCAHMS SC1324316, 1971) and plan (RCAHMS SC1202662, Undated) 123
Figure 74: Baberton House (1622-3): plan and view of the South-East facade before the eighteenth-century additions (Macgibbon and Ross, 1887-92)..... 124

Figure 75: Pinkie House (1613): section (RCAHMS MLD 69/29, 1947) and decorated ceilings 125
Figure 76: Kinross House (1679-93): view from West and plan (RCAHMS SC 1223494, Undated) 126
Figure 77: Duff House (1735-40): view from South 127
Figure 78: Douglas Castle (1757-61, demolished in 1939): view from South (RCAHMS SC 943434, Undated) 127
Figure 79: The structural changes in late seventeenth-century Scottish buildings which affected roof structures: gable walls with high pitches - as in Darnaway Castle (top) (RCAHMS DP 161383, 2013, RCAHMS DP 222837, 2015) are replaced by hipped arrangements, low pitches and heavy plaster ceilings - as in Duff House (bottom) 128
Figure 80: Culzean Castle (1776-92): view from North-East (left) and interior of the Drum tower (right) 128
Figure 81: St Andrew's and St George's church in Edinburgh (1782-4): view from South-East (left), plan (centre), view of interior (right) 129
Figure 82: Timeline showing the main historical events of seventeenth- and eighteenth-century Scotland, the main patrons, craftsmen and designers, and a few representative buildings of the period 132
Figure 83: Schematic of common rafter roofs, called Sparrendach in German (Lohrum and King, 2006) 133
Figure 84: Schematic of purlin roofs, called Pfettendach in German (Lohrum and King, 2006)..... 133
Figure 85: Schematic of purlin roof supported by trusses (trenched purlins)..... 134
Figure 86: Schematic of trussed roof with longitudinal bracing (butt purlins)..... 134
Figure 87: Schematic of king post in compression 134
Figure 88: Schematic of hanging king post in tension..... 134
Figure 89: Schematic of cruck roof 134
Figure 90: Schematic of hammer-beam roof..... 134
Figure 91: Common rafter roof in St Kastor church in Karden, Germany (1216) (Binding, 1991) 135
Figure 92: Common rafter roof with primary and secondary frames and longitudinal bracing in the Vrouwe Church in Kortrijk, Netherlands (1250) (Janse, 1989); colours added by author..... 135
Figure 93: Common rafter roof with principal rafters, primary and secondary frames and longitudinal bracing in Saint-Pierre Cathedral, France (thirteenth century) (Corvol-Dessert et al., 2009); colours added by author 136
Figure 94: Schematic of German portal frames/leaning trestles (Holzer and Kock, 2008) 136
Figure 95: Mansard roof at the Sorbonne Chapel in Paris (1635-42) (Corvol-Dessert et al., 2009) ... 136
Figure 96: Purlin roof of Hopital Neuf in Pons (1220-54) (Hoffsummer, 2011) 137
Figure 97: Purlin roofs in Germany (Ostendorf, 1908) 137
Figure 98: Trusses in Sant'Agata di Mugello church in Scarperia, Florence (sixteenth century) (Tampone, 1996) 137
Figure 99: Roof with tension-absorbing posts in Saint-Pierre-de-Montmartre church in Paris (1164-74) (Corvol-Dessert et al., 2009)..... 137
Figure 100: Reconstruction of common rafter roof of Waltham Abbey in Essex (twelfth century) (Hewett, 1980) 139
Figure 101: Roofs with side purlins and principal rafters in Chichester: Cathedral (top) and Bishop's Palace (bottom) (late thirteenth century) (Munby et al., 1983)..... 139
Figure 102: Hammer-beam roof over Stranger or Pilgrim's Hall in Winchester (early fourteenth century) (Smith, 1958)..... 139
Figure 103: Trussed roof at Stoke Bruerne, designed by I. Jones (1630) (Yeomans, 1992) 140

Figure 104: Roof truss drawn by Baldi (1621) at p.102; Yeomans (1992) considers Baldi the main source of inspiration for Jones and Wren, but Valeriani (2006) contradicts this by highlighting the different treatments of the joint post/tie-beam *140*
Figure 105: Details of trussed roofs drawn by Price (1733)..... *140*
Figure 106: Trussed roofs and details drawn by Nicholson (1797)..... *140*
Figure 107: The roof of Darnaway's Castle Great Hall (1387) (RCAHMS SC 433080, 1998)..... *141*
Figure 108: The roof of Glasgow Cathedral's central nave (thirteenth century) (RCHAMS DPM 1900/67/2, 1909) *141*
Figure 109: The roof of the Great Hall at Edinburgh Castle (1510) (RCAHMS SC 1201162, 1888)..... *142*
Figure 110: The roof of the central nave of Holy Rude church in Stirling (1455) (RCAHMS SC 738897, 1959) *142*
Figure 111: Cruck-framed Cottage in Torthorwald (RCAHMS SC 383456, 1970) *143*
Figure 112: Massive stone vaults in Dunglass Parish Church (1423) (RCAHMS SC 1164646, Undated, RCAHMS SC 1171792, Undated)..... *143*
Figure 113: The roof of Alloa Tower (1497, maybe older) (Ruddock, 1995)..... *143*
Figure 114: The roof of 339-343 High Street, Kirkcaldy (1600) (Ruddock, 1995); the graphic scale in Figure 113 is valid for this Figure too *143*
Figure 115: The roof of 68-74 High street in Brechin (1575) (Crone et al., 2004) *144*
Figure 116: The roof of a tenement in Edinburgh Lawnmarket (1580), demolished before 1884 (Peddie, 1883) *144*
Figure 117: The evolution of roof construction in South-East Scotland until 1650, extracted from Hanke (2006)..... *144*
Figure 118: The roof of Dysart Bay Horse Inn (1583) (RCAHMS SC 989070, 1969) in Hanke (2006).. *145*
Figure 119: The roof of Northfield House (1611) (Hanke, 2006) *145*
Figure 120: The roof of the North range of Newark Castle (1598) (Hanke, 2012) *145*
Figure 121: The roof of Halkerston Lodge (1638-42) (Hanke, 2004)..... *145*
Figure 122: Schematic of the English rafter foot (Ruddock, 1995)..... *146*
Figure 123: Schematic of the Scottish rafter foot (Ruddock, 1995)..... *146*
Figure 124: The roof of Ruldoc Abbey Church in Holland (twelfth century) with a rafter foot similar to the Scottish one (Courtenay, 1985) *146*
Figure 125: The scissor-braced roof of Moray House (1623) (Hanke, 2006)..... *147*
Figure 126: The roof of Ardchattan Priory (fifteenth century) (Hanke, 2006)..... *147*
Figure 127: The arch-braced roof of Linlithgow Town House of the Knights of St John (early sixteenth century, demolished) (RCAHMS SC 1047690, 1886)..... *147*
Figure 128: The roof of Parliament Hall in Edinburgh (1631-40) *148*
Figure 129: The roof of Tron Church in Edinburgh (1636-48)..... *148*
Figure 130: Timeline of Scottish timber roofs mentioned in literature divided by structural typology (for details see Appendix A); crucks are not included since they are used only in vernacular buildings *148*
Figure 131: The roof of Tullibardine Chapel with intersection visible on the left (Author)..... *149*
Figure 132: Schematic of the roofs of Newark Castle with intersections visible on top right and bottom left (Hanke, 2012)..... *149*
Figure 133: William Adam's design for the roof of Glasgow New College Library, 1720 (Adam, 1812) *149*
Figure 134: Schematic of the roof of St Andrew and St George's church (1782-4) (Hanke, 2008)..... *149*
Figure 135: Timeline of different roof structures types used in continental Europe and England, compared to what is reported in litertature about Scottish roofs..... *150*

Figure 136: The species and provenance of timbers used in Scottish roofs according to archival research carried out by Newland (2007, 2010, 2011, 2012a, 2012b, 2012c) and Thomson (1991) and dendrochronological analysis carried out by Crone (2001, 2008b, 2008a, 2011) and others (Crone and Fawcett, 1998, Crone and Gallagher, 2008, Crone et al., 2004, Crone and Mills, 2007, Crone and Mills, 2008, Crone and Mills, 2011, Crone and Mills, 2012, Crone and Sproat, 2011, Mills and Crone, 2012) *152*
Figure 137: The dressing of timber beams: A. scoring; B. hewing; C. flattening (Drdácký et al., 2006) *154*
Figure 138: Hand-sawn oak collars in the roof of the Mansion House at Drum Castle (1598-1621) (Crone and Mills, 2011) *154*
Figure 139: Roof drawn by Scamozzi (1615) at p. 228 ..... *156*
Figure 140: Trussed roof drawn by Palladio (1570) in chapter 12 ..... *156*
Figure 141: Trussed roofs drawn by Serlio (1545) at p. 197 ..... *156*
Figure 142: Roof drawn by Du Cerceau (1576-9), vue 81 ..... *156*
Figure 143: The development of Scottish timber roof structures (Serafini and Gonzalez Longo, 2015b). From left to right: Darnaway Castle, 1387 (RCAHMS DP 161383, 2013, RCAHMS DP 222837, 2015); Dunglass Church, 1423 (RCAHMS SC 1164646, Undated, RCAHMS SC 1171792, Undated); Alloa Tower, 1497 or older; Holyrood Palace, 1670s (RCAHMS SC 1209320, 1922); St Andrew's in the Square Church, 1751-3 ..... *158*
Figure 144: Maquettes of Scottish common rafter roofs produced by the attendees of the workshop "Traditional Scottish Timber Frames" held by the author at Glasgow City Heritage Trust on 19/04/2016 (left) and by the Master students of Edinburgh University during a workshop held by the author on 12/02/2015 (right) *159*
Figure 145: The common rafter roof of Culross Palace (1597-1610): sections (left), the rafter foot (centre), the ceiling underneath (right) *160*
Figure 146: The common rafter roof in the West range of Royston House (1683-96): sections (left), the joint between rafter and collar (centre), the ceiling underneath (right) *160*
Figure 147: Timeline of the development of structural arrangements of Scottish timber roof structures; adapted from Serafini and Gonzalez Longo (2016) *161*
Figure 148: The roof of Holyrood Palace (1671-9): sections with tension-absorbing joints highlighted in black (top), bird's eye view taken from Google Maps (bottom left), view of roof space (bottom right) *161*
Figure 149: Drochil Castle (1578): plan (Macgibbon and Ross, 1887-92) (left), bird's eye view (RCAHMS DP 143824, 2012) (centre), West facade (RCAHMS SC 937335, 1963) (right) *162*
Figure 150: The roofs of Kinross House (1679-93) (top) and Melville House (1697-1703) (bottom).. *163*
Figure 151: The roof of Tweeddale house (1750-6): reference plans and sections (top), general view from inside (bottom left), cleats reinforcing the rafters' section where the purlins abut (bottom centre), vertical struts supporting the collars (bottom right) *164*
Figure 152: The roof of Yester House (1729-48): sections (top), connection with the lateral walls (bottom left), ceiling underneath (bottom right) *165*
Figure 153: The roofs of Newhailes House (1730) (top) and Robert Gordon's College (1731-2) (bottom) *166*
Figure 154: The king-post trusses in the staff block of Fort George (1762-6) *166*
Figure 155: The princess-post trusses in the Chapel of Fort George (1763) *167*
Figure 156: The queen-post trusses in Oakshaw Trinity church (1754-6) *167*
Figure 157: The trussed roof of Hopetoun House (1721-48) *167*
Figure 158: The purlin roof of Melville House (1697-1703) *169*

Figure 159: The purlin roof of Hopetoun House (1721-48)..... 170
Figure 160: A representative sample of different types of joints found in the surveyed Scottish roofs structures 172
Figure 161: Joggles: the Ordnance Store of Fort George (1759-61) (left), the Chapel of Bishop's Palace in Chirchester (second half of thirteenth century) (Munby et al., 1983) (centre), truss drawn by Antonio da Sangallo il Giovane in his 1539 translation of Vitruvius' treatise (Munafò, 2002), Serlio (1545) (top right), truss drawn by Serlio (1545) (bottom right) 173
Figure 162: Notches: Glasgow Trades Hall (1791-4) (left), Brodie Castle Stables (end eighteenth century) (centre), Glasgow Tron Theatre (1793-4) (right)..... 173
Figure 163: Bulb shaped joggles: Aunchinleck House (1755) (left), Stirling Tolbooth (1785) (centre), Culzean Castle (end eighteenth century) (right) (Serafini and Gonzalez Longo, 2015a) 173
Figure 164: The roof of the church of Sant'Agata di Mugello in Scarperia (Tampone 2001)..... 174
Figure 165: Truss drawn by Mariano di Jacopo (1449 in Munafò 2002)..... 174
Figure 166: Cleats used to reinforce the connection between tie-beams and longitudinal purlins in the trussed roof of Oakshaw Trinity church (1754-6)..... 174
Figure 167: Cleats used to reinforce the joint between struts and rafters in the trussed roof of Brodie Castle Stables (end eighteenth century)..... 174
Figure 168: Cleats used to reinforce the connection between collars and longitudinal purlins in the trussed roof of Auchinleck House (1755-62) 174
Figure 169: Cleats used to reinforce the connection between rafters and purlins in the common rafter roof of Touch House (end seventeenth century, but the purlins might be a later addition) 174
Figure 170: Redundant lapped/halved joints found in Blair Castle (1745)..... 175
Figure 171: Redundant chase mortice and tenon joints found in the North-West corner of Stirling Castle Palace (1719)..... 175
Figure 172: Timeline of types of joints and fasteners found in the surveyed Scottish roofs..... 176
Figure 173: Connection with the lateral walls: simple contact between the rafter ends and the wall-head in Sailor's Walk (1670s) (left), rafter feet in Culross Palace (1597-1610) (centre) and Methven Castle (1678) (right) 177
Figure 174: Timeline of different types of connections with the lateral walls found in the surveyed roofs 178
Figure 175: Connection with the wall in Holyrood Palace (1671-8): this is the first Scottish roof to employ wall-plates as well as sprocket rafters and a raised wall-head to protect the rafter ends and create a 'bell-cast' profile..... 178
Figure 176: Connection with the wall in Melville House (1697-1703): this is one of the first Scottish roofs to employ a tie-beam and a tension absobring ashlar post..... 178
Figure 177: Connection with the wall in St Andrew's in the Square church (1751-3): the tie-beam simply sits on the ashlar masonry 179
Figure 178: Connection with the wall in Oakshaw Trinity church (1754-6), somehow reminiscent of the traditional rafter foot: the tie-beam is raised and supported by a slanted brace springing from a point lower down on the masonry 179
Figure 179: Dragon ties in Haddo House (1732-6) (left) and Glasgow Tron theatre (1793-4) (right) 179
Figure 180: A broken sarking deal in Cockenzie House (1680-3) reveals the tar layer on top of the deals and the slates above..... 181
Figure 181: Nails on rafter feet of Cockenzie House (1680-3) left after the removal of the sarking boards 181
Figure 182: Sarking boards in the North range of Touch House (late seventeenth century) 181
Figure 183: Timber pegs used to secure the slates to the sarking deals in Pinkie House (1613)..... 181

Figure 184: Timeline of the pitches of the surveyed roofs *182*
Figure 185: Timeline of the different roofing materials used in the surveyed roofs *182*
Figure 186: An original slate of Methven Castle (1678) with its wooden peg and a piece of sarking *183*
Figure 187: Slate roof at Pinkie House (1613) *183*
Figure 188: Lead roofs at George Heriot's Hospital (1633-37) *183*
Figure 189: Pantile roofs at Culross Palace (1597-1610) *183*
Figure 190: Tool marks on hewn timber found in the surveyed roofs *184*
Figure 191: Timeline of the timber dressing found in the surveyed roofs *184*
Figure 192: Saw marks on collars in King's Old Buildings at Stirling Castle (1557) (left), collars in Kelburn Castle (1581) (centre), struts in Newhailes House (1733-51) (right) *185*
Figure 193: Timeline of the height and base of primary structural timber elements (rafters and purlins) in the surveyed roofs *185*
Figure 194: Marks of geometric tracing in Craigston Castle (1604-7) (left), Oakshaw Trinity church (1754-6) (centre), Glasgow Trades Hall (1791-4) (right) *186*
Figure 195: Big sawn roman numerals in Malleny House (1635) (left), Balcaskie House (1668-74) (centre), Brodie Castle Stables (end eighteenth century) (right) *186*
Figure 196: Small chiselled roman numerals in Duff House (1737) (left), Trades Hall (1791-4) (centre), Culzean Castle (after 1791) (right) *187*
Figure 197: Roman numerals used in the surveyed roofs *187*
Figure 198: Timeline of types of carpentry marks used in the surveyed roofs *188*
Figure 199: Carpentry marks in Melville House (1697-1703) *188*
Figure 200: A representative sample of different types of carpentry marks found in the surveyed roofs *189*
Figure 201: Carpentry marks in Falsterbo church in Sweden (picture by Karl Magnus Melin) (left), in Saint Pierre Cathedral in Beauvais (after 1573) (Corvol-Dessert et al., 2009) (centre), in Bovenkarspel Herv. church in Netherlands (1540) (Janse, 1989) (right) *190*
Figure 202: Sample of Scots pine extracted from a sarking board of the roof in Cockenzie House (1680-3): transversal section macro (left); transversal section X100 (centre left); radial Section X100 (centre right); tangential section X100 (right) *191*
Figure 203: Sample of oak extracted from a peg securing the joint between a rafter and an upper beam in the roof of the North range of Holyrood Palace (1671-9): transversal section macro (left); transversal section X50 (centre left); radial Section X50 (centre right); tangential section X100 (right) *192*
Figure 204: Sample of spruce extracted from a post of the roof in Newhailes House (1733-51): transversal section X100 (left); radial Section X100 (centre); tangential section X100 (right) *192*
Figure 205: Timeline of the timber species identified microscopically in the case studies investigated *193*
Figure 206: Timeline of the timber quality assessed in the case studies investigated *194*
Figure 207: Part of the VSG results of the roofs of Holyrood Palace (top) and Touch House (bottom) *194*
Figure 208: Timeline summarizing the development of Scottish timber roof structures in terms of overall structural arrangements, construction methods and details and timber species and provenance *196*
Figure 209: Working teams of wrights, architects, masons and other craftsmen identified during the research; only the teams which have worked together in more than one building have been included *197*

Figure 210: A sketch of Brechin's roof structure included in the assessment of James Baine's work drafted by Thomas Bachop in 1694 (Newland, 2010) *200*
Figure 211: The common rafter roof covering the Chapel of George Heriot's Hospital (1633-7) (Serafini and Gonzalez Longo, 2015b) *201*
Figure 212: The trusses in the central part of the roof of George Heriot's Hospital Chapel (1835) (Serafini and Gonzalez Longo, 2015b) *201*
Figure 213: Alterations in time to the roof structure and ceiling of George Heriot's Chapel: a) hypothesis of the original ceiling, that might have been similar to the 1626 one in Provost Skene's House (RCAHMS SC 1327346, 1952); b) an undated drawing probably showing what the 1787 ceiling looked like (Lockhart, 2003); c) remains of the eighteenth century plaster decorations visible in the roof space; d) a view of the ceiling today, as renewed in 1835 (Serafini and Gonzalez Longo, 2015b) *203*
Figure 214: Alterations in time to the roof structure and ceiling of George Heriot's Chapel; the letters correspond to those in Figure 214 (Serafini and Gonzalez Longo, 2015b) *204*
Figure 215: The roof of St Martin's in the fields church as drawn by James Gibbs (1728) *206*
Figure 216: The roof of the portico of St Martin's in the fields church as built (Yeomans, 1987) *206*
Figure 217: The roof of St Andrew's in the Square church (1751-3) *206*
Figure 218: The roof of Marybole Chapel (Gibbs, 1728) *206*
Figure 219: William Adam's design for the roof of Glasgow New College Library, 1720 (Adam, 1812) *208*
Figure 220: King-post trusses shown by Serlio (1545) at p. 197 ..... *208*
Figure 221: The roof of Glasgow Trades Hall, as designed by Robert Adam on the left (SM Adam 48/25, 1791), and as built on the right; the graphic scale relates to both drawings (Serafini and Gonzalez Longo, 2015a) *209*
Figure 222: Repair works to the roof structure of Glasgow Trades Hall (1791-4): a timber wedge inserted between a slanted brace and a horizontal beam (left); steel rods, plates and brackets added in 1990s (right) *210*
Figure 223: The original timber structure of the dome of Glasgow Trades Hall (1791-4) surveyed by W. Underwood in 1950s (ML Shanks 152/T6, 1955) (left) before the replacement in steel (right)... *211*
Figure 224: The ceiling of Glasgow Trades Hall (1791-4): an undated picture probably showing the original ceiling (ML T-TH 1/34/3, Undated) (left) and the present ceiling, installed by W. Underwood in 1950s (right) *211*
Figure 225: Strengthening of the roof of Glasgow Trades Hall (1791-4): drawing by Charles Wilson architect dated 1856 showing in yellow the original structure, in red new timber elements added by C. Wilson, in blue metal work added by C. Wilson (TDH 1/899, 1856) *211*
Figure 226: Design for the dome of Edinburgh Assembly Rooms and Musical Society by James Adam (SM Adam 7/225, 1755) *212*
Figure 227: Design for the roof of Invereray Castle (copy of drawing found in John Adam's diary held at Blair Adam House) *212*
Figure 228: The location, date, structural typology, architect, wright and patron of the roofs of the 8 case studies investigated *214*
Figure 230: The roof of St Andrew and St George's church (1782-4) *216*
Figure 231: The roof of St Andrew and St George's church: the connection with the wall (left), carpentry marks on a post (centre) and a big knot in a strut (right) *216*
Figure 232: The roof of St Andrew and St George's church: compression cracks in a strut and in the joggle of a post *217*

Figure 233: The roof of St Andrew and St George's church: strengthening of a joint between post and upper beam *217*
Figure 234: St Andrew's in the square church (1739-57): plan (left) and view from West (right)..... *218*
Figure 235: The roof of St Andrew's in the Square church (1751-3)..... *218*
Figure 236: The roof of St Andrew's in the Square church: the dressing of a butt-purlin (left) and unusual carpentry marks on a strut (right) *219*
Figure 237: Sample of Scots pine extracted from a strut of the roof of St Andrew's in the Square Church: transversal section macro (left); transversal section X100 (centre left); radial section X100 (centre right); tangential section X100 (right)..... *219*
Figure 238: Fungi attack in the North-West gable of the roof of St Andrew's in the square church, affecting the butt-purlin, the common rafter and the sarking..... *220*
Figure 239: Resin injections used in 1980s to treat insect attack in the roof of St Andrew's in the square church *220*
Figure 240: Cracks in a butt-purlin of the roof of St Andrew's in the square church..... *220*
Figure 241: A rotation of the principal rafter causing the opening of the joint with the central post in the roof of St Andrew's in the square church *220*
Figure 242: Rotation of the central post causing the opening of the joint with the strut and steel strengthening interventions added in 1990s in the roof of St Andrew's in the square church..... *221*
Figure 243: A joint between strut and collar with steel strengthening interventions added in 1990s in the roof of St Andrew's in the square church *221*
Figure 244: Cockenzie House (1680-3): plan (left) and view from South-East of the central block (right) *221*
Figure 245: The roof of the central block of Cockenzie House (1680-3)..... *222*
Figure 246: The roof of Cockenzie House: redundant joint on a collar (left), rafter feet (centre left), big sawn roman numerals on a rafter (centre right), lap joint between collar and rafter secured by metal nail (right)..... *223*
Figure 247: Moisture content readings in two frames of Cockenzie House *224*
Figure 248: Broken sarking in the roof of Cockenzie House *224*
Figure 249: Open-air water tanks in the roof of Cockenzie House *224*
Figure 250: Thermal image showing humidity stains on the inner West gable of the attic of Cockenzie House..... *224*
Figure 251: Thermal image showing lower temperatures in proximity of the flashings in the attic of Cockenzie House..... *224*
Figure 252: Insect attack on a rafter in the roof of Cockenzie House..... *225*
Figure 253: Fungi attack on a rafter foot in the roof of Cockenzie House..... *225*
Figure 254: Holyrood Palace (mainly sixteenth century and 1671-9): plan (left) and view from West (right) *225*
Figure 255: The roof of the North range of Holyrood Palace (1671-9)..... *226*
Figure 256: The connection with the wall of the roof of the North range of Holyrood Palace seen from the roof space..... *227*
Figure 257: Strengthening of the rafter ends and floor beams on the South side of the North range of Holyrood Palace *227*
Figure 258: The roof of the North range of Holyrood Palace: the dressing and carpentry marks on two rafters (left), the joint between rafter and upper beam (centre), unusual carpentry marks on a rafter (right) *227*
Figure 259: Redundant joints in purlin on West side of the roof of the North range of Holyrood Palace *228*

Figure 260: Old insect attack treated with insecticides on a purlin of the roof of the North range of Holyrood Palace 229
Figure 261: New bore dust suggesting active attack on a strut of the roof of the North range of Holyrood Palace 229
Figure 262: A degraded peg causing the disconnection and slip of a joint between rafter and upper beam of the roof of the North range of Holyrood Palace..... 229
Figure 263: Fungi attack - status and type not identified - on a beam of the roof of the North range of Holyrood Palace 229
Figure 264: Micro-drill graph of point a in the North strut of frame 42 of the roof of the North range of Holyrood Palace identifying external and internal section loss 230
Figure 265: Micro-drill graph of point b in the South upper beam of frame 19 of the roof of the North range of Holyrood Palace identifying external and internal section loss 230
Figure 266: Newhailes House (1702-51): plan (left) and view from South-West (right) 231
Figure 267: The roof of the North-West wing of Newhailes House (1733-51) 231
Figure 268: The roof of the North-West wing of Newhailes House: a dovetail lap joint between struts and upper beam (left), the dressing of a strut (centre), carpentry mark on a post (right)..... 232
Figure 269: Recently replaced purlins and sarking boards in the roof of the North-West wing of Newhailes House 233
Figure 270: Cross joint between struts with an opening of 1cm in the roof of the North-West wing of Newhailes House 233
Figure 271: Pinkie House (mainly sixteenth century and 1613): plan (left) and view from East (right) 234
Figure 272: The roof of the long gallery at Pinkie House (1613) 235
Figure 273: The roof of the long gallery at Pinkie House: the connection with the wall on the West side, with the rafters simply sitting on the wall-head (left), a thermographic image of the wall-head and ceiling on the East side, taken from the gallery below (right)..... 235
Figure 274: The roof of the long gallery at Pinkie House: the dressing of the rafters (left), the oak pegs securing the slates to the sarking (centre left), carpentry marks on collars (centre right), mortice and tenon joint between rafter and collar secured with a timber peg (right)..... 236
Figure 275: Drawing showing the strengthening intervention carried out in 1950s in the roof of the long gallery at Pinkie House (RCAHMS LOR/M/17/5, 1953) 237
Figure 276: Struts probably added in eighteenth century and double collars added in 1950s in the roof of the long gallery at Pinkie House..... 237
Figure 277: Micro-drill graph of measurement point 10 on frame I of the long gallery roof at Pinkie House..... 238
Figure 278: Micro-drill graph of measurement point 1 on frame XVII of the long gallery roof at Pinkie House..... 238
Figure 279: A degraded peg in a mortice and tenon joint between rafter and upper collar in the roof of the long gallery at Pinkie House..... 239
Figure 280: A failed joint between rafter and lower collar with an opening of 8cm in the roof of the long gallery at Pinkie House; the peg is broken 239
Figure 281: A failed joint between rafter and lower collar with an opening of 4cm in the roof of the long gallery at Pinkie House; the rafter is broken 239
Figure 282: Stirling Castle King's Old Buildings (1557): plan (left) and view from East (right)..... 240
Figure 283: Stirling Castle Palace (1530-55): plan (left) and view from West (right)..... 240
Figure 284: The roof of the King's Old Buildings (1557) at Stirling Castle 242

Figure 285: The roof of the King's Old Buildings: tool and carpentry marks on collars (left), mortice and tenon joint between rafter and upper collar (centre), scarf joints in rafters (right)..... 242
Figure 286: The roofs in the North-East (above) and South-West (below) ranges of Stirling Castle Palace (after 1719)..... 243
Figure 287: The roofs of Stirling Castle Palace: dovetail lapped joint securing a collar to a rafter in the South-West range (left), carpentry marks on collars in the North-West range (centre), wavy grain and knots in a collar in the North-East range (right)..... 243
Figure 288: The roofs of Stirling Castle surveyed by Thomas Moore in 1719: the King's Old Building (NLS MS1646 Z.02/18b, 1719) and the Palace (NLS MS1646 Z.02/18b, 1719) 244
Figure 289: The roof of the North-West corner of Stirling Castle Palace (after 1719) with a picture of the blocked mullion window in the East gable..... 245
Figure 290: Insect attack on a rafter in the North-East range of Stirling Castle Palace..... 246
Figure 291: Insect attack on a purlin in the North-West corner of Stirling Castle Palace 246
Figure 292: Fungi attack on a purlin in the North-West corner of Stirling Castle Palace..... 246
Figure 293: Old insect attack on rafter in the South-East range of Stirling Castle Palace..... 246
Figure 294: Micro-drill graph of point a' in the South rafter of frame 3 in the North-East range of Stirling Castle Palace identifying extensive external section loss and limited internal section loss ... 247
Figure 295: Micro-drill graph of point a' in the South rafter of frame 12 in the South-West range of Stirling Castle Palace identifying extensive external and internal section loss 247
Figure 296: Touch House (sixteenth century and 1757-62): plan (left) and view from South-East (right) 248
Figure 297: The roof of the central block of Touch House (1757-62) 248
Figure 298: The roof of the central block of Touch House: double mortice and tenon joint securing a common rafter to a purlin (left) and unusual carprenty mark found on a common rafter (right)..... 249
Figure 299: The roof of the North-West range of Touch House (end seventeenth century) 250
Figure 300: two collars with a different dressing in the roof of the North-West range of Touch House 250
Figure 301: A cleat reinforcing the joint between a rafter and a butt-purlin in the roof of the North-West range of Touch House 251
Figure 302: Carpentry marks and redundant joints on collars in the North-West range of Touch House; recently added struts are also visible 251
Figure 303: Remains of sarking on the North side of the roof of the North-West range of Touch House 251
Figure 304: Additional collars and struts reinforcing the roof of the North-West range of Touch House 251
Figure 305: The dampness disintegrating the East gable in the roof of the North range of Touch House 252
Figure 306: Broken sarking in the roof of the North-West range of Touch House..... 252
Figure 307: Insect attack on the West side strut of the roof of the central block of Touch House..... 253
Figure 308: Fungi attack on a purlin of the roof of the central block of Touch House, near a gable wall 253
Figure 309: Respondents to the online questionnaire: number (left) and types (right) 256
Figure 310: Accessibility and visibility of the surveyed roofs according to the respondents of the online questionnaire and compared to what we have found during our surveys..... 257
Figure 311: Frequency of inspections and programmed works to the roof structure, covering and flashings according to the respondents of the online questionnaire; 35/40 respondents replied 257

Figure 312: Professionals called to carry out inspections and programmed works to the roof structure, covering and flashings according to the respondents of the online questionnaire; 33/40 respondents replied 258
Figure 313: Current problems to the roof structure, covering, flashings and attic ceilings according to the respondents of the online questionnaire and compared to what we have found during our surveys 258
Figure 314: Building documentation according to the respondents to the online questionnaires: information on past repairs, inspection reports, historic documents, name of previous owners 258
Figure 315: Types of documents related to the building that respondents to the online questionnaire know of..... 259
Figure 316: Available academic and training courses offered to conservation professionals dealing with historic timber structures in Scotland and North England 261
Figure 317: Proposed repairs to the roof of Newark (in red): steel brackets reinforcing the rafter feet and steel wires connecting them transversally (Demaus Building Diagnostics Ltd, 2007)..... 263
Figure 318: Detail of the steel brackets proposed as reinforcement for the rafter feet of the roof of Newark Castle (Demaus Building Diagnostics Ltd, 2007)..... 263
Figure 319: Repairs carried out in the roof of Alloa tower: some rafter ends, sole pieces and ashlar posts partly replaced with new timber and connected to the original timber with scarf joints and steel bolts..... 264
Figure 320: Repairs carried out in the roof of Methven Castle: many original rafters substituted with reused nineteenth century timbers, but many original collars retained and steel plates used to reinforce the lap joints between them 264
Figure 321: Replacements and alterations to surveyed roofs 265
Figure 322: Estimated causes of the pathologies identified in the surveyed roofs 268
Figure 323: Mechanical damage in common rafter roofs: schematic of the transversal opening of roofs (left), joint disconnection in a rafter foot of Sailor's Walk (1670s) (centre), an open joint between lower collar and rafter in the roof of the long gallery at Pinkie House (1613) (right)..... 269
Figure 324: The transversal opening of eighteenth century roofs without a tie-beam: open scarf joint in a tie-beam of the roof of Oakshaw Trinity church (1754-6) (left), wooden peg inserted in an open joint between a slanted strut and a horizontal beam in the roof of Glasgow Trades Hall (1791-4) (right) 269
Figure 325: Mechanical damage in common rafter roofs: schematic of the stacking up of frames (left) and pictures of the roof of Geilston House (1666) (centre and right); the black line in the central picture represents the position that the frame should have if there was no out of plomb..... 270
Figure 326: The roof of Oakshaw Trinity Church (1754-6) 271
Figure 327: The roof of the Ordnance Store in Fort George (1759-61): as drawn by engineer William Skinner in 1762 after completion (NLS MS1647 Z.02/55a, 1762) (left), as surveyed by the author (right) 271
Figure 328: Mechanical damage in trussed roofs: drawing showing in red and blue the timber and steel added to the roof of the Trades Hall in Glasgow (TDH 1/899, 1856) (left), joint disconnection in the roof of Fort George Ordnance Store (1759-61) (top right) and in the roof of Oakshaw Trinity Church (1754-6) (bottom right)..... 272
Figure 329: Mechanical damage in purlin roofs and complex frames: deflected purlin in Melville House (1697-1701) (left), deflected purlin in Touch House (1757-62) (centre), crack in strut supporting the purlin in Touch House (1757-62) (right) (Serafini and Gonzalez Longo, 2016)..... 272
Figure 330: The central part of the roof of the main block of Touch House (1757-62) 272

Figure 331: Material degradation in common rafter roofs: old insect attack in Malleny House (1635) (left), active insect attack in Cockenzie House (1680s) (centre), fungi attack in Kelburn Castle (1581) (right) 273
Figure 332: Estimated status of the insect attack affecting the surveyed roofs 273
Figure 333: Number of micro-drills carried out in the roofs of Stirling Castle Palace, Holyrood Palace and Pinkie House, organized according to the position and extent of the degradation detected 274
Figure 334: Examples of micro-drill graphs that show external degradation limited to the sapwood, up to 2cm deep. From the top: 274
Figure 335: Examples of micro-drill graphs showing extensive external degradation (more than 2cm deep). 275
Figure 336: Examples of micro-drill graphs showing internal degradation. From the top: 275
Figure 338: Past interventions: timber and steel elements counteracting the hip rafters' deflection in Oakshaw Trinity church (1754-6) (left), a secondary beamcut to make place for the steel reinforcements in Oakshaw Trinity Church (1754-6) (centre), filled checks in the roof of the Ordnance Store at Fort George (1759-61) (right) 277
Figure 339: Accessibility and visibility issues found in the surveyed roofs 278
Figure 340: Surveyed roofs affected by inadequate environmental conditions 278
Figure 341: Moisture content readings in one frame in the roof of the North range of Touch House (left) and in one frame in the roof of Cockenzie House (right) 279
Figure 342: Unfavourable conditions in simple frames: over-insulation in the roof of King's Old Buildings in Stirling Castle (1557) (left), uncovered water tank in Kelburn Castle (1581) (centre), pigeons' droppings in George Heriot School (1630s) (right) 279
Figure 343: Results of the ultrasonic measurements taken in the roofs of Stirling Castle Palace, Holyrood Palace and Pinkie House 290
Figure 344: Ultrasonic wavs velocities grouped according to the categories of the corresponding micro-drills: HQ = High Quality, MQ = Medium Quality, LQ = Low Quality, LD = Low Degradation, HD = High Degradation 292
Figure 345: Extent of material degradation estimated for the micro-drill graphs in the measurement points where the unstable signal has not allowed recording the ultrasonic wave velocity 294
Figure 346: Graph showing the failed ultrasonic measurements, that could not be recorded due to the unstable signal (highlighted in black) distributed according to the thickness of the timber elements tested 295
Figure 347: Graph showing the correspondance between the ultrasonic results and the micro-drill results distributed according to the thickness of the timber elements tested 295
Figure 348: Comparison between assessment techniques used during the surveys; the best grade is 1; x=non destructive test, x=minor destructive test 303

List of Tables

Table 1: existing non-destructive and semi-destructive tests used on timber structures (dynamic/monitoring tests have not been included); regular = global testing methods*, italic = local testing methods; MOE = modulus of elasticity; MOD = modulus of deformability; MOR = modulus of rupture; CS = compressive strength*..... *49*
Table 2: The structure type, dating and method of dating of the 59 roof structures surveyed *87*
Table 3: The selection of the case studies (framed in black) amongst the surveyed roofs..... *90*
Table 4: The selection of assessment techniques to investigate specific aspects: only devices available on the market have been included; light grey = available in Scotland or virtually cost-less. The selected techniques are framed in black. *92*
Table 5: The testing equipment used in the detailed investigations of the case studies..... *93*
Table 6: A summary of the tests carried out in the case studies *98*
Table 7: The maximum values allowed for each of the strength affecting parameters corresponding to strength classes I, II, III (UNI 11119, 2004) *101*
Table 8: Maximum stresses [N/mm^2] for Pinus Sylvestris at 12% moisture content (UNI 11119, 2004) *101*
Table 9: Calculation of the time of flight of the ultrasonic measurement shown in Figure 62 ..... *104*
Table 10: Calculation and correction of the ultrasonic wave velocity of the time of flight calculated in Table 9..... *105*
Table 11: Relative wave velocity decrease calculated by comparing the velocity calculated in Table 10 with reference velocities and estimation of density loss..... *106*
Table 12: Measurements and tests carried out in the roofs of Stirling Castle..... *241*
Table 13: Pathologies identified in the roofs surveyed, and estimated causes; the damage types are as represented in Figure 64. The roofs with no pathology have not been included. For details see Appendix E and F *265*
Table 14: Summary of the effectiveness and reliability of the assessment techniques used during the surveys. The effectiveness column details on the requirements needed to obtain useful results, such as accessibility, visibility, sampling, environmental conditions, instrumental resolution, and timber thickness. The reliability column specifies wether the results obtained from each technique can be considered reliable and to what extent...... *281*
Table 15: The most significant thermograms taken in the attic and roof spaces of the case studies, with at least one example (when available) for both the roof space and the attic space of each case study. The measured air temperature/humidity and wood moisture content are also reported to show the environmental conditions in which the thermograms have been taken..... *284*
Table 16: Example of measurement taken in the roof of Holyrood Palace: comparison between density loss calculated based on the ultrasonic results and extent of material degradation identified by the micro-drills. The density loss has been calculated based on the measured time of flight of ultrasonic waves, from which their velocity has been calculated, corrected based on grain orientation and moisture content and compared to reference velocities, as detailed in chapter 2 (section 2.4.3.4) *291*
Table 17: Example of measurement taken in the roof of Pinkie House, where the ultrasonic test results do not correspond to the results of the micro-drill test: the ultrasonic test measured a high velocity, while the micro-drilling test highlighted internal decay *293*
Table 19: Knowledge and skills needed to implement the assessment techniques used..... *298*

Glossary

The need for a glossary stems from the fact that this thesis includes different subjects such as history of architecture, construction history, conservation, assessment and diagnosis of historic structures, wood technology and engineering: there are dictionaries addressing each of these subjects, but none of them includes all of the terms used in this work, even because some terms are specifically Scottish. Moreover, the definition of some terms remains controversial, as types of roof structures, elements and connections have different names in different countries, and even the terminology associated to different damage/failures types is not always clear for English-as-a-second-language speakers. Thereafter the need to define them graphically as well as verbally, as follows.

Arch brace — A curved brace, usually used in pairs to support a roof frame and give the effect of an arch (Ching, 2011, Harris, 2006) (Figure 1).

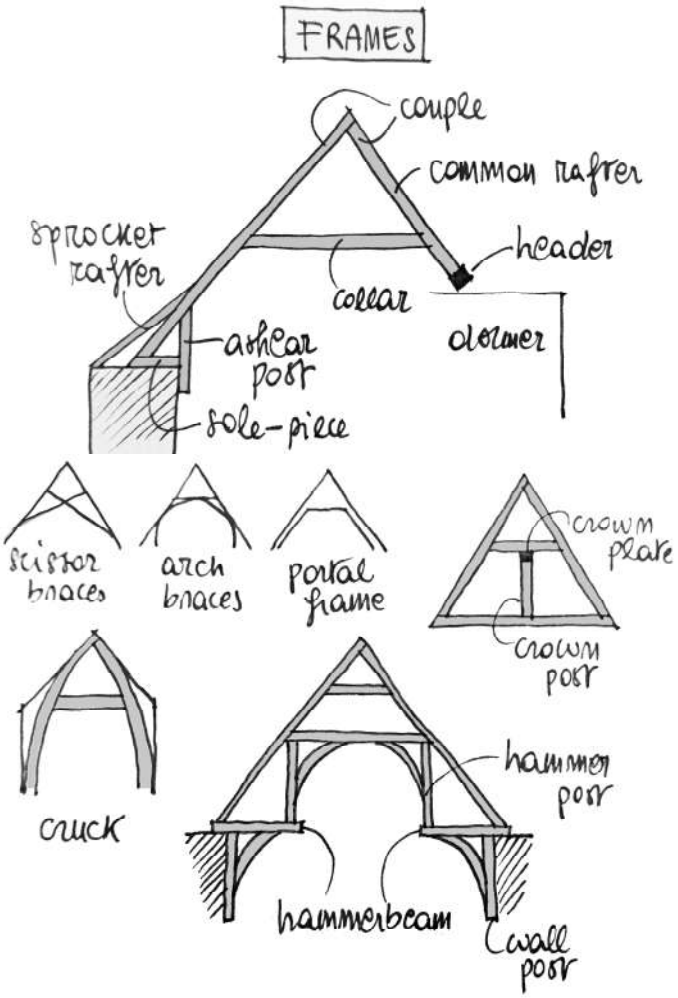

Figure 1: Elements composing a simple frame and other types of frames

Ashlar post ashlaring — In a traditional timber roof construction, a short post running from a wall plate to a principal rafter as part of ashlaring (Davies and Jokiniemi, 2012). In garrets, the short wood upright pieces between the floor beams and

ashlering	rafters, to which wall lath is attached (Harris, 1977). In Scottish roofs ashlar posts connect common rafters to sole pieces (Figure 1) or to tie-beams.
Batten	In roofing, a wood strip applied over boards or roof structural members; used as a base for the attachment of slate, wood, or clay-tile shingles (Harris, 2006) (Figure 2).

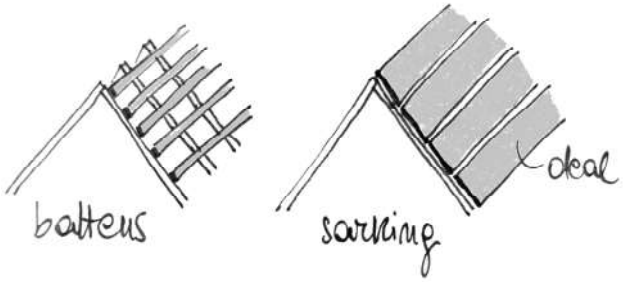

Figure 2: The difference between battens and sarking, and the elements composing the sarking

Balk baulk	A squared timber used in building construction (Harris, 2006).
Birdsmouth	A re-entrant angle at the end of a piece of timber to allow the end to sit astride the corner of a supporting timber (Corkhill, 1948) (Figure 3).
Brace	In frame structures, any structural element which stiffens and reinforces the angle between two members; a diagonal structural member, strut or rod providing rigidity to a frame; 'bracing' is any system of structural members designed to maintain the rigidity of a structure, frame, etc (Davies and Jokiniemi, 2008).
Bridle joint	Joint in which a slot is cut in the end of one member to fit over part of the adjoining member against which it abuts; usually used at the foot of a principal rafter or inclined strut (BS 6100, 1992). A joint similar to the stub mortice and tenon joint, but with the positions of the mortice and tenon reversed; it is often used for angles less than right angles (Corkhill, 1948) (Figure 3).
Butt-purlin tenon purlin tenoned purlin	In timber roof construction, a purlin that is tenoned into the side of principal rafters (Davies and Jokiniemi, 2008) (Figure 4).
Chamfer	The splayed surface formed when a corner is removed from an acute or right angle, usually at 45° (Davies and Jokiniemi, 2008) (Figure 3).
Chase mortice	Mortice that is extended in the length of the member in which it is formed, its depth tapering out to the surface, to enable the tenon of a framed member to be slid into position when the supporting member is already fixed (BS 6100, 1992). A mortice for a stub tenon with a chase so that the tenon can slide into position (Corkhill, 1948) (Figure 3).
Check	A longitudinal shake in wood that does not go through the whole of the cross-section, due to rapid and faulty seasoning (Corkhill, 1948). A small crack running parallel to the grain in wood and across the rings; usually caused by shrinkage during drying (Harris, 2006) (Figure 5).
Circular saw	A power-operated saw in the form of a circular steel blade with teeth along

buzz saw
mechanical saw

the perimeter (Harris, 2006) (Figure 6).

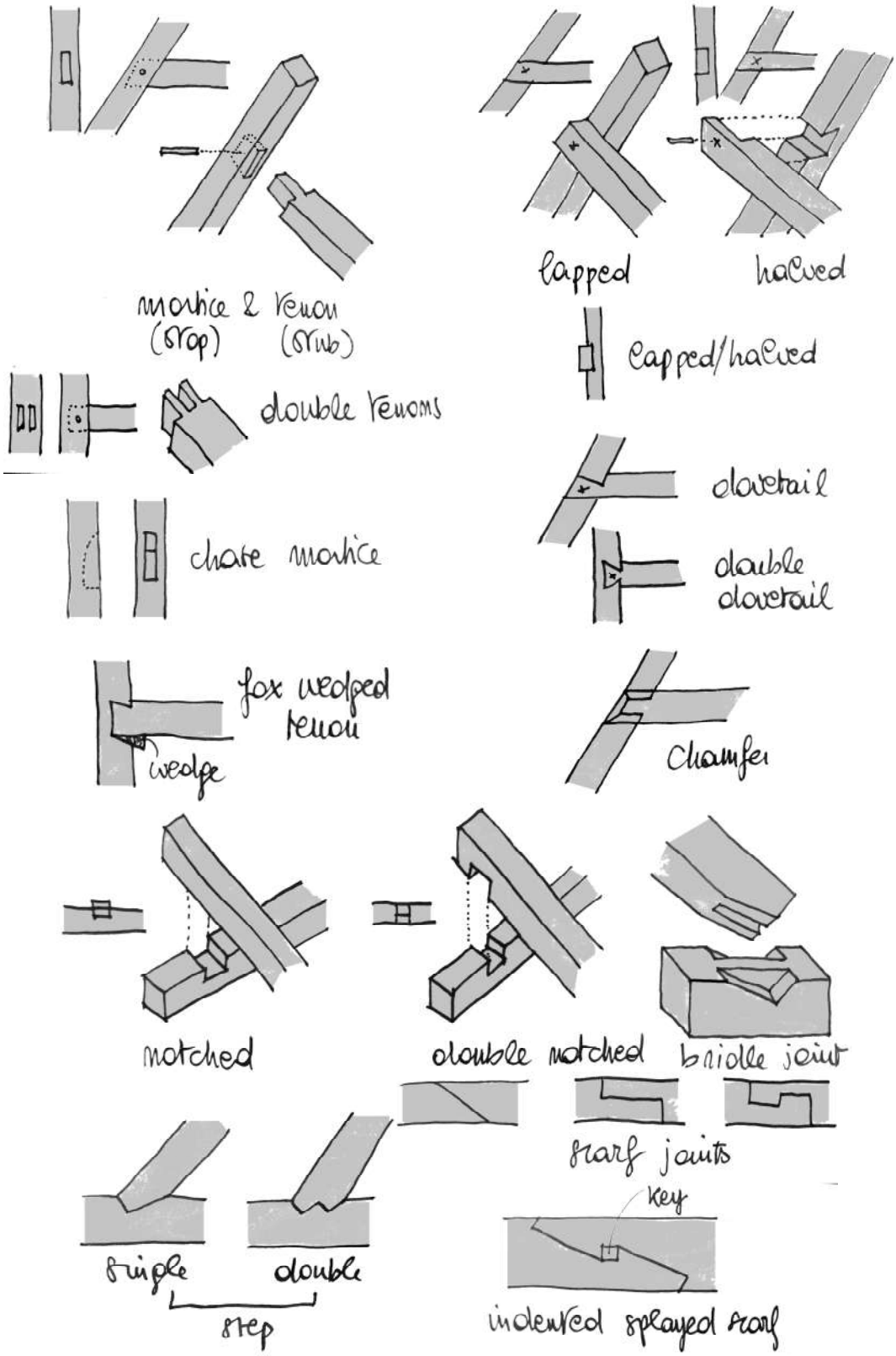

Figure 3: Some types of carpentry joints

Clasped purlin — Purlin carried directly by the collar and clasped between this and the principal rafter (Yeomans, 1992) (Figure 4).

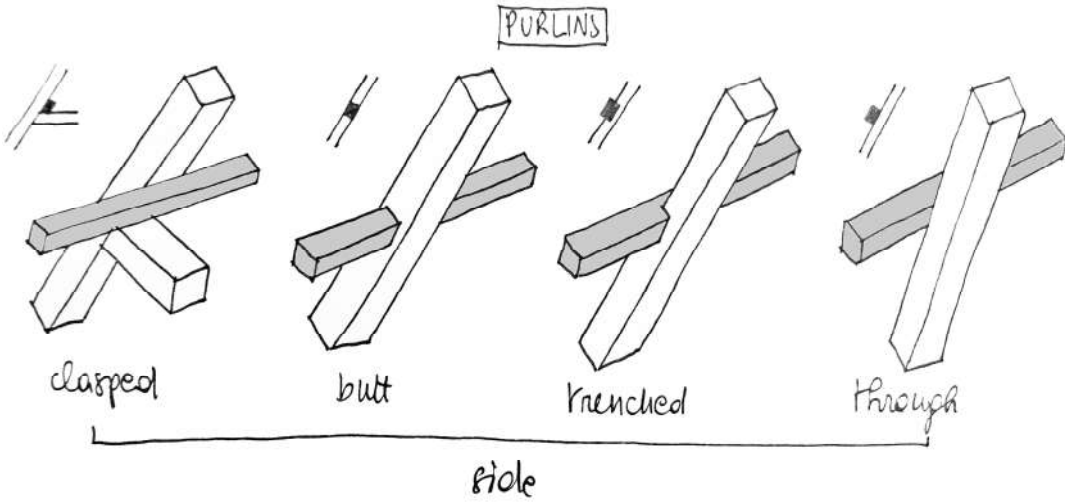

Figure 4: Different types of side purlins

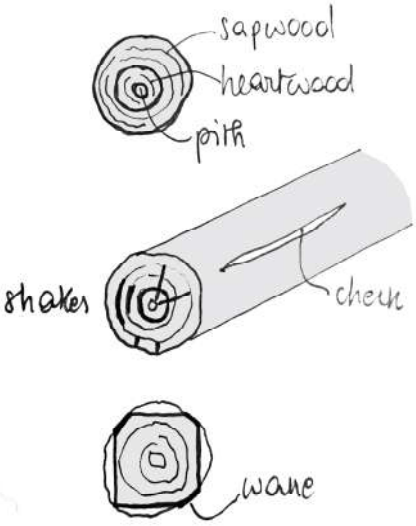

Figure 5: Main parts and defects of a timber log

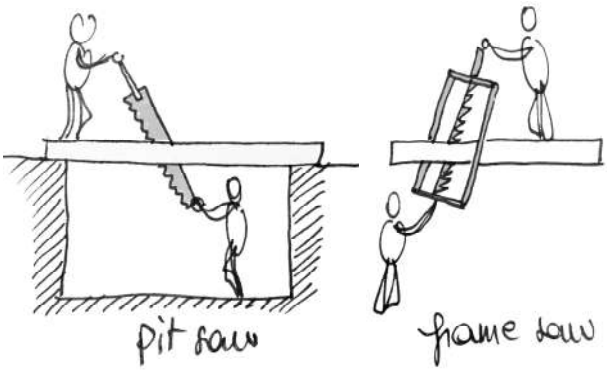

Figure 6: Types of hand saws used for wood

Cleat — A small block or strip of wood nailed on a member or on a surface; used to support a brace or to hold a member or object in place temporarily (Harris, 2006). A block receiving the thrust from an inclined member (Corkhill, 1948). In Scottish roofs it is used to reinforce joints of struts (Figure 7) and purlins.

Collar
collar-beam
spanpiece
sparpiece
top beam
wind beam — A horizontal member which ties together (and stiffens) two opposite common rafters, usually at a point about halfway up the rafters in a collar beam roof (Harris, 2006). The tie-beam of a roof truss when at a higher level than the feet of the rafters, or above wall-plate level (Corkhill, 1948) (Figure 1).

Common rafter
auxiliary rafter — One of a series of rafters of uniform size regularly spaced along the length of a pitched roof, or placed as intermediates between principals, with one end attached to the wall-plate and the other to the opposite common

cushion rafter — rafter at the ridge; a pair of common rafters is a couple (Stevens Curl, 2006) (Figure 8, Figure 1).

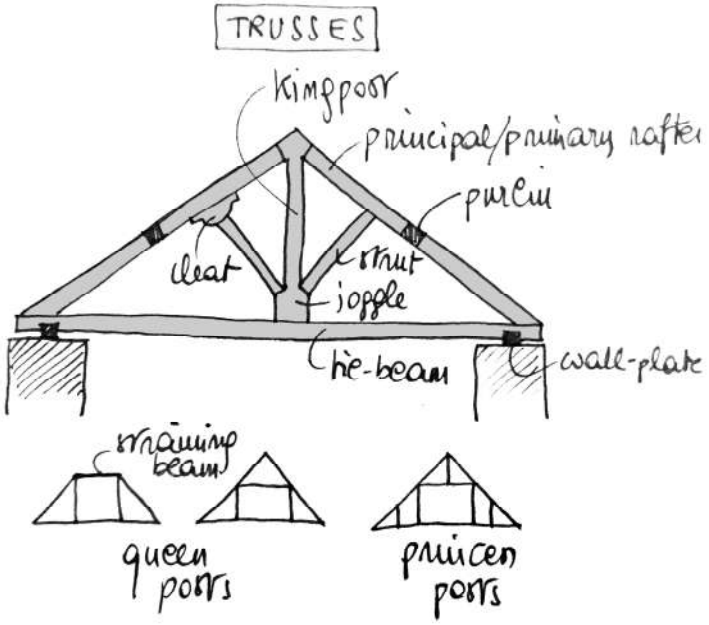

Figure 7: Elements composing a king-post truss and other types of trusses

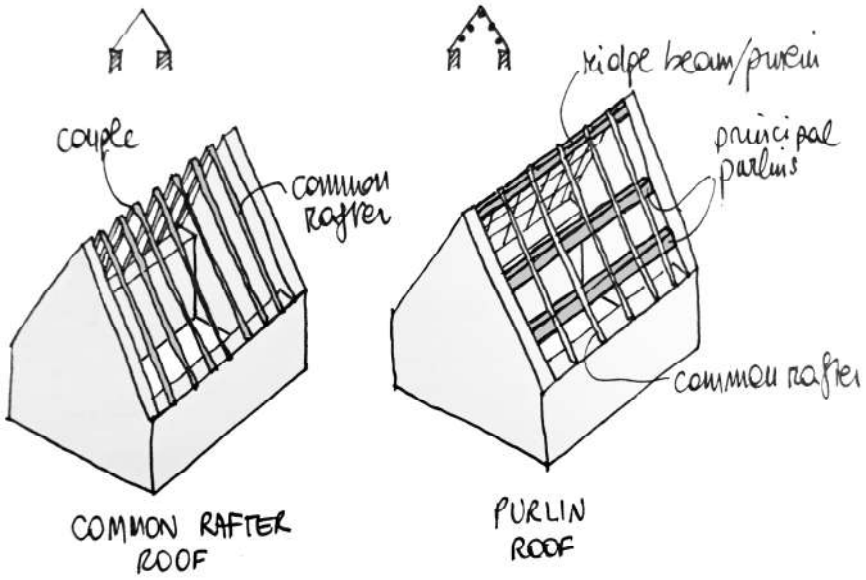

Figure 8: The difference between rafter roofs and purlin roofs and the elements composing them

Common rafter roof
collar(-beam/-tie) roof
common roof
couple roof
single roof — A roof of small span consisting of pairs of rafters or one formed of close couples (with tie-beam) or collar-beam rafters (Corkhill, 1948). A roof supported only by common rafters; principals, purlins, and roof trusses are not used (Harris, 2006). *Sparrendach* in German: a pair of *Sparren*, or rafters, are tightly joined at the apex, while their feet are fixed somehow against shifting (Lohrum and King, 2006) (Figure 8).

Conical roof — A roof in the shape of an inverted cone (Harris, 2006) (Figure 9).

Crown plate — Longitudinal timber in a crown-post roof, supported on crown-posts and

collar plate collar purlin	bearing the collars (Stevens Curl, 2006) (Figure 1).

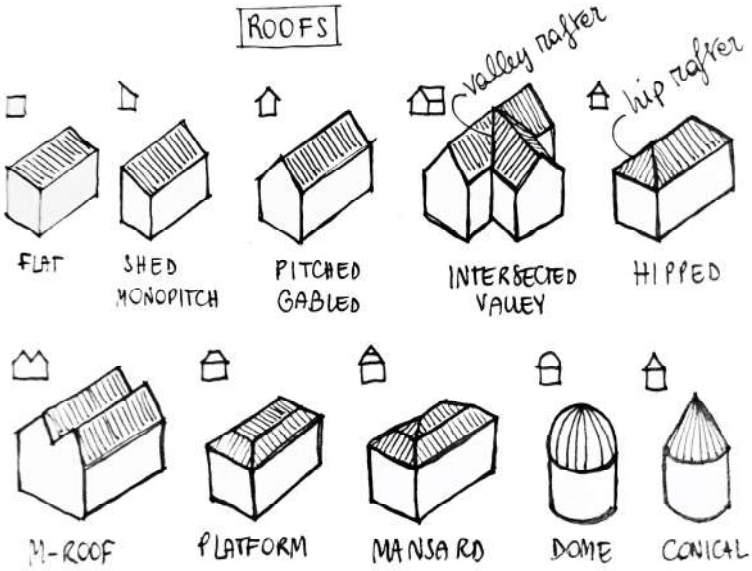

Figure 9: Different roof geometries

Crown post	The vertical member in a crown-post roof that spans from the tie beam to the crown plate, which in turn supports the collars (Gorse et al., 2013) (Figure 1).
Cruck	One of a pair of naturally curved timbers, forming one of several arched frames supporting the roof of an old English cottage or farm building (Ching, 2011).
Deal	Late variant of daill dele (deil, delle, deile, deyll, deale, deal); sawn plank (Robinson, 1999). A term applied to converted softwoods between 2 and 4 inches in thickness and 9 and 11 inches in width; the sizes vary at different ports (Corkhill, 1948). In Scotland deals were also used for the sarking (Figure 2); for different types and dimensions used in Scotland see Newland (2010).
Dome	Curved roof structure spherical in shape (Harris, 2006) (Figure 9).
Double notch joint	See *notched joint* (Figure 3).
Double tenons	Two tenons within the thickness of a member (BS 6100, 1992) (Figure 3).
Dovetail joint	Joint in which a projection is formed in a member so that when fitted into a recess of corresponding shape it will resist withdrawal by tension in the direction of its length (BS 6100, 1992) (Figure 3).
Dragon beam	A short, horizontal piece of timber which bisects the angle formed by the wall plate at the corner of a woodframe building; one end serves to receive and support the foot of a hip rafter, the other end is supported by a dragon tie (Harris, 2006) (Figure 10).
Dragon tie angle tie	An angle brace which supports one end of a dragon beam (Harris, 2006) (Figure 10).

Flat roof	A horizontal roof either having no slope, or a slope sufficient only to effect drainage, its pitch being ususally less than 10° (Harris, 2006) (Figure 9).
Fox wedged tenon	Stub tenon fitted into a stopped mortice of slightly dovetailed shape, having one or more small wedges inserted into sawcuts in the end of the tenon before the tenon is inserted into the mortice so that, as the tenon is driven home, the wedges spread the sides of the tenon to fit the dovetailed shape of the mortice (BS 6100, 1992) (Figure 3).

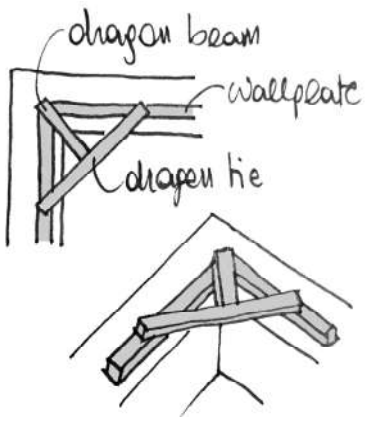

Figure 10: The dragon tie and the dragon beam

(Roof) Frame	The timberwork that encloses and supports structural components of a building (Harris, 2006). Usually applied to an assembly of pieces connected by halving, housing, mortice and tenon joints, or similar connections, and serving as a support or enclosure (Corkhill, 1948) (Figure 1).
Frame saw	A saw with several blades in one frame, used to cut several pieces of wood in one pass (Gorse et al., 2013) (Figure 6).
Gabled roof	Roof having a single slope on each side of a central ridge; usually with a gable at one or at both ends of the roof (Harris, 2006). A roof finishing against a gable and open to the rafters (Corkhill, 1948) (Figure 9).
Halving joint	Joint at the intersection of two members of equal thickness, flush with one another, in which half the thickness of each is removed so that they fit together (BS 6100, 1992) (Figure 3).
Hammer-beam	One of a pair of short horizontal members attached to the foot of a principal rafter at the level of the wall plate, used in place of a tie-beam (Ching, 2011) (Figure 1).
Hammer-beam roof	A roof supported by hammer beams (Ching, 2011) (Figure 1).
Hammer post	A vertical timber set on the inner end of a hammer beam and braced to a collar beam above to support a purlin (Ching, 2011) (Figure 1).
Header	A framing member which crosses and supports the ends of joists, rafters, etc., transferring the weight of the latter to parallel joists, rafters, etc. (Harris, 2006) (Figure 1).
Heartwood duramen	Wood at the core of an exogenous tree; normally darker and much more durable than sapwood (Harris, 2006) (Figure 5).

Hip rafter angle rafter	A rafter placed at the junction of the inclined planes forming a hipped roof (Harris, 2006) (Figure 9).
Hipped roof	A roof comprising adjacent flat surfaces that slope upward from all sides of the perimeter of the building, requiring a hip rafter along each intersection of the inclined surfaces (Harris, 2006). A roof with inclined ends instead of with gable (Corkhill, 1948) (Figure 9).
Indented splayed scarf	A fished joint in which both plate and beam are cut, or idnented, to prevent the sliding of one surface on the other due to shear or tension (Corkhill, 1948) (Figure 3).
Intersected roof valley roof	Any pitched roof that has one or more valleys (Harris, 2006) (Figure 9).
Joggle	A small projection on the end of a framed member to strengthen morticed and other forms of angle joints; in structural work it allows for housing, and provides a better bearing resistance (Corkhill, 1948). An enlarged area of a post for supporting the foot of a strut or brace (Ching, 2011) (Figure 7).
Key	Piece of timber inserted in a joint to prevent movement between adjacent surfaces (BS 6100, 1992) (Figure 3).
King-post	In a truss, as for a roof, a vertical member extending from the apex of the inclined rafters to the tie beam (Harris, 2006). The vertical member at the middle of a king-post roof truss, which is the usual type of wood roof truss for spans between 20 and 30 feet (Corkhill, 1948) (Figure 7).
King-post truss king truss	A pitched truss having a king-post (Ching, 2011) (Figure 7).
Lapped joint	Joint in which one member overlaps the other and the members are secured by nails, bolts, adhesives or other (BS 6100, 1992) (Figure 3).
M-roof happer roof (Scottish) ridge and valley roof	A roof formed by joining two parallel gable roofs, creating a valley between them, resembling the capital letter M in section (Harris, 2006) (Figure 9).
Mansard roof curb roof double pitched roof	A roof that has two slopes on each face, with the lower at a steeper angle than the upper slope, also known as a French roof (Gorse et al., 2013) (Figure 9).
Mortice and tenon joint	Joint in which a tenon on the end of one member is fitted into a mortice cut in the other member (BS 6100, 1992) (Figure 3). For different types see *chase, double, fox wedged, joggle, notch, slot, stopped*.
Notched joint	Joint in which a notched member is supported by another, that, in the case of a double notched joint, is itself notched (BS 6100, 1992) (Figure 3).
Pit saw	An old method of handsawing timber lengthwise; the log is supported over a pit to provide easy access by men using a double-ended saw (Harris, 2006) (Figure 6).
Pitched roof double pitched roof two-slope roof	A steep gable roof having the same pitch on each side of a central ridge. Occasionally, a synonym for a gable roof (Harris, 2006) (Figure 9).

Pith	The soft central core of a log (Harris, 2006) (Figure 5).
Plank	A long, wide, square-sawn thick piece of timber (Harris, 2006). For different types and dimensions used in Scotland see Newland (2010).
Platform roof	A roof which terminates in a horizontal plane; any roof which is truncated (Harris, 2006) (Figure 9).
Portal frame multi-tiered structure trestle	Structural frame consisting of two stanchions connected to beams fixed at angles corresponding to the roof-pitch and rigidly joined at the apex and the tops of the stanchions (Curl and Wilson, 2015) (Figure 1).
Post	A vertical timber acting as a support (Corkhill, 1948). A strong, stiff, vertical structural member or column, usually of wood, stone, or metal, capable of supporting a framing member of the structure above it and/or providing a firm point of lateral attachment (Harris, 2006). See *crown*, *king, princess, queen*.
Princess-post side post	In a truss, a vertical post between the queen post and the wall to supplement the support of the queen post (Harris, 2006); auxiliary posts in a queen-post roof truss; the truss itself is often called a princess-post truss (Corkhill, 1948) (Figure 7).
Principal purlin arcade plate plate purlin under purlin	Timber section used as a bearing for other members; note: always supported along its length (BS 6100, 1992). Any timber, e.g. a wall-plate, laid horizontally on posts or walls serving as the support for other timbers above, its main functions being to provide fixings and to distribute the loads (Stevens Curl, 2006) (Figure 8).
Principal rafter primary rafter	The main rafter in a traditional trussed roof that provides support for the purlins; the purlins then provide support for the common rafters (Gorse et al., 2013) (Figure 7).
Purlin perling purline	In roof construction, a horizontal beam running parallel to the ridge to give added intermediate support for roof joists or rafters (Davies and Jokiniemi, 2008). See *butt, clasped, principal, side, through, trenched.*
Purlin roof double roof	A roof in which purlins are supported directly on walls rather than rafters (DictionaryOfConstruction.com, 2017). *Pfettendach* in German: a pair of inclined pieces called *Rofen*, or common rafters, are carried by *Pfette*, purlins (Lohrum and King, 2006) (Figure 8).
Queen-post	One of the two vertical supports in a queen-post truss (Harris, 2006). The two vertical members in a queen post roof truss, or the two principal posts of any framed truss (Corkhill, 1948) (Figure 7).
Queen post truss queen truss	A roof truss having two vertical posts between the rafters and the tie beam; the upper ends of the vertical posts are connected by a straining piece (Harris, 2006) (Figure 7).
Rafter	The sloping beam that spans from the ridge to the eaves of a roof (Gorse et al., 2013). See *common* and *principal.*
Raised tie-beam	See collar
Ridge beam ridge board	A beam at the upper ends of the rafters, below the ridge of a roof (Harris, 2006). The horizontal timber to which the tops of the common rafters are

ridge pole	fixed (Corkhill, 1948) (Figure 8).
Sapwood alburnum	The wood of a tree between the bark and heartwood; normally lighter in color than the heartwood; equal in strength to heartwood but usually not as decay-resistant (Harris, 2006) (Figure 5).
Sarking (board) roofers	A thin board for sheathing, laid under tiles or slating of a roof construction (Harris, 2006). Close boarding to carry roof tiles, shingles, or slates (Corkhill, 1948). In Scotland it is made with deals (Newland, 2010) (Figure 2).
Scarf joint scarph fish	Heading joint (joint in which the two pieces are in line end to end) in which the ends of the members are tapered and overlap one another, part of each being cut away so that the overall cross section remains constant - it is indented when the mating surfaces are notched together to provide resistance to stress in tension (BS 6100, 1992) (Figure 3).
Scissor brace	Ties that cross each other and are connected to the opposite rafters at an intermediate point along their length (Harris, 2006) (Figure 1).
Shake	A cleavage, or split, in wood; a separation between adjacent layers of fibres (Corkhill, 1948). A separation in wood between or along the annual rings (Harris, 2006) (Figure 5).
Shed roof half-span lean-to mono-pitch pent single pitch to-fall	A roof consisting of one sloping surface (Corkhill, 1948) (Figure 9).
Side purlin bridging rib side timber side weaver	Horizontal beam carried on roof trusses in order to give intermediate support to the common rafters (Curl and Wilson, 2015). Horizontal beam lying on the backs of the principal rafters of a roof truss, between ridge and wall-plate, to carry the common rafters (Corkhill, 1948) (Figure 4).
Sole-piece sole-plate	Short timber laid across a wall (i.e. with its length at 90° to the naked of the wall), supporting the foot of a rafter and an ashlar-piece in a timber roof (Stevens Curl, 2006) (Figure 1).
Sprocket rafter sprocket sprocket piece	Short rafters fixed at a less pitch at the feet of common rafters to form projecting eaves; they form a break in the roof surface and are used for aesthetic reasons and to shorten the common rafters (Corkhill, 1948) (Figure 1).
Step joint	A structural notched joint; when it has more than one notch it is a double-step joint (Corkhill, 1948) (Figure 3).
Stop mortice & stub tenon blind mortice	Mortice that does not penetrate the full width or thickness of the member in which it is formed; tenon not passing completely through the member in which the mortice is formed (BS 6100, 1992) (Figure 3).
Straining beam straining piece	A horizontal timber between the heads of queen posts; a horizontal strut in structural framing (Corkhill, 1948) (Figure 7).

Strut	A brace or any piece of a frame which resists thrusts in the direction of its own length; may be upright, diagonal, or horizontal (Harris, 2006). An inclined compression member of a frame, as in a roof truss, centre, etc (Corkhill, 1948) (Figure 7).
Through purlin	Continuous through the length of the structure, as opposed to butt-purlins (Hourihane, 2012). A purlin resting on the backs of the principal rafters (Davies and Jokiniemi, 2008) (Figure 4).
Tie-beam	In roof framing, a horizontal timber connecting two opposite rafters at their lower ends to prevent them from spreading (Harris, 2006) (Figure 7).
Trenched purlin	Purlin carried on the backs of the principal rafters with the latter trenched to receive it (Yeomans, 1992). A purlin notched into the upper surface of principal rafters (Davies and Jokiniemi, 2008) (Figure 4).
(Roof) Truss	A rigid triangulated framework of wood or iron, designed and arranged to transfer the loads acting on the frame to the supports; triangulation = arranging the members of a frame or truss in triangles to build up a structurally perfect frame, which allows for accurate and rigid designs (Corkhill, 1948). A structure composed of a combination of members (such as chords, diagonals, and web members), usually in some triangular arrangement so as to constitute a rigid framework (Harris, 2006). A structure with hanging posts that act as ties, 'trussing up' the tie-beam and thus counteracting its deflection and creating an efficient triangulation (Yeomans, 1992) (Figure 7).
Valley rafter	In a roof framing system, the rafter in the line of the valley; it connects the ridge to the wall plate along the meeting line of two inclined sides of a roof which are perpendicular to each other (Harris, 2006) (Figure 9).
Wall-plate	Structural member along the top of a wall or built into its length, that distributes the forces from joists, rafters or roof trusses (BS 6100, 1992) (Figure 7).
Wall-post	Post next to a wall (BS 6100, 1992) (Figure 1).
Wane	A rounded edge or bark along an edge or at a corner of a piece of lumber (Harris, 2006). Applied to converted wood in which the corner is missing at the circumference of the log, due to too economical conversion; the defect denotes the presence of sapwood (Corkhill, 1948) (Figure 5).
Wright (Scottish)	A constructive workman, one who deals with wood, a carpenter, a joiner (Oxford English Dictionary, 2016). A woodwright, a carpenter (Robinson, 1999). From wryhta/wurtha: a workman, one by whom anything is framed, from wyrc-an = to work (Jamieson, 1808). A craftsman, a woodwright, a carpenter (Historic Environment Scotland, 2011). An outdated or vernacular word for a carpenter (Davies and Jokiniemi, 2012).

List of abbreviations

ADCRU	Architectural Design and Conservation Research Unit at the University of Strathclyde (Glasgow)
BARR	Buildings At Risk Register in Scotland
BNS	British National Standards
CARE	Conservation Accreditation Register for Engineers
COST	Intergovernmental framework for European Cooperation in Science and Technology
E5	Eurocode 5
ECA	Edinburgh City Archives
EM	Electromagnetic
EUL	Edinburgh University Library
GH	George Heriot School private archives
GPR	Ground Penetrating Radar
GTM	Global Testing Methods
HES	Historic Environment Scotland
HS	Historic Scotland (now incorporated in Historic Environment Scotland)
IHBC	Institute of Historic Building Conservation
IRT	Infrared thermography
LTM	Local Testing Mehods
MC	Moisture Content
MDT	Minor Destructive Tests
MLG	Mitchell Library in Glasgow
NDT	Non-destructive tests
NHTG	National Heritage Training Group
NLS	National Library of Scotland
NTS	National Trust for Scotland
NRS	National Records of Scotland
RCAHMS	Royal Commission on Ancient and Historic Monuments of Scotland (now incorporated in Historic Environment Scotland)
SCAN	Scottish Archive Network

SDT	Semi-destructive tests
SML	Soane Museum in London
STSM	Short Term Scientific Mission
TCH	Touch House private archives
TDH	Glasgow Trades Hall private archives
TG3	Task Group 3
TLS	Terrestrial laser scanning
TWH	Tweeddale House private archives
WG1	Working Group 1

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Abstract

This thesis researches seventeenth- and eighteenth-century timber roof structures in Scotland, which had been largely forgotten up to now. Previous studies fail in characterizing the extent and nature of historic timber roofs in Scotland, especially post-1650, mainly because of the scarcity of measured surveys. This lack of knowledge, together with the lack of specific standards and training for the assessment of existing timber structures, hinders good conservation practice. Scottish professionals rely mainly on traditional methods and past experience, which makes it difficult for them to reach a confident structural assessment. The result is that many roofs are heavily altered or replaced.

The thesis investigates the extent, nature and condition of seventeenth- and eighteenth-century timber roof structures in Scotland in order to raise awareness about their value and contribute in improving conservation practice. A database of 1500 Scottish buildings of the period has been created and a representative sample of 59 original timber roofs has been surveyed. Archival research has also been carried out. This has allowed tracing the historic development of seventeenth- and eighteenth-century timber roof structures in Scotland and demonstrating that they form a heritage of great extent and quality. For the first time overall structural arrangements, construction methods and details, the species and quality of the timber employed, the role of architects, wrights and patrons in the design process and foreign influences have been comprehensively described and classified. The data gathered during the surveys has also been used to identify typical pathologies and possible causes for each roof structural typology. Moreover, the assessment techniques used during the surveys have been evaluated in terms of effectiveness, reliability, costs and training needed, in order to inform specific training for conservation professionals.

1 Introduction

1.1 Context and Background

This thesis researches the conservation of seventeenth- and eighteenth-century timber roof structures in Scotland. It is part of a wider research on the conservation of Scottish architecture of the period being carried out by the Architectural Design and Conservation Research Unit (ADCRU), at the Architecture Department of the University of Strathclyde (Glasgow). The aim is to recognize the value of this important built heritage in an integrated and comprehensive way, beyond the usual external descriptions, and to contribute in improving current knowledge and conservation practice.

Despite the great extent and quality of seventeenth- and eighteenth-century architecture in Scotland - we have identified more than 1500 buildings of great value so far -, this heritage has not been sufficiently researched. Structural arrangements, construction techniques and materials are only partially known since most buildings of the period have only been researched concerning their external architectural composition, as discussed below.

Scotland is generally not mentioned in books discussing the history of European architecture; even very influential historians like Summerson (1953) consider this country to be characterized by a 'delayed development' until the Union with England in 1707, and state that after this moment Scotland must be treated as 'a provincial extension of the English school'. This lack of recognition is a consequence of the limited research carried out in the field of Scottish architecture, even though in the last thirty years scholars such as Dunbar (1978), Rykwert (1985), Howard (1995), McKean (2001) and Glendinning and MacKechnie (2004) have made significant efforts to raise awareness about the value of Scottish architecture and its distinct contribution in the European context.

These efforts have concentrated mainly on vernacular architecture (Naismith, 1985, Scottish Vernacular Buildings Working Group, 1992), Medieval and Renaissance architecture (Howard, 1995, McKean, 2001) and post-eighteenth-century architecture (McKean et al., 2000, Stamp and Sayer, 1999), leaving the great country houses and stately buildings of seventeenth- and eighteenth-centuries to be further investigated. Some studies of single buildings from this period have been published (Dunbar, 1972, Rowan, 1984), but very few contributions have specifically addressed this part of the Scottish heritage more comprehensively (Gow, 1995, Strachan, 2008).

The importance of many patrons, architects and builders has to be discovered yet, as there are only a few known names to which many of the buildings are attributed due to lack of further evidence. For example, more than fifty buildings are currently attributed to Robert Adam (Rykwert, 1985), only because the period and design style match his own. Only recently the contributions of less known architects like Allan Dreghorn (Lewis, 2015) or John Douglas (Theodossopoulos, 2015), mason-architects like James Smith (González-Longo, 2012) or John Mylne (Harding, 2012) and other less known builders (Lewis, 2006) are being investigated in more detail. Wrights (carpenters in Scotland), in particular, have not been considered worth researching and to date, despite a substantial recent contribution by Newland (2012b), little is known about their relation with architects and their role in the design process.

Moreover, research so far has concentrated mainly on stylistic and architectural features rather than on construction techniques and materials. Contributions to Scottish construction history are in fact very few (Bell, 2004, Gonzalez-Longo and Theodossopoulos, 2012, Jenkins, 2012, Scottish Vernacular Buildings Working Group, 1976, Walker, 2006). No comprehensive research has been published so far on structural aspects of seventeenth- and eighteenth-centuries Scottish architecture: overall structural arrangements and elements still have to be identified, their evolution traced and their condition assessed, in order to encourage their conservation. Some scholars have investigated single structural elements, like timber roofs (Hanke, 2006) or stairs (Simpson, 2007), but the extent and condition of these structures is still uncertain. It is also important to understand if these structures have been designed and built in a vernacular way, and what are the factors that drove their design, such as architectural fashion of the time and availability of materials. The migration of technical knowledge is another crucial aspect: seventeenth- and eighteenth-centuries saw the emergence of professional architects that travelled and studied in Italy, France, and other European countries (Nenadic, 2012). Some foreign influences in Scottish architecture have in fact already been traced (González-Longo, 2012, Howard, 2001, Ottenheym, 2007), but related to architectural design rather than construction techniques and materials.

The development of construction techniques goes hand in hand with the development of architectureas any design change demands for a change in construction methods. This is particularly true for roof structures since the span that a roof structure can achieve necessarily restrains the width of the space that can be built below it. Nevertheless timber roof structures emerge as a neglected topic of research, even because they are often hidden behind decorated ceilings. The result of this lack of knowledge on their extent and nature is that their value is not appreciated and many of the original roofs are replaced with new structures and irredeemably lost.

Some research on the use of timber in Scottish architecture has been published (Apted, 1966, Bell, 2004, Crone and Sproat, 2011, Peddie, 1883) but there has been little focus on its structural role,

particularly in roofs. Medieval open roofs have been widely discussed (Crone and Fawcett, 1998, Crone and Gallagher, 2008, Gomme, 2002, Oldriev, 1916, Stell and Baillie, 1993), but roofs hidden behind timber and plaster ceilings, which, according to Hay (1976), Ruddock (1995), Stell (2004) and Hanke (2006), represent the vast majority, have been mostly forgotten. Despite the above mentioned contributions and few more (Crone et al., 2004, Peddie, 1883) we are still unable to say what is the extent and nature of original Scottish timber roofs because the research to date has focused on a restricted chronological and geographical frame and has drawn more on archival documents than on in situ inspections. In particular, very few post-1650 Scottish roofs have been studied making it difficult to assess how structural carpentry has evolved during the important architectural developments of late seventeenth century and eighteenth century. Moreover, little attention has been paid to details such as joints between elements, dressing of the timbers, carpentry marks, and very few seventeenth- and eighteenth-century roofs have been dated with dendrochronology so far. This lack of knowledge makes it difficult to confidently trace a historic development of Scottish roof carpentry.

Even less research has been carried out on the present condition of these structures: very few examples can be found in literature (Murdoch, 2010, Oldriev, 1916, Ruddock, 1995). Research on conservation of Scottish built heritage has been published mostly by Historic Environment Scotland (HES) in the form of technical reports and papers - only few contributions on the assessment of Scottish built heritage have been published by professionals (Gonzalez-Longo, 2008). However, most HES publications focus on upgrading and improvement of historic buildings (Fabian and Dobbie, 2014) - especially regarding energy efficiency (Snow, 2013) -, rather than their condition assessment. Moreover, investigations are either focused on historical and stylistic aspects (Historic Environment Scotland, 2014) or on very technical ones (Baker, 2008), often lacking of a more comprehensive and interdisciplinary approach.

Listings by Historic Environment Scotland mention roof structures very rarely, making it difficult to limit and control interventions carried out on this part of the building. Owners, building managers and professionals taking care of the building maintenance do not always recognize the importance and value of their roof structures, although the integrity of any building largely depends on the protection given by its roof. Consequently inspections and maintenance works are not programmed regularly, accessibility and visibility requirements are often not met and works are poorly documented.

On the other hand, a lack of specific training for conservation professionals makes it difficult for them to reach a confident structural assessment and carry out punctual and effective interventions. The assessment of historic timber structures can be challenging, since the material is organic and has variable properties. Although recent research (Dackermann et al., 2014, Kloiber et al., 2015b, Riggio

et al., 2014, Tannert et al., 2014) on the assessment and diagnosis of historic timber structures has made impressive progress, developing many non-destructive and semi-destructive testing methods which can help reducing the assumptions made, professionals in many countries still rely mainly on traditional methods and past experience (Feio and Machado, 2015). This is because the available testing and modelling methods require considerable skills and experience and can be expensive and labour intensive (Machado, 2013). Moreover, many countries do not have the relative regulations and standards (Augelli, 2014) and do not provide the necessary training, as is the case in Scotland. In some cases these challenges have been successfully resolved but these experiences have not been sufficiently analysed, discussed and shared in order to inform other projects. The result is that sometimes the impossibility to reach a confident structural assessment forces engineers to 'stay on the safe side' and carry out unnecessary or over-dimensioned interventions, or completely replace the structure, depriving future generations of part of this important heritage.

1.2 Aims and Objectives

The thesis aims to contribute in improving both current knowledge and conservation practice of seventeenth- and eighteenth-century timber roof structures in Scotland. This aim is pursued by researching about the extent, nature, value and condition of these structures, by assessing current conservation practice and by identifying reliable and effective state-of-the-art methods and tools that can be used for their initial assessment and are accessible to the majority of professionals.

The intent is to demonstrate that seventeenth- and eighteenth-century timber roof structures in Scotland form a heritage of great extent and quality whose study can contribute to the understanding of the history of European carpentry. These roofs are an important and integral part of the buildings they cover, both from a historic and architectural point of view and in structural terms. It is thus imperative to adequately conserve them in order to secure the knowledge of future generations and to ensure long life to the buildings they are part of.

The research also aims to demonstrate that currently these structures are not always adequately conserved. The reason is that their value is seldom recognized but also that professionals who take care of the built heritage are not adequately equipped with the knowledge and skills necessary to deal with historic timber structures. State-of-the-art methodologies and instruments for the in situ assessment of historic timber structures remain to date largely employed in academic research only. The thesis aims to demonstrate that they can be partly implemented by a wider range of users even with a limited knowledge in the field if targeted training is provided. This would certainly improve current conservation practice as it would allow reaching a more confident assessment of the existing

structure, which is the fundamental basis to proceed with the design of the necessary alterations, repairs or strengthening interventions.

In order to reach these aims, specific objectives have been pursued:

- Identify seventeenth- and eighteenth-centuries buildings in Scotland and gather all available information on their location, typology, geometry, design, history;
- Understand what types of timber roof structures were used in their original design and later alterations;
- Assess their extent and condition and identify typical pathologies and possible causes;
- Assess current conservation practice of these structures in Scotland (skills, methods, tools, etc), to understand what can be improved;
- Evaluate the reliability and effectiveness of state-of-the-art assessment techniques in this context and identify the knowledge and skills needed to implement them.

1.3 Methodology

A methodology has been devised to pursue the above-mentioned objectives. This introductory section details on the structure of the adopted methodological approach to provide a general context for the extensive discussion on specific methods hosted in chapter 2.

The founding step to this research project consisted in identifying buildings of the period and in gathering the available information on their location, typology, geometry, design, history and condition. While a large amount of information is available in online databases, such as HES (Historic Environment Scotland website - Designations, 2016), RCAHMS (Canmore website - Sites, 2016) and BARR (Buildings at Risk Register website - Buildings, 2016), these resources are not searchable based on any parameter other than the building name and location. It was thus necessary to create a new searchable resource. To do this, the author, in collaboration with another colleague at ADCRU, developed a novel relational database using Microsoft Access, that allows storing, querying and analysing a large amount of data, and ArcGIS software, that allows mapping the data to geographical locations. The database has been fed with information collected from HES, RCAHMS and BARR databases and existing literature on Scottish architecture, including unpublished work (Hanke, 2014, Rock, 2015) (Figure 11).

As expected, a lack of information on timber roof structures emerged and it was therefore necessary to carry out fieldwork on a selected a sample of reference buildings in order to collect first hand data on the roofs' construction techniques, typologies and present condition. The buildings were selected

amongst the 1500 identified and included in the database, with the help of a series of queries based on criteria that will be detailed in the next chapter. Briefly, the sample includes buildings of a certain scale designed by architects, because they have been less investigated so far. Amongst these, buildings that represent key moments in Scottish architectural history have been selected. In addition, in order to identify the buildings more likely to retain the original timber roof structure, the availability of information on roof structures and wrights and the preservation of original features have been considered. Finally, buildings were chosen based on accessibility.

To plan the surveys, the owners of 140 selected buildings were contacted. Among them, 80 replied, but some replied too late for a visit to be arranged and some others denied access to their roof space. Eventually, 28 buildings or groups of buildings were surveyed during summer 2014 (Figure 11).

Following the methodologies proposed by Cruz et al. (2015) and Riggio et al. (2014), surveys were preceded by a desk study aimed at gathering all the necessary information on the buildings. Then, a preliminary visual and measured survey was carried out (Figure 11). During these surveys, a series of fixed parameters were recorded in order to compare the structures and draw conclusions from a historical, typological, technological and structural point of view. Namely, these parameters include: roof form and geometry, type of internal structural arrangement, type of connection with the supporting structures, elements' scantlings and section shape, timber dressing, type of joints and fasteners, timber species, roofing material and fasteners, carpentry marks, evidence for reused timber. A preliminary condition survey was also carried out recording if the roof space was in use, the accessibility conditions, the presence of decorative features, unfavourable environmental conditions (poor ventilation, etc), poor maintenance, past alterations and repairs and signs of mechanical damage (deformations, cracks, etc) and material degradation (fungi/insect attack, etc). These initial surveys were carried out using a measurement tape, a laser meter and a digital camera.

Whilst carrying out the surveys, the online catalogue of the Scottish Archive Network (SCAN, 2015), that allows to search all the documents available in Scottish archives, was searched for documents related to the surveyed buildings and wrights of the period (Figure 11). A list of all retrieved documents is included in Appendix E and F. Due to time constraints, the archival research was limited to Glasgow and Edinburgh archives (NLS, NRS, RCAHMS, ECA, EUL, ML) and to some of the building owners' own records. The consulted documents include accounts, estimates, minutes, correspondence, pictures and drawings related to seventeenth- and eighteenth-century wright work. In addition, documents related to St Mary's incorporation of wrights were also consulted. A full list of the consulted documents is included in Appendix G, whilst the transcriptions are included in the surveyed buildings forms (Appendix E and F). Despite being very limited in number, the consulted documents including useful information on roof structures and wrights have allowed to date some

roof structures and past interventions. At the same time, these documents provide a basis to start understanding the design process and the role of architects and wrights. Other potentially interesting sources of information have been identified for future research; a list is provided in Appendix D.

The experience and knowledge acquired during the surveys have been used during a Short Term Scientific Mission (STSM) at the IVALSA institute (San Michele all'Adige, Italy) to further develop a structured form produced by the members of COST Action FP1101 to assist the survey and analysis of historic timber roof structures (Riggio et al., 2015a) (Figure 11). The COST Action members had already defined specific objectives and drafted a form using Microscoft Word software. The STSM work focused on reorganizing the contents of the form in both format and structure using Microsoft Access software in order to allow for the analysis of a large amount of data. Classifications of types of roof structures and mechanical damage were also developed and integrated within the form, along with graphics to support the relevant terminology (Figure 11).

The parameters and classifications included in the form were used to guide further surveys carried out in summer 2015. This second survey round considered a sample of buildings chosen based on the previous analysis. In particular, major developments in roof carpentry, leading to buildings with big internal spans, were observed during late seventeenth- century and early eighteenth-century. Therefore, the 2015 selection included buildings of this period with big internal spans. These buildings were identified by analysing plans and sections found in literature and in RCAHMS. In addition, the 2015 selection also considered buildings where access to the roof space had already been granted in 2014. Other criteria such as travel cost and accessibility were considered. Overall, 25 buildings were visited during summer 2015 (Figure 11).

In total, 53 reference buildings or groups of buildings were surveyed. Amongst these, 44 only retained one or more seventeenth- or eighteenth-century roof structure (a few examples date from end sixteenth century) for a total of 59 roof structures surveyed. The surveys were useful to validate the form produced during the STSM and to adjust it to the research purposes. The analysis of the surveys output, together with the information retrieved from archival research, lead to the first identification and dating of different roof structural types of the period, along with a diagnosis of their typical pathologies and possible causes.

In order to understand if these pathologies are adequately addressed by current conservation practice, past alterations and repairs identified during the surveys and in literature were analysed and evaluated. Since past works are often poorly documented and very few examples are published in literature, the assessment of conservation practice on Scottish roofs was complemented by questionnaires and interviews aimed at understanding what are the current approaches of building

owners and professionals. An online questionnaire was sent to the owners, users or managers of the surveyed buildings (Figure 11) to understand their approach to the maintenance and documentation of the building. Three conservation engineers were interviewed (Figure 11) to investigate what kind of know-how, skills and approach these professionals exercise when assessing a timber roof structure and how they choose, design and carry out the necessary repair works. Two engineers were selected amongst the most mentioned for repair works in the database, and one was selected because he works for HES, the lead public body taking care of Scottish built heritage. An online research and e-mail exchanges with some course directors was carried out to ascertain what postgraduate and training courses are offered to professionals such as engineers, architects, and craftsmen to acquire specific knowledge about conservation of timber structures.

This work highlighted that current conservation practices in Scotland can be improved by the introduction of specific training for conservation professionals dealing with historic timber structures. In order to understand what the focus of this training should be, more deatailed investigations were carried out in 8 case studies (Figure 11). These investigations were also aimed at learning more about the present condition of the roof structures. The methodology of this further investigation has been devised considering the available resources and the state-of-the-art tools, methods and standards for the assessment of historic timber structures (Figure 11). The timber species and quality have been investigated, along with the environmental conditions of the roof space, hidden parts of the structure and the residual resisting section of the timbers. Further archive research was carried out to find information related to the original construction and later alterations of the roof structures. The structured form was expanded to accommodate the new data.

The case studies were selected amongst the surveyed reference buildings based on criteria of representativeness (roof structure type and date, creating a homogeneous spread amongst the identified types and the two centuries considered), accessibility (geographical location limited to the Scottish central belt, visibility of roof structure and easy access, owner's permission to carry out tests) and availability of other sources of information (archive material and dendrochronological analysis). Buildings with more than one roof structure were preferred. Buildings owned or in care of Historic Environment Scotland were included to understand if the same methodology is applicable to non-privately owned buildings.

The detailed investigations on the case studies allowed an initial assessment of their current condition and, most importantly, they allowed understanding which testing techniques are most reliable and effective in the assessment of these structures. As detailed in chapter 5, the equipment used has been evaluated and compared considering the costs and the knowledge and skills needed for the on-site operation and the interpretation of results.

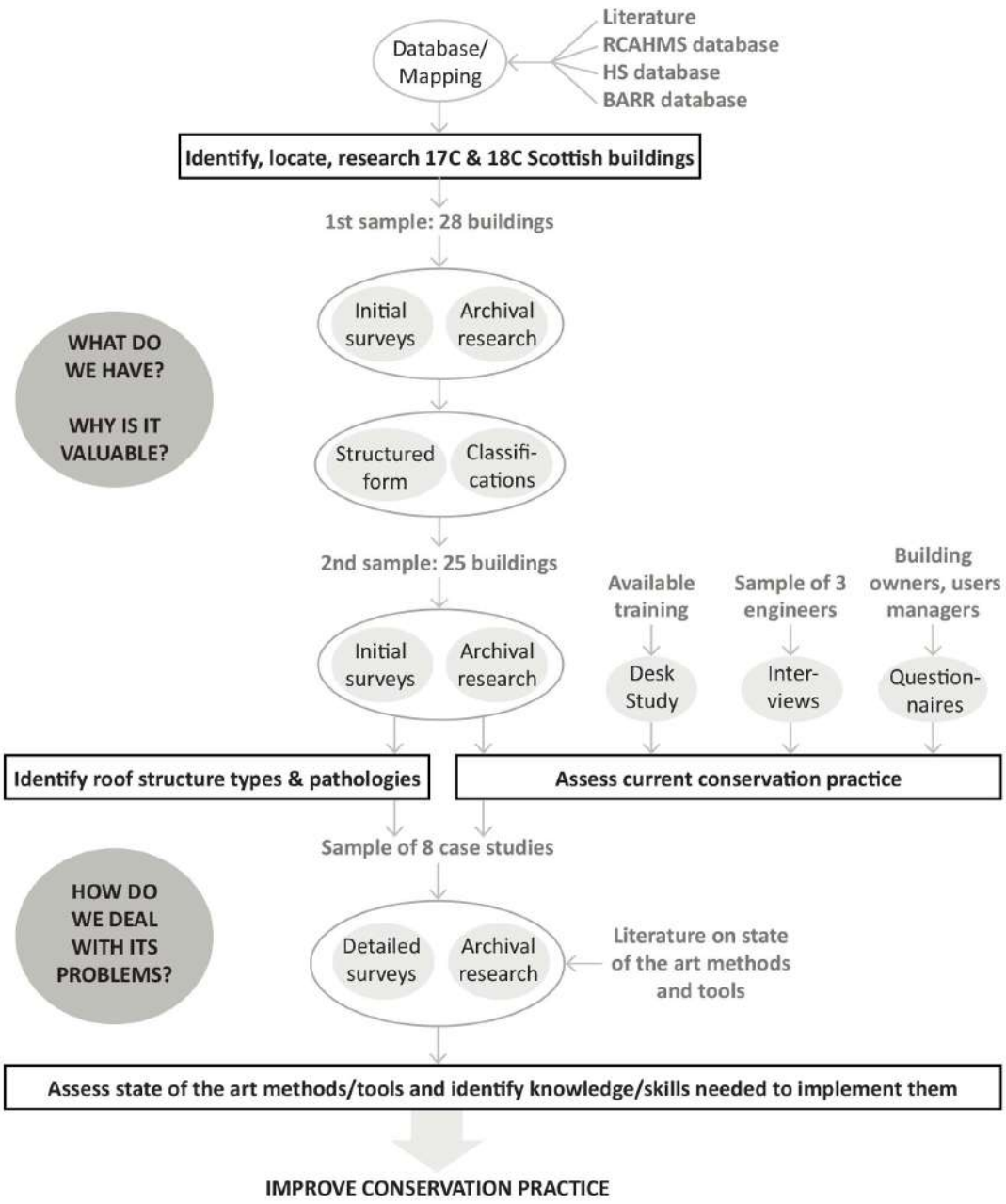


Figure 11: The research methodology employed in this thesis

1.4 Research Limitations

As previously explained, the research investigates a small sample of 53 buildings selected amongst the 1500 identified. Every effort has been taken in selecting the most representative reference buildings and case studies, but it is still a limited sample and future research should focus on widening this sample. We hope the methodology set in the thesis will allow for this work to be continued. The sample of owners, managers, tenants and professionals who have participated in the

online questionnaire and have been interviewed is also limited if we consider all the figures involved in conservation projects (craftsmen, contractors, funders, etc).

The research has concentrated on double pitch roofs, the most common, although two shed roofs and two conical structures have been surveyed, because it was difficult to identify the shape of the roofs prior to the visits. Other structural typologies such as flat roofs and steeple roofs have not been included in the research because the considerable number of examples (Hanke, 2006) suggests they deserve to be treated in a separate study. Although there are a few examples of seventeenth- and eighteenth-century crucks (Crone & Mills, 2011) they have not been considered either because they are used in vernacular buildings only.

Time limitations prevented from consulting further archival sources. A complete list of the consulted archival documents is provided in Appendix G, while the information they contain about roof structures and wrights is provided in Appendixes E and F. A list of other sources of information that have not been consulted is provided in Appendix D.

Another important aspect to consider is that the surveys and tests have been carried out mostly by the author alone, only rarely assisted by another PhD student, as noted in the individual case studies. Both the author and the other PhD students had limited previous experience and knowledge in the field. Different results may have been achieved by more experienced people; this however reproduces the intention of the thesis to propose assessment methodologies for a wider range of users, not just specialists as it has been the case until now.

1.5 Structure of the thesis

Apart from this initial chapter, which sets the context, aims and objectives of the research, the thesis consists of 5 chapters: chapter 2 describes the methodology employed during the research; chapter 3 discusses the results of the research in terms of historic development of Scottish timber roofs; chapter 4 describes in detail the case studies; chapter 5 discusses the current conservaton practice of Scottish timber roofs and the results of the research in terms of the assessment of the condition of these roofs; chapter 6 covers the conclusions.

Chapter 2 reviews the available tools, methods and standards at European level for the assessment of historic timber roof structures and then clarifies the methodology used to pursue the research objectives. The sections follow the main steps of the research: the creation of a relational database, the initial survey of 53 reference buildings, the detailed survey of 8 case studies and the creation of a structured form integrated within the database, used to guide the surveys and analyse their results.

Chapters 3 discusses the results of the research in terms of historic development. The architectural context of seventeenth- and eighteenth-century Scotland is set and existing knowledge on timber roof structures of the period is discussed. The results of the research are then used to trace the development of seventeenth- and eighteenth-century timber roof structures in Scotland. Structural arrangements and construction details are discussed within the European context to identify distinct Scottish features and possible foreign influences, discussing the role of architects and wrights in the design process. These aspects are described in detail for each of the 8 case studies in chapter 4. along with the present condition of the structures, whose results are then discussed in chapter 5.

Current conservation practice of Scottish roofs is examined in chapter 5 by looking at the approach of building owners and professionals, affected by the lack of specific standards and training. The findings in terms of present condition and typical pathologies of Scottish roof structures are then presented, discussing the opinion of the interviewed conservation engineers, the results of the visual inspection in the 53 reference buildings and the results of the detailed assessment carried out in the 8 case studies. In the last section the assessment techniques used during the research are evaluated and compared and the skills needed for the initial assessment of timber roof structures are analysed in order to inform the design of specific training for conservation professionals. Chapter 6 summarizes the results of the thesis, giving recommendations for future research.

2 Investigating seventeenth- and eighteenth-century timber roof structures in Scotland: methodology

This chapter reviews the state-of-the-art tools, methods and standards in Europe for the assessment and conservation of historic timber roof structures and then clarifies the methodology used to pursue the research objectives. The review of available tools and methods includes visual inspection, visual strength grading, non-destructive and semi-destructive testing and structural analysis. International and national standards are then reviewed, including Swiss and Italian standards, which are the most complete. Based on this review, a research methodology has been devised, as detailed in the subsequent sections: the creation of a relational database and related mapping of seventeenth- and eighteenth-century Scottish buildings, the measured and condition surveys of a representative sample of timber roofs, the archival research, the detailed investigations in 8 case studies, the establishment of specific classifications and the creation of a structured form integrated within the database, used to collect, report and analyse all the research data.

2.1 Review of the available tools, methods and standards in Europe for the assessment of historic timber roof structures

The decision over what should be conserved of a historic structure and how it should be conserved entails a thorough understanding of its value and present condition. Evaluating existing timber structures is particularly challenging because timber is an organic material: it is heterogeneous and anisotropic and consequently its properties are highly variable; it is vulnerable to biological attack and very sensitive to moisture, thus characterized by large shrinkage and swelling coefficients; its natural features (knots, shakes, etc) can strongly affect the strength and distribution of stresses.

This high variability requires a multidisciplinary approach and a broad knowledge of disciplines spanning from biology to mechanics. The most recent research on the assessment of historic timber structures is reviewed below, looking at methods, tools and standards available, and discussing their principles, purpose, reliability, drawbacks and limitations.

The evaluation of the present condition of existing timber structures involves the identification of the extent of damage, material degradation and natural defects, and the determination of the mechanical properties of wood. All of these aspects influence the behaviour of a timber structure and therefore must be included in the structural anlaysis carried out to evaluate its safety.

It is important to combine results from different sources in order to make the most reliable estimations: the state-of-the-art methodology involves in fact a good coordination between visual inspection, visual strength grading (VSG), non-destructive (NDT) or semi-destructive (SDT) tests carried out in situ and in laboratory, and structural analysis (Cruz et al., 2015, Feio and Machado, 2015). The visual methods and the in situ and laborastory tests are used to gather information about the roof structure that can then be used to carry out a structural analysis and evaluate its safety. It is an iterative process rather than a linear one because the structural analysis must be continuously updated with the information gathered during the surveys (Cruz et al., 2015, Feio and Machado, 2015). A preliminary assessment informs a first structural analysis to identify highly stressed areas that need to be further investigated (Figure 12). Once these investigations are carried out, the structural analysis is updated and used to verify if the structure complies with the ultimate state requirements (Figure 12). If it fails, a more detailed survey (using other tests) must be carried out and the structural analysis updated again (Figure 12).

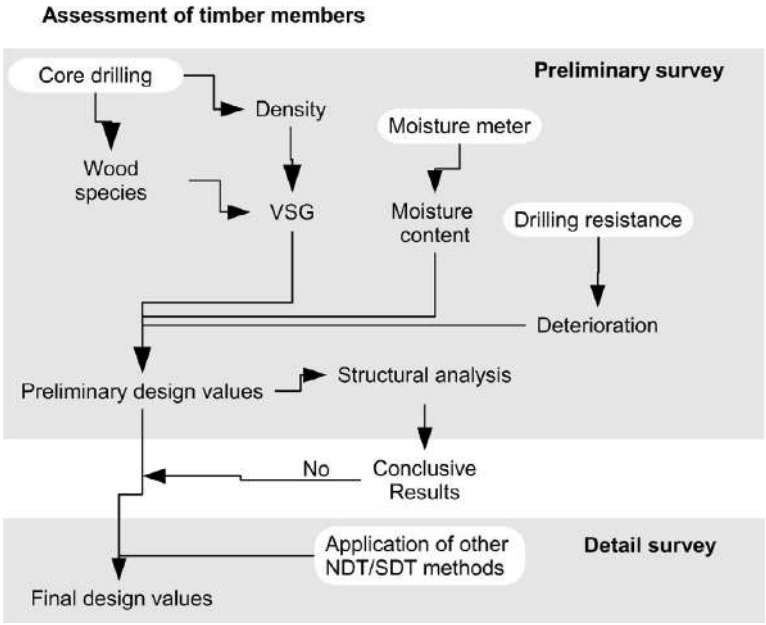


Figure 12: Methodology for the assessment of existing timber structures (Feio and Machado, 2015)

We know the type of data that we need to collect during an inspection and the tools that can be used to collect it, but only recent research has looked into how this data can be reorganized in order to ensure the most reliable assessment. The use of regression models (Machado, 2015), artificial neural network (ANN) models (Feio and Machado, 2015), Bayesian methods (Sousa et al., 2015) and

other types of data analysis (Sandak et al., 2015b) is proposed, but these are still under study as many variables are involved. All publications agree that the expert's opinion remains a crucial aspect in the final decision on the structure's level of safety.

We will know discuss in detail the different methods and tools mentioned above: visual inspection, Visual Strength Grading (VSG), non-destructive and semi-destructive testing in-situ and laboratory, structural analysis. Lastly, we will review the standards available for these methods.

2.1.1 Visual Inspection

Visual inspection is the basis of any structural assessment and its most important step. It is fundamental in the process of understanding how the structural system works and what is its overall health condition. The results of the visual inspection form the basis on which the need for further investigations is assessed and planned.

It comprises different levels of in-depth investigations (Cruz et al., 2015, Riggio et al., 2014). A preliminary visual, geometrical and technological survey is aimed at assessing accessibility conditions, identifying the structure typology and details, measuring overall and specific dimensions and identifying materials, loads and environmental conditions. Past and recent alterations and repairs must be recorded as well as any obvious damage and critical areas, in order to determine the need for emergency interventions and set a strategy for further assessments.

A further step comprises a more detailed visual survey aimed at identifying the extent and position of defects (knots, checks, shakes, slope of grain, etc), mechanical damage (cracks, deflections, etc) and material degradation (biological attack or fire damage), even in the supporting structures (walls) (Figure 13). Joints should be subject to a particular detailed survey, considering both their geometry (dimensions and position of fastener, elements' section reduction, etc) and condition, as even surface degradation may have a considerable impact on their performance (Cruz et al., 2015).



Figure 13: Example of graphics reporting results of visual inspection of a timber truss (Massari et al., 2010)

The assessment of defects, damage and degradation must include a thorough record of their position, extent and type, in order to decide if further investigations are needed. Natural features such as knots, shakes, deviated slope of grain, drying fissures, etc, as described by Tampone (1996), can considerably alter the structure's strength and overall behaviour. Material degradation caused by insects and fungi (Ridout, 2000), corrosion or humidity can reduce the resisting section of timber elements. Mechanical damage is indicative of how the structure is behaving and can allow us understanding what the primary causes of damage are. Different types of cracks, depending on the stresses applied, are discussed by Tampone (2007) (Figure 14).



Figure 14: Failure of a rafter caused by the instability of the strut and favoured by a knot in the rafter and the notch for the joint; the efficient connection of the rafter to the post is the cause of the bending of the post (Tampone, 2007)

2.1.2 Visual Strength Grading

Visual Strength Grading (VSG) can be used to assign strength classes or maximum loads to timber elements, based on the timber species and the natural features and defects assessed visually. Specific standards must be used: Feio and Machado (2015) and Cruz et al. (2015) suggest that if VSG regulations are not available in a specific country, grading rules used elsewhere for the same species can be used; if VSG rules are not available for a specific species, those applicable to species with similar density and modulus of elasticity can be used. The Italian Standard (UNI 11119, 2004) is used by researchers and professionals in many countries as it is the only one specific for grading in-situ historic timber (Feio and Machado, 2015), as we will discuss in section 2.1.6.

Recent guidelines (Cruz et al., 2015) integrate these standards by stressing that strength grading should be carried out in relation to the applied stresses: there is no point in grading a strut, which will only be loaded in compression, for characteristics that can only affect the ability of a member to resist bending. For the same reason, the knots' size allowance should vary depending on their particular position along the section and length of the element. It is proposed to apply different VSG approaches to each type of structural element:

- members subject to bending (ex: purlins): knots are more dangerous in areas of high bending moments and on the tension side; the slope of grain has more severe effects near the supports where shear forces are high; if there is load-sharing the timber mechanical properties should be increased by 10%.
- members in compression only (ex: posts, struts): the effects of defects are negligible.
- members in compression and bending (rafters, collars, posts with braces): defects are more dangerous in the area of maximum moment; this is true for the following two types of members as well.
- members in tension (posts in trusses): defects are critical only close to joints, fissures are not problematic.
- members in tension and bending (tie-beams, collars): all defects can be problematic; allowance must be made for the reduction in section produced by joints.

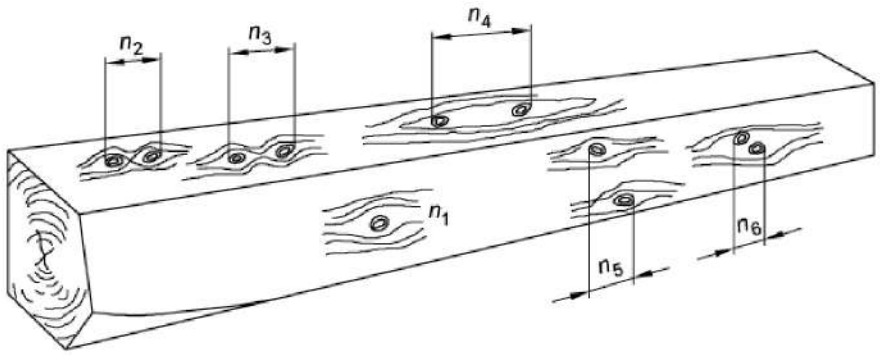


Figure 15: Knots classification according to UNI 11035 (2003): $n_1/n_3/n_5$ = single knots, $n_2/n_4/n_6$ = groups of knots

2.1.3 Non-destructive and semi-destructive testing

Visual methods are very powerful but they can be limited by the subjectivity and low experience of an inspector, reduced accessibility of the timber structure, internal features which cannot be visually assessed (Nowak et al., 2013) and lack of specific criteria in most national standards (Piazza and Riggio, 2008). VSG also requires the timber species identification, which is not always doable (Macchioni 2010). Moreover, the mechanical properties estimated through VSG are generally overly conservative and this can lead to the replacement/demolition of healthy elements (Feio and Machado, 2015). Therefore, even though visual methods must be the first step of any assessment, they are often not sufficient and need to be supported by in situ and laboratory tests.

Destructive tests can give a complete and reliable assessment. However, in the case of historic structures, non-destructive tests (NDT) and semi-destructive tests (SDT) (or minor-destructive, MDT) are preferred since the overall appearance and integrity of the structure is to be preserved. They can be Global Test Methods (GTM), providing large scale analysis, or Local Test Methods (LTM), providing punctual information. The information provided can be qualitative or quantitative.

Results obtained through local methods must be used to make inferences about the same parameters in other parts of the structure. This is clearly a disadvantage considering the high variability of timber. Extensive testing can partly solve the problem, but it is not possible in the case of semi-destructive tests, due to the disruption caused. Global methods would therefore be preferable, but local methods are necessary to obtain information such as the timber species, the moisture content, and the mechanical properties. Unfortunately most of the local methods are also semi-destructive.

Recent publications give a systematic overview of available testing techniques, looking at the equipment used and their applicability and limitations (Table 1). Unfortunately, many techniques have been developed for other materials (as GPR for concrete) or for trees (as Acoustic Tomography), and therefore are not configured for structural timber testing (Dackermann et al., 2014). Different devices doing the same test can give different results, because both the test procedure and the results interpretation require a lot of experience (Hasníková and Kuklík, 2014). There are often accessibility limitations that hinder the use of some bulky devices, such as the Resistance micro-drill (Tannert et al., 2014), while others are not on the market yet (Crespo de Antonio et al., 2016, Kloiber et al., 2015b). This is why NDTs/SDTs remain mainly academic (Machado, 2013), while most professionals rely chiefly on experience, even though this can lead to underestimating the structure's condition and replacing or over strengthening it.

Table 1: existing non-destructive and semi-destructive tests used on timber structures (dynamic/monitoring tests have not been included); regular = global testing methods*, italic = local testing methods; MOE = modulus of elasticity; MOD = modulus of deformability; MOR = modulus of rupture; CS = compressive strength*

TEST	Info obtained	Limitations	References
NON DESTRUCTIVE			
Thermography	Moist areas, hidden geometry, superficial defects	Qualitative and superficial; better results in heated environments (active thermography)	Riggio et al. (2015b)
Radiography	Internal condition, density	Density estimated; extent and depth of internal features not quantifiable; requires access to both sides; safety issues	Riggio et al. (2014) Lechner and Kliger (2015)
Photogrammetry	Geometry, visible condition	Superficial; accuracy depends on devices; requires good illumination	Riggio et al. (2015b) Arce et al. (2016)
Laser scanning	Geometry	Superficial; long post processing; expensive and bulky device	(Bertolini Cestari et al., 2013)

Detector dogs	Internal condition	Early stages of infestation not detected; extent and depth of internal damage not quantifiable; must be trained for each insect species	Zahid et al. (2012)
Microwave reflectometry	Internal condition	Good resolution only in first 20cm of depth; not effective with high moisture contents	Riggio et al. (2016)
Ground Penetrating Radar	Internal condition	Qualitative; extent and nature of internal features not quantifiable; not effective with high moisture contents; requires high expertise to interpret data	Riggio et al. (2014) Riggio et al. (2015b)
Acoustic tests: time of flight, tomography, echo	Internal condition, Dynamic MOE	Resolution depends on wavelength and distance between sources; early decay not detectable; requires species identification and moisture content measurement; requires density to estimate MOE	Dackermann et al. (2014) Llana et al. (2016) Machado et al. (2009)
Sounding with rubber hammer	Internal condition	Reliable only for extended damage; not effective for timbers with big sections	Ross et al. (1999)
Moisture content readings	Moisture content	Punctual in time, unless long-term monitoring in place; requires species identification	Riggio et al. (2014) Kasal and Lear (2010)
Endoscopy	Internal condition, hidden geometry	Needs access (holes or other)	Kloiber et al. (2015a)
Chemical analysis	Type and level of decay	In situ procedure only tells if the wood is affected or not: samples are needed to determine type of fungi	Brozovsky and Zach (2008)
SEMI DESTRUCTIVE			
Microscopic analysis	Wood species	Not always possible to identify specific species	Macchioni (2010)
Infrared spectroscopy	Type and level of decay, wood species, mechanical properties	Superficial; prediction model available for one species only	Sandak et al. (2015a)
Dendrochronology	Wood species, date and provenance	Not always conclusive in terms of dates and provenance; leaves 15mm ⌀ hole	Pignatelli (2010)
Resistance micro-drilling	Internal condition, Resistographic measure, preliminary dendrochronology	Low correlations with material properties; device dimensions reduce applicability; needle often deviates; leaves 3mm ⌀ hole	Tannert et al. (2014) Nowak et al. (2016) Kraler et al. (2012)
Needle Penetration	Internal condition, Density	Superficial; not very reliable for rectangular cross sections; material properties estimated	Tannert et al. (2014)

Hole drilling	Stresses	Device not on the market; results influenced by timber dressing and loading; material properties estimated; leaves hole	Crespo de Antonio et al. (2016)
Screw Withdrawal	Density, Shear strength, CS, MOE, MOR	Superficial; material properties estimated; leaves 3.9mm ⌀ hole	Kloiber et al. (2015b) Tannert et al. (2014)
Hardness test	MOE	Superficial; material properties estimated; leaves 10mm ⌀ hole; requires measurement of moisture content; device not on the market	
Core Drilling	CS parallel to grain, MOE, density	Leaves 10mm ⌀ hole; does not take into account influence of defects; underestimates properties due to misalignment; results not on site	
Tension Micro-specimen	Tensile strength, MOD	Superficial; invasive; high variability of results due to limited dimensions of specimen; does not take into account influence of defects; results not on site	
Pin Pushing	Internal condition, Density, CS	Material properties estimated; device dimensions limit applicability; leaves 2.5mm ⌀ hole; does not take into account influence of defects; requires species identification & moisture content measurement; device not on the market	
Loading Jack	CS parallel to grain, MOD	Leaves 12mm ⌀ hole; does not take into account influence of defects; device not on the market	Kloiber et al. (2015b)
Tension Meso-specimen	Tensile MOE	Superficial; invasive; does not take into account influence of defects; at least 4 samples per element needed; results not on site	

Most tests also have poor correlations with material properties and none of them give a complete description of the strength characteristics, therefore it is preferable to combine more than one technique together (Jasieńko et al., 2013). We will now discuss which tests can be used and combined together to assess the main characteristics of a timber structure: the geometry, the timber species, the environmental conditions, the residual resisting section and the mechanical properties.

2.1.3.1 Geometry

The geometric survey of particularly complex structures can be supported by close-range digital photogrammetry (Riggio et al., 2015b, Luhmann et al., 2014) and terrestrial laser scanning (Park et al., 2007, Kosciuk, 2012, Barber and Mills, 2011). Close-range digital photogrammetry is an optical method that derives the shape and location of an object from photographs of that object. It allows extracting three-dimensional metric models of objects in digital form (coordinates and derived geometric elements) or graphical form (images, drawings, maps) from photographic images taken

from different angles: the position and size of objects is calculated using triangulation based on the location a picture was taken and the size of a reference object in the image. It is called "close-range" because the object is at a distance of maximum 300m from the camera.

To reconstruct an object from images it is necessary to describe the light sources, properties of the surface of the object, the medium through which light travels, sensor and camera technology, image processing and further processing. Every image stores all of this information. For every image point, radiometric data (intensity, grey value, colour value) and geometric data (position in image) are obtained throught methods of image interpretation and measurement. The object is modelled from this information and a mathematical transformation between image and object space.

The fundamental mathematical model used by photogrammetry is 'central projecting image' (Figure 16): shape and position of an object are determined by rays joining each image point P' to the corresponding perspective centre O' (placed where the camera is); if the imaging geometry within the camera and the location of the imaging system in object space are known, every image can be defined in 3D object space. While the number of images can be unlimited, a minimum of two images is necessary: the object point can be located in three dimensions by intersecting two corresponding image rays. The accuracy of the restitution depends on the image scale, on the geometry of the acquisition scheme, on the accuracy of the interior and exterior orientation of the camera and on the light source.

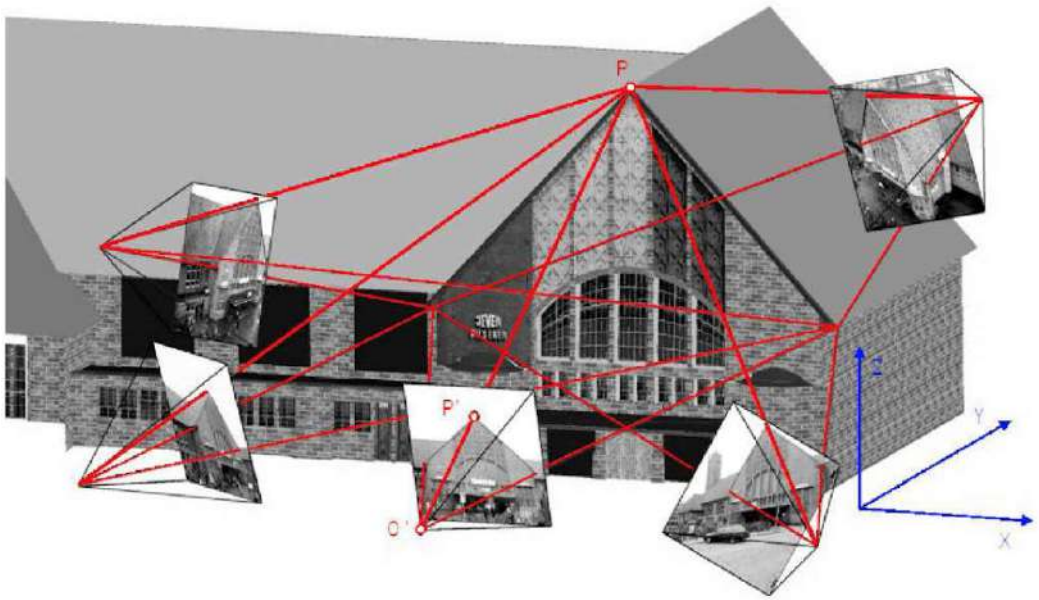


Figure 16: principle of photogrammetric measurement (Luhmann et al., 2014).

Photogrammetry can also be used to support VSG to detect defects, damage and distortions visible on the surface of the object. The photographs taken allow in fact creating a very accurate textural

database for the surfaces of the object: this can be used to analyse the superficial extent and position of material features and to extract, by image processing techniques, metric information of defects, damage and distortions.

Terrestrial laser scanning (TLS) has similar results but relies on the principle of pulsed time-of-flight measurement: the distance between the origin of the scanner's own coordinate system and the target is calculated based on the time the laser takes to travel from the instrument to the target and return; the distance is calculated based on the travel speed of the pulse. Scans from different locations are usually required to ensure full coverage of the object. 3D coordinates of points on the object's surface are collected automatically and in a systematic pattern at a high rate (hundreds of thousands of points per second). RGB values can be recorded too.

The result is a dense cloud of measured three-dimensional points. This cloud of points is transformed into a meshed model that must be manually edited. 2D drawings can also be generated by using the point cloud as a base from which features are traced; however, this is not an automatic process and requires skill and experience. The accuracy and loss of original data fidelity during the post-processing of the scans is variable, depending on the distance between the instrument and the measured points (it falls in range of 10^{-4} part of the measuring distance between a few meters and 100m) and the degree of automation of the postprocessing method.

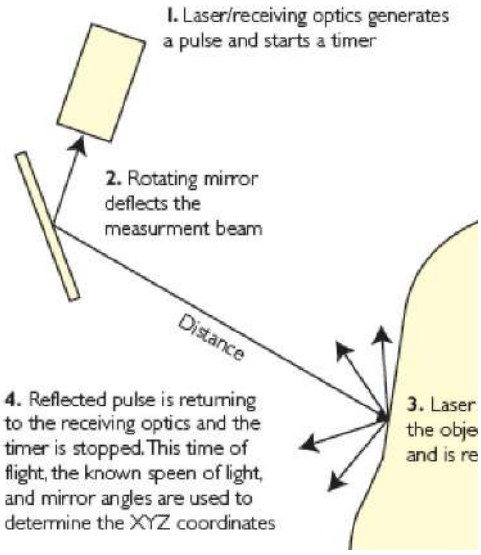


Figure 17: Schematic of time-of-flight laser scanning measurements (Bertolini Cestari et al., 2013, Park et al., 2007, Barber and Mills, 2011)

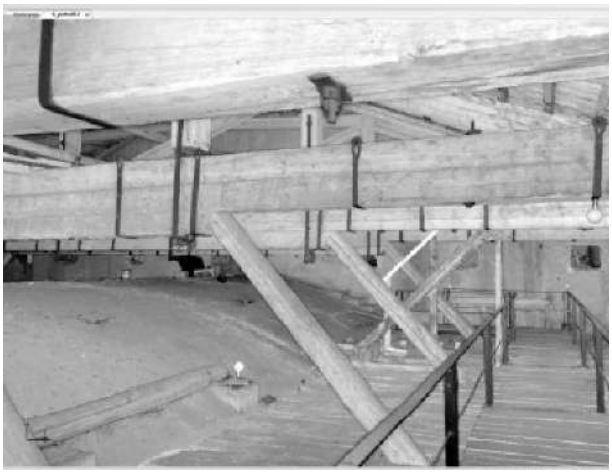


Figure 18: 3D laser scan model of a roof structure (Lamborghini et al., 2015)

Neither close-range photogrammetry nor terrestrial laser scanning are accurate enough for absolute measures, but they can be useful in identifying overall deformations and highlighting asymmetric

behaviours of a structure. Photogrammetry has the advantage of being relatively low-cost compared to laser scanning, and the post processing of data acquired is less time consuming. However, TLS is less sensible to light than photogrammetry and does not require the computation for coordinate information upon image acquisition. An example of the use of photogrammetry can be found in Arias et al. (2007). Examples of the use of laser scan can be found in Cescatti et al. (2014), Lamborghini et al. (2015) (Figure 18), Bertolini Cestari et al. (2015). The two techniques can also be combined as in Massari et al. (2010) and Arce et al. (2016).

Infrared thermography (IRT), also called thermal imaging, is a quick non-destructive test that detects infrared radiation emitted by objects, which increases with their temperature: every pixel in the image records a spot temperature (Riggio et al., 2015b, Young, 2014). Therefore it allows visualising and quantifying temperature variations across surfaces, that can be linked to moisture and water infiltrations, thermal bridges, voids, cracks or delamination, areas of heat loss or air leakage. It's a rapid method, non-destructive and non-contact.

IRT cameras for building thermography work with electromagnetic waves with wavelenghts between 8 and 14μm (that do not pass through glass: objects behind glass cannot be assessed). The resolution is usually not as high as that of photographic cameras: it varies from 60x60 pixels to 640x480 pixels. Their thermal sensitivity also varies, providing more or less detail in the resulting thermal image. For useful images to be recorded there needs to be a temperature contrast; it is thus sometimes necessary to wait for the sun to heat the surface to be assessed (outdoors) or to use an artifical heating source such as lamps or heaters (indoors). A certain period of heating is needed before thermal imaging is commenced, in order to allow time for the heat to penetrate the depth required. For the same reasons, windy and/or rainy conditions are not optimal for outdoors assessments.

We will discuss in section 2.1.3.3 the use of IRT to assess environmental conditions and superficial defects/damage. In this section, related to geometry, we are interested in its use for assessing the presence of hidden voids and the geometry of hidden structures: the IRT camera only sees the temperature of surfaces, but it can provide information about the deeper structure where this affects surface temperature. A good example of this application can be found in Cantini et al. (2013), where a vault is analysed through thermography to determine the position of the timber structure above it (Figure 20).

The internal geometry of joints can instead be investigated through x-ray radiography (Riggio et al., 2015b, Riggio et al., 2014, Kasal et al., 2010), resistance micro-drilling and endoscopy (Kloiber et al., 2015a). X-ray radiography was originally developed for medical imaging but it is used for in situ structures since 1960s. It is non-destructive as it uses soft x-rays (electromagnetic waves with wavelength between 10-8m and 10-12m) that are absorbed depending on the material density and

thickness. The object to be assessed is placed between the x-ray transmitter and the detector. The test result is a two dimensional x-ray attenuation image, such as the one in Figure 21, showing a wood to wood connection with an internal wood dowel. It is thus useful to detect internal heterogeneities, such as different densities, knots, connectors, material degradation etc.

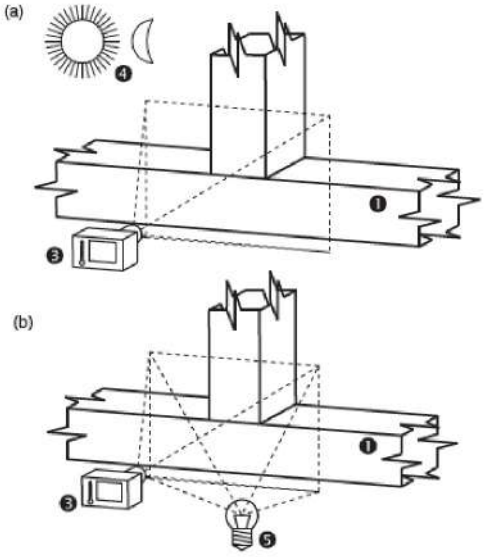


Figure 19: Principle setup for active (a) and passive (b) thermography (Riggio et al., 2015b).

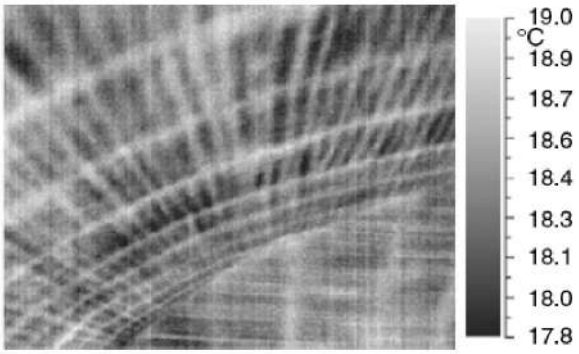


Figure 20: Thermographic image of a vault showing the timber structure behind the plaster (Cantini et al., 2013)

The image sharpness depends on how close the instrument is to the object surface and on energy levels of radiation. Lower energy radiation produces higher quality contrasts, but it is limited in its penetration ability and in he range of densities it can produce on an image. Radiography is not widely used because it has safety issues, it requires access to both sides of the timber element and does not always provide precise information on the extent and depth of internal features.

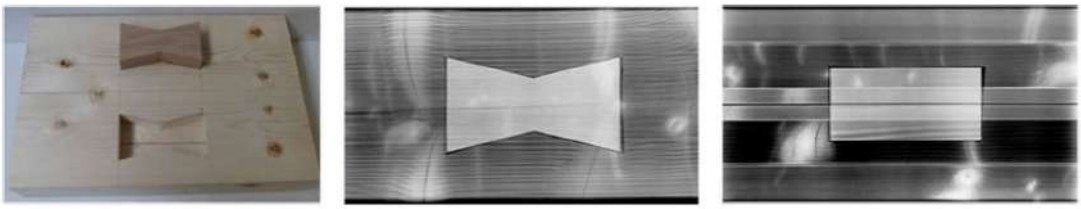


Figure 21: wood to wood connection in softwood with hardwood dowel, and the x-ray radiographies (Riggio et al., 2015b)

Resistance micro-drilling measures relative density profiles of wood by recording the penetration resistance of a thin needle (shaft diameter 1.5mm, tip diameter 3mm) into wood with constant penetration and rotation speed (Tannert et al., 2014, Jasieńko et al., 2013, Nowak et al., 2016, Rinn, 2012). It measures density profiles of wood and thus allows detecting and giving precise information

on the extent and position of decay, insect damage, cracks, defects and hidden geometrical features. Points of measurements and drilling angles have to be selected carefully, especially when inspecting joints, to avoid needle deflection. Ideally, the needle should penetrate the tree rings perpendicularly. The drills should be made also based on the desired assessment: for quantitative analysis, drilling patterns at regular intervals are necessary, while for geometry/defects/decay detection, drillings should be made at all locations where there are doubts about the wood internal condition. Each drill results in a density profile where areas of low resistance (drops and low points in the graph) correspond to areas of low density: decay, cavities, cracks (Figure 22). Profiles should be interpreted and evaluated immediately in situ: if a profile cannot be explained, further drillings should be made.

Resistance micro-drilling is certainly one of the most used tests to determine the internal condition of structural timber and joints as it is very reliable and quick. It has been proven to be useful also for preliminary dendrochronological analyses (Kraler et al., 2012). It is however semi-destructive and punctual and there can be accessibility issues caused by the fact that the instrument is heavy and bulky. Examples of use of the resistance micro-drill test to detect internal features in wood can be found in Palaia et al. (2008), Frontini et al. (2015), Bajno et al. (2015), Wang et al. (2013), Massari et al. (2010), Vilches Casals et al. (2015), Riggio et al. (2016).

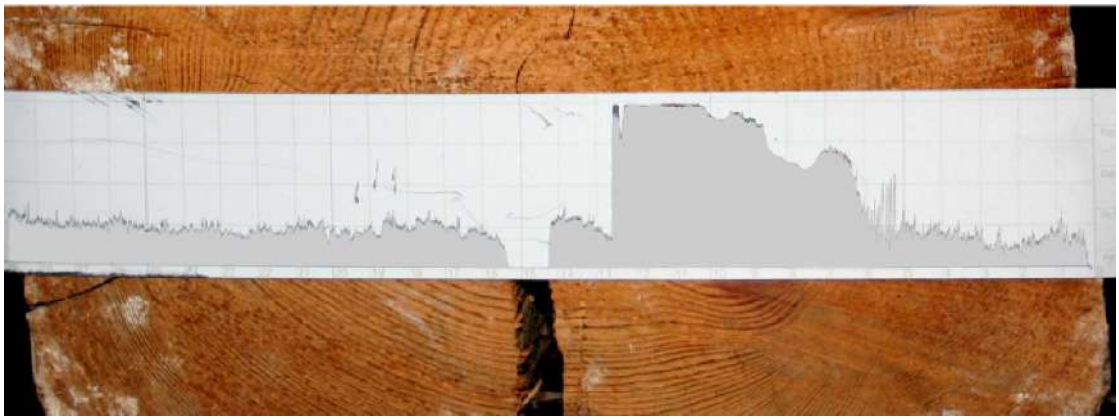


Figure 22: Example of graph resulting from the Resistance micro-drilling test (Nowak et al., 2016)

Local introspective analysis can be performed using endoscopy. The endoscope probe is inserted in small cavities and allows inspecting the condition of wood in inaccessible areas, for example when detached decorative layers hide it. It can be used also to check the presence of appropriate ventilation at beam ends. The inspected area is displayed on a monitor and both pictures and videos can be recorded during the inspection (Riggio et al., 2016). Existing openings can be used to carry out the test, otherwise openings can be expressily made, as in Kloiber et al. (2015a) (Figure 23).



Figure 23: Example of pictures taken with an endoscope inside a borehole in a timber strut (Kloiber et al., 2015a)

2.1.3.2 Timber species

The traditional procedure to identify the timber species is divided in three steps: sampling, macroscopic evaluation and microscopic evaluation (Macchioni, 2010). It is fundamental to carry out a correct sampling in terms of number, representativeness and dimensions of the samples, otherwise the macroscopic and microscopic evaluations can lead to partial or incorrect results. Therefore, the first step is to examine thoroughly the whole structure in order to assess its homogeneity in terms of species, looking at colour, vein, texture, and determine the need for sampling (Macchioni, 2010).

The macroscopic and microscopic evaluations use comparative techniques: characteristic aesthetical and anatomical features are identified in the three sections of a sample - transversal, radial, tangential - and compared with standards in a scientific atlas of wood species (Nardi Berti et al., 2006). The macroscopic evaluation can be carried out with a magnifying glass. A list of macroscopic features is provided by Crivellaro et al. (2016) (Figure 24). Unfortunately it rarely allows to a confident identification, especially in case of softwood. Thus it is often necessary to proceed with the microscopic evaluation by means of optical or electronic microscopes. Microscopic features are provided by Nardi Berti et al. (2006) (Figure 25). In some cases it is still necessary to terminate the identification at a level higher than the species within the botanic taxonomy.

Alternatively, radiography and tomography are used, especially for wooden artefacts such as paintings, where sampling is not feasible (Van den Bulcke et al., 2009). Automated imagine recognition techniques are used in the wood industry to analyse a great amount of samples more quickly (Hang-jun et al., 2013, Shuaiqi et al., 2015).

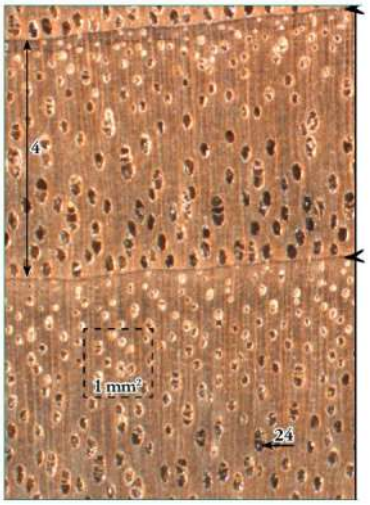


Figure 24: Example of identification of macroscopic features in the transversal section of a sample of Alder (alnus sp.); 4=semi-porous annual ring, 17=between 6 and 20 vessels per mm², 24=tyloses (Crivellaro et al., 2016)

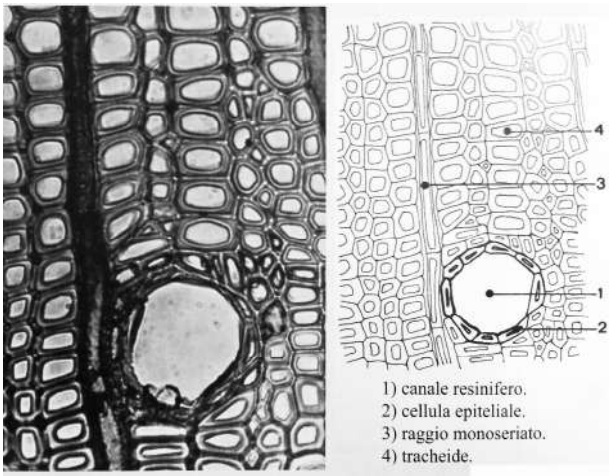


Figure 25: Example of identification of microscopic features in the transversal section of a sample of Douglas fir (pseudotsuga douglasii) (Nardi Berti et al., 2006); 1=resin canal, 2=epithelial cell, 3=uniseriate ray, 4=tracheid

2.1.3.3 Environmental conditions

As previously mentioned, timber is vulnerable to biological attack and it is very sensitive to moisture. The presence of biological attack strongly depends on the environmental conditions in which the structure is. Thermometers, hygrometers and thermal cameras can be useful in measuring the air temperature and relative humidity, the wood moisture content and in detecting humid areas.

Wood moisture content (MC) represents the proportion of water to the proportion of wood material [%]. The only direct method for determining MC in timber is to measure the quantity of water in a wood sample or the weight of the sample when oven-dry; it is however semi-destructive and time consuming. The alternative is to estimate MC in situ by means of indirect methods that use the relationships between MC and other measurable physical–chemical properties of wood: hand-held electric moisture meters using the resistance, capacitance or hygrometric method (Kasal and Lear, 2010, Riggio et al., 2014). The meters can be pin-less, taking measurements on the surface, or with pins, taking measurements at different depths, which is preferable although semi-destructive (Figure 26). Measurements must be calibrated based on wood temperature and species.

MC readings are necessary to carry out a correct VSG and to calibrate the results from NDTs/SDTs, but also to understand if there are favourable conditions for biotic attack. Environmental conditions can be quite variable, with daily and yearly changes. The best way to assess them is through long-term monitoring. However, even punctual measurements should remain inside a certain range in order to avoid biotic attack: air temperature should remain between 15° and 21° and the relative

humidity between 45% and 65% (Ridout, 2000). MC should never be too far from the equilibrium moisture content, calculated based on the air temperature and relative humidity (Figure 28), and it should always remain between 8% and 18% (Ridout, 2000). Only few specialized insects can survive moisture contents beneath 18%: beetles (that can survive up to 12%, a few up to 8%) and termites (in warmer regions). Fungi generally will not appear under 20% moisture content (Ridout, 2000).

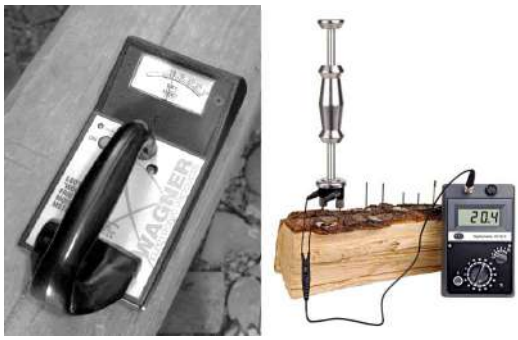


Figure 26: Example of moisture meter without pins on the left and with pins on the right

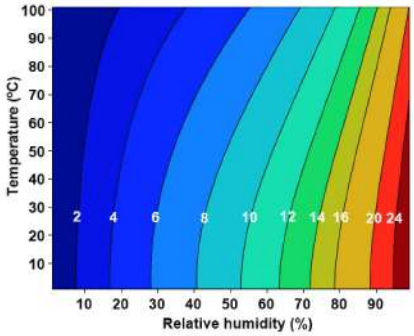


Figure 27: Equilibrium moisture content based on the air temperature and relative humidity (Ross, 2010)

Infrared thermography can be useful in spotting thermal bridges or areas with high humidity, caused by water ingress problems (Figure 28), as in Rodríguez Liñán et al. (2015), Morales-Conde et al. (2013), Riggio et al. (2016). It can also be used as support for VSG as in Colla and Gabrielli (2015) (Figure 29), especially if the timber surface is not visible (e.g. it is painted). Knots, shrinkage cracks and other fissures appear as colder features, or warmer if they are passing-through cracks. Results are however limited to the surface and can be affected by surface roughness/porosity and by environmental conditions (wind, temperature, etc). As previously discussed, active thermography in heated environments is in fact far more efficient than passive thermography in unheated environments (Riggio et al., 2015b).

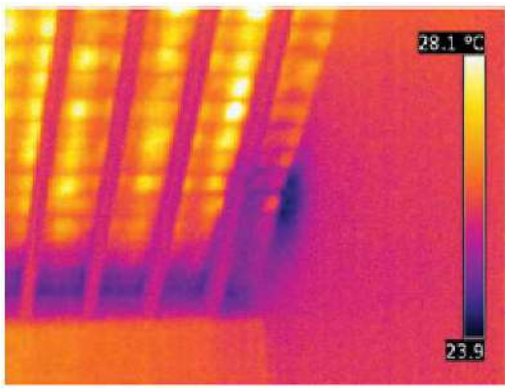


Figure 28: damp areas identified in thermographic imaging (Rodríguez Liñán et al., 2015)

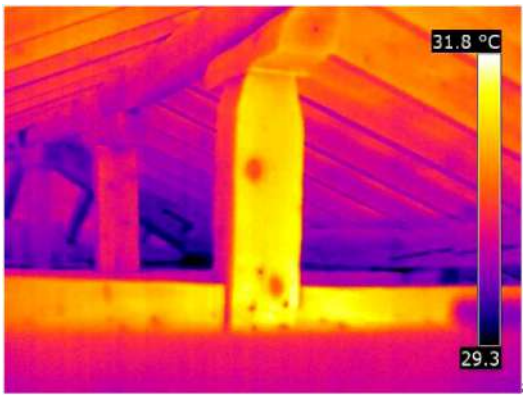


Figure 29: Thermographic image showing knots in a timber roof structure (Colla and Gabrielli, 2015)

2.1.3.4 Residual resisting cross section

Historic timber structures may show significant variation in the cross section geometry along the same element, as a result of both construction methods and deterioration. 3D laser scanning and digital photogrammtery can be useful to measure the cross section from outside, as discussed in section 2.1.3.1, but a reliable assessment of the internal condition of wood is fundamental to be able to estimate the overall dimensions correctly. Acoustic tests, resistance micro-drilling, x-ray radiography, detector dogs, ground penetrating radar (GPR), endoscopy, needle penetration and pin pushing can all provide information on the internal condition of timber elements, including natural defects, damage and material degradation (Table 1). Non-destructive methods (acoustic tests, x-ray radiography, detector dogs, GPR, endoscopy) are often used as screening tests to decide where to use SDTs.

Acoustic tests and resistance micro-drilling are the most used tests for this purpose. Resistance micro-drilling has already been discussed in section 2.1.3.1. Acoustic tests are of various types, ranging from the simple sounding with a rubber hammer, to time-of-flight methods, tomography and ultrasonic echo (Dackermann et al., 2014, Ross and Hunt, 2000, RILEM, 2010). The traditional method of sounding with a blunt object (typically a rubber hammer) is widely used to detect interior deterioration. Based on the tonal quality of the sounds resulting from the strike, large interior voids or decay can be identified. However, the test is highly subjective and high expertise is required to hear differences in the sounding because conditions other than decay can contribute to variations in the sound quality. Moreover, the test does not provide any quantitative information and is not effective for early or intermediate stages of decay nor for timber with big sections. An example of its use can be found in Frontini et al. (2015).

In order to address the drawbacks of traditional sounding various non-destructive testing methods have been developed. One of the most common and simplest is to measure the time-of-flight of sound waves, also called stress waves. Stress waves are induced by striking the specimen with an impact device instrumented with a sensor that sends a start signal to a timer. Another sensor, placed on the other side of the specimen, records the arrival of the propagating stress waves and sends a stop signal to the timer. This allows measuring the time needed for stress waves to travel accross the specimen. The velocity of the waves (V) is then calculated based on this time (T) and the distance (d) between the sensors:

$$V = \frac{d}{T}$$

Acoustic waves are of elastic type, hence they provide indications about the elastic properties of a material: their velocity of propagation is a function of Young Modulus of Elasticity (E), material

density (p) and Poisson coefficient (v). The wave velocity increases proportionally with the increase of the elastic modulus:

$$Vp = \sqrt{\frac{E}{p}} \frac{1 - v}{(1 + v)(1 - 2v)}$$

This means that waves with higher velocity identify denser, sound material, while slower waves identify degraded material, characterised by voids, cracks or decay. Wave velocity is also related to frequency (f) and wavelength (λ):

$$V = f \times \lambda$$

Wavelength (λ) is inversely proportional to frequency. High-frequency waves (ultrasonic) have shorter wavelengths: they detect smaller defects and thus have a higher resolution, but they are attenuated more quickly and thus cannot penetrate thick specimen or low density degraded material. Instead, low-frequency waves (sonic) with longer wavelenghts can cross thick specimen and degraded material, but are characterized by a lower resolution. The resolution of sonic signals equals to about one third of the wavelenght: the smallest detectable defect is greater than one third of the wavelength.

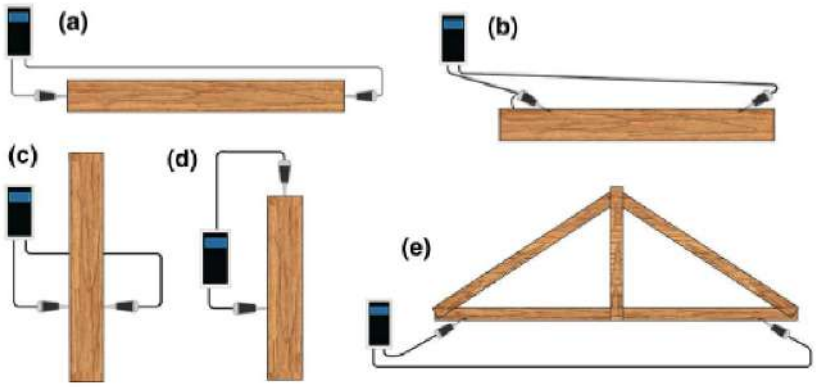


Figure 30: time-of-flight measurements in structural timber using different wave propoagation modes: direct longitudinal (a), indirect longitudinal (b and e), transverse (c), semi-direct (d) (Dackermann et al., 2014)

The velocity of stress waves is also affected by the moisture content and temperature (high MC causes an increase in propagation time while high temperature causes an increase in velocity) and by wood anatomy. Velocity is higher in grain longitudinal direction, where there are few or no boundaries to cross, and lower in grain transverse direction, where waves encounter numerous cell walls. For most structural members fibers of the wood align more or less with the longitudinal axis of the member. The test can be carried out in both directions and various modes (Figure 34:). For sound wood, longitudinal stress wave velocities generally range between 3500 and 5000 m/s,

depending on the timber species, while transverse stress waves fall in the range of 1000-1500 m/s. Reference velocities for various species can be found in literature (Dackermann et al., 2014) and compared with the measured velocity to assess the internal conditions of the timber specimen. The relative decrease ($\Delta Vrel$) between the reference velocity ($Vref$) and the measured one ($Vmes$) indicates the amount of decay between the two sensors:

$$\Delta Vrel = \frac{Vref - Vmes}{Vref} \times 100$$

Sonic and ultrasonic tomography uses the same method (time-of-flight) but with more sensors distributed on the surface of the specimen allowing to obtain cross-sectional or three dimensional imaging of the object (Figure 31). The number of sensors is nearly unlimited, allowing to adapt the resolution to case by case requirements. The wave propagation time, recorded for each pair of sensors, and the coordinates of the points where the sensors are placed, are the input data for the tomographic analysis. As shown in Figure 31, the received signal provides a projection of the object's internal conditions: the coloured lines in the 2D-tomogram indicate apparent stress-wave speed between sensor positions - green lines indicate intact and mechanically connected parts while red lines show areas where the waves traveled around an anomaly.

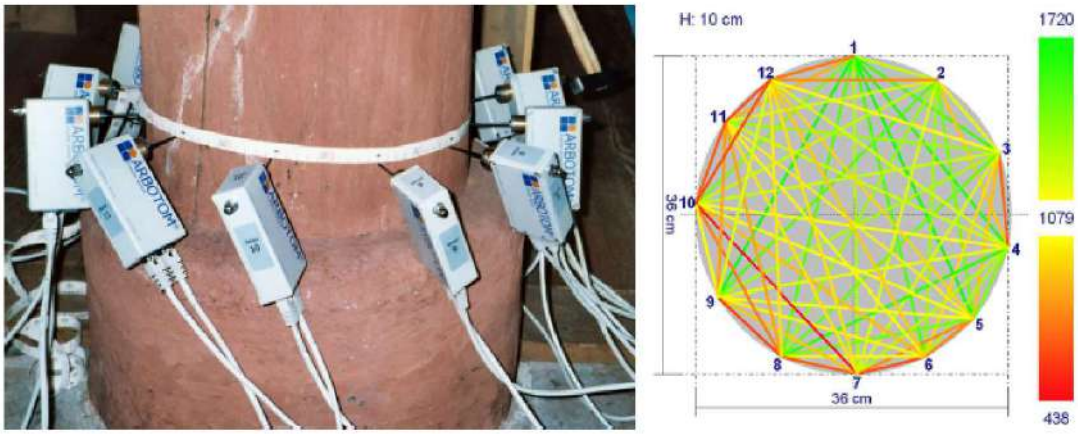


Figure 31: sensor chain for cross-sectional tomography (left) and 2D-tomogram of the timber post (right) (Dackermann et al., 2014)

After correcting the results for timber anisotropy (by relating the sonic pulse velocity in a generic direction inside the timber element to the pulse velocity in radial direction) iterative or direct inversion algorithms can be used for tomographic reconstruction: the result is a velocity map to which the timber section perimeter can be overalapped to ease interpretation (Figure 32). In the example in Figure 32 it appears that the average velocity through the section is low, below 1000 m/s, and only in limited areas, particularly at the centre and top, the recorded velocities seem to indicate sound material (Colla, 2015).

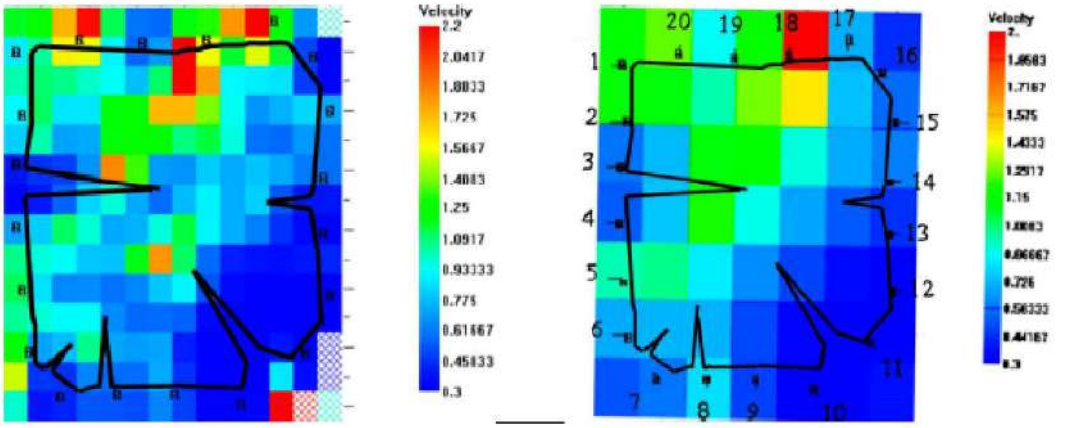


Figure 32: velocity model (14x14 pixels) of a timber section, corrected for material anisotropy, obtained from 5 iterations of straight type and 6 iterations of curved type; signal velocity legend from 300 to 2200 m/s (left) - velocity model (7x7 pixels) of the same timber section after 5 straight iterations and 5 curved iterations; signal velocity legend from 300 to 2000 m/s (Colla, 2015)

Tomography is time consuming and requires high expertise, but the resolution is much improved compared to simple time-of-flight methods. As in simple time-of-gflight methods, access to both sides of the specimen is required. The ultrasonic echo technique, on the contrary, can be carried out with one face of the specimen accessible only. It is in fact based on the reflection of ultrasonic stress waves on material inhomogeneities, such as the back surface of the investigated object (called back wall - this allows assessing the thickness of the object) or other interfaces such as a damaged area. During the measurement, a sensor placed on the object's surface emits a sonic wave which passess through the object and is reflected by the back wall. Any irregularity in the wooden structure changes the structure of the reflected signal, called back-wall echo.

Results of the ultrasonic echo technique are usually presented as A-scans (Figure 33 right) and B-scans (Figure 33 left). A-scans show the transmission time and intensity of the pulse, while B-scans are cross sections of the investigated object obtained by composing various A-scans recorded with a defined distance. B-scans enable to identify changes in signal structure along the measured axis: in Figure 33, for example, the back wall at 9.5cm and the knot at 4.5cm are clearly detected in the B-scan on the left. Other detailed tests need to be carried out in areas with no or an unexpectedly early echo from the back wall, because this can be a sign of damage. With the ultrasonic echo tenchique only it is in fact difficult to locate the exact position of damage within the specimen and to distinguish between one large irregularity and a cluster of small ones.

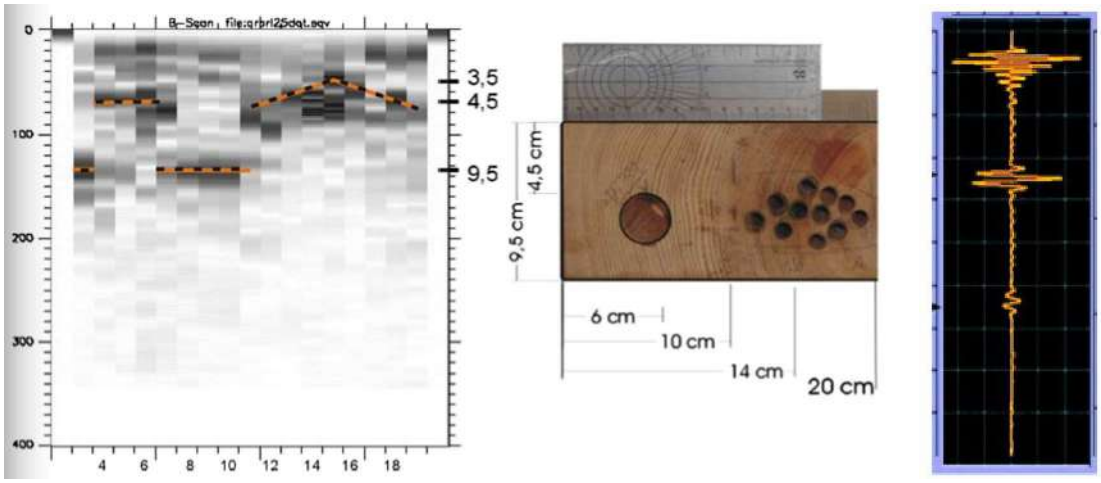


Figure 33: Example of elements investigated with the ultrasonic echo technique: in the centre a section of the investigated element (Dackermann et al., 2014), on the left an A-scan (Dackermann et al., 2014) and on the right a B-scan (RILEM, 2010)

In conclusion, acoustic tests are appealing because they are non-destructive. However, they cannot detect early decay and they require the identification of the species and the measurement of the moisture content to calibrate their results. Examples of use of acoustic tests can be found in Rodríguez Liñán et al. (2015), Cescatti et al. (2014), Morales Conde et al. (2015), Palaia et al. (2008), Colla and Gabrielli (2015), Bajno et al. (2015), Brozovsky and Zach (2008), Wang et al. (2013). Acoustic tomography is preferable as it is a global method, but it can be limited by attenuation or low resolution and the test set-up is time-consuming. Examples of use of tomography can be found in Imposa et al. (2014), Colla (2015), Riggio et al. (2015b) and Riggio et al. (2016).

X-ray radiography and endoscopy can also be useful to assess the residual resisting section, as already discussed in section 2.1.3.1. A very traditional technique uses detector dogs to detect insect infestation: they are very effective but only for the insect species they have been trained to identify (Zahid et al., 2012).

GPR is an electromagnetic (EM) technique based on the propagation and reflection of very short pulses (<10ns) inside the investigated object (RILEM, 2010, Riggio et al., 2014). An antenna in contact with the surface of the tested object moves along survey lines and emits EM signals into the object. These signals are reflected by interfaces between material layers with different dielectric properties. Measurements can be performed in reflection mode (one antenna used for both transmission and rececption of the signals) or transmission mode (investigated object placed between two antennas).

The propagation velocity and attenuation of EM waves are directly related to the permittivity of dielectric materials such as wood:

$$v = \frac{c}{\sqrt{\varepsilon}}$$

c is the propagation velocity of EM waves in free space, ε is the material dielectric constant or permittivity. The permittivity of wood depends on several parameters: moisture content, density, temperature, fiber direction and applied frequency.

Data recorded by GPR is visualized in real-time bi-dimensional images called radargrams: on the horizontal axis there is the distance covered by the antenna and on the vertical axis the signal reflection time. The vertical axis can be converted to depth (d) by knowing or estimating the dielectric constant of the materials or by knowing the thickness of the investigated element:

$$d = vt/2$$

v is the wave propagation velocity and *t* is the measured reflection time. By analysing the position and amplitude of the reflections inner defects and features can be detected. In the radargram in Figure 34, especially after applying a ground removal filtering (bottom radargram), metal carpentry and inclusions are clearly visible, as well as knots; the reflection of the rear side of the beam is also visible as a continuous line (b) parallel to the surface reflection line (a) (Colla and Gabrielli, 2015).

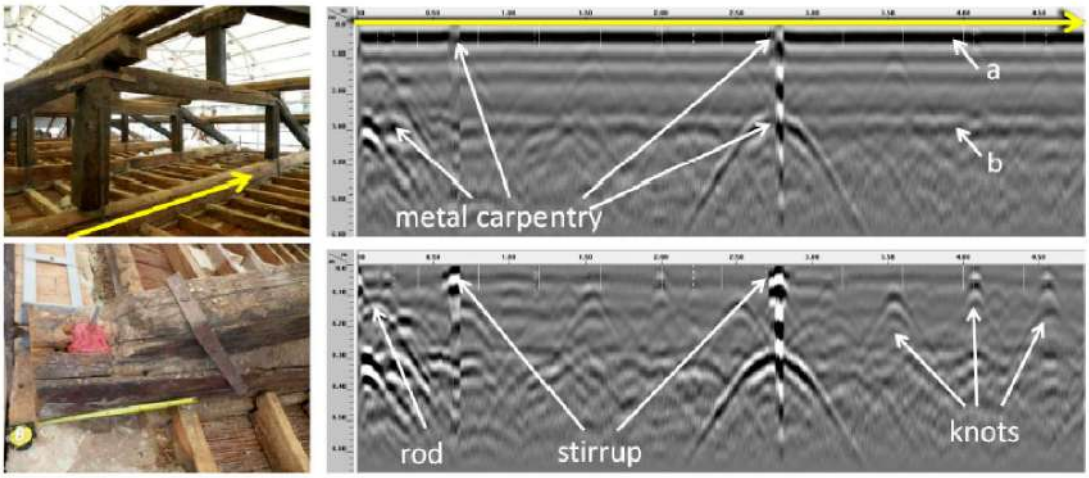


Figure 34: GPR test carried out on a timber tie-beam in reflection mode: survey line on th elatera face of the tie-beam (top left in yellow), detail of the metal elements near the beam head (bottom left), raw and post-processed radargrams (right, top and bottom) (Colla and Gabrielli, 2015)

The advantage of GPR is its ability to investigate a large surface within relatively short time. The application of GPR to timber structures is still limited, however, because GPR signals are affected by several paramenters (moisture content, salinity, material density) and thus it requires high expertise to collect data and to post-process and interpret the results. An example of its use for timber elements can be found in Colla and Gabrielli (2015).

The needle penetration test measures the penetration depth of a pin shaped striker into a wood specimen resulting from a defined impact loading on the striker (Tannert et al., 2014, Kloiber et al., 2014b). The depth of penetration of the striker is an indication of the wood's resistance: the shallower the indentation, the higher the resistance. Thus it determines the condition of a wood member at or near the surface, allowing detecting superficial degraded/damaged areas. The results are primarily related to wood density, wood species, moisture content and ring orientation. The device with the brand name "Pilodyn" is widely used for this test, becoming a synonym for such test (Figure 35). Examples of its use can be found in Imposa et al. (2014), Palaia et al. (2008), Brozovsky and Zach (2008), Massari et al. (2010) and Branco et al. (2010).

Compared to needle penetration, the pin pushing test allows assessing the condition of the investigated object at various depths, as it is based on the recording of a force applied to a pin gradually pushed into wood (up to 11cm depth) in relation to the measured distance of pin displacement (Kloiber et al., 2015b). The device can be fixed to the investigated element with a fabric strap and the pin is pushed into the material by a rack and pinion gear driven by two opposite manual crancks for both hands (Figure 36).

The output is a graph of the applied pin pushing force (Figure 37) which can be used to establish the mechanical resistance of wood: the peaks of the graph correspond to a higher force and thus a higher wood resistance, while the lower values of force indicate a lower resistance. The resistance depends on the wood species, density and moisture content, thus the test results should be interpreted considering these parameters. Moreover, the test is accurate only when the pin penetrates in the radial direction, perpendicular to the grain. Disadvantages of the test are that it is semi-destructive, local and that the developed device is not on the market yet.



Figure 35: Pilodyn device: the penetration depth of the striker can be read directly on the scale attached on its side (Tannert et al., 2014)

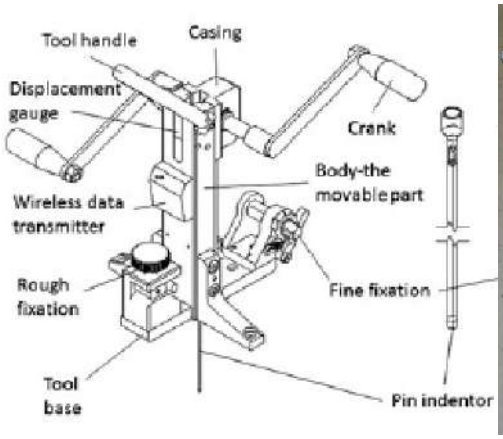




Figure 36: The device developed for the pin pushing test (Kloiber et al., 2015b)

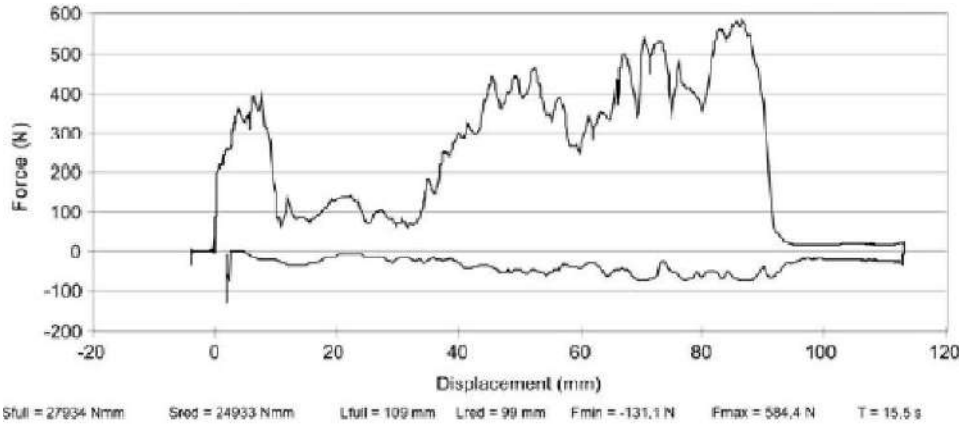


Figure 37: The output graph of the pin pushing test: the x axis is the depth to which the pin was pushed, the y axis is the force needed for pushing (Kloiber et al., 2015b)

The future of timber diagnosis could be image recognition: researchers are developing the integration of high resolution images of wood texture (obtained through digital photogrammetry) and non-destructive imaging of internal defects (obtained through ultrasonic tomography), to understand how external and internal features are correlated and if external ones can help interpreting the internal ones (Riggio et al., 2013). Unfortunately, an in situ test procedure has not been developed yet.

2.1.3.5 Mechanical properties

Mechanical properties are often estimated based on the timber species, but they can vary a lot from one piece of timber to the other, even if of the same species, because timber is anysotropic and heterogeneous. VSG helps taking into account the defects of timber, but it is generally overly conservative. That is why NDTs and SDTS are used to support VSG results.

Density, bending strength and modulus of elasticity are three main characteristics of timber from which other important parameters can be derived based on of empirical relations. Some tests can measure them directly: tension micro- and meso-specimens, core drilling, loading jack (Table 1). Other tests can only estimate these parameters through correlations with their output parameters. Unfortunately correlations are often poor, variable and not reliable, mostly due to the natural variability of timber properties, but also because of the test conditions (Feio and Machado, 2015).

Tension micro-specimens are used to measure tensile strength (which is very close to bending strength) of timber elements by testing small samples taken from its surface (Tannert et al., 2014, RILEM, 2010, Kloiber et al., 2015b). Triangular micro-specimen (5/8mm reduced to 8/12mm^2 in the central part) or meso-specimen (15x15x25mm reduced to 10x5mm^2 in the central part) are extracted with a circular or jig saw on the element's surface in order to have their length parallel to the grain. A careful choice of sampling place is fundamental in order to avoid defects and degraded areas.

Wooden blocks are glued to both ends of the samples in order to be able to insert the samples in simple grips and load them in a common testing device (Figure 38). The tensile strength and the modulus of deformability are measured to calculate the modulus of elasticity. The test is unfortunately semi-destructive and its results are related to the superficial layer of the element in that particular area where the sample was extracted. Moreover, the limited dimensions of the specimen cause high variability of results (Kloiber et al., 2015b). The interpretation of the results carried out on small wood samples can in fact be problematic (Lechner, 2013). An example of its use can be found in Kloiber et al. (2010).

Core drilling is also a local, semi-destructive test: cores of small diameters of about 5mm (at least 20mm long) are extracted from timber elements and tested in a compression device (Figure 39) (Kloiber et al., 2015b, Kasal, 2010). It allows evaluating the compressive strength and modulus of elasticity. Manual or electrical driven drills are used for core extraction. The resulting holes (10mm diameter) are smaller than most knots found in timber and do not compromise the element's overall strength. The samples must be extracted from healthy, undamaged wood in the radial direction.

The loading jack test (Kloiber et al., 2015b, Kloiber et al., 2014a) is particularly interesting compared to the others as it is the only that can be carried out in-situ. The device measures the compression behavior of clear wood zones of timber members as they are loaded by a miniature loading jack inserted into a pre-drilled hole of 12mm diameter. Simmetrically arranged grips/jaws are pushed apart inside the hole to get as close as possible to pure compression-loading mode in a laboratory (Figure 40). The test can be repeated at different depths up to 115mm. Unfortunately, it is again a local semi-destructive test and the device is not on the market yet. An example of its use can be found in Kloiber et al. (2015c).



Figure 38: Tensile test of a triangular bar (Kloiber et al., 2015b)

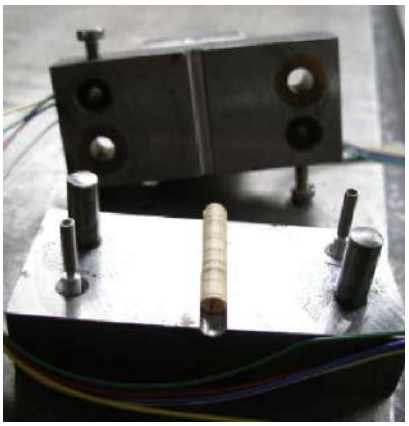


Figure 39: Compression device to test radial cores (Kloiber et al., 2015b)



Figure 40: The loading jack device (Kloiber et al., 2015c)

Destructive tests on samples give the most reliable results. Even though they are necessarily invasive, one sample can sometimes be used to obtain more than one parameter, maximising its value: samples from core drilling can be used, for example, to identify the species (Macchioni 2010), to carry out mechanical tests to determine the compressive strength, modulus of elasticity and density (Kloiber et al., 2015b), to measure the moisture content (Kasal and Lear, 2010), to evaluate the type and level of decay (Kasal, 2010) and to determine the felling date and provenance through dendrochronological analysis (Pignatelli 2010). Unfortunately all this information is related only to the specific point in the timber element where the core has been extracted; more cores can be collected but only up to a limited number since they are dirsuptive (Kasal, 2010).

Some in situ semi-destructive tests are less invasive and still reliable: the hole drilling, the hardness test, the pin pushing, the loading jack, the needle penetration and the screw withdrawal (Table 1). Unfortunately, the first four devices are not on the market yet (Crespo de Antonio et al., 2016, Kloiber et al., 2015b). The pin pushing, loading jack and needle penetration have already been discussed. While the results of the first two tests have good correlations with wood density and compression strength parallel to the grain (Kloiber et al., 2015b), needle penetration is widely used as it is not invasive, very quick and easy to use, but the correlations with density of its results have been found to be quite poor (Íñiguez-González et al., 2015).

Hole drilling was born to measure residual stresses in technological metallic devices and was later used for isotropic materilas only; a recent study (Crespo de Antonio et al., 2016) shows its potential for in situ timber structures. A rosette of three strain gauges is glued around the area where the stresses want to be measured (Figure 41). One gauge is parallel to the fibre direction, another one is perpendicular to the fiber direction and the last one is on the bisector. This area must be on the bottom face of a timber element under bending, where the maximum tensile stresses are. A small hole is then drilled in the area inside the gauges to relief the stresses, allowing measuring strains around the hole. The results of this first attempt to use the technique on in situ timber structures are promising, but the technique's reliability will be clear only once other studies are made.

The hardness test proposed measures the resistance to plastic deformation due to a constant load (Tannert et al., 2014, Kloiber et al., 2015b). A variable load is used to produce a given depth of impression on the lateral surface of wood, orthogonal to the grain direction. The test device is a mechanical or electric actuator equipped with a load cell, eventually electronic, and a displacement transducer, all attached to the investigated timber element with collars (Figure 42). The instrument has a 10mm diameter steel hemispherical bit as indenting device. The instrument measures the load force R required to embed 5mm the indenting device into wood. A correction factor δ is used to correlate R with the elastic modulus parallel to the fiber direction $E_{0,mean}$ in order to take into account the presence of defects:

$$E_{0,mean} = \delta \text{ x A x } R^{0,5}$$

A is a coefficient that depends on the timber species, the value of the applied force and the wood moisture content. Several factors influence the hardness measurement of wood, such as anisotropy, heterogeneity, moisture content, surface orientation of wood and the shape and size of the object applying the force. Nevertheless the test has been successfully used since the 80s; an example of its use can be found in (Tomasi et al., 2008).

The screw withdrawal test is used to estimate wood density, modulus of elasticity and modulus of rupture (Tannert et al., 2014, Kloiber et al., 2015b). Two devices are available for this test: one is a screw-extraction-force tool where the load cell measures pull out loads of screws; the other is a clamp type tool that mounts a load cell in the clamp (Figure 43). Commercially available wood screws can be used as probes; they should be long enough for the entire depth of wooden objects. The probes are pulled out of pre-drilled lead holes. Coaxial multiple-withdrawal testing can be used to obtain axially distributed withdrawal resistances. The relationship between withdrawal resistance (*P*) and wood density (*D*) is:

$$D = a\ x\ P + b$$

The regression constants *a* and *b* are obtained from a database. The relationship between the withdrawal resistance (*P*) and compression strength (*C*) is:

$$C = c\ x\ P + d$$

The regression constants *c* and *d* are obtained from a database. The relationship between the withdrawal resistance (*P*) and dyinamic modulus of elasticity *(MOE*) is:

$$MOE = e\ x\ D\ x\ v^2 + f$$

D is average density obtained from the withdrawal test, *v* is the stress wave speed determined by stress wave timers and *e* and *f* are regression constants obtained from a database. The relationship between the withdrawal resistance (*P*) and modulus of rupture *(MOR*) is:

$$MOR = g\ x\ P\ x\ v^2 + h$$

v is the stress wave speed determined by stress wave timers and *g* and *h* are regression constants obtained from a database. The test is semi-destructive and local, but most of all it is difficult to compare results with other studies since the probes are not standardized. The results are also affected by moisture content, size, and the presence of sap wood and heart wood.



Figure 41: A rosette of three gauges placed around the drilled hole to measure bending stresses (Crespo de Antonio et al., 2016)



Figure 42:The test device used for the hardness test (Kloiber et al., 2015b)



Figure 43: The device used for screw withdrawal (Kloiber et al., 2015b)

There have also been efforts to correlate results obtained through resistance micro-driling with results from destructive tests measuring mechanical properties of timber. The resistance measure (*RM*) is correlated to density, strength and modulus of elasticity through relative resistance (*RA*) and drilling depth (*H*):

$$RM = \frac{\int_0^H RA\ x\ dh}{H}$$

Many studies show that the correlations between *RM* and timber mechanical propertires are however quite poor and the fact that there are many different devices available on the market requires separate calibration for each device (Jasieńko et al., 2013, Nowak et al., 2016). The main goal of resistance micro-drilling is therefore not the assessment of timber mechanical properties but the verifiфcation of results obtained from other non-destructive tests. Examples of use of *RM* to estimate timber mechanical properties can be found in Cescatti et al. (2014), Morales-Conde et al. (2013) and Kloiber et al. (2015a).

Time-of-flight acoustic tests are the most used in situ to estimate the mechanical properties of timber because they have the advantage of being completely non-destructive. The dynamic modulus of elasticity (MOE_d) can be estimated by correlating the stress wave velocity (*V*) and the timber density (ρ):

$$MOE_d = V^2 x\ \rho$$

They are the only non-destructive test that can be used for this purpose, even though recent research is looking into using thermography (Carpentier et al., 2015) and radiography (Lechner and Kliger, 2015) to determine wood density. The results of time-of-flight acoustic tests require however a calibration based on the timber species and the moisture content, and the density is needed to estimate the Modulus of Elasticity (Dackermann et al., 2014). Usually, tabulated values for various species are used to estimate density, since its direct measurement cannot be carried out non-destructively. Moreover, correlations have been found to be variable, even because they are often obtained with tests on small defect-free samples that do not represent adequately the in situ timber's complexity (Rodríguez Liñán et al., 2015). The influence of operational conditions seems to be critical as well (Feio and Machado, 2015). Examples of the use of time-of-flght acoustic tests for the assessment of timber mechanical properties can be found in Rodríguez Liñán et al. (2015), Cescatti et al. (2014), Morales-Conde et al. (2013), Morales Conde et al. (2015), Bajno et al. (2015), Vilches Casals et al. (2015).

2.1.4 Structural Analysis

All the information gathered through visual assessment methods and tests are used to carry out a structural analysis in order to evaluate the level of safety of the structure. Structural analysis of historic structures is a challenging task because it involves many uncertainties, such as load history, boundary conditions, etc. This is particularly true for timber structures where it is difficult to estimate the geometry of the resisting section, the material's mechanical properties, the strength of joints, and the behaviour of spatial structures. It must be kept in mind that historic timber structures are generally more flexible than those designed today, so it is not appropriate to apply modern service limit states to them. Moreover, they are often very robust: more than one load path must be considered, because decay in one member might just transfer stresses on a neighbouring member. It is thus suggested to use an iterative procedure with subsequently increased complexity, where structural analys is continuously updated with the information gathered during the surveys (Cruz et al., 2015, Holzer, 2016). The important parameters for structural analysis are the dimensions and shape of the elements' resisting cross section, the mechanical properties and the behaviour of joints.

As previously discussed, the measurement of the elements' resisting cross section and its subsequent modelling can be difficult and time consuming. A study was carried out by Lourenço et al. (2013) to understand if using average values of the cross section dimensions provides adequate levels of safety. Four different roof structures were considered and modelled with the real sections, average sections, minimum sections and average section ±10% variation. It was concluded that using a probabilistic model with mean cross sections equal to the results from inspection and a coefficient of variation of 10% results in reasonable estimates of safety. It was also found that assuming all deteriorated timber as non-resistant leads to erroneous results – a remaining capacity factor for the

residual cross section area of 10% provides more consistent results (Lourenço et al., 2013). The shape of the resisting section is generally approximated to round (Lourenço et al., 2013) or rectangular (Pompejano et al., 2015), although no study has been carried out to assess the influence of this parameter.

Mechanical properties assessed through VSG and NDTs/SDTs are often higher than expected; it is thus suggested to use a partial material factor γ_M>1,0 (Cruz et al., 2015). The results from VSG are often preferred because they are more conservative and keep into consideration the defects of timber (Rodríguez Liñán et al., 2015).

The connections between elements are often the weakest point of the structure (Branco et al., 2010, Holzer, 2016). Most traditional carpentry joints are only able to partially transfer moments, compression and shear forces and they are only minimally able to transfer tensile forces (Jasienko et al., 2014). This is true especially if the fasteners are decayed or have failed. Moreover, the weakening of the cross section of the elements caused by the joints' indentations is rarely taken into consideration. According to Cruz et al. (2015), only if suitable data is available for the joints' moment-rotation capacity their contribution to the overall structural performance may be taken into account instead of assuming them as pinned joints; in any case no allowance should be made for the capacity of timber pegs. Holzer (2016) agrees on the fact that complex modelling of joints should be implemented only when strictly necessary and in any case in a second step of the analysis.

In case of spatial load-bearing systems numerical analysis with 3-dimensional models is necessary (Cruz et al., 2015). The presence of sarking boards connecting all the frames together and to the gable walls transforms Scottish roofs into veritable 3D structure (similar to an upside-down boat). Numerical analysis is thus necessary to consider the sarking's contribution. There are not many published examples of structures with sarking boards, and the few that have been investigated with a structural analysis have not always considered the contribution of the sarking (Pompejano et al., 2015). In the case of Valentino's Castle in Turin (Italy) the structure was modelled at first without the sarking, and it was not verified. Then the contribution of the sarking was added, in the form of an equivalent flat shell of the same stiffness with equivalent thickness equal to 7cm, and the structure was verified (Bertolini Cestari et al., 2015) (Figure 45). This further proves the sarking's contribution to the overall structural performance.

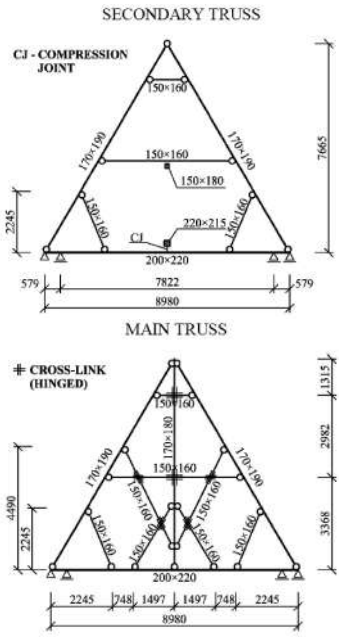


Figure 44: Non-linear joints modeled by Gocal et al. (2015)

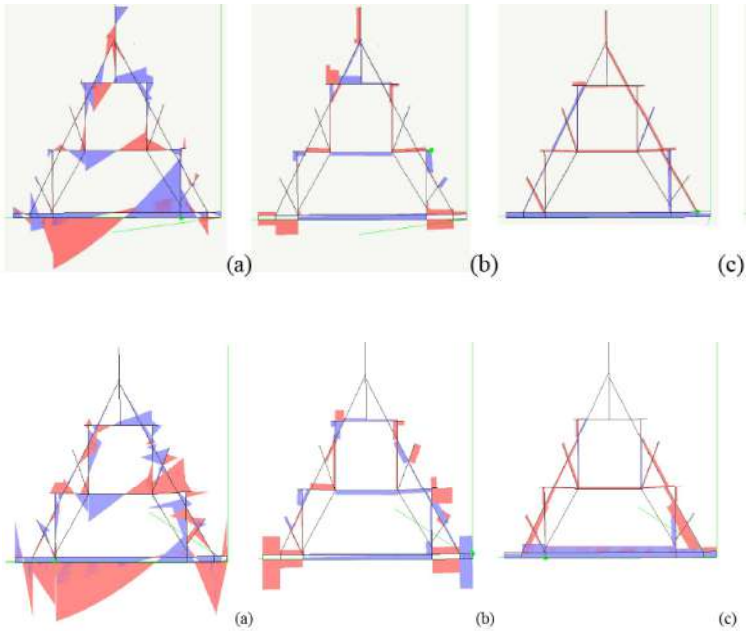


Figure 45: Example of stresses in a truss considering the contribution of the planking (above) and disregarding it (below); a) bending moment, b) shear force, c) axial force in a truss (Bertolini Cestari et al., 2015)

2.1.5 Standards

Standards allow professionals to carry out assessments more confidently and provide them with more reliable results. An overview of standards for the in situ assessment of timber structures is given by Macchioni et al. (2010) and Augelli (2014).

The Eurocode program by CEN up to now lacks of adequate tools. The only international standards which partly address the conservation of historic timber structures are ISO 13822 (2001) and EN 16069 (2012). The first applies to timber only partially since it relates to all building materials and its principal aims are structural safety and economy, not conservation. The latter is not specific for timber either, as it gives guidelines on how to carry out an initial survey of any artefact belonging to the built cultural heritage.

At a national level, Italy has the most complete series of standards related to the conservation of historic timber structures: UNI 11161 (2005) and UNI 11138 (2004) establish criteria and requirements for the assessment and interventions on historic timber structures, UNI 11119 (2004) is related to the condition assessment and Visual Strength Grading of single timbers elements, UNI 11118 (2004) gives guidelines for the species identification, UNI 11141 (2004) for dendrochronological analysis and UNI 11130 (2004) and UNI 11035 (2003) define the specific terminology. These standards have been developed by the Work Group 20 'Wood and wood based

products' of the Technical Committee UNI-NORMAL, created in 1996 in Italy, following an agreement between the Ministry of Culture and the Italian Standardisation body (UNI) (Macchioni and Piazza, 2006). The need for specific standards related to historic timber structures sparked from the safety needs of many public historic buildings and many bad restoration examples. Fourty experts from different entities (universities, private companies, professionals, public administrations, etc.) were involved in the activity of Work Group 20, organized through the institution of ad hoc groups working on the development of a common terminology and a common standard.

The Italian standards are used today by professionals and researchers in Italy (Bertolini et al., 2010, Macchioni et al., 2011, Massari et al., 2010) and other European countries such as Portugal (Lourenço et al., 2013, Sousa et al., 2015, Sousa et al., 2013), Belgium (Schueremans, 2009), Greece (Bertolini Cestari et al., 2007). In fact, they have been developed as standards valid on a national level but suitable for proposal on a European level.

UNI 11138 (2004) is of great importance as it allows controlling the quality of interventions on wooden artefacts by establishing criteria for the assessment, design and implementation of interventions on historic load-bearing timber structures. It specifically describes the need to evaluate the present condition of the timber structure in order to understand its real structural behaviour and its role within the building. A process of survey and analysis is prescribed, which includes a geometrical characterization, decay, damage and defects characterization and a full report on the current situation comprising thematic detail drawings.

According to UNI 11161 (2005) the assessment of historic timber structures must include:

- the description of the present state: historical documentation, written description and graphical/photographic documentation of the structure and its present condition, including classification and quantification of damage and decay;
- the diagnosis of the single elements: the dating, the identification of the timber species, existing and future thermo-hygrometric conditions and moisture content of wood, condition diagnosis of all wood components, and classification and quantification of potential decay.

UNI 11119 (2004) specifies how to proceed with the detailed survey of each wooden element, evaluating its original characteristics and any modifications occurred during its service life. To conduct the inspection correctly, the object must be accessible, clean and visible; otherwise the lack of full access must be recorded and alternative investigations conducted. The assessment must include the identification of the wood species, the wood moisture content, the class of biological risk (EN 335-2, 2006, EN 335, 2013), the geometry, the position and extension of any defects, decay and

damage and of critical areas. All these characteristics are then used to grade the entire wood member and, if necessary, each critical area separately; if an alteration occurs due to mechanical damage or localized biological decay, only the efficient section must be considered. Each grade corresponds to maximum values of stresses that can be applied. The standard also specifies what information should be included in the report.

Other countries have standards for visual strength grading of timber: EN 1912 (2007) gives guidance on existing grading standards and the species to which they are normally applied. UNI 11119 (2004) is however the only standard for grading in situ historic timber.

Switzerland published in 2011 a new series of standards (SIA 269/5, 2009), comprehensively described by Brühwiler et al. (2012) and Kohler and Steiger (2011). The part on wood is based mainly on UNI 11119 (2004). Following the Swiss example, Scotland could provide itself with a set of standards for historic timber structures based on the Italian ones. This would ensure that professionals follow a standardized procedure during the assessment and the design and implementation of interventions.

The above mentioned standards, together with recommendations given by ICOMOS (1999b), emphasize the importance of surveying thoroughly timber structures before any intervention, and give guidelines on what should be recorded. They do not however explain how to graphically report the survey and how to represent damage and decay in an accurate and codified way. As underlined by Augelli (2014), there is the need for a codified representation mode for timber structures, such as the one available for masonry (UNI 11182, 2006), to allow for clarity and understanding amongst the different professionals involved in the conservation of timber structures.

2.2 A novel database of seventeenth- and eighteenth-century buildings in Scotland

The following sections describe the methodology used in this thesis to investigate Scottish timber roofs, which has been devised based on the state-of-the-art tools, methods and standards reviewed in the previous section. It includes the creation of a database and related mapping, archival research, preliminary geometrical, technological and condition surveys in 53 buildings and detailed investigations in 8 case studies. A structured form has also been developed to collect, report and analyse all the research data.

2.2.1 Data acquisition

To assess the extent, nature and condition of seventeenth- and eighteenth-century Scottish timber roofs, the first step was to identify Scottish buildings of the period and gather all available information on their location, typology, geometry, design, history and condition. This information has been collected from the available literature and from online databases providing descriptions and locations of buildings listed or scheduled by HES (Historic Environment Scotland website - Designations, 2016), drawings/pictures/historical records of buildings surveyed by RCAHMS (Canmore website - Sites, 2016) and a description of the condition of historic buildings in disrepair (Buildings at Risk Register website - Buildings, 2016).

Unfortunately these descriptions, pictures and drawings do not always include a record of the inside of the buildings and very rarely mention construction techniques and structural aspects. Moreover, although they store and provide a great amount of information, they are not searchable: it is not possible to search buildings based on the construction date, or based on the name of a person who designed/built/transformed them (architect/mason/wright/patron), or any other parameter different from the building name and location. It is therefore not possible to assess the extent of seventeenth- and eighteenth-century Scottish buildings with these tools alone.

This is why it has been necessary to create a new relational database and related mapping of seventeenth- and eighteenth-century Scottish buildings able to store, manage, search and analyse a great amount of data. The database has been developed with Microsoft Access and ArcGIS. The data, collected from the above mentioned databases and from the available literature, is stored in Access, while ArcGIS is used to plot results of searches and queries.

This tool has been used to locate seventeenth- and eighteenth-century Scottish buildings and record their history, identifying the different types of interventions carried out (alterations, repairs, extensions, etc), the corresponding dates and the people involved in each intervention (commissioners, architects, masons, etc). All the available information on the structural and typological aspects as well as the present condition of the buildings has been recorded. The dates of birth and death, provenance, apprenticeship, and any other information about patrons, architects, masons, etc, has been included as well. Drawings, pictures and other documents are stored through external links. About 1500 buildings have been identified so far, but the database is continuously populated and expanded by the members of ADCRU.

Metadata has been included through qualifiers, in order to be able to keep a record of the 'quality' of data. For intervention dates, for example, a qualifier has been introduced to be able to distinguish between an intervention which is reported to have been carried out in the last quarter of the

seventeenth century, and one reported to have been carried out between 1675 and 1700: they have the same start and end dates (1675-1700) but the former has '25' as qualifier and the latter '1', because the date range is precise only in the second case.

All data has been referenced to literature, the HES/RCHAMS/BARR databases or other websites, or personal comments of scholars, professionals and building owners. Discrepancies between references have been reported too, when present.

2.2.2 Selection of reference buildings

A sample of 53 reference buildings has been researched and surveyed in order to collect first hand data to integrate the database. These reference buildings have been selected with the help of a series of queries run in the database, based on certain criteria aimed at identifying the buildings more likely to retain the original roof structures and, amongst these, the most representative of the architecture of the period and those for which more sources of information were available.

It was decided to focus on stately buildings designed by architects, since they have been less researched so far, as previously discussed: public buildings, stately homes and outstanding town houses. The selection process implemented amongst these buildings can be summarized in 4 phases (phase 2 and 3 ran parallel):

1) At the time when the first selection was made, in spring 2014, 1240 buildings were included in the database - the following criteria were used in this first phase:

- All the demolished, never built and ruinous buildings were discarded;
- Other buildings were discarded because the whole building, or a big part of it, was rebuilt after 1800;
- Buildings with flat roofs were discarded as well, since it was decided not to include this structural typology in the study;
- A further shortlist was created by selecting buildings that had a major intervention during seventeenth or eighteenth centuries and no major alteration/restoration after 1800.

2) The first phase ended with 450 buildings; a further selection was made by including buildings:

- whose timber roof is mentioned in literature or in the HS/RCAHMS/BARR databases;
- whose timber roof structure is visible in drawings held at the RCAHMS archives;
- that still retain the original plaster ceilings, and so probably the above original structure too;
- whose records report the name of the wrights that worked there;

- that represent key moments in Scottish architectural history, due to innovative ideas/techniques/forms that have been used in their design and construction;
- in which dendrochronological analysis has been carried out, so that information on timber species and felling dates is available;
- owned by HES or the National Trust for Scotland (NTS), easier to access.

3) In the meantime, the surveyors/archaeologists/architects working for NTS and HES were contacted to ask for information on buildings in their care. In some cases they were able to say straight away if the original roof structure is still in place and if it is accessible. They also suggested other buildings that had not been included in the shortlist resulting from phase 1.

4) Phase 2 and 3 ended with a shortlist of around 100 buildings. The owners were contacted to ask for information and accessibility. When the contacts were not found, a letter was sent by post. When someone replied and a visit was agreed, other buildings in the same area were selected (picking from the list resulting from phase 1), in order to optimize the trip time and expenses.

Among the contacted owners, 80 replied. Some replied too late for a visit to be arranged (the winter season does not provide optimal environmental conditions to carry out surveys) and some denied access to their roof space for various reasons: lack of interest, attic spaces used for activities that could not be interrupted, presence of bats, no knowledge of how to access the roof structure, etc. Eventually, 28 buildings or groups of buildings (such as Stirling Castle) were visited during summer 2014.

In order to widen the sample, a second selection of buildings was made in 2015 based on criteria of proximity (Glasgow and Edinburgh) and accessibility and based on the findings of the surveys carried out the year before: late seventeenth- and early eighteenth-century buildings showed innovations in roof carpentry, especially those with big internal spans. Therefore plans and sections found in literature and online (Canmore website - Sites, 2016) were analysed to find buildings of this period with wide internal spans. At the time when this second selection was made, 1500 buildings were included in the database.

A total of 49 building owners were contacted and 25 visits were arranged for summer 2015. Thereafter 53 reference buildings or groups of buildings were surveyed in total (Figure 46, Figure 47). The roof structure of one of these buildings was not visible nor accessible as it was hidden behind plaster and no hatches were available. Moreover, during the survey of 8 of the buildings it became apparent that the roof structures were not the original ones and dated to post-1800: this was established by looking at their arrangements and details (discussed in chapter 3). The survey of these structures was not carried out in detail.

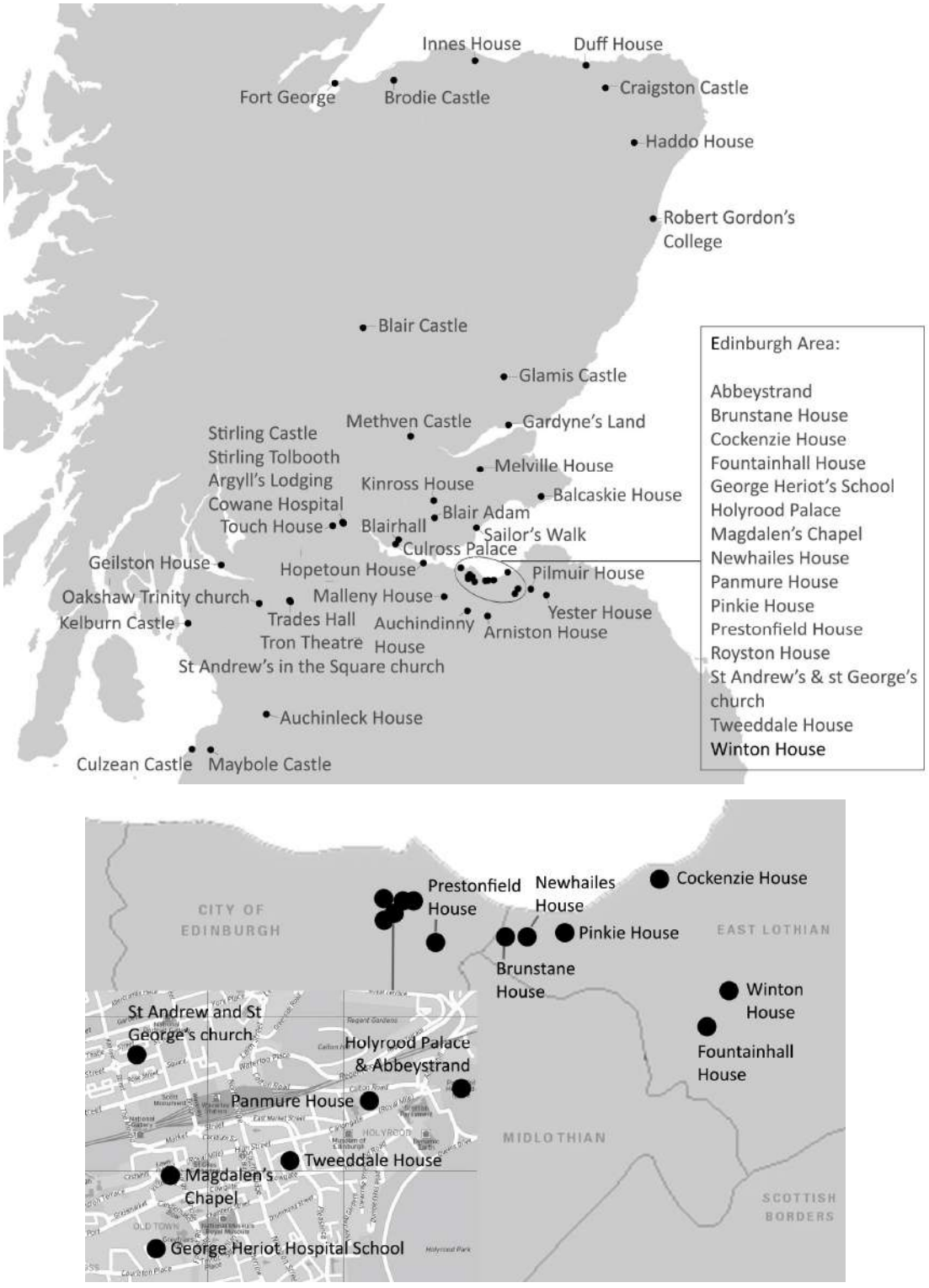


Figure 46: Names and locations of the 53 reference buildings surveyed - adapted from Serafini and Gonzalez Longo (2016) - with a zoom on the Edinburgh area

The final sample of surveyed buildings retaining seventeenth- and eighteenth-century roof structures (a few examples date to end sixteenth century) is of 44 (Figure 47). Some of these buildings have more than one roof structure, either because they are groups of buildings (as Stirling Castle) or

because their roof structures are structurally independent or correspond to different construction phases, as in Touch House (Figure 48). Thus we surveyed a total of 59 roof structures (Figure 47).

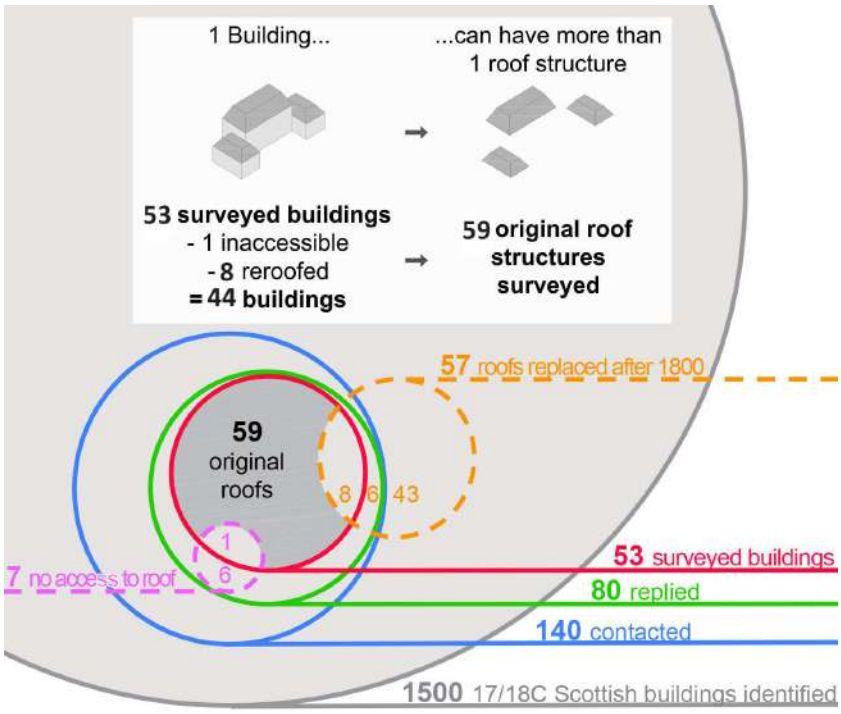


Figure 47: The selection process of the reference buildings surveyed and the results of the surveys in terms of number of original roof structures found - adapted from Serafini and Gonzalez Longo (2016)

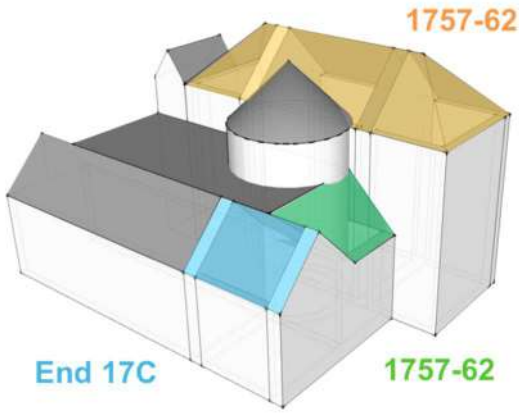


Figure 48: A model of Touch House seen from North-West showing the three roof structures surveyed

Only three of the surveyed roofs had already been researched and published: Stirling Castle (Hanke, 2008), Methven Castle (Murdoch, 2010) and Magdalen Chapel (Ross and Brown, 1916). The dendrochronological analysis of the roof timbers in Gardyne's Land, Duff House and Fort George is reported in unpublished reports (Crone, 2001, Crone, 2008a, Crone and Mills, 2008) as well as the surveys of the roofs of Geilston House, Sailor's Walk, Panmure House and Brodie Castle Stables (Addyman, 2000, Addyman, 2011, Addyman et al., 2006, Lelong et al., 1998).

2.3 Preliminary surveys carried out in 53 buildings

2.3.1 Data collection

A preliminary survey has been carried out in the selected 53 reference buildings to identify the geometry, construction techniques and typologies of roofs and to start assessing their present condition. A desk survey was carried out at first to gather all available information related to the building, also through e-mail or phone contact with the owners, tenants, managers or professionals taking care of the buildings. The second step was a half-day or one day visit to the building to carry out in situ geometrical, technological and condition surveys. Archival research was carried for some of the surveyed buildings, based on availability and accessibility of documents. The collected data is reported through texts, drawings and photographs included in Appendix E.

2.3.1.1 Geometrical and technological survey

As suggested by Riggio et al. (2014) and Cruz et al. (2015) a preliminary geometrical and technological survey was carried out to identify the roof structural typology and its construction details and to measure its overall dimensions. A tape meter, a laser meter and a digital camera were used. In order to be able to compare the structures and draw conclusions from a historical, typological, technological and structural point of view, a series of fixed parameters were recorded:

- roof form (gabled, hipped, dome, etc);
- roof geometry (maximum span, height, pitch, length, etc);
- internal structural arrangement (common rafter roof, purlin roof, etc);
- connections with the supporting structure (wall-plates, rafter feet, etc);
- elements' scantlings and section shape (square, renctangular, etc);
- timber dressing (hand-axed, hand-sawn, etc);
- joint types (mortice and tenon, lapped, etc) and fasteners (metal nails, wooden pegs, etc);
- timber species (macroscopic analysis);
- roofing material (slates, lead, etc) and its fasteners (nails, pegs, etc);
- carpentry marks;
- evidence for reused timber (redundant joints, etc);

The dimensions shown in the final drawings in Appendix E (span, height, length, scantlings, etc) result from the average of a minimum of two measurements (Figure 49). The pitch has been deduced based on the span and height. When the plan or internal structure were more complicated further measurements were taken. The geometry of joints was not measured at this stage.

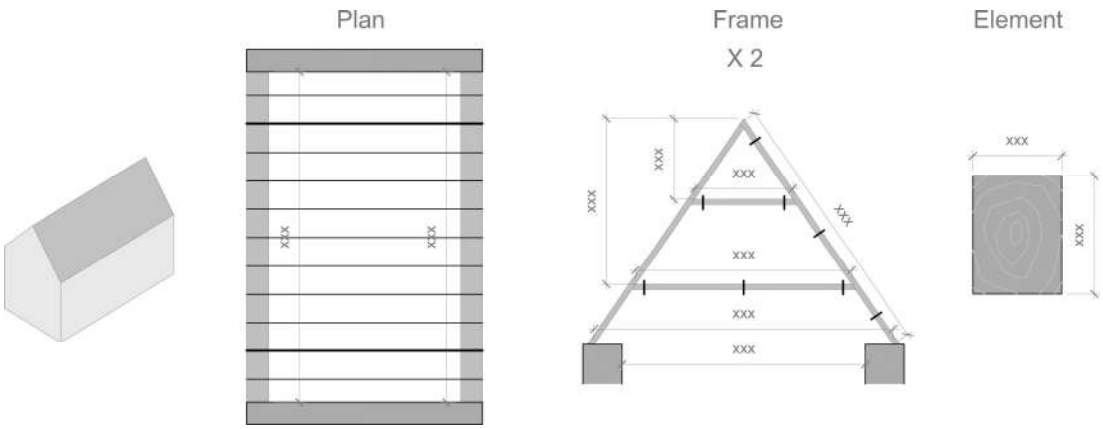


Figure 49: Diagram of measurements taken during the preliminary surveys in a typical common rafter roof

2.3.1.2 Condition survey

The preliminary survey was also aimed at assessing accessibility and identifying any obvious damage and critical areas (Cruz et al., 2015, Riggio et al., 2014). It included in fact the recording of:

- the use of the roof space, e.g. if it is partly occupied by attic rooms;
- accessibility conditions: which parts of the structure are visible, which are accessible and measurable, is the roof space well lit and easily accessible, etc;
- the presence of decorative features which might restrict repair interventions;
- the presence of unfavourable environmental conditions (poor ventilation, presence of pigeons/wasps/bats, etc) and/or poor maintenance;
- past or recent alterations and repairs;
- signs of mechanical damage (deformations, cracks, etc) and material degradation (fungi/insect attack, etc).

The extent and position of damage, degradation and defects were not documented at this stage.

2.3.1.3 Archival research

Archives were searched for information on the surveyed buildings and on wrights of the period. Documents were found through the SCAN online catalogue (Scottish Archive Network, 2016). A list of the archival documents available for the surveyed buildings is provided in each building form in Appendix E. Due to time constraints, only documents found in archives in Glasgow and Edinburgh or in the buildings themselves were consulted: pictures, drawings, accounts, estimates, minutes, correspondence and registers held at National Records of Scotland (NRS), National Library of Scotland (NLS), the Royal Commission on Ancient and Historical Monuments of Scotland (RCAHMS), Edinburgh University Library (EUL), Edinburgh City Archives (ECA), Mitchell Library (ML), George

Heriot Hospital, Glasgow Trades Hall, Touch House, Tweeddale House. A full list of the consulted documents is provided in Appendix G.

The number of consulted documents including useful information on roof structures and wrights is limited but it has nevertheless been of aid to the research. Some drawings and photographs in RCAHMS and NLS showed roof structures (Appendix A) and were thus useful to select buildings to visit and integrate the sample of surveyed roofs. Other documents were useful to date the roof structure, as in Stirling Castle (NLS MS1646 Z.02/18b, 1719, NRS GD124/15/471, 1707), George Heriot Hospital (NRS GD421/5/2, 1633-42), Glasgow Trades Hall (ML T-TH 1/1/7, 1787-98), Touch House (TCH letter to Mr Seton, 1751, TCH account by Paterson, 1757, TCH account by Deas & Co, 1757-8), Tweeddale House (NLS MS14665/64, 1750-6, NLS MS14551/115, 1750, NLS MS14551/126, 1753). In other cases drawings were useful to identify and date past interventions, as in George Heriot Hospital (GH reports, 1997), Glasgow Trades Hall (TDH 1/899, 1856, ML Shanks 152/T6, 1955), Pinkie House (RCAHMS LOR/M/17/5, 1953, HES report by Adams, 1954), Touch House (RCAHMS LOR/T/1/5, 1928), Tweeddale House (NLS MS14680, 1779-82, TWH drawings/pictures, 1980s), Yester House (NLS MS14551/109, 1742-49). Documents related to St Mary's Chapel Incorporation (ECA SL 34/4/1, 1706-74, ECA SL34/4/2, 1706-1774, NLS ACC 70/56, 1711-33, ECA SL 34/1/7, 1740-55) and others discussed in section 3.3.4 were used to start understanding the timber procurement, the design process and the role of architects, wrights and patrons.

Future research should focus on carrying out a more thorough archival research. In fact, we have already identified other potentially interesting archive material, not consulted due to time constraints; a list is provided in Appendix D.

2.3.2 Identification and dating of different types of roof structures

We have grouped the surveyed roof structures in four main types, based on their design and structural arrangements: purlin roofs and three types of rafter roofs - common rafter roofs (or simple frames), complex frames, and trussed roofs (Figure 50). 3D trusses form a subgroup of trussed roofs and composite roofs are composed of more than one type of structure.

In purlin roofs the rafters, devoid of any load-bearing function, rest on purlins, which are the real supporting elements. The purlins span from one gable wall to the other; in one example only (Touch House) they are also supported by vertical/slanted timber elements. Rafters generally have notches in correspondence with purlins; in Touch House only they are morticed in the purlins and therefore composed of two separate timber elements.

Common rafter roofs (or simple frames) are composed of closely spaced rafter couples joined at the apex and connected transversally by one or more collars and longitudinally by the sarking boards.

There is no structural hierarchy amongst the rafters: they are all load-bearing. The vast majority of these roofs supports a simple pitched gabled roof, but some have intersections and some others support hipped, M or shed roofs.

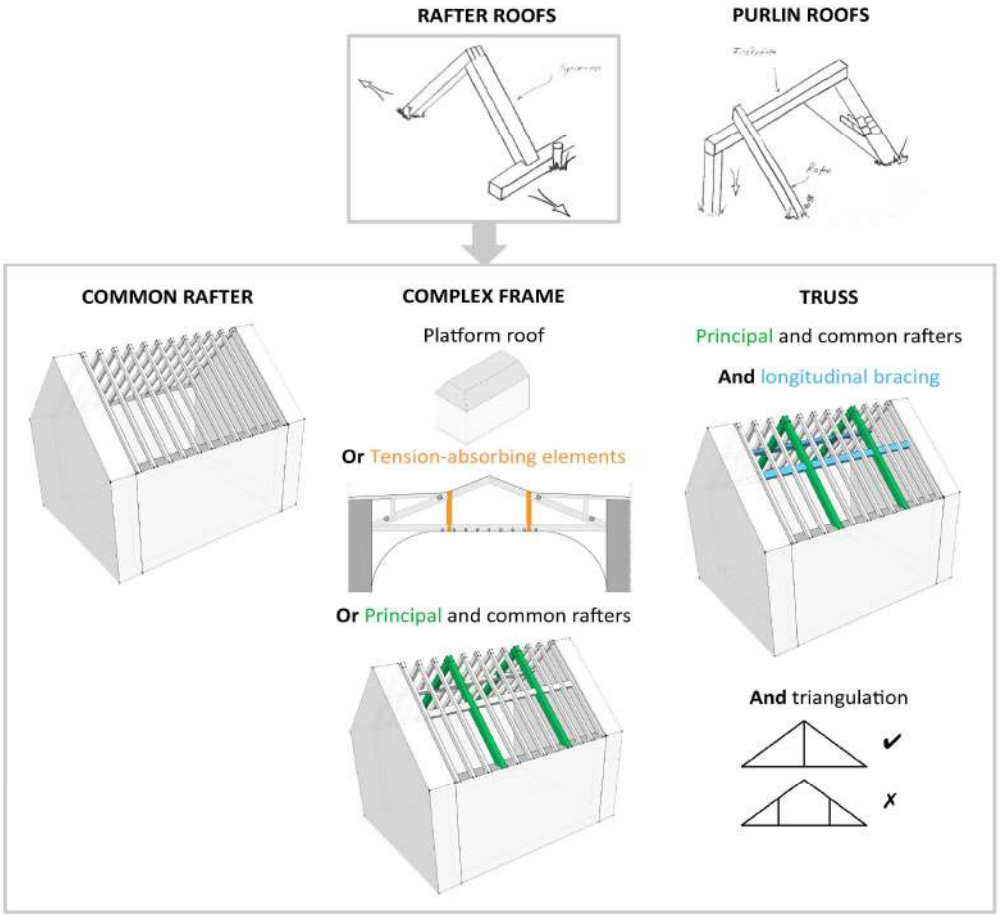


Figure 50: Diagram showing the classification in structural types established for the surveyed roof structures

Complex frames are similar to simple frames but they are characterized by one or more of these three features: platform arrangements, tension-absorbing elements, subdivision in primary (load-bearing) and secondary (non load-bearing) rafters. These features are important because they change the structural behaviour of common rafter roofs: the platform eliminates the joint at the rafter apex and places a horizontal element in its place, posing deflection and joint-opening issues; tension-absorbing elements reveal awareness of the fact that timber can work in tension and that ties can be used to counteract deflection in other elements; the subdivision in primary and secondary rafters allows to concentrate loads only in certain areas of the supporting masonry.

The structures we have included in the group of trussed roofs strongly differ from roof structures used in Scotland previously and their design suggests foreign influences, as we will discuss in chapter 3. They all employ principal and common rafters, butt-purlins and triangulation, although not always effective. Butt-purlins are morticed in the rafters, rather than vice versa, thus they only provide

longitudinal rigidity to the structure (Figure 85, Figure 86). The 3D trusses sub-group includes trusses that develop spatially: Culzean Castle and St Andrew and St George's church employ radial trusses, whilst Glasgow Tron church employs trusses in both directions, transversally and longitudinally.

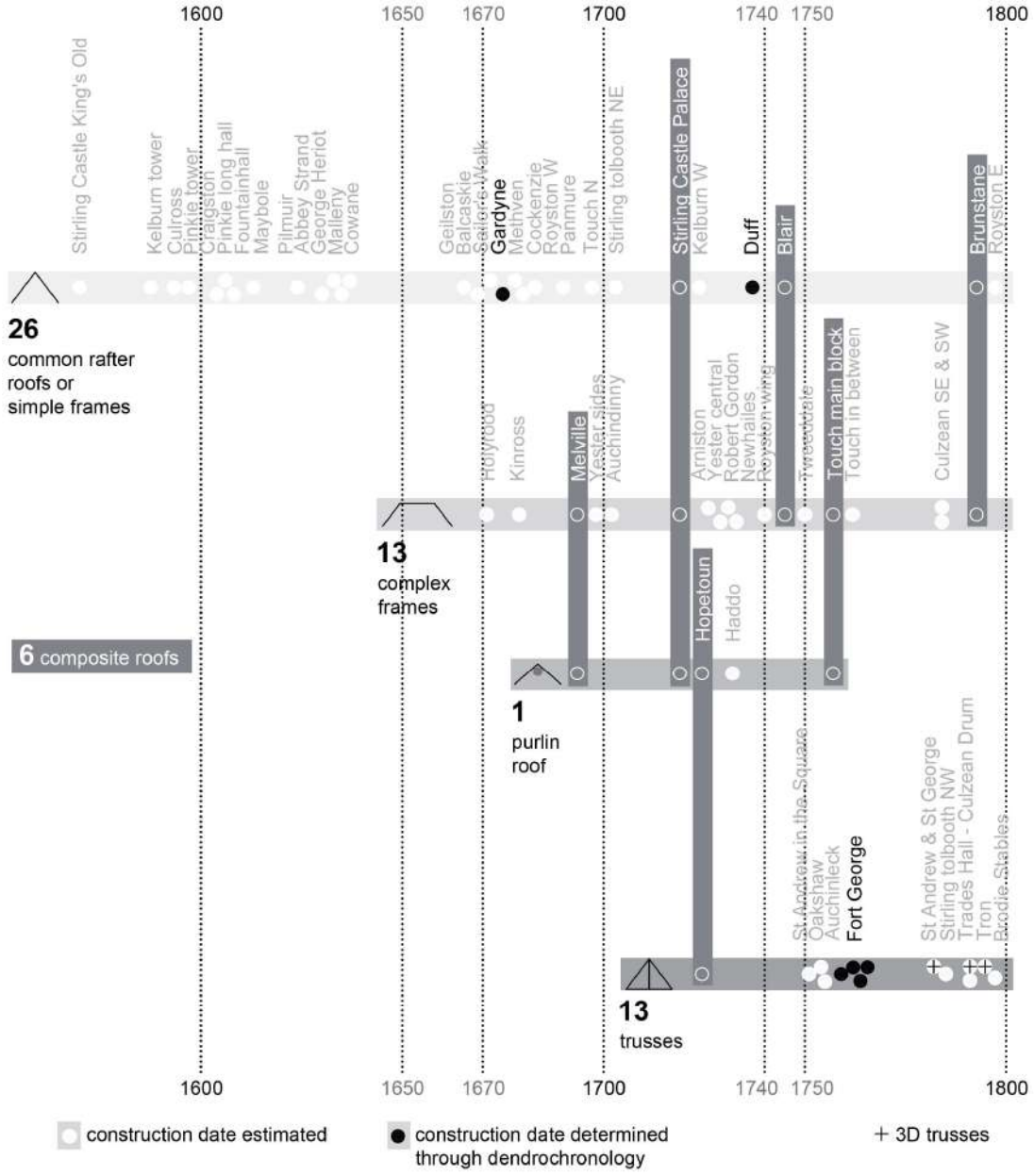


Figure 51: Timeline showing the chronological distribution of the 59 roof structures surveyed classified in different structure types: common rafter roofs, complex frames, purlin roofs, trusses (top to bottom) and composite roofs (in dark grey); the construction dates have either been estimated (white circles) or determined through dendrochronology by previous research (black circles)

Figure 51 shows how the different structure types are distributed chronologically. Unfortunately, the construction date of the roof structures is certain only in a few cases, where dendrochronological analysis has been carried out: Gardyne's Land (1675-90), Duff House (1737), Fort George (1747-69).

All the other construction dates have been estimated based on the buildings' construction history and the comparison with the other surveyed roof structures.

Extensive archival research and in situ investigations are required to properly date a building; in the case of 6 of our buildings this has not been done yet so their construction date has been estimated by scholars based on stylistic features. Moreover, the roof construction date does not always match the building construction date, because sometimes roofs are replaced at a later date. Most of the surveyed roof structures have been considered to be contemporary to the building construction, but 7 of them have been considered to be of later date: their dating has been estimated based on other reported intervention dates or by comparison with other roof structures. Table 2 reports the structure type, dating and method of dating of the 59 roof structures surveyed.

Table 2: The structure type, dating and method of dating of the 59 roof structures surveyed

Building name and roof location	Roof structure type	Roof date	Dating of original roof construction (not considering later alterations) based on:				
			Dendrochronology	Building construction date		Building other date reported	Comparison with other roofs
				reported	estimated		
Abbey Strand	SF	1630			x		
Arniston House	CF	1726-55		x			
Auchindinny House	CF	1702-7		x			
Auchinleck House	T	1755-62		x			
Balcaskie House	SF	1668-74		x			
Blair Castle	C (SF+CF)	1745				x	
Brodie Castle Stables	T	end 18C					x
Brunstane House	C (SF+CF)	end 18C				x	
Cockenzie House	SF	1680-3		x			
Cowane's Hospital	SF	1637-48		x			
Craigston Castle	SF	1604-7		x			
Culross Palace	SF	1597-1611		x			
Culzean Castle South-East	CF	1784-92		x			
Culzean Castle South-West	CF	1784-92		x			
Culzean Castle Drum Tower	3D T	after 1791				x	
Duff House	SF	1737	x				
Edinburgh Panmure House	SF	1690			x		
Edinburgh St Andrew's and St George's Church	3D T	1782-4		x			
Fountainhall House	SF	early 17C			x		
Gardyne's Land	SF	1675-90	x				

Geilston House	SF	1666		x				
George Fort Staff block	T	1762-4	x					
George Fort Museum	T	1764	x					
George Fort Chapel	T	1763	x					
George Fort Store	T	1759-61	x					
George Heriot's Hospital	SF	1633-7		x				
Glasgow St Andrew's in The Square Church	T	1751-3		x				
Glasgow Trades Hall	T	1791-4		x				
Glasgow Tron Church	3D T	1793-4		x				
Haddo House	P	1732-6		x				
Holyrood Palace	CF	1671-8		x				
Hopetoun House	C (P+T)	1721-48				x		
Kelburn Castle tower	SF	1581		x				
Kelburn Castle West wing	SF	1722		x				
Kinross House	CF	1679-93		x				
Malleny House	SF	1635		x				
Maybole Castle	SF	early 17C			x			
Melville House	C (CF+P)	1697-1703		x				
Methven Castle	SF	1678-81		x				
Newhailes House	CF	1733-51		x				
Oakshaw Trinity Church	T	1754-6		x				
Pilmuir House	SF	1624		x				
Pinkie House tower	SF	end 16C			x			
Pinkie House long hall	SF	1613		x				
Robert Gordon's College	CF	1731-2		x				
Royston House West	SF	1683-96		x				
Royston House wing	CF	1740-1		x				
Royston House East	SF	end 18C						x
Sailor's Walk	SF	1670s			x			
Stirling Castle Palace	C (SF +CF+P)	after 1719						x
Stirling Castle The King's Old Buildings	SF	1557		x				
Stirling Tolbooth North-East	SF	1703-5		x				
Stirling Tolbooth North-West	T	1785				x		
Touch House main block	C (P+CF)	1757-62		x				
Touch house in between	CF	1757-62		x				
Touch House North range	SF	end 17C						x
Tweeddale House	CF	1750-6				x		
Yester House central	CF	1729-48				x		
Yester House sides	CF	1699-1728		x				

2.3.3 Selection of case studies

Further investigations have been carried out in 8 case studies selected amongst the surveyed roof structures according to the following criteria:

- Type: based on the number of surveyed examples per group, more simple frames were selected, followed by complex frames and trusses, and lastly by purlin roofs and composite roofs (Figure 51);
- Date: based on the chronological distribution, more examples from eighteenth century (cell highlighted in grey in Table 3) were selected, because there are more structure types during the eighteenth century rather than during the seventeenth century (Figure 51);
- Location: restricted to the Scottish central belt (Glasgow, Edinburgh, Stirling), in order to be able to easily revisit the buildings if necessary;
- Availability of other sources of information (archive material - A in Table 3 - and dendrochronological analysis - D in Table 3);
- Accessibility: structure visible in most of its parts and roof space well lit and easily accessible in order to be able to bring in and around the assessment equipment (roofs with problems in accessibility are in grey in Table 3);
- Complexity: buildings with more than one roof structure whose typology and/or construction date is different (in bold in Table 3), so that with one visit more than one roof structure can be tested;
- Ownership: buildings owned or in care of HES or NTS (underlined in Table 3), to test if the methodology is applicable to non-privately owned buildings.
- Permission: owner's permission to carry out tests (roofs with problems in permission are in grey in Table 3).

The following buildings were selected (Table 3, Figure 52):

- Cockenzie House (1680-3) with a simple frame;
- Holyrood Palace (1671-8) with a complex frame;
- Newhailes House (1733-52) with a complex frame;
- Pinkie House (1613) with a simple frame;
- Stirling Castle Palace (after 1719) with a composite roof structure (simple frame, complex frame and purlin roof);
- Touch House with a simple frame (end seventeenth century) and a composite roof structure (complex frame and purlin roof, 1757-62);
- St Andrew's in the Square church (1751-3) with a trussed roof;
- St Andrew's and St George's church (1782-4) with a 3D trussed roof.

Table 3: The selection of the case studies (framed in black) amongst the surveyed roofs

SIMPLE FRAMES	COMPLEX FRAMES	TRUSSES	PURLIN ROOFS	COMPOSITE ROOFS
Abbey Strand	Arniston House A	Edinburgh St Andrew's And St George's Church	**Touch House main block** A	Brunstane House
Cockenzie House A	*Auchindinny House*	Glasgow St Andrew's In The Square Church A	**Touch House in between** A	Hopetoun House A
Cowane's Hospital A	Holyrood Palace A	Glasgow Trades Hall A		**Stirling Castle Palace** A
Edinburgh Panmure House	Newhailes House A	*Glasgow Tron Church*		
Geilston House	**Royston House wing**	Oakshaw Trinity Church		
George Heriot's Hospital School A	*Tweeddale House A*	***Stirling Tolbooth***		
Malleny House	***Yester House A***			
Pilmuir House	***Yester House A***			
Pinkie House long hall A				
Pinkie House tower A				
Royston House West				
Royston House East				
Stirling Castle_The King's Old Buildings A				
Stirling Tolbooth				
Touch House North A				

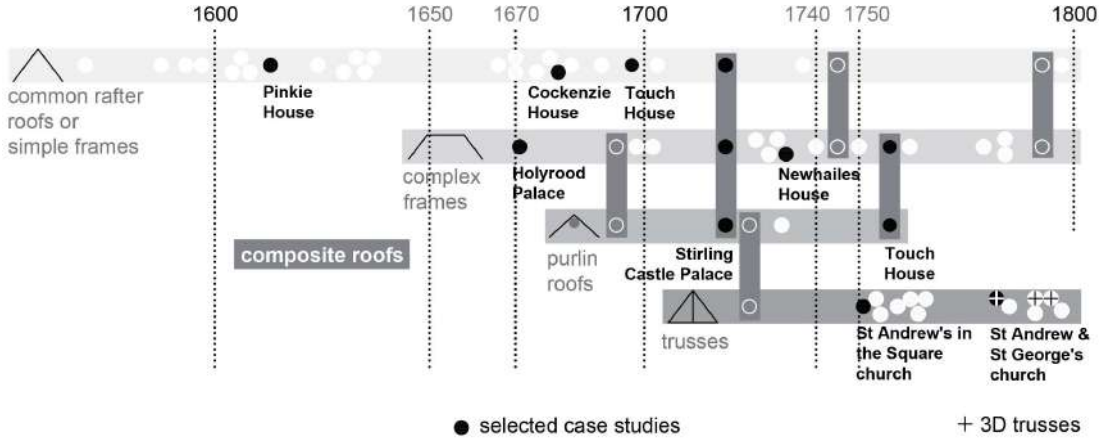


Figure 52: Timeline showing the chronological distribution of the selected case studies amongst the 59 roof structures surveyed

2.4 Condition surveys and material Investigations carried out in the case studies

2.4.1 Selection of assessment techniques

In the selected case studies in-depth surveys and investigations have been carried out to learn more about their construction and present condition. Specific objectives, identified after surveying the 53 reference buildings, have been pursued:

1. Identify the timber species and quality, to understand if different species were used for different structures and if the timber trade influenced the development of different structure types or vice versa;
2. Assess the environmental conditions of the roof spaces to understand their influence on the roof condition;
3. Find strategies to assess the geometry and condition of invisible/inaccessible parts of the structure, such as the connection with the lateral walls;
4. Compare different tests to assess internal damage and material degradation in order to estimate the residual resisting section of the timber elements;
5. Identify the skills involved in the assessment and compare tests based on their cost, training needs and reliability of results, to discuss which could be introduced to professionals through specific training.

As discussed in section 2.1.4.5, many testing devices used to assess the mechanical properties of timber are not on the market yet and those that are require a calibration through laboratory testing that could not be carried out in the time-frame available. This is why this aspect has not been investigated.

A series of assessment techniques have been selected to investigate the above-mentioned aspects, considering the available equipment in Scotland (highlighted in light grey in Table 4) and the state-of-the-art research on the assessment of existing structural timber, discussed in section 2.1. Criteria of cost, reliability of results and expertise required to operate the equipment and interpret the results have been considered, as discussed below.

There is only one way to assess the timber species and quality and to measure the air temperature/relative humidity and the wood moisture content in situ, as discussed in section 2.1. Data loggers can be used for long-term monitoring of environmental conditions, but they are quite expensive, which is why they have not been used (Table 4). On the contrary, different tests can help assessing parts of the structure hidden behind timber or plaster: thermography, endoscopy and Ground Penetrating Radar (GPR) (Table 4). The first two have been preferred because they require less expertise in the interpretation of results and because they are less expensive (Kloiber et al.,

2015a, Riggio et al., 2015b). Moreover, thermography can also be useful in identifying moist areas and as support to VSG (Colla and Gabrielli, 2015). Many tests are available even for the assessment of the internal condition of timber (Table 4). However, the needle penetration test gives only superficial results, detector dogs need to be trained for every specific insect species and cannot detect early stages of decay, radiography involves safety issues, GPR requires high expertise and is not effective when there are high moisture contents, just as microwave reflectometry. Therefore acoustic tests have been preferred. Despite being expensive and semi-destructive the resistance micro-drilling has also been selected because it is very reliable and quick: it is the one that gives more precise information on the extent and position of internal features, allowing a reliable estimation of the residual resisting section and a verification of the results from other tests.

Table 4: The selection of assessment techniques to investigate specific aspects: only devices available on the market have been included; light grey = available in Scotland or virtually cost-less. The selected techniques are framed in black.

<table>
<tr><th colspan="2">1. material</th><th colspan="2">2. environmental conditions</th><th rowspan="2">3. invisible structure</th><th rowspan="2">4. internal condition</th></tr>
<tr><td>timber species</td><td>timber quality</td><td>air</td><td>moisture content</td></tr>
<tr><td>macroscopic analysis</td><td>Visual Strength Grading (VSG)</td><td>thermometer</td><td>hygrometer</td><td>thermography</td><td>detector dogs</td></tr>
<tr><td>microscopic analysis</td><td colspan="3">monitoring</td><td>endoscopy</td><td>microwave reflectometry</td></tr>
<tr><td colspan="4"></td><td>Ground Penetrating Radar (GPR)</td><td>Ground Penetrating Radar (GPR)</td></tr>
<tr><td colspan="5"></td><td>acoustic tests</td></tr>
<tr><td colspan="5"></td><td>micro-drill</td></tr>
<tr><td colspan="5"></td><td>needle penetration</td></tr>
<tr><td colspan="5"></td><td>radiography</td></tr>
</table>

The testing equipment used is summarized in table 5:.

- a chisel and a hammer to collect samples, hand lenses (x10/20 magnification) to analyse the samples macroscopically and a light transmission microscope (James Swift model MP3502) to analyse the samples microscopically;
- an air thermometer to measure the air temperature and relative humidity and a hygrometer (GANN Hydromette RTU 600) to measure the wood moisture content;
- a thermal camera (FLIR E4) to spot humid areas and assess hidden parts of the structure together with a snake camera (Northvision NC-Z04N);

- a rubber hammer, a portable ultrasonic device (Proceq Pundit PL-200) and a micro-drilling device (IML RESI F-400) to assess the internal condition of timber and estimate the residual resisting section of the elements.

A device for acoustic tomography (ARBOTOM) was also available but it was decided not to use it as it is very bulky and heavy and therefore difficult to operate alone.

Table 5: The testing equipment used in the detailed investigations of the case studies

identification of the timber species	measurement of environmental conditions	assessment of hidden parts of the structure	assessment of internal condition of timber
chisel, hammer 	thermal camera (FLIR E4) 		rubber hammer 
hand lenses (x10/20 magnification) 	air thermometer 	snake camera (Northvision NC-Z04N) 	ultrasonic device (Proceq Pundit PL-200) 
light transmission microscope (James Swift model MP3502) 	hygrometer (GANN Hydromette RTU 600) 		micro-drilling device (IML RESI F-400) 

2.4.2 Assessment methodology

Since some tests require to be calibrated based on parameters obtained from other tests, the assessment has been carried out according to a defined sequence, explained in Figure 53. The timber species and the air temperature/relative humidity are needed to calibrate the wood moisture content measurements when they are taken (Riggio et al., 2014). Therefore the hygrometer could only be used after the species had been identified and the air temperature/relative humidity measured. The macroscopic analysis of the timber species can be carried out in situ (Macchioni,

2010), thus, when it was sufficient to confidently identify the timber species, phase 1, 2 and 3 were carried out on the same day. However, the collection of samples and their microscopic analysis was often necessary; in this case phases 1, 2 and 3 were carried out in sequence. This has happened during the first assessments, when the macroscopic analysis could not be carried out with sufficient confidence yet. The timber species and the wood moisture content are necessary to calibrate the results of the ultrasonic device only during the post-processing (Dackermann et al., 2014); therefore the ultrasonic test could be carried during phase 1 as well. In practice this has never happened due to lack of time. The micro-drilling device, which is semi-destructive, has always been used at the very end, after all the data from the other tests had been analysed, in order to identify the critical areas to test and minimize the disruption to the structure.

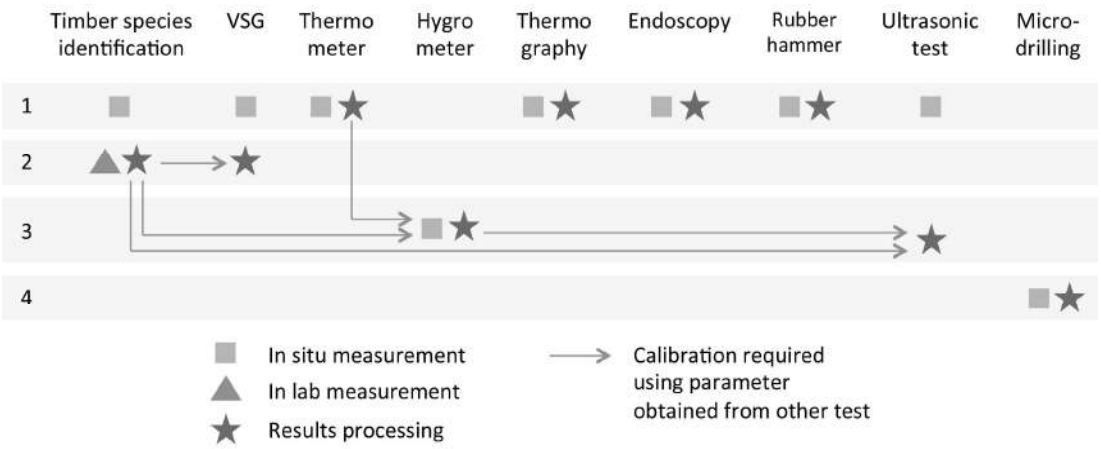


Figure 53: Assessment phases resulting from the need to calibrate some tests with parameters obtained from other tests

The tests have been carried out at specific locations. The number of elements composing the roof structures of the selected case studies is high, especially in the case of simple and complex frames. The complex frame in Holyrood Palace, for example, is composed of around 600 elements. It was therefore not feasible to carry out during an initial assessment VSG and testing of all the elements, as required by UNI 11119 (2004). As previously discussed, most of these roof structures are not composed of primary and secondary rafters and frames, therefore it was not possible to select the elements to test based on their structural importance. Hence the decision to choose a certain number of frames in each roof structure as a representative sample. A similar procedure has been applied by Podestà et al. (2013). These frames have been called 'reference frames' and chosen based on their position: the first and last as close as possible to the gable walls or the extremities of the roof, and the others distributed at regular intervals (Figure 54). In some case studies additional critical elements (affected by material degradation, mechanical damage or significant strength affecting defects) have been identified during the detailed visual inspection and measured/tested together with the elements composing the reference frames.

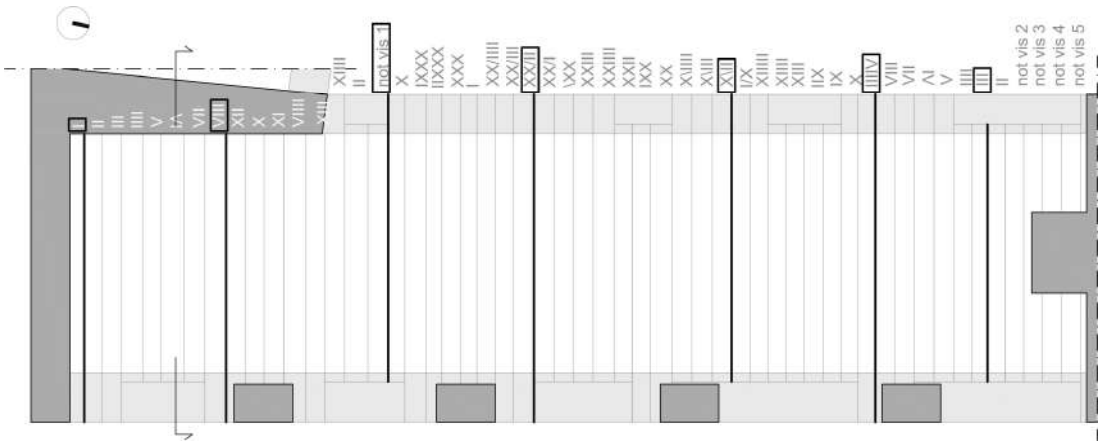


Figure 54: The plan of the roof above Pinkie Houses' long hall with the reference frames highlighted in black

The assessment has been divided in 2 parts:

PART I, to assess the timber species and quality, to measure the environmental conditions and to find ways to assess the geometry and condition of invisible/inaccessible parts of the structure:

1. Macroscopic and microscopic timber species identification (Figure 55);
2. Measurement of the air temperature and relative humidity (Figure 55);
3. Use of a thermal camera to spot humid areas and study the geometry of hidden structures;
4. Use of a snake camera to study the geometry and condition of hidden structures;
5. VSG of all elements of a sample of reference frames to assess the timber quality (Figure 56);
6. Moisture content readings of all elements of a sample of reference frames (Figure 56).

PART II, to assess the internal condition of timbers and estimate their residual resisting section:

7. Detailed mapping of visible pathologies to identify critical elements (affected by material degradation, mechanical damage or significant strength affecting defects) (Figure 55, (Figure 56);
8. Moisture content readings of critical elements identified;
9. Sounding with rubber hammer in the same points where the moisture content has been measured;
10. Ultrasonic test in the same points where the rubber hammer has been used (Figure 56);
11. Micro-drilling test where a high moisture content (>18%) has been measured, where visible material degradation has been identified, where the ultrasonic device has recorded a low velocity or an unstable signal (Figure 56).

Part I has been carried out in all eight case studies, while Part II has been carried out in four roof structures: the simple frame above the painted gallery in Pinkie House, the complex frame above the

North range of Holyrood Palace, the simple frame above the South-West range of Stirling Castle Palace and the complex frame above the North-East range of Stirling Castle Palace. These roof structures have been chosen because they represent well the two most numerous structure types (simple frames and complex frames), they have very good accessibility and their owners were interested in proceeding with further investigations. Table 6 summarizes the tests carried out in the case studies.

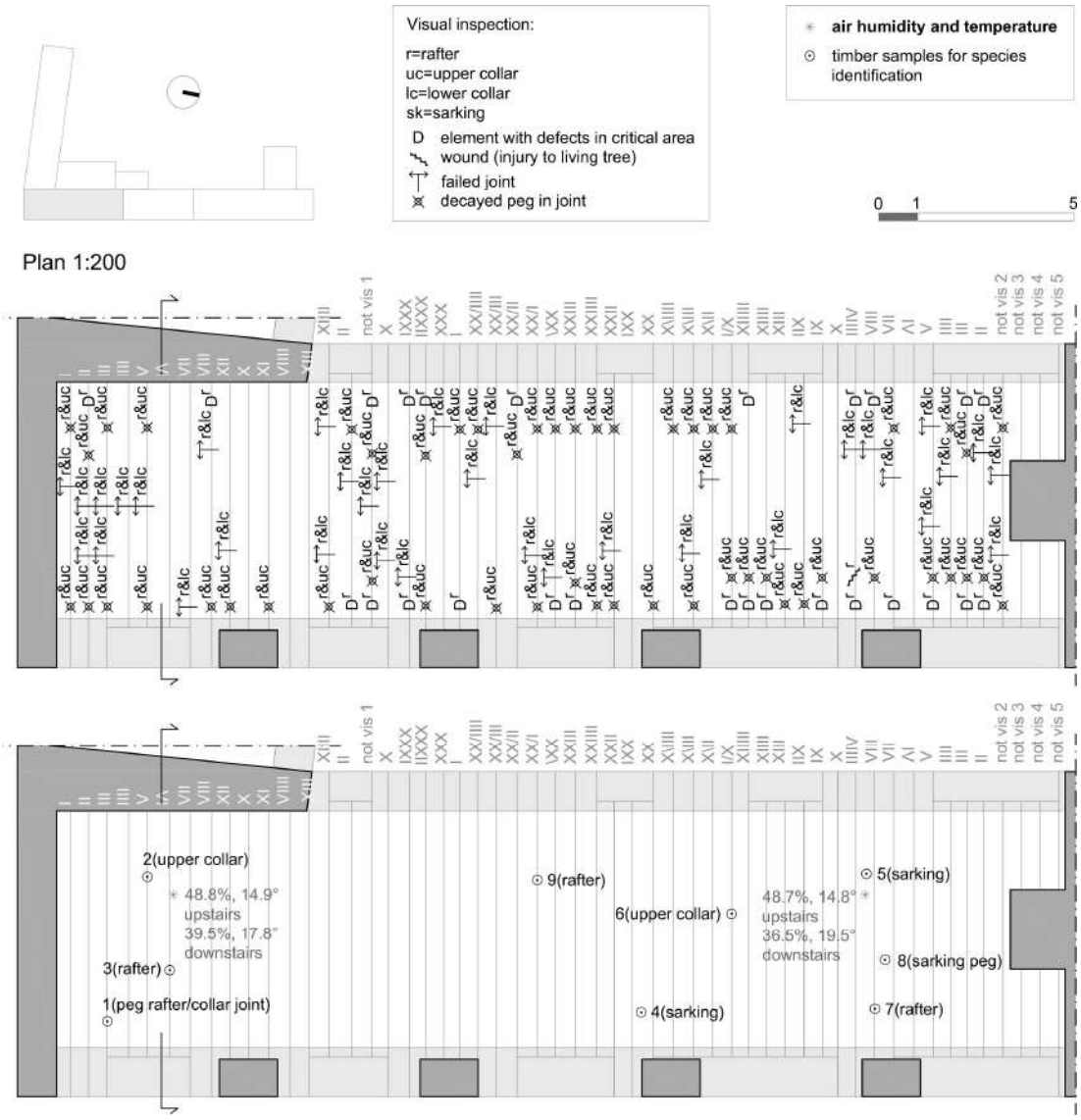


Figure 55: the plan of the roof of Pinkie Houses' long hall with the results of the detailed visual inspection and of the air temperature and relative humidity measurements, and the location of the sampling for the timber species identification

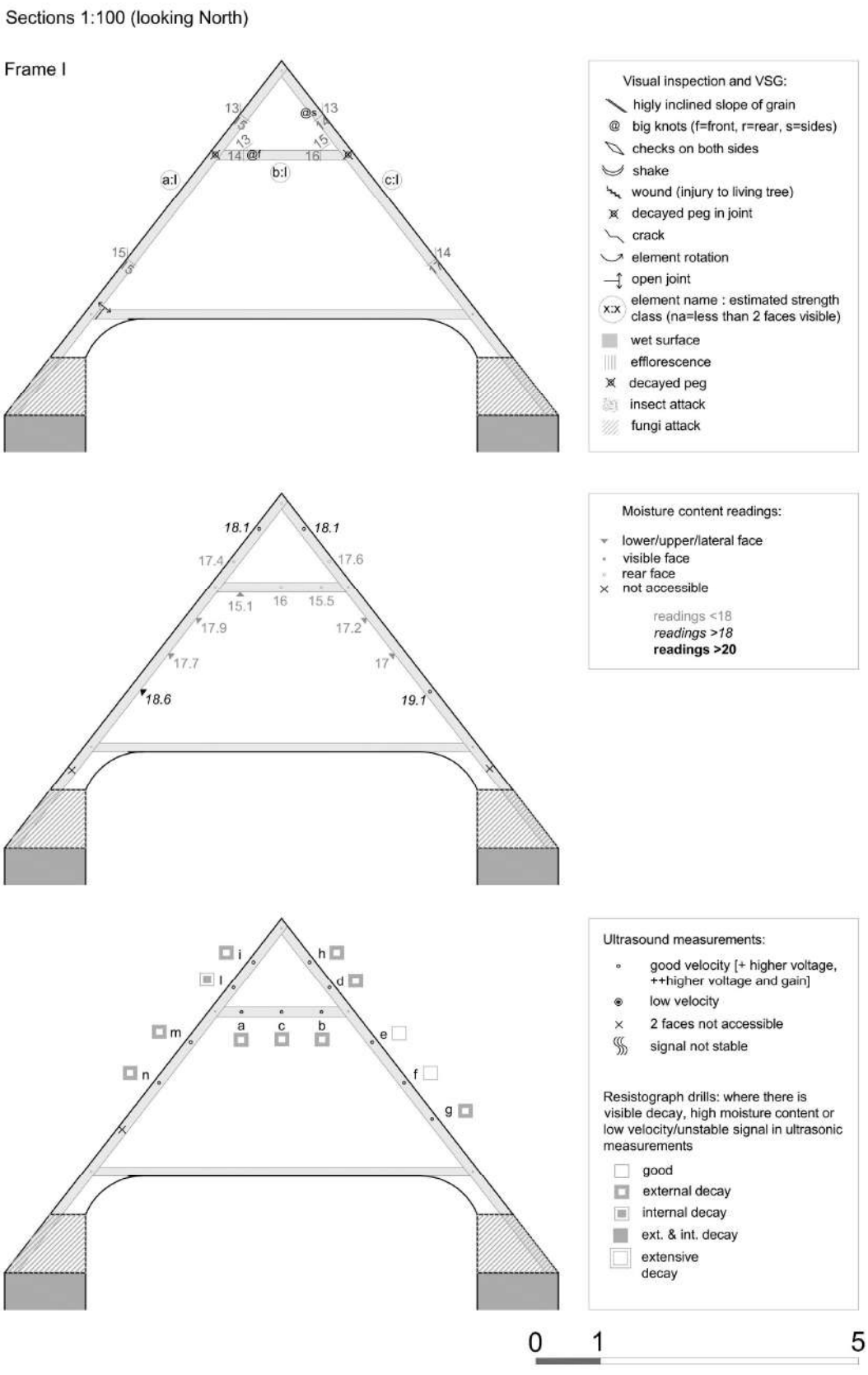


Figure 56: The results of the assessment of one of the reference frames of the roof above Pinkie Houses' long hall; the lower collars could not been assessed because they are hidden underneath insulation sheets

Table 6: A summary of the tests carried out in the case studies

	Timber Species Identif.	Air Temp. Humid.	Thermal camera - snake camera	Visual Strength Grading	Moisture Content Readings	Detailed Visual insp.	Rubber hammer	Ultrasonic test	Micro-drill
St Andrew's & St george's church	x	x	x	1 truss	1 truss	1 truss			
St Andrew's in the Square church	x	x	x	1 truss	1 truss	1 truss			
Cockenzie House	x	x	x	12 frames	11 frames	1 section of roof			
Holyrood Palace	x	x	x	3 frames	3 frames & critical elements	all roof	3 frames & critical elements	78 points	78 points
Newhailes House	x	x	x	2 frames	2 frames	2 frames			
Pinkie House above long hall	x	x	x	7 frames	7 frames	all roof	7 frames*	25 points	25 points
Stirling Castle Palace NE Range	x	x	x	3 frames	3 frames & critical elements	all roof	3 frames & critical elements	45 points	45 points
Stirling Castle Palace SW Range	x	x	x	3 frames	3 frames & critical elements	all roof	3 frames & critical elements	32 points	32 points
Stirling Castle Palace NW Corner	x	x	x	all primary elements					
Stirling Castle Palace W Range	x	x	x	3 frames					
Stirling Castle King's Old Buildings	x	x	x						
Touch House North range	x	x	x	4 frames	4 frames	4 frames			
Touch House main block	x	x	x	all primary elements	all primary elements	all primary elements			

* no critical elements identified

Holyrood Palace and Stirling Castle are in the care of HES and have been chosen to prove that the methodology is applicable even to not privately owned buildings. Scheduled Monument Consents were approved to carry out tests in both buildings. However, the need for permissions provoked delays, which have to be taken in consideration when programming testing campaigns.

2.4.3 Tests procedure and interpretation of results

2.4.3.1 Macroscopic and microscopic identification of the timber species

The timber species has been identified following procedures and suggestions in Macchioni (2010) and Nardi Berti et al. (2006) and personal training given by Alan Crivellaro (University of Padova).

The whole structure has been assessed visually in order to decide where to take samples. At least one sample has been collected from each structural element type (rafter, collar, etc) (Figure 55). When possible, the sample has been collected where loose splinters were readily available, in order to minimize the disruption to the structure.

The samples have been analysed through comparative techniques macroscopically in situ with hand lenses (Figure 57) and later in the laboratory with a light transmission microscope (Figure 58). Some pegs securing the joints between elements have been identified macroscopically only, to avoid collecting samples and disrupting the overall appearance and functioning of the elements.

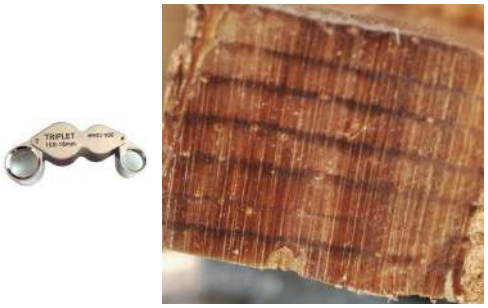


Figure 57: Hand lenses used for the macroscopic identification of the timber species (left) and a sample of pinus sylvestris taken from Cockenzie House (right)

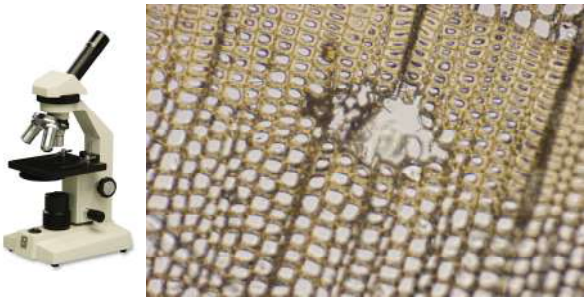


Figure 58: The light transmission microscope used for the microscopic identification of the timber species (left) and the same sample as in Figure 57 (right)

2.4.3.2 Environmental Conditions

An air thermometer has been used to measure the air temperature and relative humidity. It has been left for 15 minutes in the measurement location to allow it to get used to the environment before reading the measurement. When the roof space was big, 2 or 3 measurements have been taken in different areas and then averaged (Figure 55). The readings have been analysed considering that the air relative humidity should remain between 45% and 65% and the air temperature between 15° and 21° in order to avoid optimal conditions for biotic attack (Ridout, 2000).

The hygrometer GANN Hydromette RTU 600 has been used to measure the wood moisture content (Figure *59*). It has been operated according to RILEM guidelines (Riggio et al., 2014) and to the manufacturer's instructions. Insulated pins have been used and the measurements have been

calibrated according to the air temperature and timber species. The readings have been analysed considering that the wood moisture content should never be too far from the equilibrium moisture content (Figure 27), and should always remain between 8% and 18% (Ridout, 2000).

2.4.3.3 Thermography and endoscopy

The thermal camera FLIR E4 has been used according to the manufacturer's instructions and to personal suggestions given by Maureen Young, an HES conservation scientist. It has been used both in the roof spaces and in the rooms underneath to spot humid areas and to assess the geometry of the structure hidden behind the plaster/timber panelling (Figure 60).

The USB snake camera Northvision NC-Z04N has been used to assess the condition of the connection with the wall-head, by inserting the probe in the space in-between the rafters. In Cockenzie House the probe was also inserted through three small holes opened in the panelling in the attic rooms.



Figure 59: The hygormeter GANN Hydromette RTU 600 used during the surveys (left) and a picture of the author while taking measurements with it (right)

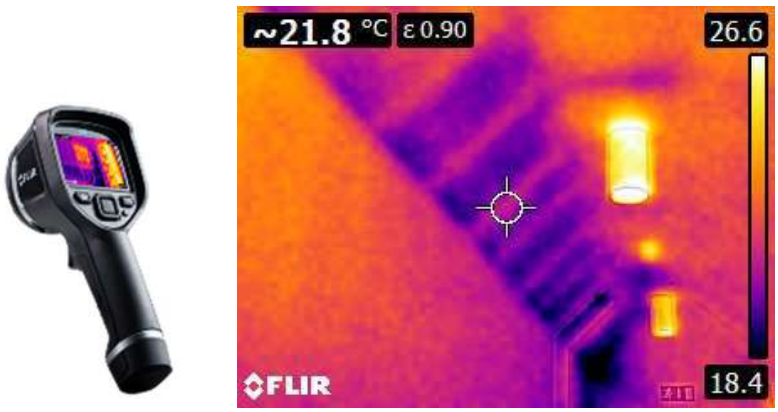


Figure 60: The FLIR E4 thermal camera used during the surveys (left) and a thermographic image taken in the attic rooms of Stirling Castle Palace (right)

2.4.3.4 Visual Strength Grading

Visual Strength Grading (VSG) has been carried out on all elements of the reference frames according to the Italian Standard UNI 11119 (2004) and recent guidelines (Cruz et al., 2015). An extract of the Italian Standard, showing the maximum values for each of the parameters considered as 'strength affecting' in order for the timber element to correspond to strength class I, II or III, is reported in Table 7; Table 8 shows the maximum stresses corresponding to each strength class for *Pinus Sylvestris*, the species found in all of the assessed case studies.

As suggested by Cruz et al. (2015), we have evaluated the importance of defects in relation to the applied stresses and we have not taken into consideration wane nor vertical drying fissures because they are not actually 'strength affecting' parameters: wane reduces the negative effect of knots and slope of grain and drying fissures are dangerous only when they very deep and on the sides of an element, reducing the height of its resisting section. On the contrary, the position of the pith has been recorded as it is a strength affecting defect (Tampone, 1996).

Accessibility and visibility issues sometimes hindered from grading the timber elements. When three out of four faces were visible the timbers were graded but the limitation was reported in the results.

Table 7: The maximum values allowed for each of the strength affecting parameters corresponding to strength classes I, II, III (UNI 11119, 2004)

Strength affecting parameters		**Strength Classes**		
		I	**II**	**III**
wane		≤1/8	≤1/5	≤1/3
various defects/frost fissures/shakes		absent	absent	limited
single knots		≤1/5 ≤50mm	≤1/3 ≤70mm	≤1/2
groups of knots		≤2/5	≤2/3	≤3/4
slope of grain [%]	radial	≤1/14 (~7%)	≤1/8 (~12%)	≤1/5 (~20%)
	tangential	≤1/10 (~10%)	≤1/5 (~20%)	≤1/3 (~33%)
checks/drying fissures		not passing through		

Table 8: Maximum stresses [N/mm^2] for Pinus Sylvestris at 12% moisture content (UNI 11119, 2004)

Strength Classes	**Compression parallel to grain**	**Compression Perpendicular to grain**	**Bending**	**Tension parallel to grain**	**Shear parallel to grain**	**Modulus of Elasticity**
I	11	2	12	11	1	13000
II	9	2	10	9	0.9	12000
III	7	2	8	6	0.8	11000

2.4.3.5 Acoustic tests

Timber sounding and a time-of-flight method have been used to assess the internal condition of timbers. A rubber hammer has been used as a first screening test, according to personal suggestions by Alan Crivellaro (University of Padova). The centre of each element has been struck to understand if the element is loaded and to identify extensive damage. The elements have also been struck at regular intervals all along their length to identify internal material degradation.

The ultrasonic device has been used according to RILEM guidelines (Dackermann et al., 2014) and to the manufacturer's instructions (Figure 61). Direct transversal measurements have been taken to assess the internal conditions of timber elements. Longitudinal measurements, which can be used to estimate the timber mechanical properties, have not been carried out because the correlations with strength/stiffness are not always high (Feio and Machado, 2015) and they require the input of density. Moreover they have been found to be very difficult to carry out in-situ: the signal was often too unstable for the ultrasonic device to record automatically a measurement.



Figure 61: The ultrasonic device Proceq Pundit PL-200 used during the surveys (left), PhD student Bowen Qiu using it during the surveys in Stirling Castle Palace (centre) while the author applys the transducers to the timber (right)

The use of sonic stress waves (below 20 KHz) rather than ultrasonic waves (above 20 KHz) is recommended by RILEM (Dackermann et al., 2014) for timbers with a depth greater than 89mm, such as the ones found in the analysed roof structures. This is because higher frequency waves have shorter wavelengths that are able to detect more subtle interior defects, but cannot travel long distances due to greater attenuation. Nevertheless, many studies have used ultrasonic devices to test timbers of bigger sizes (Cescatti et al., 2014, Morales Conde et al., 2015, Rodríguez Liñán et al., 2015), therefore we have decided to use 54 KHz standard transducers.

At first, we coupled the transducers to the timber with gel and a thin sheet of latex, but the irregular surface of the timbers caused the measurements to be unstable. Thus visco-elastic silicone polymer putty (silly putty) was eventually chosen as coupling agent, as it can adapt well to the surface but,

unlike gel, it is stiff enough to resist the pressure (suggested by Dr Daniel Ridley-Ellis, Napier University).

The Voltage and Gain have been left to the default values (200Vpp and 100 respectively) unless the signal was unstable: in this case the Voltage was gradually increased, and then the Gain as well, up to the maximum level. Nevertheless, in some cases it was still impossible to take a measurement. Five measurements have been taken in each measurement point and averaged. The distance between the transducers was manually measured and input into the ultrasonic device, which then automatically calculated the velocity.

The measurement of the time of flight calculated automatically by the ultrasonic device is often not accurate, due to the noise underlying each measurement. In order to remove this noise, the signal has been manually processed in the following way (Table 9):

- The arithmetic mean and standard deviation of the signals in the last part of the graph, where only the noise remains (highlighted in grey Figure 62), have been calculated;
- an upper and lower threshold have been calculated according to the following formula: $AM \pm 5 \text{ x } SD$ [µs] (AM = arithmetic mean; SD = standard deviation; factor 5 was chosen because the thresholds calculated with factor 3 produced invalid results);
- the first signal greater than the upper threshold and lower than the lower threshold have been identified, the resulting time of flight being the lowest between the two;
- the five measurements have then been averaged.

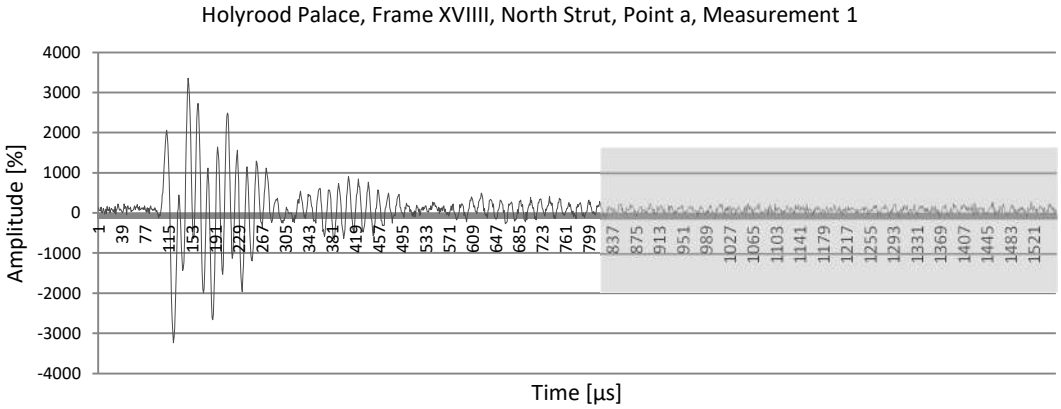


Figure 62: Signal curve of an ultrasonic measurement taken in Holyrood Palace; the last part of the graph, where only the noise remains, is highlighted in grey (only about 1/10 of the graph is here shown due to space limit). The time of flight has been calculated here to be 101 (Table 9)

Table 9: Calculation of the time of flight of the ultrasonic measurement shown in Figure 62

Distance [m]	Arithmetic mean of noise [µs]	Standard Deviation of noise [µs]	Upper threshold (A+5SD) [µs]	Lower threshold (A-5SD) [µs]	First Less Than [µs]	First Greater than [µs]	**Time of flight [µs]**	Arithmetic mean [µs]
0.1	89.43	61.52	397.03	-218.17	114	101	**101**	101.6
	90.04	62.45	402.30	-222.23	114	102	**102**	
	90.03	61.00	395.05	-214.99	114	101	**101**	
	90.02	60.67	393.35	-213.31	114	101	**101**	
	90.55	62.58	403.47	-222.37	115	103	**103**	

The velocity has been calculated according to the following formula (Table 10):

$$V = \frac{d}{TOF} \ [m/s]$$

(V = velocity; d = distance between the transducers; TOF = time of flight)

The velocity has then been corrected according to the grain orientation and the moisture content (Table 10). The relative angle between the impact direction and the grain orientation influences the speed of sonic waves (Dackermann et al., 2014): the slowest wave is for an impact of 45° orientation to the annual growth rings; the fastest is for radial excitation and is about 30% faster than with 45° orientated rings; the tangential is about halfway between the radial and the 45°. Therefore the result of the ultrasonic measurement needs to be manually increased with adjustment factors of 1.3 in case of an impact of 45° orientation to the annual growth rings and 1.15 in case of an impact tangential to the annual growth rings. The example measurement in Table 10 has been taken with an impact of 45°, hence the velocity has been increased by 1.3.

The moisture content also influences the speed of sonic waves. Its influence is different for each timber species. We have adjusted the velocity based on the measured moisture content (Table 10) using an equation developed for *Pinus Sylvestris* by Rodríguez Liñán et al. (2015) to refer all ultrasonic measurements perpendicular to the grain to the same moisture content (12%):

$$V_{12} = 15.89 \ (H_x - 12) + V_x \ [m/s]$$

(V12 = ultrasonic velocity perpendicular to the grain with a moisture content of 12%; Hx = moisture content different from 12%; Vx = ultrasonic velocity perpendicular to the grain with an Hx moisture content)

The Ultrasonic velocity should be corrected also according to the time lag dependent on the device and the timber species and knottiness (Llana et al., 2016). Unfortunately correlations for the used device, the Proceq Pundit PL-200, are not available yet.

Table 10: Calculation and correction of the ultrasonic wave velocity of the time of flight calculated in Table 9

Distance [m]	Time of flight [µs]	Velocity [m/s]	Velocity corrected according to direction [m/s]	Moisture Content [%]	**Velocity corrected according to moisture content [m/s]**
0.1	101.6	985	1280	15.7	**1340**

The ultrasonic test measures the time-of-flight of sound waves travelling through wood. Sound waves propagate quickly through dense, solid materials; on the contrary they are attenuated and diverted by voids, cracks, or decay, because they must find a path around these defects and this results in increased transmission times. Therefore, the internal conditions of timber can be evaluated by comparing the measured wave velocities with reference velocities for sound wood. Two different reference velocities have been found for *Pinus Sylvestris*: 1470 m/s in Dackermann et al. (2014) and 1200 m/s in Rodríguez Liñán et al. (2015). The relative velocity decrease has been calculated for both reference velocities according to the following equation (Dackermann et al., 2014) (Table 11):

$$\Delta V = \frac{V_{ref} - V_{mes}}{V_{ref}} \; 100 \; [\%]$$

(ΔV = relative decrease of the wave velocity; V_{ref} = reference wave velocity; V_{mes} = measured wave velocity)

The relative velocity decrease has been analysed considering the relationship proposed by Dackermann et al. (2014):

- up to 10% decrease = no decay;
- 10/20% decrease = 10% decayed area;
- 20/30% decrease = 20% decayed area;
- 30/40% decrease = 30% decayed area;
- 40/50% decrease = 40% decayed area;
- >50% decrease = >50% decayed area.

The density loss has been estimated according to the equation developed by Rodríguez Liñán et al. (2015) for ultrasonic measurements perpendicular to the grain (Table 11):

$$\Delta d = 53.257 - 0.0396 \; V \; [\%]$$

(Δd = density loss; V = ultrasonic velocity perpendicular to the grain)

According to Rodríguez Liñán et al. (2015), timber is deteriorated when the density loss is > 30% (wave velocity < 600 m/s).

Table 11: Relative wave velocity decrease calculated by comparing the velocity calculated in Table 10 with reference velocities and estimation of density loss

Location	Visible Decay	Moisture Content [%]	Velocity [m/s]	Relative Velocity Decrease [%]		**Density Loss [%]**
				Reference 1470 m/s	Reference 1200 m/s	
Holyrood Palace Frame XVIIII North Strut Point a	no	15.7	1340	8.9	-11.5	**0.3**

In conclusion, areas with possible internal damage/decay have been identified where the ultrasonic device has measured waves with a low velocity (>10% decrease compared to the reference velocity 1470 m/s, as suggested by Rodríguez Liñán et al. (2015)) and where it has not been possible to take measurements because the signal was not stable enough.

2.4.3.6 Micro-drilling test

The ultrasonic waves test has been designed for concrete structures and its application to timber structures is quite recent. Some research has been carried out providing us with correlations, correction factors, and reference velocities, as discussed above, but these results are based mostly on laboratory tests carried out on clear wood samples, which do not reflect the complexity of in-situ timber and do not consider the limits and difficulties of in situ measurements.

The resistance micro-drilling test is on the contrary very reliable, but it is minor-destructive as it leaves a 3mm diameter hole through the section of the timber element. If the ultrasonic test, which is completely non-destructive, could be used as 'screening test' to decide where to use the micro-drilling device, as is currently done in tree health inspection, this would considerably reduce the amount of drills needed and therefore the damage to the structure. In order to understand if the ultrasonic device used gives reliable results for the analysed timber roof structures, the micro-drilling device has been used as 'verification' test: micro-drills have been carried out not only where the ultrasonic device has identified possible internal damage/decay, but also in other areas (Figure 56): where a high (>18%) moisture content has been measured and where visible external decay has been identified during the visual inspection.

The micro-drilling device IML RESI-F400 has been used according to RILEM guidelines (Tannert et al., 2014) and to the manufacturer's instructions. Although there have been efforts to correlate results obtained through micro-drilling with strength/stiffness of timber, correlations have been found to be quite variable and not always reliable (Nowak et al., 2016). The drilling graphs have therefore been evaluated only qualitatively, looking at areas with decreased velocity which can correspond to

internal decay/damage (Tannert et al., 2014). Areas with zero resistance have been highlighted in red and areas with decreased resistance have been highlighted in yellow (Figure 63: in grey is the part of the graph outside the timber element). Areas with very high resistance, corresponding to knots, have been highlighted in green.

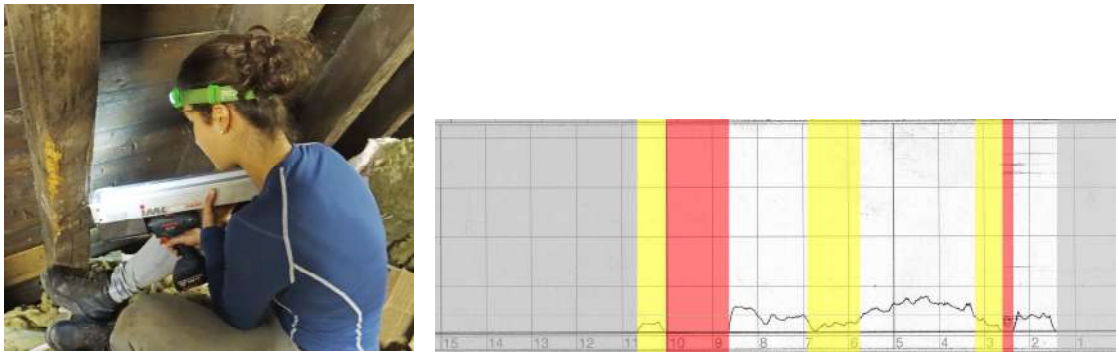


Figure 63: The micro-drilling device IML RESI-F400 used during the surveys (left) and an example of micro-drill graph from Holyrood Palace - North range, frame 43, North strut, point b (right)

2.5 A novel structured digital form to support the survey and data analysis

The data collected during the historical and archival research and the surveys has been reported in a structured form integrated within the database. The form has been produced in collaboration with COST Action FP1101 (Serafini et al., 2016) (Appendix I) and then further developed and adapted by the author to meet the purposes of this research. It has been useful to guide the surveys and to produce consistent results, but also to analyse the data.

2.5.1 Approach

Structured forms have been used since 1980s for vulnerability surveys and post-event damage recognition surveys. The form by Benedetti and Petrini (1984) was developed to assess the seismic vulnerability of masonry buildings in Italy. More recent research has produced different types of forms to assess seismic damage (Baggio et al., 2007), to assess causes of failures in 20th century timber roof structures (Frese and Blaß, 2011, Hansson, 2011, Toratti, 2011) and to assess the seismic vulnerability of traditional Italian timber roof structures (Parisi et al., 2013). In all of these studies the first step is a visual examination of the structures according to a codified procedure: a series of characteristics that determine or influence the specific aspect studied are identified and then a classification criteria is defined to be able to compare different cases, identify urgent interventions and make a plan for risk reduction in the territory.

The form developed by Toratti (2011) has a two-fold purpose: help the experts in the assessment, making them aware of the relevant questions that need answers; produce consistent results that can be analysed in order to draw conclusions on typical damage and related causes. The form developed by Task Group 1 (TG1) of Working Group 1 (WG1) of COST Action FP1101 (Riggio et al., 2015a), has the same purpose but focused on timber roof structures, not addressed so far. Starting from this work, the author created a structured form using Microsoft Access during a two-week Short Term Scientific Mission (STSM) in May 2015 at CNR IVALSA Institute in San Michele All'Adige (Italy), under the suprvision of Dr. Mariapaola Riggio (Serafini et al., 2016). Prior to the STSM work, TG1 had already identified a series of objectives that the form should fulfil (Riggio et al., 2015a):

- Allow collecting a significant amount of data reporting typical damage/vulnerabilities;
- Define structural types (considering the European built asset) and a damage taxonomy to provide a consistent approach to the evaluation of structural damage;
- Distinguish between material degradation and mechanical damage;
- Support multi-level analysis (visual inspection, in-situ tests, lab-tests, etc.).

The form was however in word format, which did not allow for the analysis of a big amount of data and was not suitable for quick inspections, due to the considerable amount of pages involved. Moreover, a tree-like organisation (system, unit, element, connection) had been implemented but structure types and damage taxonomy for each level had not been clearly identified. The inclusion of VSG regulations had to be defined too, and graphics were needed to support the relevant terminology. Most importantly the form needed to be validated by applying it to real case studies.

The STSM work focused on the reorganisation of the contents of the TG1 form in both format and structure using Microsoft Access software in order to integrate it with the database of seventeenth- and eighteenth-century Scottish buildings. After the STSM, the form was validated by using it during the surveys of summer 2015, in order to identify typical damage and vulnerabilities in Scottish roof structures. This validation work brought to a semplification and adaptation of the form to the specific purposes of the research, as explained below. The filled forms can be found in Appendix E.

2.5.2 Content

The form aims at assisting the professional during inspections in recording and organising all the information needed, pointing out critical aspects that need special attention, and during the analysis of data from several inspections allowing to draw conclusions regarding construction history and typical damage and causes. The tree-like organisation of the TG1 form has been retained and enriched with a classification of types of structures and damage for each level (Figure 64). Each building can have one or more roofs (systems), composed of a primary and a secondary structure;

each of these can be composed of units (groups of elements repeated with the same arrangement), elements and connections between elements.

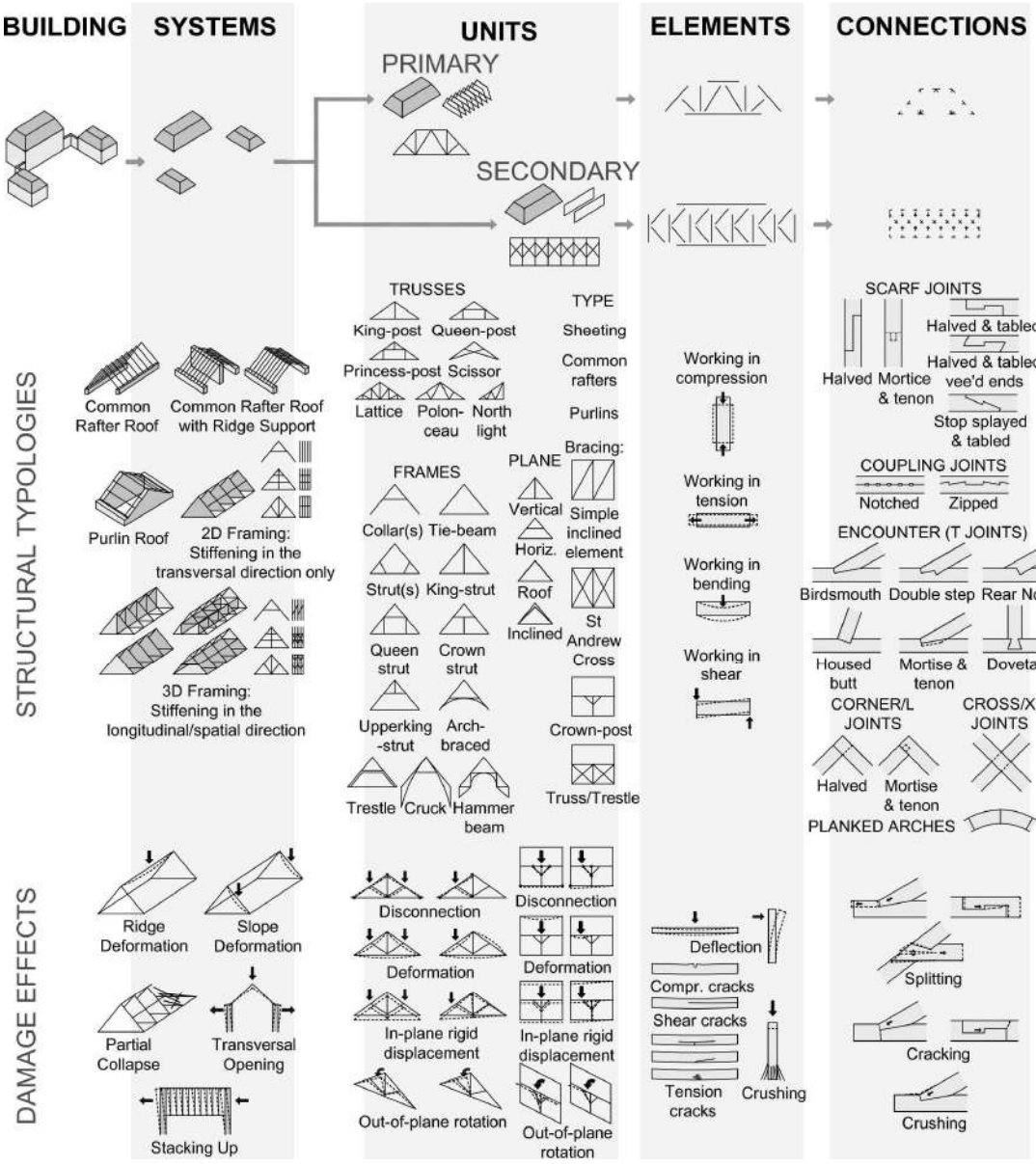


Figure 64: The tree like organization of the structured form, with a classification of structural typologies and damage effects identified for each level: building, system, unit, element, connection (Serafini et al., 2016)

Structural types have been grouped into families according to their structural behaviour rather than their geometrical arrangement. The structural behaviour has been assessed based on previous research (Lohrum and King, 2006, Szabó and Kulin, 2005, Tampone, 1996) and discussions with the members of TG1. Clearly, not all local variations have been considered.

The form is divided in three main sections: the first is related to the building, the second is related to the preliminary survey and the third to the detailed survey of the eight case studies.

2.5.2.1 The building

General information on the building's name, location, property and protection status, original and current use, geometrical aspects, interventions and literature/archival references are recorded in the first section of the form (Figure 67). X and Y coordinates and the geo-referencing system have been included in order to be able to plot the results. The property can be private, public or belong to the church. The protection status can be 'UNESCO' (part of a World Heritage site), 'National' and 'Regional'. The HES listing and RCAHMS ID (now incorporated in HES) are specified. Geometrical aspects include the number of floors above ground level and if the building is freestanding or not. All information found related to the building history and the people involved are included in the 'interventions' tab. The partial or complete transcription of the consulted archival documents is included at the end when available.

2.5.2.2 Geometry, technology and condition of the roof structure

The second section of the form starts with plans and sections of the building (1:1000) and the roof (1:500, 1:100) (Figure 68), then specific geometrical and typological information is reported (Figure 69), such as:

- Geometry (Figure 65), maximum span, height, pitch and length;
- Type and dimensions of primary and secondary structures (Figure 64);
- Type of connection with the supporting walls (Figure 66);
- Roof construction period and its method of identification (reported, estimated or assessed through dendrochronology);
- Roofing material (slates, lead, clay tiles, stone slabs, wooden shingles, copper plates, thatch) and its fixing method (metal nails, wooden pegs);
- Elements' section shape (square, rectangular, with wanes, round, trapezoid), the timber dressing (rustic: hand axed, rustic: hand sawn, civil: machine sawn) and average scantlings of the primary elements;
- Types of joints (Figure 64) and fasteners (timber pegs/dowels/wedges/keys, metal nails/bolts/straps);
- Timber species and its method of identification (macroscopic analysis, microscopic analysis, dendrochronological analysis);
- Carpentry marks;
- Signs of reused timbers such as redundant joints.

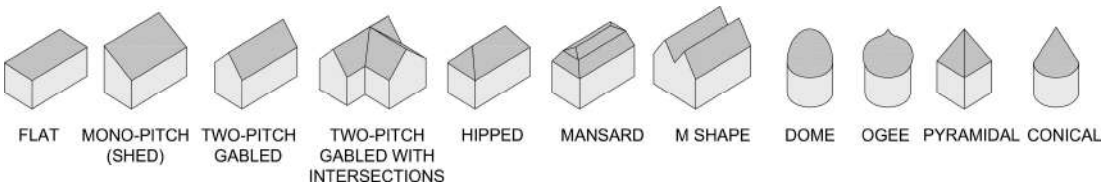


Figure 65: The classification of roof geometries included in the structured form

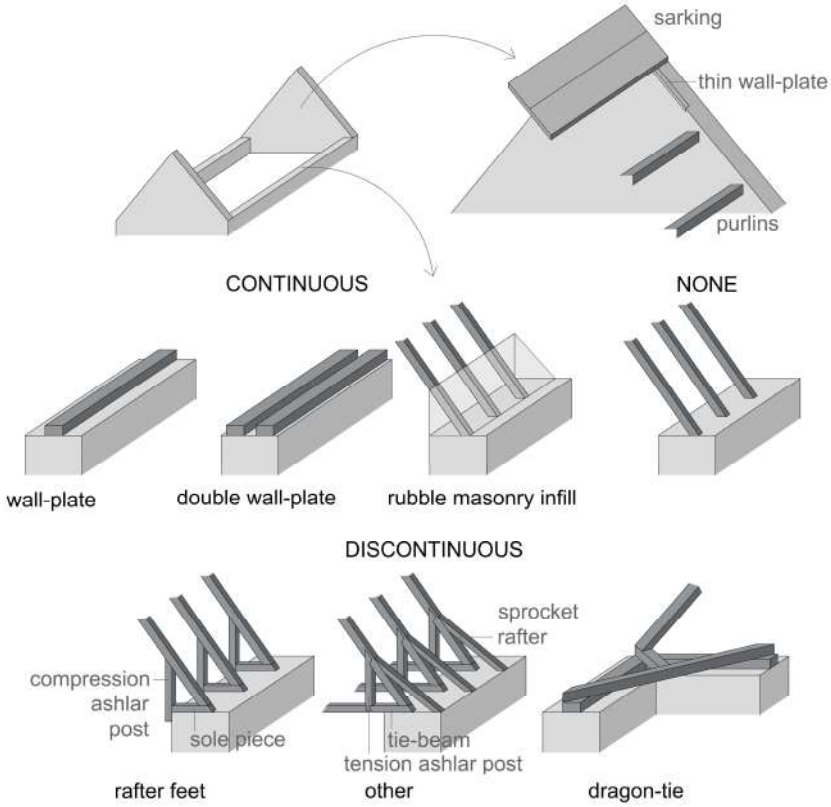


Figure 66: The different types of connections with the supporting walls included in the structured form

The roof description can include a comment on the fact that the original structural concept is different from the present behaviour: e.g. a unit might have been designed as a king-post truss but it is estimated to be behaving as a king-post frame, because of poor design, poor construction, etc.

GLASGOW ST ANDREW'S IN THE SQUARE CHURCH

Location GLASGOW, CITY OF GLASGOW (GLASGOW, CITY OF)
X coordinate 259698 Y coordinate 664681
Geogr. Referencing System BRITISH NATIONAL GRID





Property status CHURCH
Rcahms ID 44237
HS Listing A

Original Use Religious
Current Use Religious

Freestanding ✔ N. of floors above ground level 1 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1740	1757	ROOF STRUCTURE BUILT BETWEEN 1751 AND 1753	RENWICK 1911

People involved:

Last Name	First Name	Role	Attributed
DREGHORN	ALLAN	DESIGNER	
NAISMITH	MUNGO	MASON	
CLAYTON	THOMAS	PLASTERER	
ROBERTSON	JOHN	WRIGHT	
CROSS	JAMES	MASON	
LAWSON	GAVIN	MASON	
CATION	DAVID	MASON	
WILSON	JOHN	WRIGHT	
FLEMING	WILLIAM	WRIGHT	

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1874		INTERIORS	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1906			RCHAMS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1921		INTERIORS	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1980	1989	NO RECORDS - CHURCH ARCHITECT THINKS IT INVOLVED CARBON FIBRE RODS AND RESIN INJECTION BY RBR SCOTLAND LTD	CHURCH ACHITECT

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
GLENDINNING M. & MACKECHNIE A.	2004		SCOTTISH ARCHITECTURE	118
RENWICK R. (ED.)	1911		EXTRACTS FROM THE RECORDS OF THE BURGH OF GLASGOW WITH AND OTHER DOCUMENTS VOL. VI A.D. 1739-59	
WILLIAMSON E. & RICHES A.	1990		THE BUILDINGS OF SCOTLAND COLLECTION: GLASGOW	

Suggestions for further research

Anna Serafini PhD thesis - Supervisors: Cristina Gonzalez Longo and Andrew Agapiou, Architecture department, University of Strathclyde

Figure 67: First section of the structured form: information related to the building (this example shows St Andrew's in the Square church)

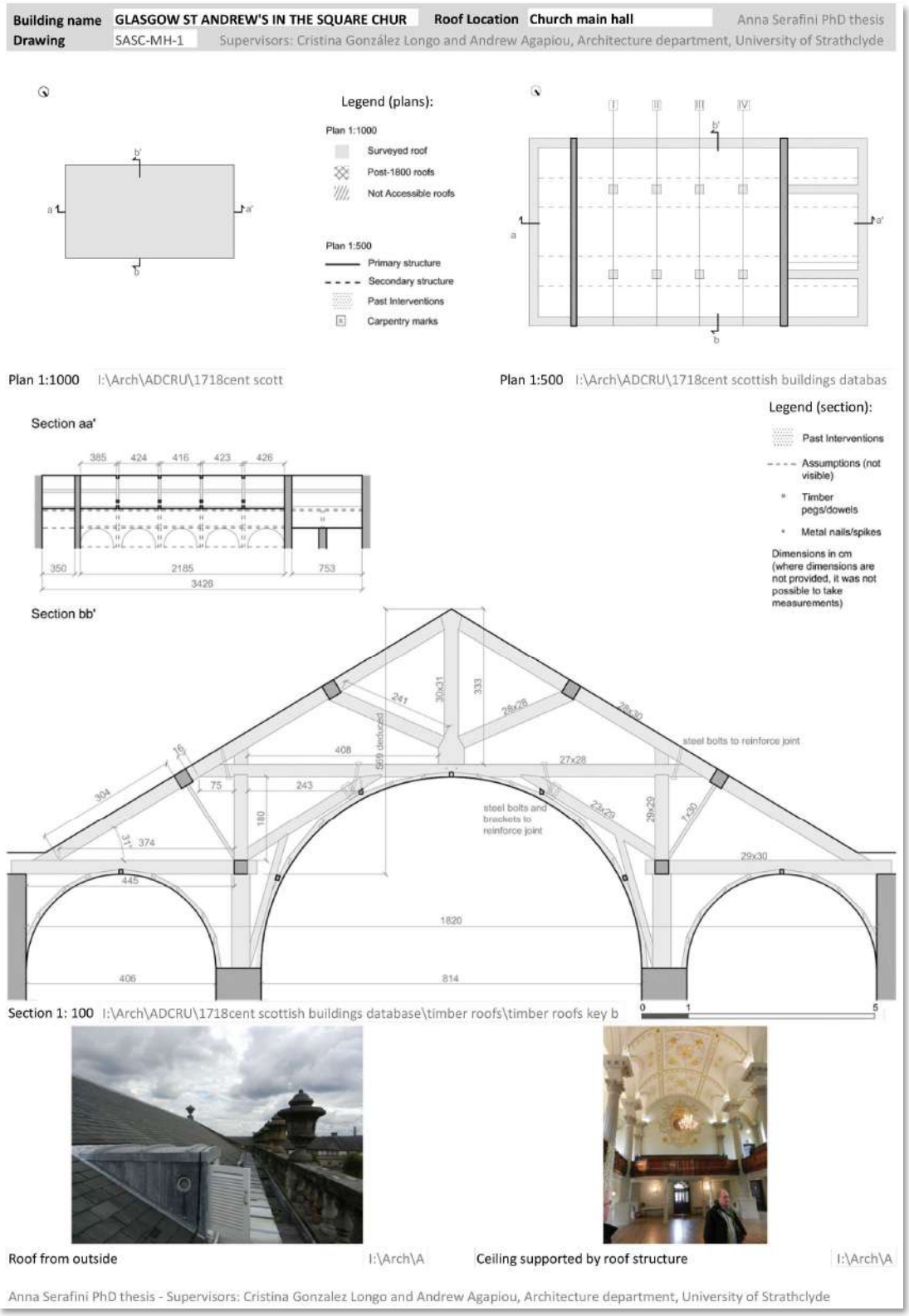


Figure 68: Second section of the structured form: plan and sections of the roof structure (this example shows St Andrew's in the Square church)

INITIAL SURVEY Building name: GLASGOW ST ANDREW'S IN THE SQUARE CHU — Roof location: Church main hall

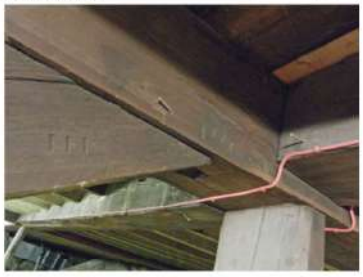
Survey date(s): 31/08/2015 — See drawing: SASC-MH-1

Roof Geometry	Two-pitch gabled
Roof Max Span [m]	8.4 - 4
Roof Height [m]	7.7
Roof Pitch/es [°]	31
Roof Length [m]	34.3
Type of Primary Structure	2D framing; Truss ✔ PRINCESS-POST; Frame ☐
Average Distance in between Primary Structure [m]	4.5
Type of Secondary Structure	common rafters, purlins, sarking
Sarking boards: width [cm]	thickness [cm]
Connection with lateral walls	None
Connection with gables	purlins
Roof Construction Period: From	1739 To 1756 Identified by: Estimated
Roof General Description	Gabled roof with steeple on northwest side. Steeple structure wasn't surveyed. Main roof supported by two transversal walls and 4 princess post trusses in the central part. All three posts have slanted struts on both sides. Trusses span reduced by intermediate columns, one on each side. Original plaster ceiling underneath.
Roofing Material	slate
Roofing Material Fixing	Metal nails
Timber elements' Section Shape	Rectangular, Square
Rafter Scantling [cm] H:	30 B: 28 Or Purlin - H: B
Timber elements' Dressing	rustic (hand-axed), rustic (hand-sawn) Bark ☐
Joint Types	joggle, mortice and tenon, notch
Fasteners Types	Timber dowel
Joints description	All mortice and tenon, timber dowels only between central post and collar. Central post has joggles. Lateral post and slanted strut between lateral post and collar have notches. Fasteners not visible.
Wood Species	pinus sylvestris — Way of identification: direct micro
Carpentry Marks Types	small chiseled roman numerals, strange marks (from scandinavia?)
Carpentry Marks Description	In sequence from I to IIII (east to west)
Signs of reused timbers	
Timber Treated	☐
Other Materials	Resin and steel bolts/brackets
Dendrochronology	


Roof structure link I:\Arch\A


Connection with wall link I:\Arch\A


Timber dressing link I:\Arch\A


Joints and carpentry marks link I:\Arch\A


carpentry marks on sarking link I:\Arch\A

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Figure 69: Second section of the structured form: geometrical and typological information related to the roof structure (this example shows St Andrew's in the Square church)

The last page of this section of the form includes information about its use, insulation, decorative features, unfavourable conditions, accessibility issues, past interventions, signs and causes of material degradation or mechanical damage (Figure 70). The effect of past interventions is particularly critical to evaluate, as they can be localised or involve the whole structure and differently affect the original behaviour of the structure (Parisi et al., 2013); thus the form includes only a description and eventually a picture/drawing of past interventions, not their evaluation.

An important distinction has been made between damage effects and causes. Damage effects (deformations, displacements, rotations, cracks, etc.), defined with the help of the work carried out by Tampone (1996, 2007, 2016) and by TG3 of WG1 of COST Action FP 1101 on traditional carpentry (Sobra et al., 2015), are recorded for each level (system, unit, element, connection) (Figure 64), and for each of the effects the damage status and role are estimated. The damage status can be 'active' or 'non-active', but it is not always possible to judge. Therefore, a simple 'intervened on' is included, meaning that an intervention has been done to repair the damage but no evaluation on its effectiveness is given. Regarding the role, a structure is often affected by a sequence of damage rather than a single one, and it is important to identify the first one(s) that caused the others: this is defined 'primary' damage, while all the others are defined as 'secondary'.

The causes of damage can also be estimated; the forms previously discussed (Frese and Blas 2011; Hansson 2011; Toratti 2011) have helped in defining them:

- Poor design (insufficient dimensions, inefficient joints, inefficient overall arrangement);
- Poor construction (poor material quality/seasoning/treatment, poor detailing, design alterations);
- Material degradation (fungi attack, insect attack, metal corrosion);
- Poor maintenance;
- Past interventions (increase of dead loads, repair/consolidations);
- External actions (wind, fire, earthquake, snow, impact loads, settlements).

These can also be recorded as potential causes of damage, called 'unfavourable conditions'. This means they have not caused damage yet but might be a problem in the future, which is why they should be recorded nonetheless. Other unfavourable conditions have been included too, such as poor ventilation, the presence of bats/wasps/pigeons, the presence of open-air water tanks.

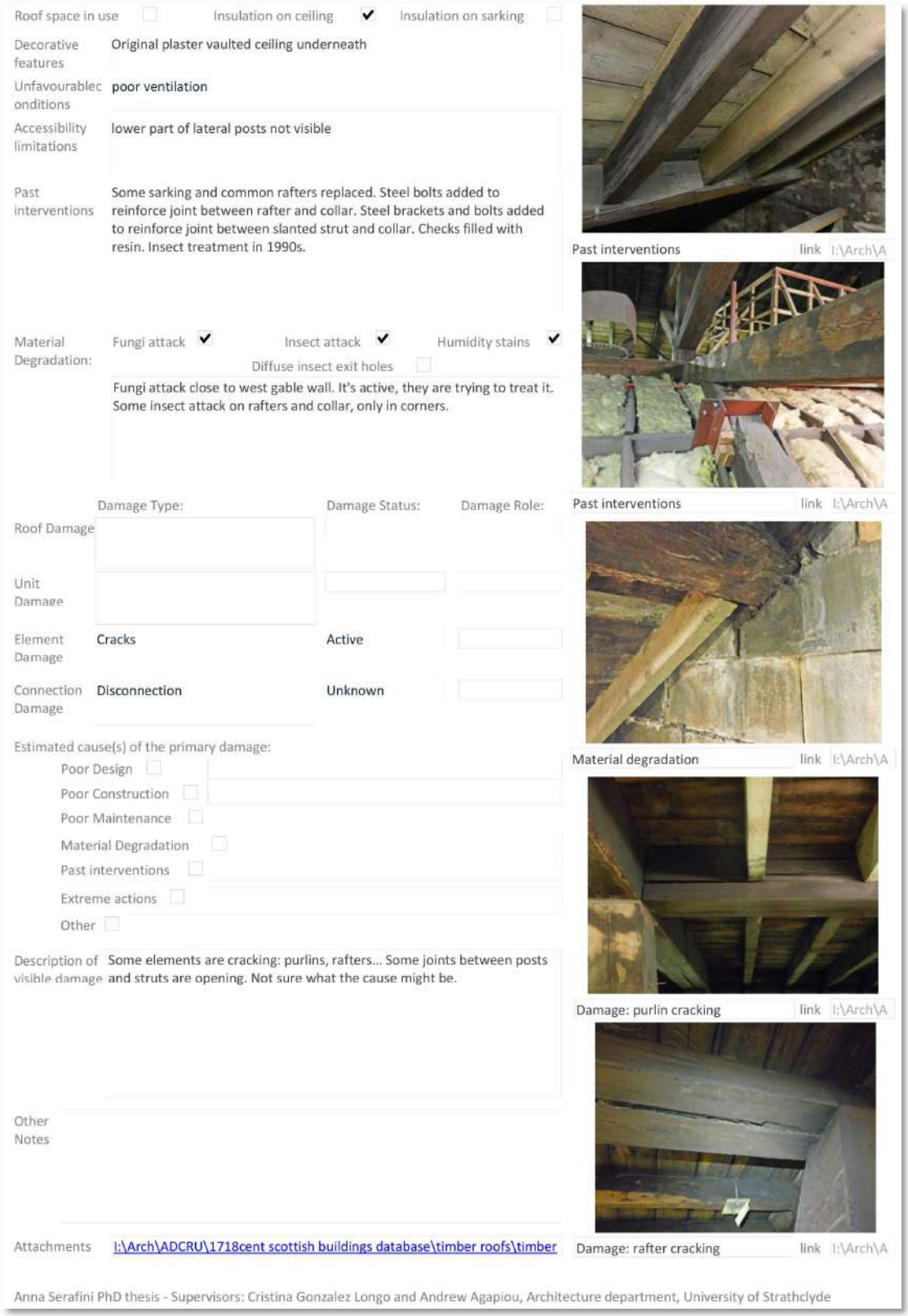


Figure 70: Second section of the structured form: use and condition of the roof structure (this example shows St Andrew's in the Square church)

2.5.2.3 Detailed assessment of the roof structure

The last section of the form reports the results from the detailed assessment carried out in the case studies (Figure 71). A summary of the characteristics of each structural element type (rafters, collars, etc) and of each structural joint type (joints between rafters and collars, joints between rafters and rafters, etc), as well as the timber species and air temperature and relative humidity measurements, are included at the beginning to give an overview of the geometrical and technological characteristics of the roof structure and its environmental conditions.

Elements have been classified as working in compression, tension, bending or shear, or a combination of the above (Figure 64). Their length, section shape, timber species and timber dressing are specified. Joints have been classified according to Sobra et al. (2015) (Figure 71). Their stresses can be estimated and the fastener types (wooden pegs/keys/dowels/cleats or metal nails/straps/bolts) and species can be recorded too (Figure 71). If an element or a joint are different from the others of their own type (e.g. a rafter is longer than the other rafters) this can be specified in the elements/joints sub-form described below.

Each unit (frame, truss, etc) has a sub-form where there is a summary of the main problems identified in that unit (Figure 71). Each element and joint is then analysed in further sub-forms, if needed (Figure 71). The element sub-form includes information related to:

- Dating (original construction, later, recent), signs of reuse, past interventions, accessibility issues, nominal and minimum size of the section, single or composite element;
- Strength affecting defects and strength class according to UNI 11119 (2004);
- Type of material degradation, status (active, non-active, unknown) and way of identification (estimated, determined); the location is specified in the drawings;
- Type of mechanical damage (Figure 64), status, role (primary, secondary, unknown) and causes (poor design, poor construction, degradation, past interventions, external actions, poor maintenance);
- Extent of material degradation and damage based on visual inspection or in situ testing;
- Results of in situ testing for each measurement point.

The joint sub-form includes a description of its geometry and information on the mechanical damage affecting it (Figure 64); the material degradation is already recorded in the elements section. A picture/drawing of the element and of the joint can be included as well. The forms are followed by drawings were all the test results are reported in plan and section (Figure 55, Figure 56). Since there is not at date a codified representation mode for the condition survey of timber structures (Augelli, 2014), a legend has been devised looking at other examples and aiming at maximum clarity.

DETAILED SURVEY **Building name** STIRLING CASTLE_PALACE **Roof location** 4: SW range

Survey date(s) 10/02/2016 07/04/2016 20/05/2016 16/06/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SCP-SW-1, SCP-SW-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafters	530	rectangular	bending, compression	pinus sylvestris	3 hand axed faces and 1 hand sawn
Collars	440	rectangular	bending, compression, tension	pinus sylvestris	the visible face is hand axed
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn
Sprocket rafters		rectangular	bending, compression		

* estimated based on drawings because not fully accessible

identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SCP-SW-1, SCP-SW-2

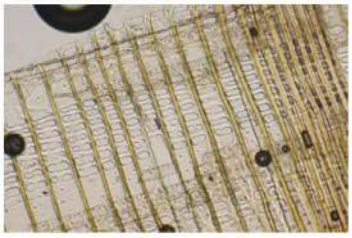
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner halved	compression	nails	
rafter & collar	Encounter dovetail	compression, tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

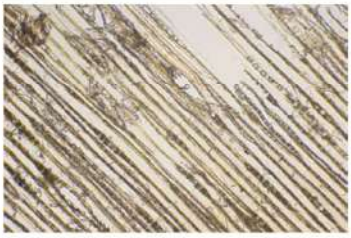
Microscopic identification of the timber species See drawing SCP-SW-2



Rafter: transv. Section x100 I:\Arc



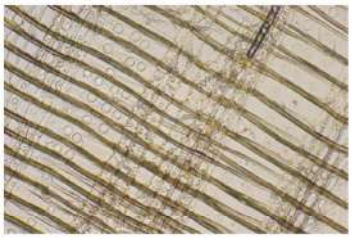
Rafter: radial section x100 I:\Arc



Rafter: tang. Section x50 I:\Arc



Sarking: transv. Section x100 I:\Arc



Sarking: radialection x100 I:\Arc



Sarking: tang. section x50 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SCP-SW-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	W side	10/02/2016	12 am	13	59

Anna Serafini PhD thesis - Sueprvisors: Cristina Gonzalez Longo and Andrew Agapiou, Architecture department, University of Strathclyde

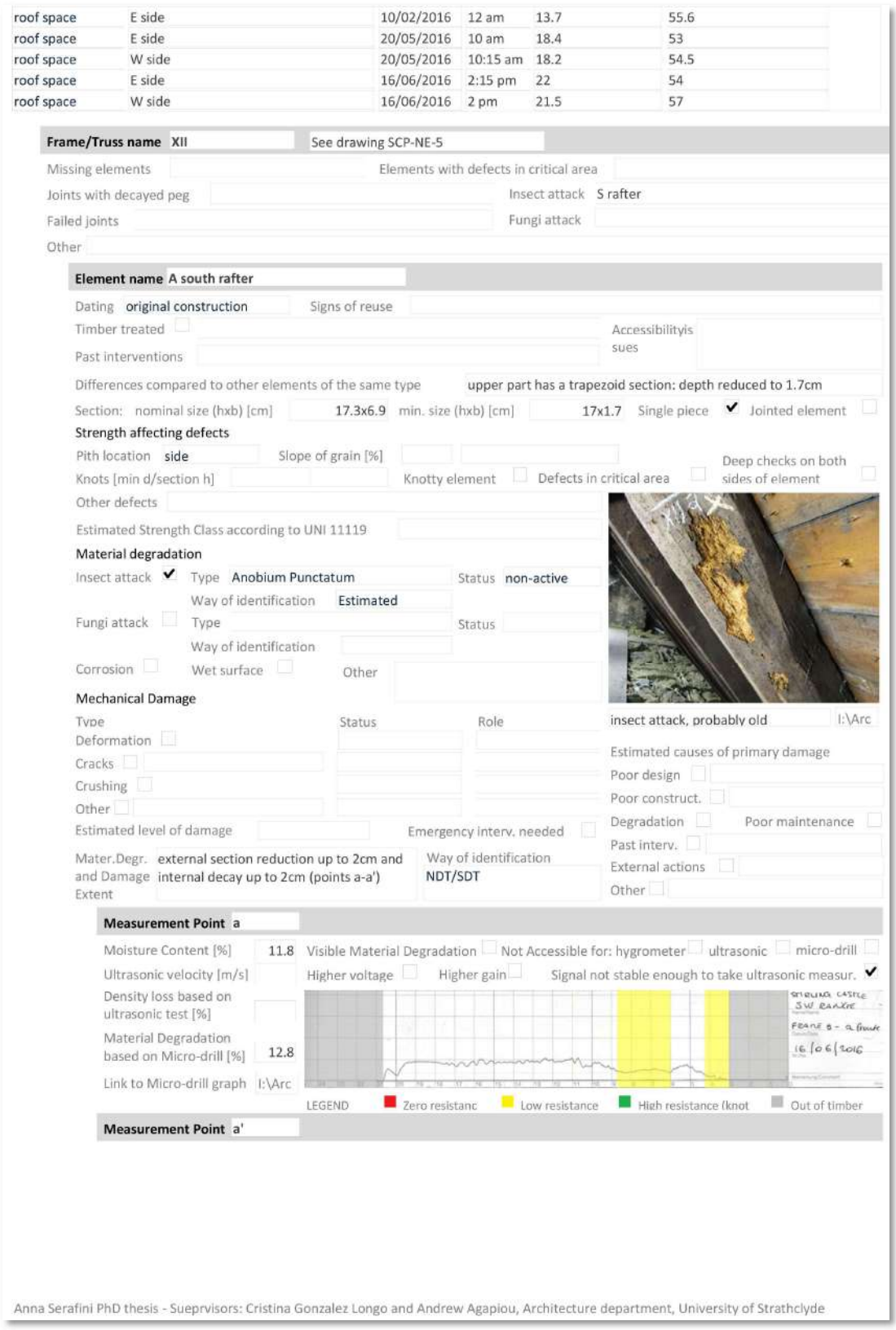


Figure 71: Third section of the structured form: detailed information related to the elements, joints, timber species and results of the tests carried out in the roof structure (this example shows the South-West range of Stirling Castle Palace)

2.5.3 Users interface

The form described above has been used during the surveys to remember which parameters needed to be recorded and thus obtain consistent results. Since it was impractical to bring the computer in the roof spaces during the surveys, a printed form was used on site and the results were later digitally recorded. The development of a phone application based on the assessment form described above, which would allow to digitally record the data directly on site, was started in collaboration with a research group at ITAM in Prague (Cacciotti et al., 2015), but the project was not completed due to lack of funds.

Nevertheless, the use of the form has allowed to identify different structure typologies and typical pathologies, from which vulnerability factors to predict failure mechanisms and identify urgent interventions could be derived in the future. Since the form is based on classifications established together with the leading researchers in the field (members of COST Action FP1101), it can potentially be used by any other researcher or professional assessing timber roof structures. For this purpose, a user-friendly interface has been devised.

Drop-down menus with fixed lists have been included to help filling the data, as they give suggestions, and analysing it afterwards, as data filled in as free text is always less homogeneous and less easily searchable. Items can be added to the drop-down lists and more than one choice can be selected where appropriate. 'Other' and 'unknown' have been included as choices in every drop-down menu, to not force in choosing something that does not match our judgment. Descriptions and pictures/sketches can also be added.

While providing space for all the information that one might want to record, all the fields have been left as 'non-required', so that they can be left blank: only the information that is available and useful for the specific purpose of each inspection should be recorded. Data can be changed and added at any time later on.

There are many terminology issues, as types of roof structures, elements and connections have different names in different countries, and even the terminology associated to different damage/failures types is not always clear for English-as-a-second-language speakers. Therefore it has been necessary to fill a glossary (reported at the beginning of this volume) and enrich the form with drawings/sketches such as the ones in Figure 65 or Figure 66 that work as legends for the drop-down menus and other terms that might be misinterpreted. Many terminology issues remain though: a work on terminology is a complex and long activity that was outside the scope of this work.

2.6 Conclusions

The review of the tools, methods and standards available in Europe for the assessment of existing timber structures highlights that recent research has made impressive progress developing many non-destructive and semi-destructive testing methods. These form, toghether with visual inspection and visual strength grading, the state-of-the-art methodology for the assessment of existing timber structures. Unfortunately, some developed devices are not on the market yet and most testing methods require considerable skills and experience and can be expensive and labour intensive. Moreover, many countries, Scotland included, do not have the relative regulations and standards. This makes it difficult to implement the-state-of-the art methodology in practice and to reach a confident structural assessment.

In order to improve knowledge on seventeenth- and eighteenth-century Scottish timber roofs structures and contribute in improving their conservation, we have devised and used, based on this review and on the techniques and tools available to Scottish professionals, a methodology to identify, research and assess this heritage. This methodology has included the creation of a relational database with related mapping and a digital structured form to handle the research data, archival research and in situ surveys. More than 1500 seventeenth and eighteenth century Scottish buildings have been identified, the roofs of 53 buildings or groups of buildings were surveyed and 8 case studies where investigated in detail. Classifications of types of roof structures and mechanical damage were also developed.

3 The historic development of seventeenth- and eighteenth-century timber roof structures in Scotland within the European context

This chapter traces the historic development of timber roof structures in Scotland through seventeenth and eighteenth centuries within the European context. The aim is to demonstrate that these roofs form a heritage of great extent and quality whose study can contribute to the understanding of the history of European carpentry. The first section sets the architectural context of seventeenth- and eighteenth-century Scotland, analysing the development of castles, villas and country houses, with special attention to the structural implications for roofs and the main actors. Research carried out up to now on Scottish timber roofs is then discussed by highlighting the main findings and the subject matters that need further investigation. The third section traces the development of Scottish timber roofs building upon archival documents and first hand data collected during the initial surveys of 53 buildings and the in depth investigations in 8 case studies. Overall structural arrangements, construction methods and details, the material employed and the role of wrights, architects and patrons are discussed within the European context to identify distinctive Scottish features and possible foreign influences.

3.1 The architectural context

3.1.1 Tower Houses, laird houses and villas: the increasing use of timber

The earliest houses of the Scottish landed classes are often called tower houses because they are characterized by a predominantly vertical development. From a structural point of view they are basically apartments placed vertically and connected with turnpike stairs; they employ very thick walls - up to 2.7m before seventeenth century (Gonzalez Manich et al., 2017) - and masonry barrel vaults, some even for the roof (Figure 72) (Hanke, 2006). The earliest plans are square or rectangular

(Smailholm Castle, fifteenth century), then L shaped (Neidpath Castle, late fourteenth century) (Figure 72) and Z shaped (Claypots Castle, 1569-88) (Figure 73); some also have a courtyard layout (Aldie Castle, early sixteenth century) (Dunbar, 1978). The spans are generally below 6m. The thick walls rise up to the roof covering, creating independent structural units, even when L and Z plans are introduced (Figure 73). This was clearly easier than creating corner structures. Steep gable walls are therefore a fundamental part of these houses, both from a structural and aesthetical point of view (Figure 73).

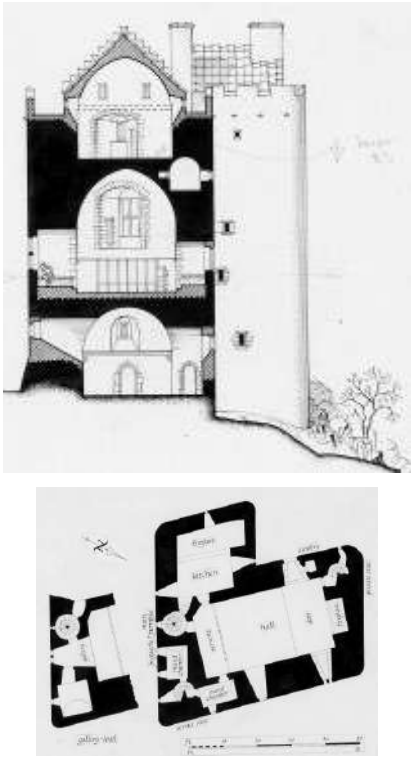


Figure 72: Neidpath Castle (late fourteenth century): section (RCAHMS DP 043860, 1959) and plan (RCAHMS DP 043862, 1964)

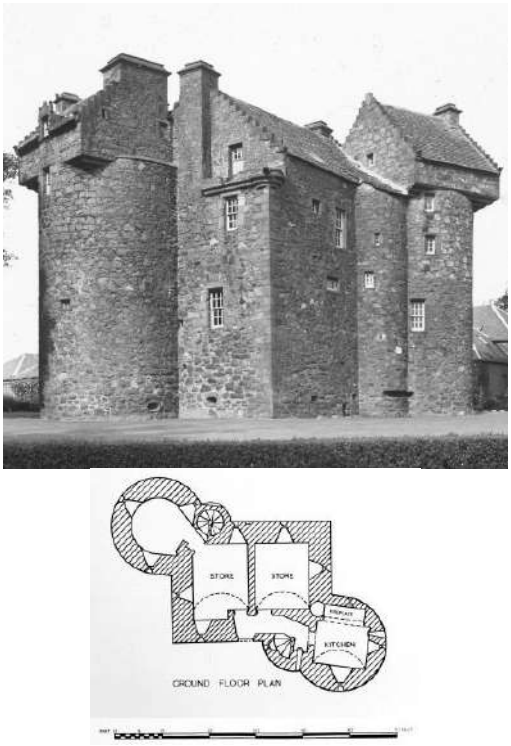


Figure 73: Claypotts Castle (1569-88): view from West (RCAHMS SC1324316, 1971) and plan (RCAHMS SC1202662, Undated)

The construction and extension of many of these tower houses sees a boom in early seventeenth century, when king James VI becomes king James I of England and moves to London, increasing the power of the landed classes. This new building wave is characterized by changes in the construction process. The direct labour system, where the commissioner himself hires tradesmen and supervises the building operations, is slowly replaced by the contract system, where a tradesman becomes responsible for hiring labour, providing materials and supervising the works: Master Masons build, remodel and extend the houses and castles of the landed classes, while Masters of Works mainly take care of the royal projects (Dunbar, 1976).

Sir James Murray of Kilbaberton (d. 1634), Royal Master of Works since 1607, is the first master mason to become part of the gentry (MacKechnie, 1994). He designed the Palace at Edinburgh Castle (1617), the North wing of Linlithgow Palace (1618-24), his own house (Baberton House, 1622-3) (Figure 74), the remodelling of Holyrood Abbey (1630) and New Parliament House in Edinburgh (1631-40) (MacKechnie, 1994). Pinkie House (1613), Winton House (1620-8) and George Heriot Hospital (1628-47) have also been attributed to him (MacKechnie, 1994). He worked closely with William Wallace (d. 1631) Royal Master Mason, introducing new decorative patterns such as buckle quoins (MacKechnie, 1994) (visible in the corners of Baberton House, Figure 74) and developing a more formal and controlled design of plans by relocating the private wing from the rear to the front facade (McKean, 2001). Murray's and Wallace's houses, in contrast with earlier tower houses, are characterized by a horizontal development rather than a vertical one, which is why they are often called 'villas' rather than castles (McKean, 2001). However, at roof elevel they are still characterized by steep gable walls (Figure 74).

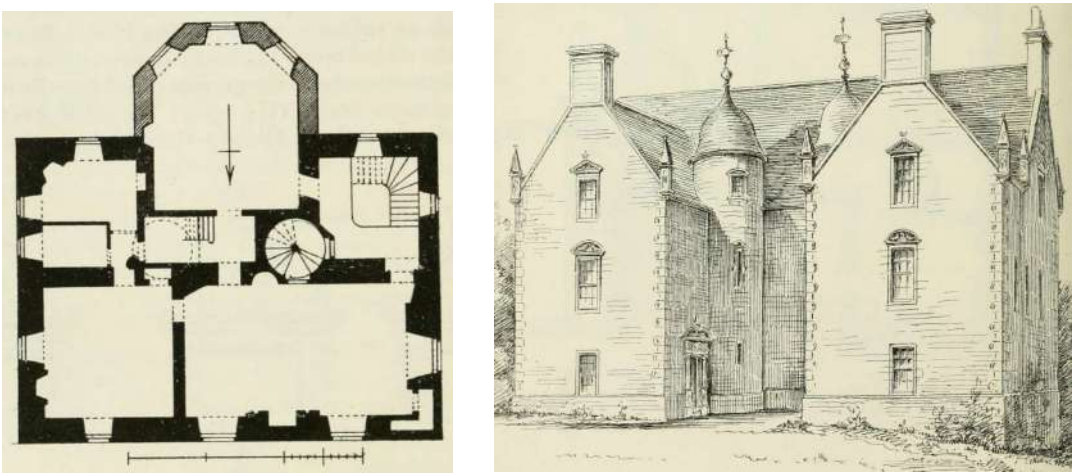


Figure 74: Baberton House (1622-3): plan and view of the South-East facade before the eighteenth-century additions (Macgibbon and Ross, 1887-92)

Since Master Masons were the main actors in the architectural boom promoted by the landed classes, they soon became more important than the Masters of Works (Summerson, 1993). The Mylne family covered the role of Royal Master Mason for generations: John Mylne (1611-67) designed Edinburgh Tron Church (1636) and Cowane's Hospital (1637) and worked at Holyrood Palace (1671-9); later his son Robert (1633-1710) worked closely with the leading Scottish architects of late seventeenth century (Harding, 2012). Wrights probably had an important role as well, although they have not been studied in detail: James Baine (1630-1704), Royal Master Wright, is the only wright known for acting as main contractor in important projects such as Panmure House in Angus (1666), Glamis Castle (1670-89) and Brechin Castle (1688-91) (Newland, 2012b).

While Murray's style is continued by Sir Anthony Alexander (d. 1637) in the Southern part of Scotland (Argyll's Lodging, 1634), the Bell family of masons builds a series of tall proud tower houses in the North-East: Midmar Castle, Crathes Castle, Fraser Castle (all late sixteenth century) and Craigievar Castle (early seventeenth century) (Glendinning and MacKechnie, 2004). However, they seem to be the exception rather than the rule because tower houses are slowly replaced everywhere by larger, lower and more comfortable laird houses and villas (McKean, 2001), such as Fountainhall House (extended in early seventeenth century), Pilmuir House (1624) and Pinkie House (1613).

In these laird houses and villas double pile plans become common and more importance is given to symmetry so T plans (Pilmuir House, 1624) and U plans are preferred, even in the North (Craigston Castle, 1604-7) (Dunbar, 1978). In structural terms the main change is that stone vaults are no longer used at most floor levels as in earlier houses (Figure 72), but only at lower levels: timber becomes more common for horizontal structures (Figure 75). This change in construction techniques and materials, motivated by the growing imports of timber from Scandinavia, allows covering slightly bigger spans (up to 7m) and reducing the thickness of walls - down to 1m (Gonzalez Manich et al., 2017) -, as well as introducing more windows of bigger dimensions (Newland, 2012c) (Figure 75). Another important development is the introduction of decorated ceilings, in timber and later in plaster (Figure 75): roof structures are no longer visible and they have to carry this additional weight.

The predominant approach is to remodel and extend the old houses, to build by accretion, rather than from scratch, in order to conserve the original family seats; but things change during the latest part of seventeenth century when new big country houses are designed and built with less and less reference to the original castellar style (Glendinning and MacKechnie, 2004).

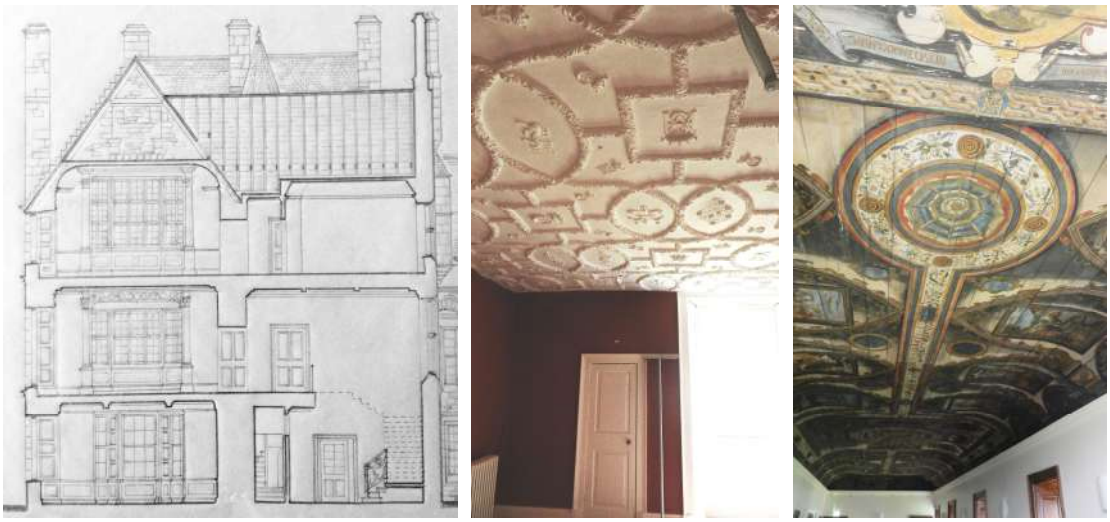


Figure 75: Pinkie House (1613): section (RCAHMS MLD 69/29, 1947) and decorated ceilings

3.1.2 Country houses: shallower pitches and wider spans

The two dominant architects of the second half of seventeenth century are Sir William Bruce (1630-1710), landowner and government official, and Mr James Smith (1645-1731), mason and last Royal Master of Works before the Union. They still remodel and expand existing buildings as Holyrood Palace (1671-9), Balcaskie House (1668-74), Drumlanrig Castle (1679-98), and Dalkeith Palace (1702-11), but their designs integrate exteriors, interiors and the landscape within a single harmonious approach (Glendinning and MacKechnie, 2004). They also start designing and building new houses with no references to the Scottish castle style: Kinross House (1679-93) (Figure 76), Melville House (1697-1703), Hopetoun House (1699-1701), Yester House (1699-1715), Auchindinny House (1702-7) and Newhailes House (1702-20). Smith, in particular, takes direct inspiration from the baroque architecture he had come in contact with during his studies in Rome, incorporating these references within the local vernacular (González-Longo, 2012).

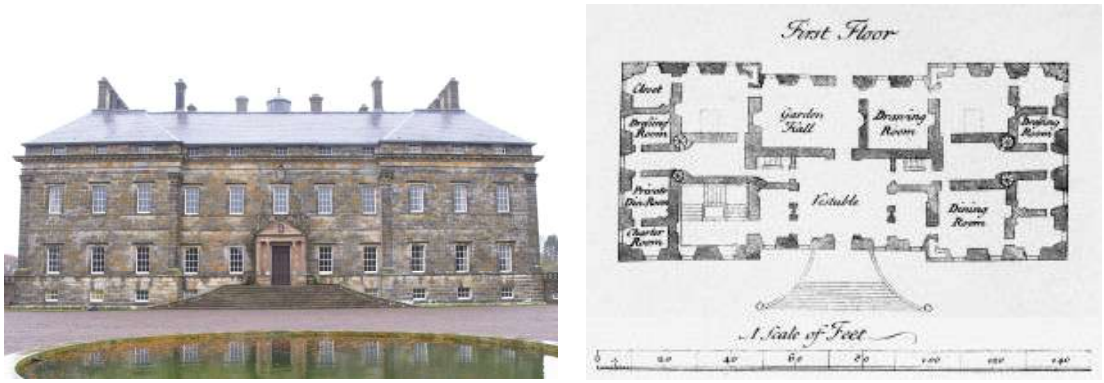


Figure 76: Kinross House (1679-93): view from West and plan (RCAHMS SC 1223494, Undated)

From a structural point of view, Bruce and Smith introduce an important innovation: their country housers are not dominated by tall masonry gables anymore; on the contrary the roofs have hipped and platform arrangements and shallow pitches, in order to harmonize with the facades (Figure 76). This clearly influences the design of roof structures. The dimensions of Bruce and Smith's country houses surpass by far those of the villas of early seventeenth century, but internal spans are not much wider because intermediate spine walls are used. These intermediate walls are to disappear only during the eighteenth century, when big undisturbed spans are achieved.

The political and economic union with England in 1707 brings strong English influences in Scottish architecture. England and Scotland see the rise of Palladianism and 'A book of architecture, containing designs of buildings and ornaments' by James Gibbs (1728) – a Scottish architect who went to Rome and practiced mainly in England - becomes one of the main sources of inspiration for contemporary designers (Glendinning and MacKechnie, 2004). Eclecticisim also spreads allowing for different interpretations of the antique combined with the national medievalism, as illustrated by

William Adam's Duff House (1735-40) (Figure 77), 'a medieval castle in a baroque dress' (Dunbar, 1978) or John Adam's neo-gothic Douglas Castle (1757-61, demolished in 1939) (Figure 78) (Glendinning and MacKechnie, 2004).



Figure 77: Duff House (1735-40): view from South

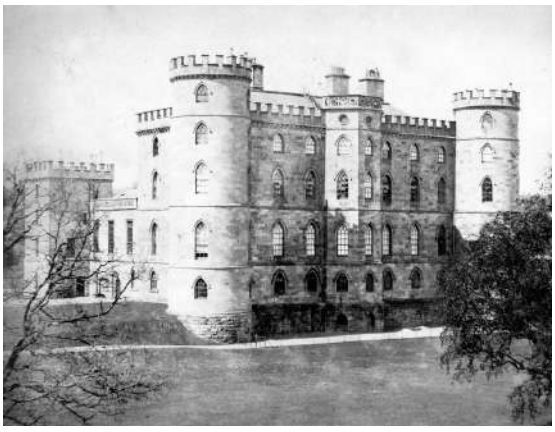


Figure 78: Douglas Castle (1757-61, demolished in 1939): view from South (RCAHMS SC 943434, Undated)

William Adam (1689-1748), industrialist, contractor, quarry-master and designer, rises rapidly to distinction winning patrons such as Sir John Clerk of Penicuik (1675-1755), known as 'arbiter of taste' (Dunbar, 1978), the II Earl of Mar (1675-1732), author of many architectural designs such as the one carried out by Adam in House of Dun (1742-3), and the III Duke of Argyll (1682-1761), promotor of the design and construction of a new town and castle at Inveraray (1744-61). William's buildings reach an internal monumental scale hitherto unknown in Scotland: Yester House, altered and extended by William between 1729 and 1748, together with Robert Gordon's College (1731-2) and Duff House (1737) (Figure 77), are amongst the first Scottish buildings to cover an undisturbed span of 9m. Earlier Scottish buildings reach even bigger spans: the great hall at Darnaway Castle (1387) is 10.7m wide, Edinburgh Parliament Hall (1631-40) is 13m wide, Edinburgh Tron Church (1637) is 16.1m wide. However, the difference with these earlier buildings is that the roof structures of Yester, Robert Gordon and Duff are not exposed: they are hidden behind heavy plaster ceilings that they support (Figure 79). Moreover, William's roofs are much shallower and do not employ gable walls, but hipped arrangements (Figure 79), which further complicates the design of roof structures.

Most of William's projects were completed by his sons after his death. In particular John, the eldest son, continued the family business in Scotland while Robert left for Italy in 1754. John's designs for Dumfries House (1754-9) and the Edinburgh Exchange (now City Chambers, 1753-61), as well as the one for Paxton House (1759-63) devised with his brother James, show a style in line with his father's, although less eclectic (Dunbar, 1978). On the contrary, Robert creates a personal style based on scholarly knowledge of antiquity and picturesque romanticism which he calls 'the movement' (Glendinning and MacKechnie, 2004). The spread of Improvement in 1760s draws him back to

Scotland where he designs many country houses and castles, such as Gosford House (1790-1800) and Culzean Castle (1776-92) (Figure 80**Error! Reference source not found.**), where he easily reaches and surpasses for the first time internal spans of 10m, despite the heavy plaster ceilings.

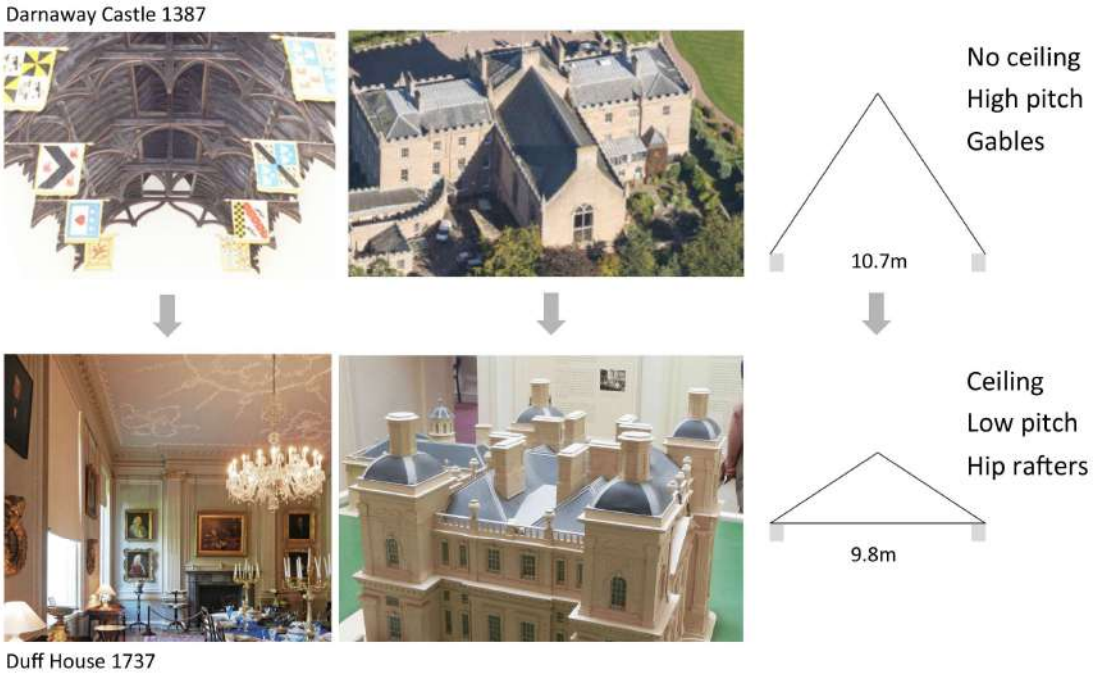


Figure 79: The structural changes in late seventeenth-century Scottish buildings which affected roof structures: gable walls with high pitches - as in Darnaway Castle (top) (RCAHMS DP 161383, 2013, RCAHMS DP 222837, 2015) are replaced by hipped arrangements, low pitches and heavy plaster ceilings - as in Duff House (bottom)



Figure 80: Culzean Castle (1776-92): view from North-East (left) and interior of the Drum tower (right)

Robert is the first Scottish architect to have a broad international influence and leaves little space for contenders such as Robert Mylne (1733-1811), author of Cally (1759-63) (Rykwert, 1985). After his

death, in the last years of the eighteenth century, inspiration starts being drawn from Greek sources rather than Roman, as in Cairness House (1791-7) by James Playfair (1755-94) (Glendinning and MacKechnie, 2004).

3.1.3 Churches and military buildings

Seventeenth century is one of the least active periods for religious building, due to the Reformation. Most churches are built in a simple oblong shape, with no subdivision in space, as in late Middle Ages (Tweedside church of Lyne, 1640-5); occasionally a small aisle is added for the laird's burial, creating a T plan (Anstruther Easter, 1634) (Dunbar, 1978). Only a few are centrally planned as Lauder Parish church (1673) designed by Sir William Bruce with a Greek-cross plan (Glendinning and MacKechnie, 2004). St Mary's old parish church in Dairsie (1622) and the Canongate parish church (1688) designed by Smith are instead more ambitious: St Mary has one of the first hipped roofs in Scotland, while the Canongate church achieves an impressive span of about 10m in the central nave.

During the second half of the eighteenth century many churches are erected with impressively wide internal spans: Oakshaw Trinity Church in Paisley (1754-6), with 19.7m span, St Andrew's and St George's Church in Edinburgh (1782-4), the first UK church with an elliptical plan of 18.9m span (Figure 81), and Tron church in Glasgow (1793-4, now a theatre), rebuilt by the Adams after a fire with a 17.8m span, incorporating an internal dome.



Figure 81: St Andrew's and St George's church in Edinburgh (1782-4): view from South-East (left), plan (centre), view of interior (right)

As a consequence of the various wars, uprisings and English occupations, both seventeenth- and eighteenth-century also see the construction of many military buildings, designed by the leading architects of the period, which work in parallel for the rich gentry and for the Crown: Bruce and Smith are Surveyors of the Royal Works from 1671 and 1683 respectively, Robert Adam is Architect

of the King's Works from 1761 (Glendinning and MacKechnie, 2004). Fortifications are built both during the English occupation in 1650s (Citadels in Ayr, Perth, Inverness, Inverlochy, Leith) and after the Jacobite uprising in the first half of the eighteenth century (barracks in Inversnaid, Bernera, Kiliwhimen and Ruthven, and Fort August, Fort William and Fort George) (Tabraham, 1995). Unfortunately, because of the destruction brought by the wars and uprisings most of these buildings have been demolished or are today ruinous. Fort George (1747-69), designed by the English engineer Colonel William Skinner and built by the Adams, is the best preserved and probably the last Scottish military construction with architectural significance.

3.1.4 Urban development: grand public buildings and foreign builders

Many of the mentioned building operations carried out in seventeenth century, such as George Heriot Hospital, New Parliament House, and Holyrood Palace, were also aimed at expanding and improving Edinburgh to establish the capital as a distinct focus of power within Britain. During this expansion some architects become property developers: Robert Mylne, for example, designs and builds the high residential blocks of Milne's Square (1684-8) and Milne's Court (1695) in Edinburgh. Glasgow starts emerging as a significant urban centre as well, with the enlargement of its tolbooth (1625-7) and the construction of one of the largest buildings of the period: Glasgow College (1632) (Glendinning and MacKechnie, 2004).

During eighteenth century over 100 new towns are funded on the coasts and towns and cities are expanded and improved to house the population displaced by the clearances. Grand public buildings replace tolbooths: some examples are Glasgow's Town Hospital (1732) and Town Hall (1735) designed by Allan Dreghorn (1706-65), Dundee Town House (1731-3) designed by William Adam, Edinburgh City Chambers (1753-61) designed by John Adam (Glendinning and MacKechnie, 2004).

During the building of Edinburgh New Town, designed by James Craig in 1766, a new wave of speculative developments is guided by a vast group of builders who form a new incorporation, the "Society of Master Builders, Wrights and Masons" led by one mason and one wright, and partly replace architects in designing and building small groups of houses and tenements (Lewis, 2006). Wrights are active builders just as much as masons, as testified by the wright John Bourgh who contracts many craftsmen and Deacons of the St Mary's Chapel incorporation to work for him in building houses in the New Town (Lewis, 2006). What is particularly interesting is that some of these builders had come from London, perhaps with the Adams, bringing along their wealth of technological knowledge (Lewis, 2006).

3.1.5 Discussion within the European context

Figure 82 summarises the development of architecture in Scotland discussed above. As underlined by Summerson (1993), it is quite different from the one in England: in Scotland there is a strong persistence of native types, in fact tower houses and castles remain almost unchanged up to seventeenth century. Summerson (1993) argues that this 'delayed development' is due to Scotland always being at war and isolated from the rest of Europe, but McKean (2001) disagrees and identifies the cause in the Scottish veneration for ancestors and family, which brought to the predilection to reuse and adapt ancient motifs rather than adopt new ones.

Whatever the reason, it is true that up to early seventeenth century traditional Scottish houses are characterized by a vertical development, thick walls, reduced spans and stone vaults, recalling medieval European architecture rather than the contemporary one. It is only during the first part of seventeenth century that these houses gradually develop into villas and country houses, three centuries later than in England and more than four centuries later than in southern Europe. Scottish castles are transformed by the introduction of timber used for horizontal structures: walls get thinner, spans increase slightly and windows become larger and in bigger quantity. At the same time, decorated ceilings become fashionable, thus timber structures are no longer exposed and have to carry the additional load of these decorations. During the latest part of seventeenth century Scottish architecture changes even more significantly: gable walls are abandoned in favour of hipped and platform arrangements and pitches become shallower, to adapt the roof geometry to the new architectural taste, now closer to the English and European one.

These developments are accompanied by the gradual change in the labour system, which sees the emergence of craftsmen working as contractors and designers, and later professional architects, property developers and builders, even from abroad. Some of them travel and take inspiration from the architecture of other countries such as Italy, France and England. Some foreign influences in Scottish architecture have in fact already been traced (González-Longo, 2012, Howard, 2001, Ottenheym, 2007), but related to stylistic and architectural features rather than construction techniques and materials. This is because contributions to Scottish construction history are still very few (Bell, 2004, Gonzalez-Longo and Theodossopoulos, 2012, Jenkins, 2012, Scottish Vernacular Buildings Working Group, 1976, Walker, 2006). In particular, since Scottish architectutre has always been considered a 'stone architecture', timber structures and wrights have been little investigated so far. We know, however, that any stylistic change demands for a change in construction methods; this is particularly true for roof structures since the span that a roof structure can achieve necessarily restrains the width of the space that can be built below it. The next sections of this chapter discuss how timber roof structures have developed in correspondance to the architectural innovations described above and what role wrights and architects had in this development.

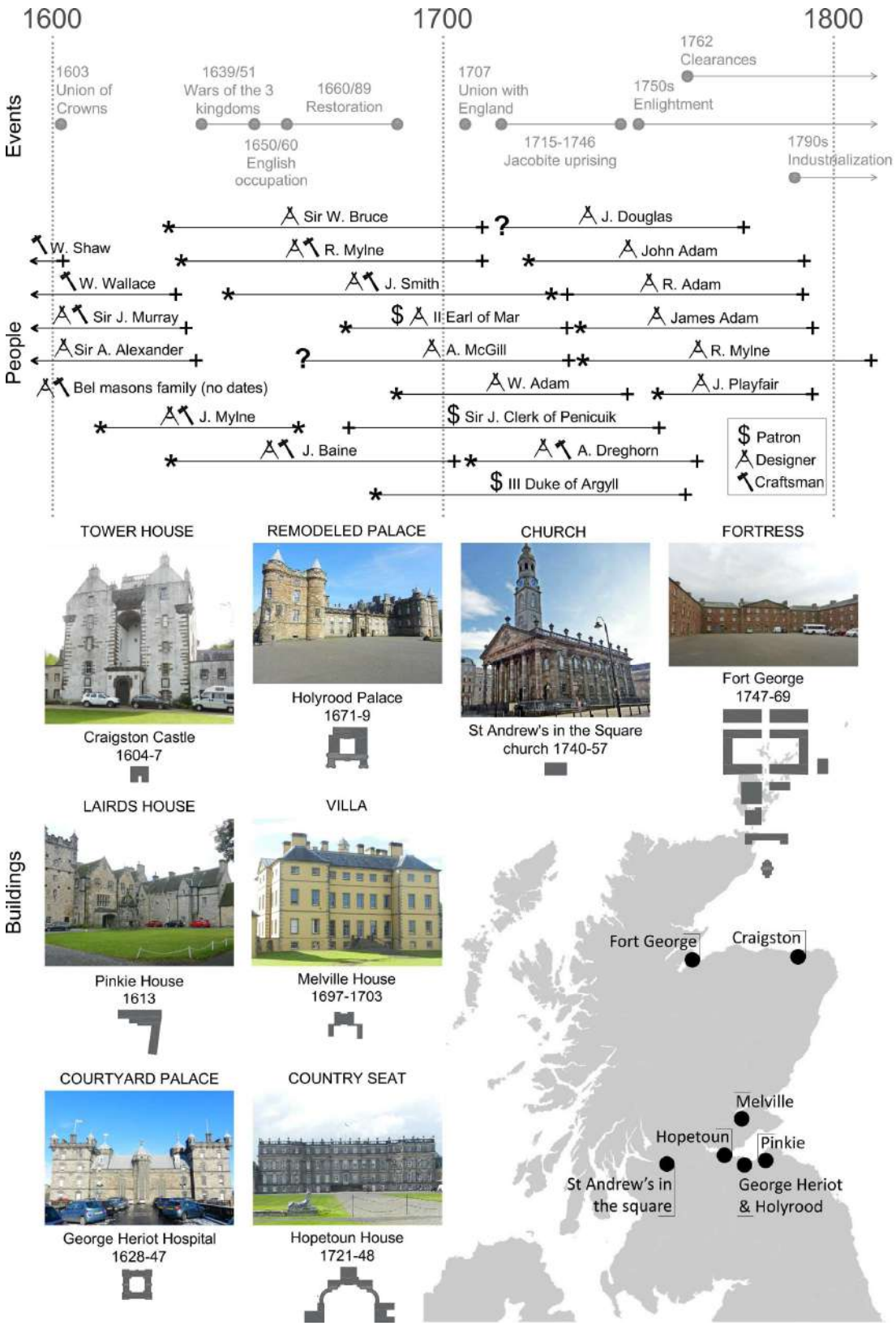


Figure 82: Timeline showing the main historical events of seventeenth- and eighteenth-century Scotland, the main patrons, craftsmen and designers, and a few representative buildings of the period

3.2 Existing knowledge on timber roof structures in Scotland

3.2.1 Structural arrangements

3.2.1.1 Types of roof structures

Timber roof structures are generally subdivided into 'common rafter roofs' and 'purlin roofs' (Corvol-Dessert et al., 2009). The German terminology is the most accurate in describing them (Lohrum and King, 2006). Common rafter roofs are called *Sparrendach:* a pair of *Sparren*, or rafters, are tightly joined at the apex, while their feet are fixed somehow against shifting (Figure 83). Their rigidity may be helped by secondary elements placed inside the frame (collars, braces, struts, etc…). Their pitch is usually steep (>40°) and the frames are very close, therefore a lot of timber is employed.

Purlin roofs, instead, are called *Pfettendach*: a pair of inclined pieces called *Rofen*, or common rafters, are carried by *Pfette*, purlins (Figure 84). The rafters, devoid of any load-bearing function, are either joined at the apex, or fixed at the base. The purlins are supported by posts, gables and/or frames/trusses, spaced at wide intervals, therefore these systems use less timber. Many roofs are actually 'false purlin roofs': in these roofs the purlins are called *Rähm* because they do not perform a load-bearing function but only a stiffening one (Figure 85, Figure 86). They were very useful in the erection process (Binding 1991 in Hanke 2006).

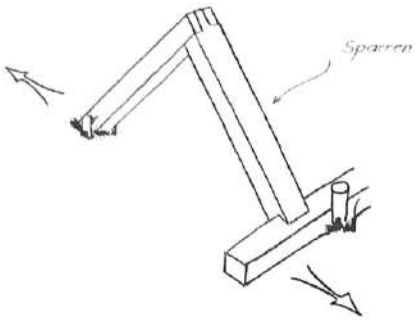


Figure 83: Schematic of common rafter roofs, called Sparrendach in German (Lohrum and King, 2006)

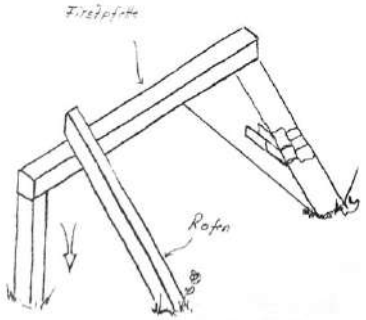


Figure 84: Schematic of purlin roofs, called Pfettendach in German (Lohrum and King, 2006)

Common rafter roofs can be classified in different ways, according to the presence of certain features: posts, scissor braces, longitudinal bracing, trestles, etc. Many countries have their own specific classifications. There are however three types which can be considered a specific group of their own: trussed roofs, cruck roofs and hammer-beam roofs.

The definition of truss is controversial as the term is often used for different types of structures. It is defined as 'a structural framework of wood or metal, esp one arranged in triangles' (Collins Dictionary, 2016), or 'a structure composed of a combination of members, usually in some triangular

arrangement so as to constitute a rigid framework' (Harris, 2006). According to these definitions, however, a common rafter roof with a tie-beam is a truss. Yeomans (1992) tries to narrow down the definition by describing the trussed roof as a structure with hanging posts that act as ties, 'trussing up' the tie-beam and thus counteracting its deflection and creating an efficient triangulation (Figure 87, Figure 88). These are also called 'Italian or Italianate trusses' (Gomme, 2002, Innocent, 1971).

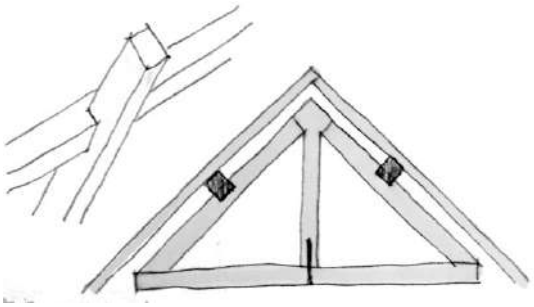


Figure 85: Schematic of purlin roof supported by trusses (trenched purlins)

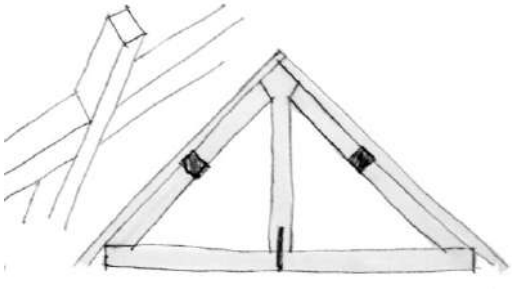


Figure 86: Schematic of trussed roof with longitudinal bracing (butt purlins)

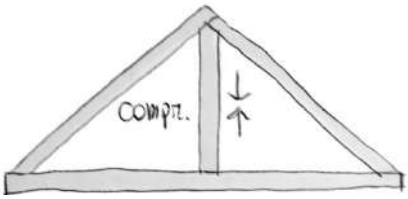


Figure 87: Schematic of king post in compression

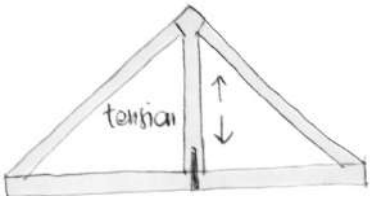


Figure 88: Schematic of hanging king post in tension

Crucks are composed of pairs of inclined blades placed on the ground and meeting at the apex of the roof (Corvol-Dessert et al., 2009) (Figure 89). Hammer-beam roofs are composed of principal frames resting on sole pieces (the hammer-beams) extended beyond the vertical plane of the wall and supporting a hammer-post at their inner end, which rises to the collar forming a triangular support for the frame; the hammer-beam also forms a lower triangle with a wall-post and an arch brace (Courtenay, 1985) (Figure 90).

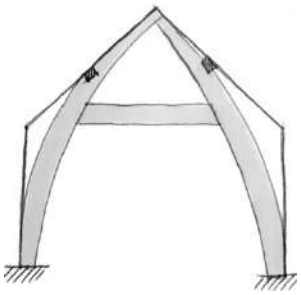


Figure 89: Schematic of cruck roof

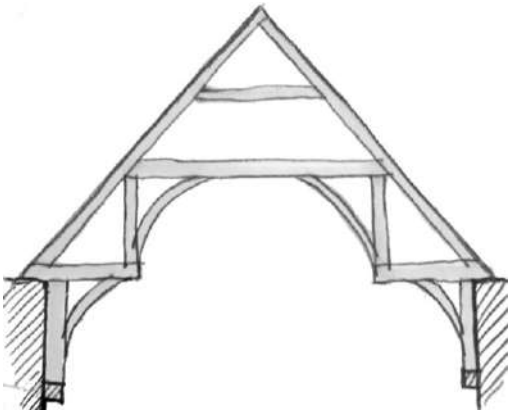


Figure 90: Schematic of hammer-beam roof

3.2.1.2 Continental Europe

Historically, North Europe preferred using common rafter roofs. The earliest examples consist in a series of closely spaced identical frames composed of a pair of rafters and a tie-beam, supported by simple or double wall plates; eventually collars, struts, braces and posts are included with different combinations. No longitudinal bracing other than the roof covering were employed (Figure 91).

A common pattern of development of this simple roof is followed by Germany, Netherlands, Sweden, Denmark, North of France, Belgium, Czech Republic, Romania, Slovakia, Poland (Bláha, 2006, Corvol-Dessert et al., 2009, Eissing, 2009, Gogolin, 2008, Janse, 1989, Madsen, 2013, Suchý et al., 2008, Szabó and Kulin, 2005, Thelin and Linscott, 2008). The twelfth and thirteenth centuries see a significant development of carpentry techniques due to the introduction of Gothic architecture. In order to reduce the amount of timber used and be able to bridge increasingly wider spans with vaulted ceilings, carpenters divide frames into primary frames – load-bearing – and secondary frames, supported by plate purlins under the collars (which also provide the first elemental longitudinal stiffening) (Figure 92, Figure 93). The tie-beams of the secondary frames are often replaced by hammer-beams or sole pieces (Figure 92, Figure 93), which allows dividing the roof into bays and introducing a vault in each bay or a barrel vault interrupted only by the primary tie-beams.

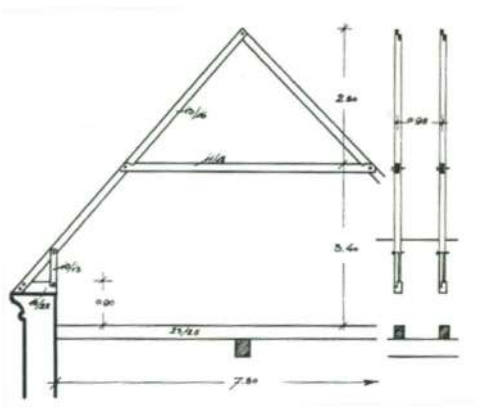


Figure 91: Common rafter roof in St Kastor church in Karden, Germany (1216) (Binding, 1991)

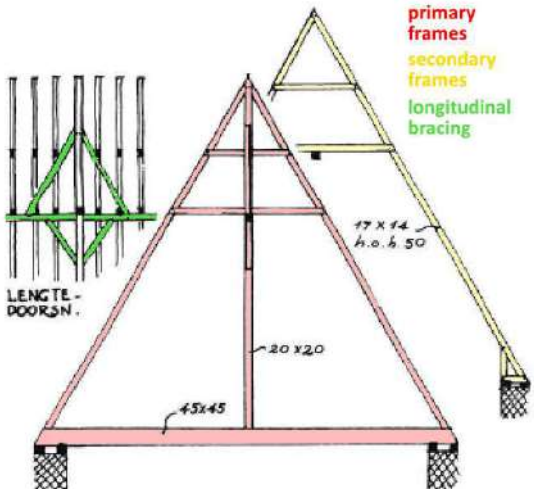


Figure 92: Common rafter roof with primary and secondary frames and longitudinal bracing in the Vrouwe Church in Kortrijk, Netherlands (1250) (Janse, 1989); colours added by author

In order to reduce the increased horizontal thrust of the roof produced by the removal of the tie-beams, the pitch of the roofs is increased to 55°-65°; this leads to greater wind pressure which is counteracted by introducing longitudinal bracing (Figure 92, Figure 93). Almost simultaneously the subdivision between principal rafters (load bearing) and common rafters (non load-bearing) is adopted (Figure 93), to concentrate the loads only in certain areas of the supporting walls.

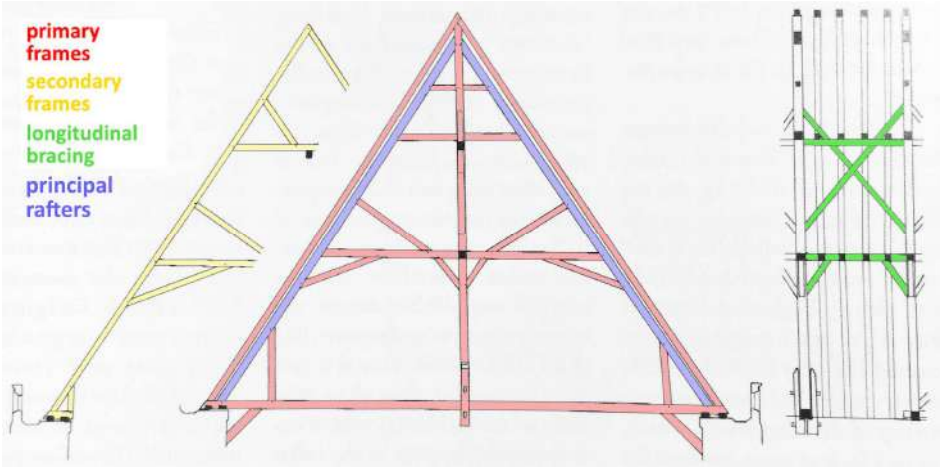


Figure 93: Common rafter roof with principal rafters, primary and secondary frames and longitudinal bracing in Saint-Pierre Cathedral, France (thirteenth century) (Corvol-Dessert et al., 2009); colours added by author

During fifteenth and sixteenth centuries the shortage in timber supplies forces to use shorter timber in lesser quantity: multi-tiered structures using portal frames or 'trestles' (Figure 94), already used in Belgium since the thirteenth century (Corvol-Dessert et al., 2009) and in Germany since the fourteenth century (Caston, 2006), become common. Elements now have different scantlings depending on their structural role, rather than being uniform in size as in the previous roofs. The ridge beam, previously used mainly in Scandinavia (Madsen, 2013), becomes common in other countries too, to ensure a solid longitudinal framing. In order to reduce the roof height and use less timber, mansard roofs are introduced in France (Figure 95), also through treatises (Forneau, 1767, Mesange, 1753). De l'Orme (1578) suggests an innovative arch system but this is fully exploited only from nineteenth century (Gómez Sánchez, 2006).

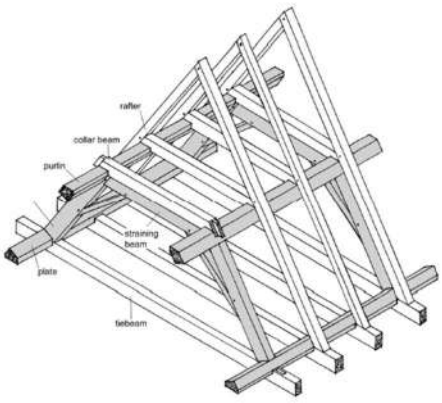


Figure 94: Schematic of German portal frames/leaning trestles (Holzer and Kock, 2008)

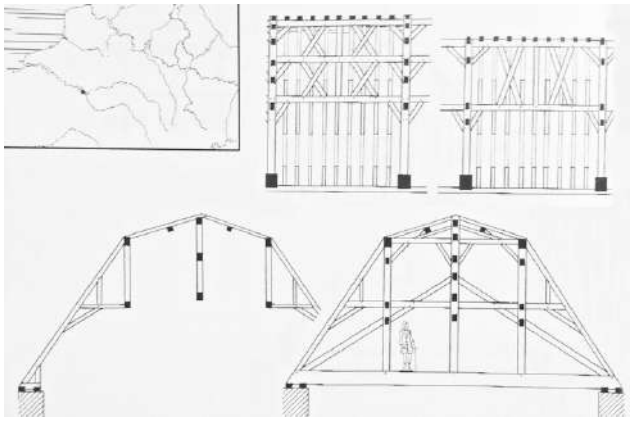


Figure 95: Mansard roof at the Sorbonne Chapel in Paris (1635-42) (Corvol-Dessert et al., 2009)

Purlin roofs were instead commonly used in Southern Europe: Italy, Switzerland, Austria, South France (Figure 96), South Germany (Figure 97), Spain and Greece (Hoffsummer, 2011, Munafò, 2002,

Ostendorf, 1908, Tsakanika, 2007). They become common in North Europe only from the end of the Middle Ages, as means to reduce the amount of timber used: in North France and Belgium from fifteenth century (Corvol-Dessert et al., 2009), in Netherlands from 1500 (Janse, 1989), in Czech Republic at the end of eighteenth century (Bláha, 2006).

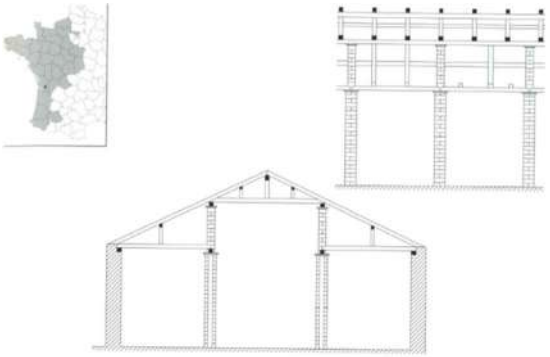


Figure 96: Purlin roof of Hopital Neuf in Pons (1220-54) (Hoffsummer, 2011)

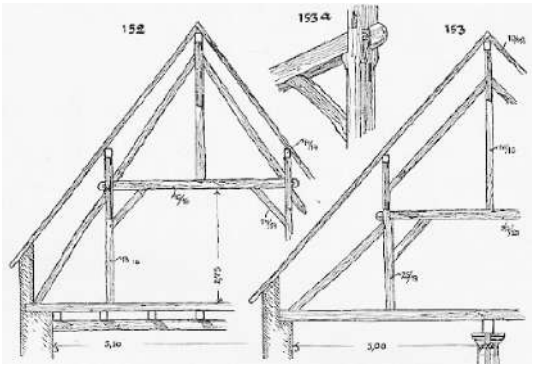


Figure 97: Purlin roofs in Germany (Ostendorf, 1908)

In Italy purlin roofs (Palladio, 1570, Vitruvius Pollio, 1556) and trusses (Figure 98) (Valeriani, 2005) are used since the Roman times and are still used today. Tension-absorbing posts, a characteristic feature of 'itlianate trusses', appear from twelfth century in France (Figure 99) (Corvol-Dessert et al., 2009) and from fifteenth century in Germany (Eissing, 2009). However, 'italianate' trusses are also characterized by timbers with bigger sections which allow to reach shallower pitches whilst covering bigger spans and using less timber, since the trusses are more widely spaced (Figure 98).



Figure 98: Trusses in Sant'Agata di Mugello church in Scarperia, Florence (sixteenth century) (Tampone, 1996)

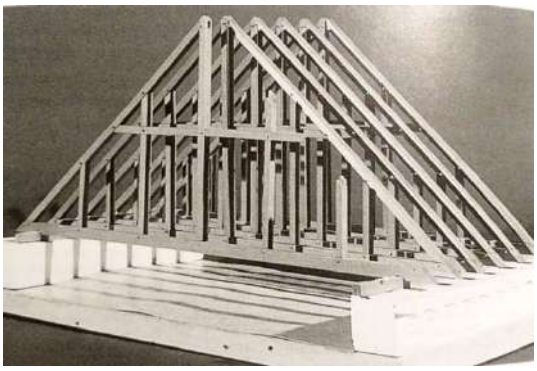


Figure 99: Roof with tension-absorbing posts in Saint-Pierre-de-Montmartre church in Paris (1164-74) (Corvol-Dessert et al., 2009)

This is why italianate trussed roofs gradually replace common rafter roofs in many countries during seventeenth, eighteenth and nineteenth centuries, as testified by carpentry treatises (Gómez Sánchez, 2006). In all countries the common rafter roof and the trussed roof coexist for some time until the trussed system is well understood and definitely established as predominant.

3.2.1.3 England

Crucks are widely used in English vernacular architecture from twelfth up to nineteenth century (Alcock, 1981) (Figure 135). The oldest examples, dating from the fifth century, are actually in Netherlands and Germany, but they seem to disappear from North Europe soon after (Corvol-Dessert et al., 2009).

English houses and churches are however covered mainly with common rafter roofs, just like the rest of North Europe (Hewett, 1980). The earliest examples are quite simple, with uniform scantlings and no longitudinal stiffening elements (Figure 100) (Fletcher and Haslop, 1969, Hewett, 1980, Smith, 1958). In the second half of the thirteenth century king and crown posts are introduced (Fletcher and Spokes, 1964, Munby et al., 1983) and false purlins such as butt purlins (already used at the ridge of crucks) start being used as longitudinal bracing in churches in the South (Hewett, 1980, Smith, 1958). This is in line with the rest of North Europe. However, by the end of thirteenth century, side purlins (which are true purlins) are used, and simultaneously rafters are subdivided into principal (load-bearing) and common (non load-bearing) (Figure 101), which allows removing some of the tie-beams (Fletcher and Spokes, 1964, Hewett, 1980, Munby et al., 1983, Smith, 1958). This is one of the earliest examples of use of side purlins in North Europe (Hanke, 2006).

In contrast to the rest of North Europe, England, just like Scotland, remained mainly feudalistic and did not develop a powerful civic class up to seventeenth century. It was thus the nobility rather than burgesses commissioning ambitious architecture, corresponding to castles and palaces rather than churches and public buildings (Summerson, 1993). This is why most of the innovations in carpentry, such as the introduction of side purlins, are introduced in domestic architecture first (Hanke, 2006). One of the main features of these palaces and castles was the great hall, which was aisled. In order to make it aisle-less English and Scottish carpenters invented the hammer-beam roof, used during fourteenth, fifteenth and sixteenth centuries (Figure 102) (Hewett, 1980, Smith, 1958).

The English preference for exposed roof structures (Brandon and Brandon, 1849), which brings to the development of hammer-beam roofs rather than trestled structures, together with the use up to nineteenth century of crucks and the early introduction of side purlins differentiates England from the rest of continental Europe (Hanke, 2006). However, seventeenth and eighteenth centuries are marked by important changes both from a political and an architectural point of view, which reinforce the connections between England and Scotland and also between Britain and continental Europe. This clearly influences developments in roof carpentry.

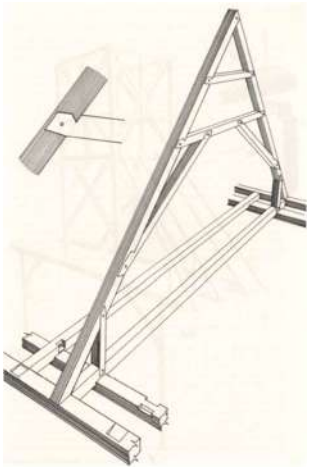


Figure 100: Reconstruction of common rafter roof of Waltham Abbey in Essex (twelfth century) (Hewett, 1980)

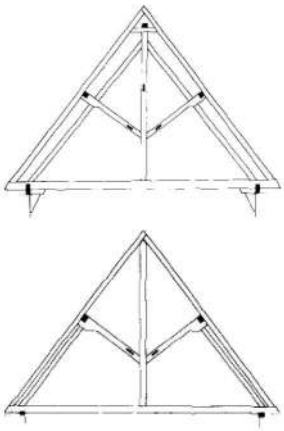


Figure 101: Roofs with side purlins and principal rafters in Chichester: Cathedral (top) and Bishop's Palace (bottom) (late thirteenth century) (Munby et al., 1983)

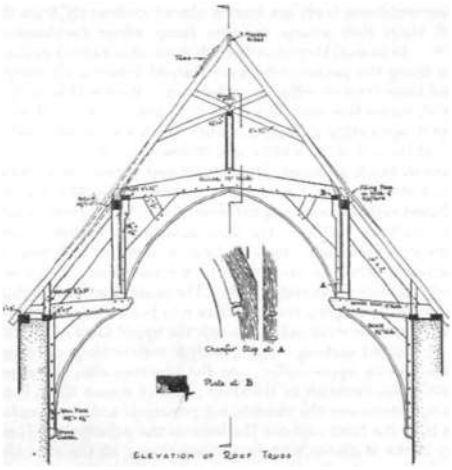


Figure 102: Hammer-beam roof over Stranger or Pilgrim's Hall in Winchester (early fourteenth century) (Smith, 1958)

Italianate trussed roofs are introduced in England in early seventeenth century by the architects I. Jones (Figure 103) and later C. Wren (Campbell, 2002, Yeomans, 1986b, Yeomans, 1992). This is a big innovation in English roof carpentry because the use of tension-absorbing elements, such as the hanging posts used in italianate trusses, was completely alien to England up to then: crucks, common rafter roofs and hammer-beam roofs employ in fact only compression members. Moreover, iron straps and scarf joints, both in use in italianate trusses, had never been used in England before. Yeomans (1992), Campbell (2002) and Valeriani (2006) have made hypotheses on how this migration of technical knowledge happened.

It appears that seventeenth-century England relied on the import of Italian treatises mainly (Gómez Sánchez, 2006, Yeomans, 1986a); in fact, the first English treatise showing trussed roofs (Price, 1733) is from early eighteenth century (Figure 105). Inigo Jones travelled to Italy, and he possessed various Italian treatises which included various examples of roof trusses, thus it seems highly probable that he took inspiration from these sources (Campbell, 2002, Valeriani, 2006, Yeomans, 1992) (Figure 104). What is interesting to note is that some of Jones and Wren's roof structures do not show a full understanding of the truss system (Yeomans, 1992). It has been argued that the reason for this is that Jones and Wren were influenced not only by Italian sources but by others as well, and that they experimented various solutions adapting the details to the local tradition (Valeriani, 2006).

Other authors produced carpentry manuals in this period but they were all quite practical and kept showing traditional English carpentry and criticising the new fashions in France (mansard roofs) (Gómez Sánchez, 2006). Treatises by Smith (1736), Langley (1740) and Salmon (1767) include many

examples of trusses, but they are mostly incorrectly drawn or poorly designed (Yeomans, 1986a). Only late eighteenth-century English treatises (Nicholson, 1797, Pain, 1796) show a thorough understanding of the trussed system: Nicholson (Figure 106), in particular, published the first account in English of the behaviour of the king post truss which clearly explained the nature of the forces in each of the members. This is reflected by practice: the architect J. Essex designs complex trussed roofs during the second part of eighteenth century, whose original solutions prove that the system was well understood and established by then.

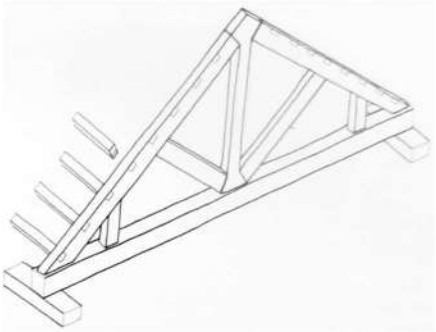


Figure 103: Trussed roof at Stoke Bruerne, designed by I. Jones (1630) (Yeomans, 1992)

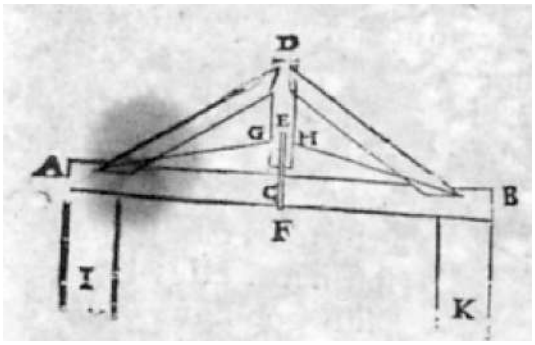


Figure 104: Roof truss drawn by Baldi (1621) at p.102; Yeomans (1992) considers Baldi the main source of inspiration for Jones and Wren, but Valeriani (2006) contradicts this by highlighting the different treatments of the joint post/tie-beam

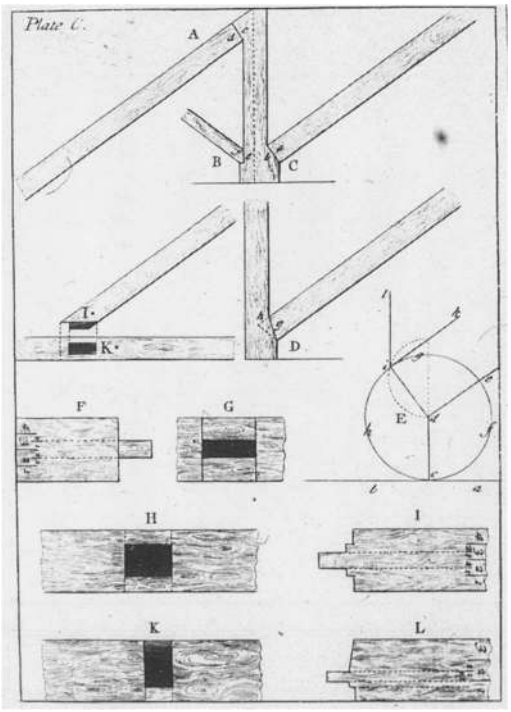


Figure 105: Details of trussed roofs drawn by Price (1733)

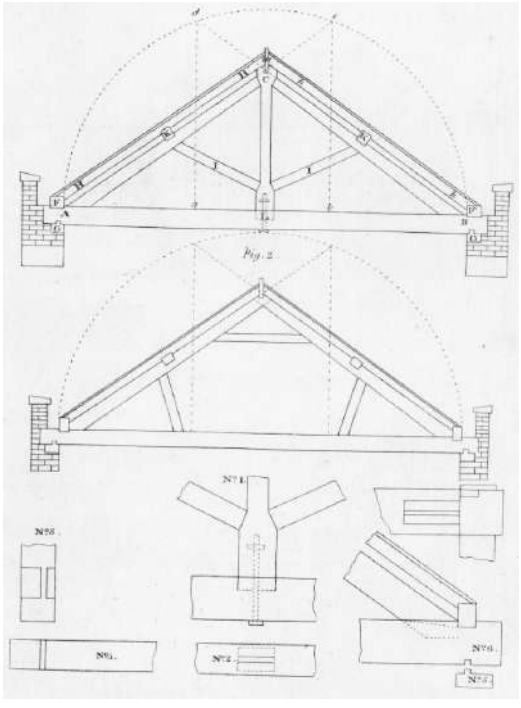


Figure 106: Trussed roofs and details drawn by Nicholson (1797)

3.2.1.4 Scotland

Research on the use of timber in Scottish architecture has been published (Apted, 1966, Bell, 2004, Crone and Sproat, 2011, Peddie, 1883) but there has been little focus on its structural use, particularly in roofs, although scholars such as Hay (1976), Ruddock (1995), Stell (2004) and Hanke (2006) have created a good base for further research. Most of the publications mention few famous roofs, mainly pre-sixteenth century, like that of Darnaway Castle (Stell and Baillie, 1993) (Figure 107), or Glasgow Cathedral (Oldriev, 1916) (Figure 108), whilst very few publications talk about roofs hidden behind timber or plaster ceilings, even though scholars (Hanke, 2006, Ruddock, 1995, Stell, 2004) agree in saying that they represent the great majority of Scottish roofs.

The roofs on which research has focused until 1990s are the 'false hammer-beam' or 'open purlin' roofs of thirteenth, fourteenth and fifteenth century that we find in the great halls of Darnaway Castle (Stell and Baillie, 1993) (Figure 107), Stirling Castle (Crone and Fawcett, 1998), Edinburgh Castle (Crone and Gallagher, 2008) (Figure 109), Holy Rude church in Stirling (Hay, 1976) (Figure 110) and in the seventeenth century Tron church and Parliament Hall in Edinburgh (Gomme, 2002). Another example of open purlin roof has been identified by Hanke (2006) in documents held at RCHAMS archives: the one in St John Church in Perth (1448) (RCAHMS SC 830680, 1927), still existing and similar to the one in Holy Rude church (Appendix A).

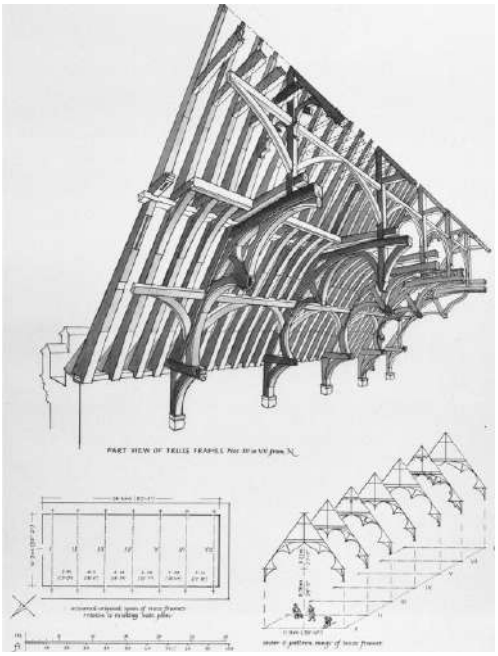


Figure 107: The roof of Darnaway's Castle Great Hall (1387) (RCAHMS SC 433080, 1998)

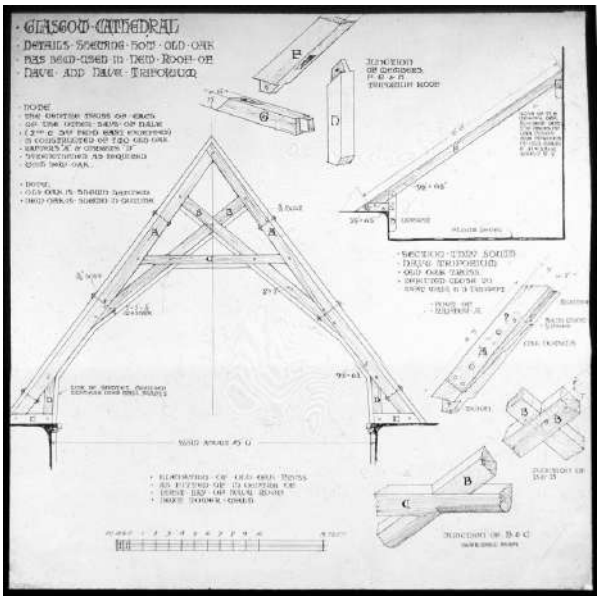


Figure 108: The roof of Glasgow Cathedral's central nave (thirteenth century) (RCHAMS DPM 1900/67/2, 1909)



Figure 109: The roof of the Great Hall at Edinburgh Castle (1510) (RCAHMS SC 1201162, 1888)



Figure 110: The roof of the central nave of Holy Rude church in Stirling (1455) (RCAHMS SC 738897, 1959)

These roofs are aligned with the English tradition of hammer-beam roofs, devised to span a wide space without the need of intermediate supports. Darnaway Castle's roof, in particular, can be seen as a 'proto-hammerbeam' roof since it predates the first English hammerbeam roof at London's Westminster Hall by roughly 20 years (Hanke, 2006). They are, however, different from the English ones because the hammer-post is often missing or its stiffening action is reduced by the fact that the hammer-beam is tenoned into its foot rather than vice versa (Gomme, 2002, Stell and Baillie, 1993). This is why they are called by Hanke (2006) 'open purlin' roofs or 'false hammer-beam' roofs. Gomme (2002) suggests that the structural arrangements of these roofs are devised in this way also to obtain decorative patterns able to convey a certain message.

These complex and elaborate open roofs, employing wall-plates, posts, struts, principal rafters, purlins and curved longitudinal braces, seem however to represent an exception rather than the rule, since most buildings of the period in Scotland are characterized by reduced spans. Scholars have investigated cruck structures covering cottages, farms and other vernacular buildings (Dunbar, 1956-7, Fenton and Walker, 1981, Hay, 1976, Stell, 1981) (Figure 111), and Hanke (2006) has highlighted the interesting use of massive stone vaults as roof structures in many buildings dating from thirteenth to seventeenth century (Figure 112). Nonetheless, Stell (1992, 2004), Ruddock (1995), Hay (1976) and Hanke (2006) all agree that up to nineteenth century the majority of Scottish roofs is characterized by a common rafter form: a sequence of closely spaced rafter couples, with no distinction between principal (load-bearing) and common (non load-bearing) rafters, whose rigidity is provided transversally by one or two collar beams and longitudinally by the gable walls and the sarking boards. Rafters simply sit on the wall-head, but additional rigidity is often provided by rafter feet with the ashlar post extended downwards on the masonry and occasionally rubble infill in

between them. Timbers have square uniform scantlings and are jointed with mortice and tenon joints secured by wooden pegs. No wall-plates, tie-beams, purlins or struts are used.



Figure 111: Cruck-framed Cottage in Torthorwald (RCAHMS SC 383456, 1970)



Figure 112: Massive stone vaults in Dunglass Parish Church (1423) (RCAHMS SC 1164646, Undated, RCAHMS SC 1171792, Undated)

Although scholars agree on this description of Scottish common rafter roofs, very few examples are mentioned and even less are actually published in detail: the roof of Alloa Tower (Figure 113) and that in a town house in Kirkcaldy (Figure 114), both described by Ruddock (1995), and two other roofs described by Crone et al. (2004) (Figure 115) and Peddie (1883) (Figure 116).

Besides these four examples, no other common rafter roof had been reported in literature prior to Hanke's research (2006). He is the only one who has extensively researched these simpler roofs, which he calls 'rafter single roofs'. His investigation is focused on roofs in Midlothian and Fife of a date up to mid-seventeenth century (Figure 117) and relies primarily on documents held at RCAHMS archives, although he has also surveyed some roofs.

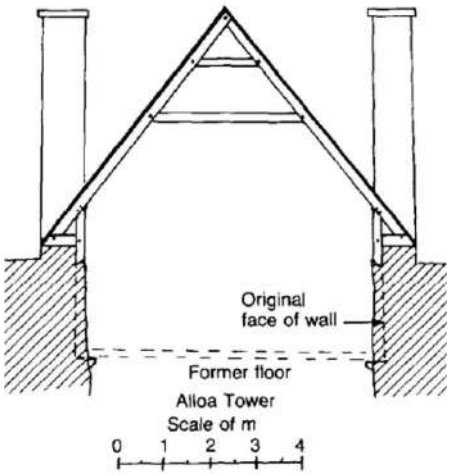


Figure 113: The roof of Alloa Tower (1497, maybe older) (Ruddock, 1995)

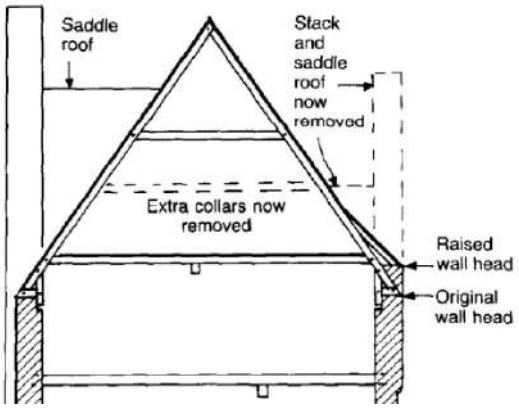


Figure 114: The roof of 339-343 High Street, Kirkcaldy (1600) (Ruddock, 1995); the graphic scale in Figure 113 is valid for this Figure too

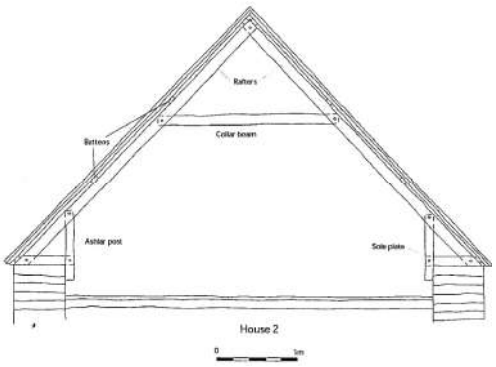


Figure 115: The roof of 68-74 High street in Brechin (1575) (Crone et al., 2004)

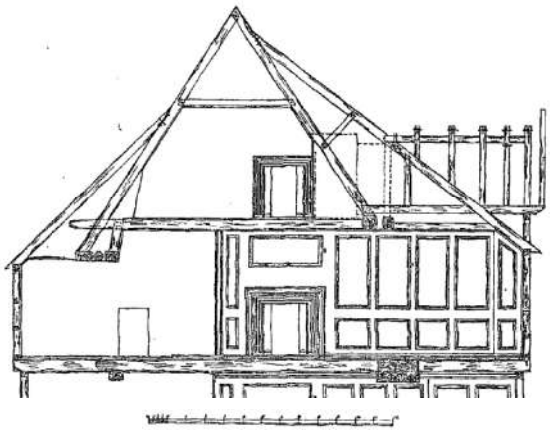


Figure 116: The roof of a tenement in Edinburgh Lawnmarket (1580), demolished before 1884 (Peddie, 1883)

Type	1251 – 1350	1351 – 1450	1451 – 1550	1551 – 1650
Massive vaults		OOOOOOO	OOOOOO	O
Mock vaults				
Rafter single roofs		O	OO	OOOOOOOOOOOO OOOOOOOOOO
Purlin roofs			OOOOO	OO
Flat roofs			O	
Pyramidal roofs				O

Figure 117: The evolution of roof construction in South-East Scotland until 1650, extracted from Hanke (2006)

The drawings and pictures collected by Hanke (see examples in Figure 118, Figure 119, Figure 120, Figure 121; the full list is in Appendix A together with other documents we have found) show that the vast majority of Scottish buildings up to 1650 are covered by simple common rafter roofs in line with the description given by Stell (1992, 2004), Ruddock (1995) and Hay (1976).

Hanke (2006) argues that although these type of roofs are aligned with the Romanesque North-West European school of carpentry, some features are distinctively Scottish: the sarking, the rafter foot with the ashlar post extended downwards on the masonry (Figure 123) and the absence of wall-plates, tie-beams and purlins. It is true that although timber boards similar to the Scottish sarking are used elsewhere (Bertolini Cestari et al., 2015, Corvol-Dessert et al., 2009, Janse, 1989, Pompejano et al., 2015, Thelin and Linscott, 2008) and similar rafter feet can be found in France and Netherlands (Courtenay, 1985) (Figure 124) they have not been so persistently used throughout the centuries as in Scotland. Moreover, Hanke (2006) correctly emphasizes that the use of this simple common rafter form without wall-plates, tie-beams and purlins up to mid-seventeenth century is remarkable considering that queen/king posts, longitudinal bracing, principal rafters and the subdivision into primary and secondary frames start being introduced in England (Fletcher and Spokes, 1964, Hewett,

1980) and Continental Europe (Bláha, 2006, Corvol-Dessert et al., 2009, Eissing, 2009, Gogolin, 2008, Janse, 1989, Szabó and Kulin, 2005, Thelin and Linscott, 2008) since twelfth century, as discussed in the previous section.

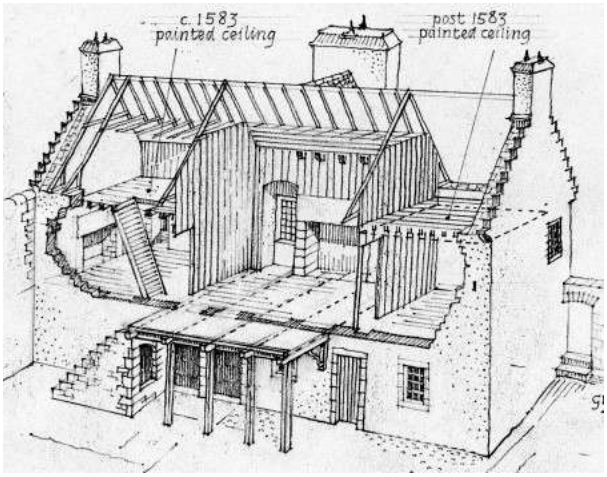


Figure 118: The roof of Dysart Bay Horse Inn (1583) (RCAHMS SC 989070, 1969) in Hanke (2006)

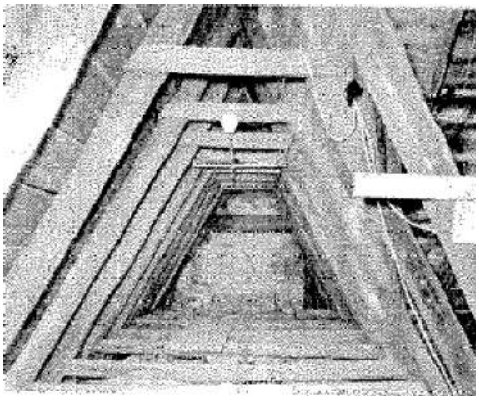


Figure 119: The roof of Northfield House (1611) (Hanke, 2006)

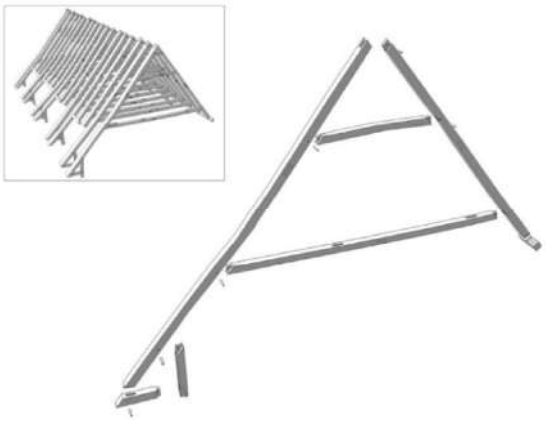


Figure 120: The roof of the North range of Newark Castle (1598) (Hanke, 2012)

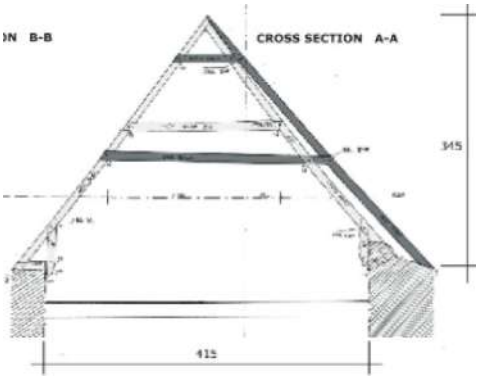


Figure 121: The roof of Halkerston Lodge (1638-42) (Hanke, 2004)

Hanke (2006) explains the absence of wall-plates and purlins with the constant presence of gable walls and of the sarking which provides longitudinal rigidity by connecting all the rafters together and with the gable walls. This explanation is reasonable since gable walls disappear in Scottish buildings only at the end of seventeenth century, as previosuly discussed. According to Ruddock (1995), the lack of wall-plates may also find an explanation in the compression-transferring nature of the extended ashlar post (Figure 123), which differentiates the Scottish rafter foot from the typical English one (Figure 122).

Moreover, Hanke (2006) argues that Scottish wrights did not use principal rafters and tie-beams because the thick and heavy stone walls of medieval and renaissance Scottish buildings easily

counteracted the horizontal thrust resulting from these roofs. This explanation is also reasonable: the thickness of walls starts being reduced already at the beginning of seventeenth century, as previously discussed, but it rarely reaches widths lower than 1m (Gonzalez Manich et al., 2017) and never reaches the diaphanous dimensions of Gothic architecture (Hanke, 2006). According to Ruddock (1995), the spreading of the rafters is also counteracted by the rafter feet arrangement, but our surveys have proven this to be largely incorrect, since the mortice and tenon joints of the rafter feet are capable of resisting very little tension forces.

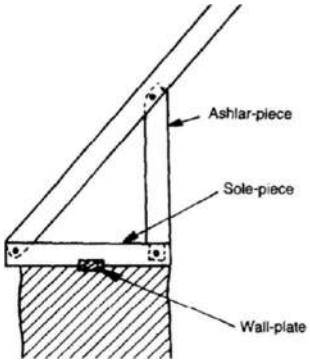


Figure 122: Schematic of the English rafter foot (Ruddock, 1995)

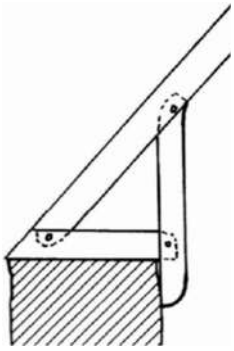


Figure 123: Schematic of the Scottish rafter foot (Ruddock, 1995)

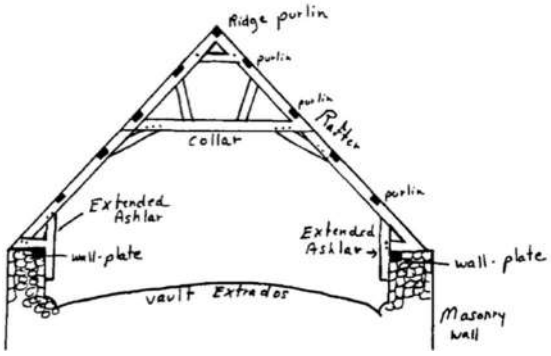


Figure 124: The roof of Ruldoc Abbey Church in Holland (twelfth century) with a rafter foot similar to the Scottish one (Courtenay, 1985)

Besides the open purlin roofs previously discussed, few other exceptions to the simple common rafter roofs are mentioned in literature: the purlin roof in Newark Castle (1597-99) (Hanke, 2012), the scissor-braced common rafter roofs in Glasgow Cathedral (thirteenth century) (Oldriev, 1916) (Figure 108), Moray House (seventeenth century) (Hanke, 2004) (Figure 125) and Ardchattan Priory (thirteenth century) (Hanke, 2006, Hay, 1976) (Figure 126), and the arch-braced common rafter roofs in Bardowie Castle (1566) and Linlithgow Town House of the Knights of St John (early sixteenth century, demolished) (Hanke, 2006, Hay, 1976) (Figure 127). Hanke (2006) identified the roof of Linlithgow Town House as an open purlin roof, but the available drawing (Figure 127) shows butt-purlins which contribute to the longitudinal stability rather than having a load-bearing function. This roof is particularly interesting as it is the only known example of Scottish rafter roof with primary and secondary frames and longitudinal bracing.

These exceptions suggest that Scottish wrights had the skills and expertise to design and construct more complex structures, when needed, and that they knew how to make an efficient use of timber. This raises the question to why they mostly opted for common rafter roofs recalling the technology used during the early Middle Ages in the rest of Europe. Hanke (2006) argues that the limited spans of domestic architecture built up to mid-seventeenth century in Scotland and the fact that roof structures start being hidden behind elaborate timber and plaster ceilings, relieving them from any

aesthetical function, explains the persistent use of common rafter roofs. The examples we have previously discussed and other documents we have found in RCAHMS archives (Appendix A) confirm however that common rafter roofs were in use much earlier than 1600, even exposed.

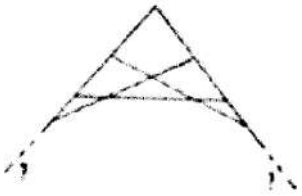


Figure 125: The scissor-braced roof of Moray House (1623) (Hanke, 2006)

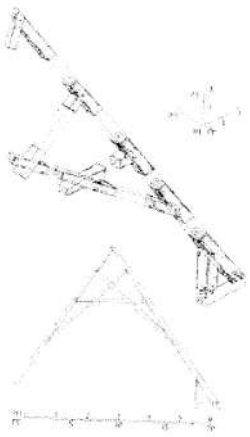


Figure 126: The roof of Ardchattan Priory (fifteenth century) (Hanke, 2006)



Figure 127: The arch-braced roof of Linlithgow Town House of the Knights of St John (early sixteenth century, demolished) (RCAHMS SC 1047690, 1886)

Hanke (2006) suggests that shortage of timber in post-medieval Scotland might be another reason for this simplification in roof construction. There are however some issues contradicting this which Hanke himself discusses. It is true that the parliament in 1503 passed Acts to protect Scottish woods from over use because Scottish forests had been 'utterly destroyed' (Newland, 2010); however, Scotland had been importing Baltic timber even before that date, thus the parliament Acts only resulted in an increase in timber imports (Crone and Mills, 2012); therefore shortage of timber was a problem only in rural areas where it was difficult to transport to. Moreover, shortage of timber in central Europe actually resulted in further innovation and optimization (Hoffsummer, 2007). On the other hand the reliance on foreign timber trade might have favoured timber architecture characterized by few standardised items such as deals and straight, relatively short timber elements, which were cheap and easy to retrieve (Hanke, 2006). This did not affect the ability of Scottish wrights to produce outstanding timber structures such as the ones in Edinburgh Parliament Hall (Figure 128) and Tron Church (Figure 129), but it prompted them to use in the vast majority of cases simple redundant common rafter roof structures.

Very little is known about Scottish roofs after mid-seventeenth century, since very few examples are mentioned in literature (Figure 130). Hay (1976) affirms that common rafter roofs continue to be used, the only difference being the joints between collars and rafters which become lapped/halved and dovetailed rather than mortice and tenon, secured by metal nails rather than timber pegs. He

mentions Skellater House (eighteenth century) as example, and Hanke (2008) describes the same kind of joints in Auchindinny House (1707), and Burntisland Parish Church (1748-1822), but neither of them provides a full survey of these structures nor do they discuss the reasons for these technological developments.



Figure 128: The roof of Parliament Hall in Edinburgh (1631-40)



Figure 129: The roof of Tron Church in Edinburgh (1636-48)

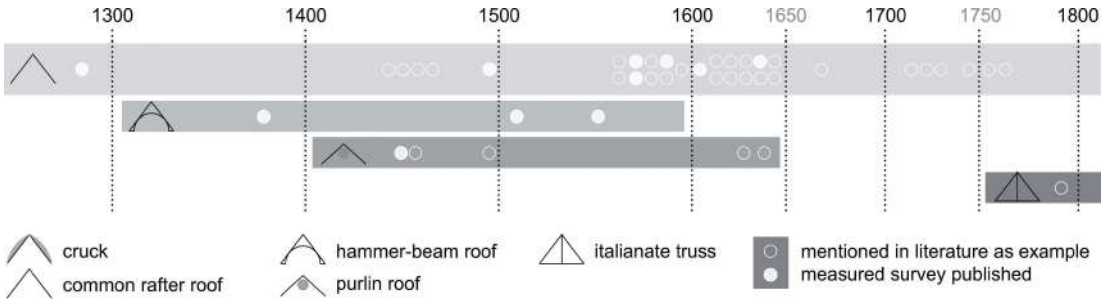


Figure 130: Timeline of Scottish timber roofs mentioned in literature divided by structural typology (for details see Appendix A); crucks are not included since they are used only in vernacular buildings

Hanke (2006) and Stell (2004) state that saddles and valleys joining up adjacent roofs, as well as hipped arrangements, start being used from late seventeenth century when gable walls disappear, as in Holyrood Palace (1671-9). Few earlier buildings are characterized by intersecting roofs and confirm once again that Scottish wrights possessed the technical knowledge necessary to erect more complex structures, but chose to employ this knowledge only occasionally: St. Nicholas church in Dalkeith (after 1390), Tullibardine Chapel (1446) (Figure 131), St. Salvator's church in St Andrews (c. 1450), Northfield House (c. 1590) and Newark Castle (1597-99) (Figure 132) (Hanke, 2008).

Gomme (2002) affirms that after mid-seventeenth century open purlin roofs are superseded for the wide spans of country houses by flat roofs with horizontal beams of large dimensions and Italian king-post trusses. Unfortunately, Gomme (2002) does not mention any example to argue his statement. Hanke (2006) disagrees with Gomme and states that Bruce and Smith continue employing common rafter roofs in their late seventeenth- and early eighteenth-century country houses. According to him, trussed roofs are introduced in Scotland by William Adam when he

designs the New College Library in Glasgow in 1720 (demolished) (Figure 133). However, just like Gomme, he does not provide any evidence for this statement; the only built trussed roof he mentions is over the late eighteenth-century St Andrew and St George's church in Edinburgh (1782-4) (Figure 134).



Figure 131: The roof of Tullibardine Chapel with intersection visible on the left (Author)

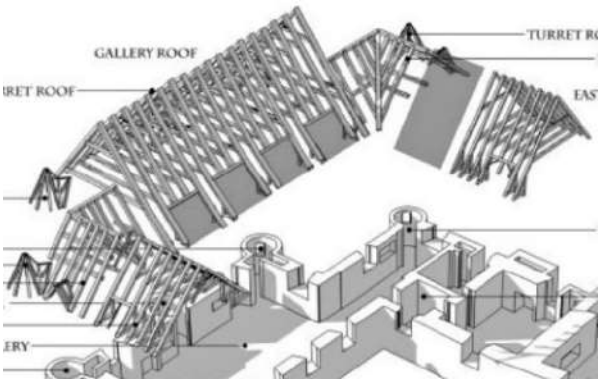


Figure 132: Schematic of the roofs of Newark Castle with intersections visible on top right and bottom left (Hanke, 2012)

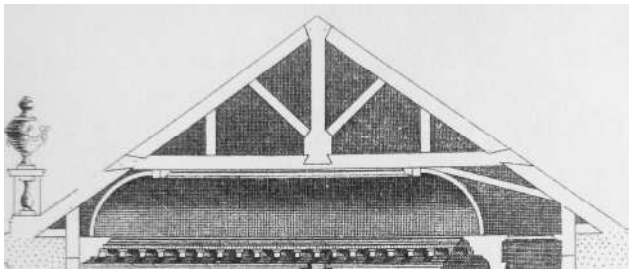


Figure 133: William Adam's design for the roof of Glasgow New College Library, 1720 (Adam, 1812)

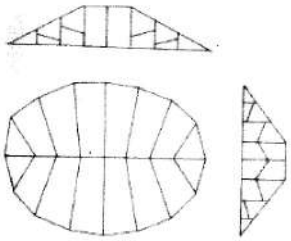


Figure 134: Schematic of the roof of St Andrew and St George's church (1782-4) (Hanke, 2008)

In conclusion, research up to now confirms that up to mid-seventeenth century Scottish roof carpentry is in line with the English one but develops distinctive features in hammerbeam roofs and common rafter roofs especially (Figure 135). However, despite the valuable contributions of Stell (1992, 2004), Ruddock (1995), Hay (1976), Crone et al. (2004) and Peddie (1883) and the extensive investigation carried out by Hanke (2004, 2006, 2008, 2009, 2012), there is still a significant lack of knowledge on the extent and nature of seventeenth- and eighteenth-century timber roofs in Scotland, caused mainly by the scarcity of measured surveys, as highlighted in Figure 130. First hand data is needed to corroborate the hypothesis made and in particular to understand how roof design has evolved after mid-seventeenth century.

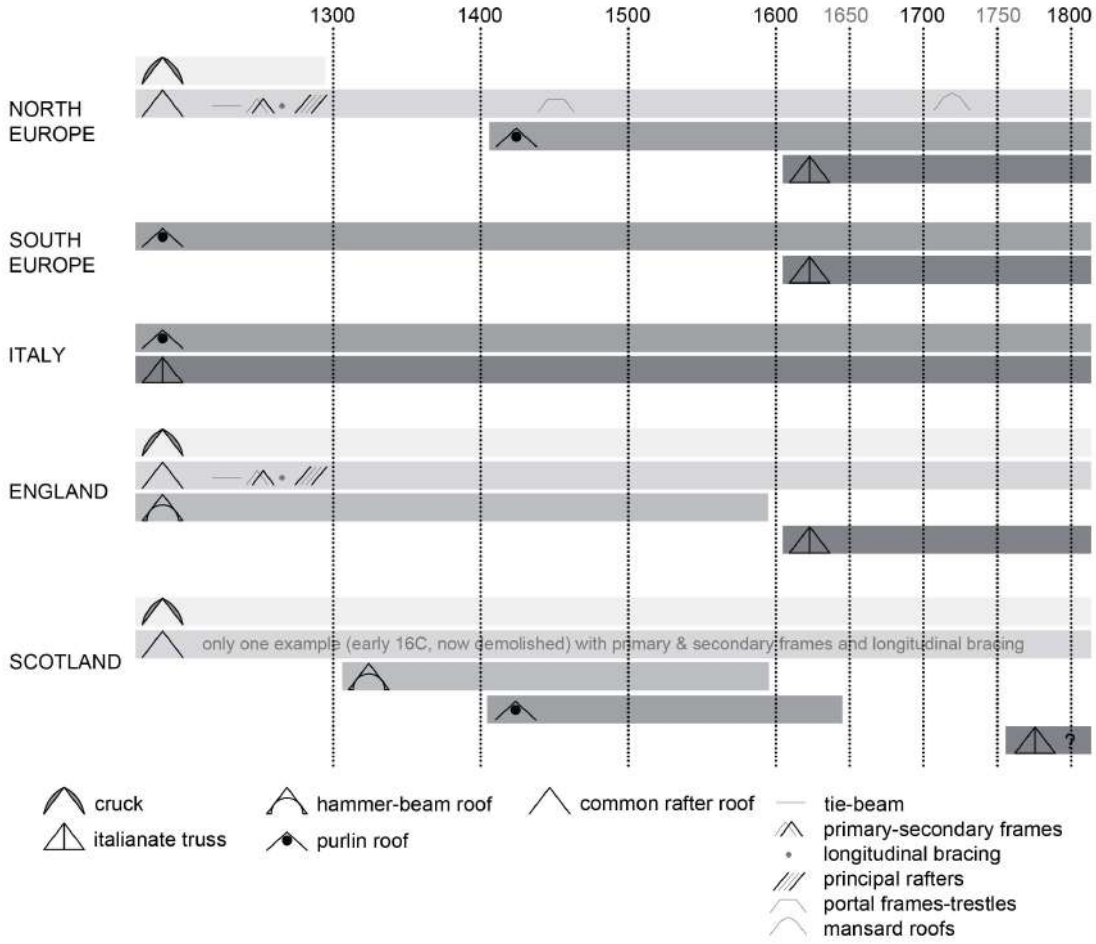


Figure 135: Timeline of different roof structures types used in continental Europe and England, compared to what is reported in litertature about Scottish roofs

3.2.2 Timber species and provenance

A big part of the timber used in seventeenth- and eighteenth-century Scottish roof structures is not native Scottish. In that period, local Scottish wood had a reputation for being of lower quality and it was difficult to transport it throughout the country; thus Scotland started very soon to import timber from the Baltic regions and Scandinavia. Newland (2007, 2010, 2011, 2012a, 2012b, 2012c) and Thomson (1991) have researched the timber sourcing and trade during seventeenth and eighteenth centuries respectively, mainly through archival documents, whilst Crone (2001, 2008b, 2008a, 2011) has carried out dendrochronological analysis of Scottish timbers, also in collaboration with other scholars (Crone and Fawcett, 1998, Crone and Gallagher, 2008, Crone et al., 2004, Crone and Mills, 2007, Crone and Mills, 2008, Crone and Mills, 2011, Crone and Mills, 2012, Crone and Sproat, 2011, Mills and Crone, 2012). Although the sample of analysed roof timbers is limited, the above mentioned research provides us with extremely helpful information on the timber species employed in seventeenth- and eighteenth-century Scottish architecture and their provenance.

Walker (2006) states that several different species were used in Scottish buildings: chestnut, oak, ash, aspen, beech, willow and other hardwoods. Hay (1976) mentions oak and imported fir. However, neither of the two provides any evidence for their statements. Dendrochronological studies have identified exclusively oak (*Quercus sp.*) and Scots pine (*Pinus Sylvestris*) in roof structures (Crone and Mills, 2012) (Figure 136); the preference for these two species has been confirmed by our surveys, as we will discuss in the following chapters. Spruce and fir are often mentioned in records and accounts of the time, but it seems that they were simply used as different terms for pine (Crone and Mills, 2012).

In most buildings there are timber elements coming from different sources and also felled in different dates, due to stockpiling practices, transportation time and reuse of timber, therefore it is not always easy to assess the exact provenance and construction date of the timber (Crone and Mills, 2012). It is relatively easy now to date imported timber, but it is still difficult to date native one because it is rare and there are fewer master chronologies available (Crone and Mills, 2011): this is the issue on which Scottish dendrochronology has focused its research lately (Mills and Crone, 2012). Another important focus should be the post medieval period, since only nine seventeenth- and eighteenth-century roofs have been dendro-dated and provenanced so far (Figure 136). The dendrochronological analysis of more roof structures would certainly allow dating roof structures based on typological aspects with more confidence. Based on the evidence collected up to today we can nonetheless draw an outline picture of the sourcing and use of timber species in Scotland.

During the Middle Ages, oak was considered to be the most valuable of timber, due to its strength and resistance, and used whenever possible for the construction of high status buildings in Scotland (Newland, 2010). During thirteenth, fourteenth and fifteenth centuries local oak is used, as testified by the roofs of Glasgow Cathedral (thirteenth century) and Darnaway Castle (1387) (Crone and Mills, 2012) (Figure 136). By sixteenth century, however, it is hard to find native oak trees suitable for building construction, due to transportation problems and low quality (Newland, 2010). After the Parliament passes Acts in 1503 to protect Scottish woods from over use, domestic timber continues to be felled for commercial use, as testified by the roof timbers in Newark Castle (1598) (Crone, 2008b), Drum Castle (1598-1621) (Crone, 2011) and Crathes Castle (1589-1591) (Crone and Mills, 2007) (Figure 136), but many woodlands start disappearing quickly and Scotland has to look abroad for new timber sources (Newland, 2010).

The import of oak, pine (called *redwood*) and spruce (called *whitewood*) from the eastern Baltic and Scandinavia increases. Norway dominates the market from 1550 (Crone and Mills, 2012, Newland, 2010). In some occasions Norwegian timber is specifically requested for building works in Scotland (Newland, 2010): George Heriot Hospital's governors, for example, order a ship to be sent specifically to Norway to buy timber for the construction works in 1627 (Lockhart, 2003).

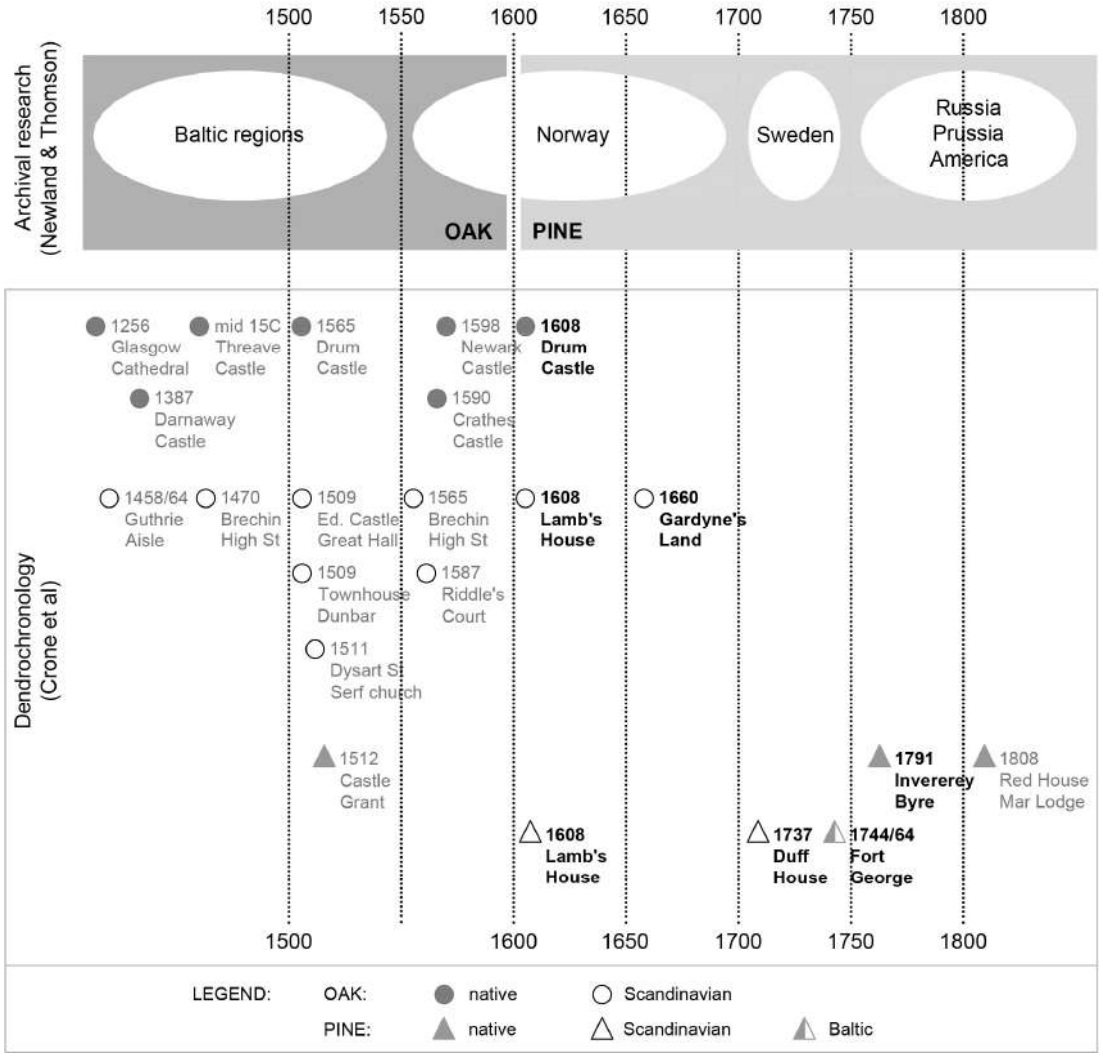


Figure 136: The species and provenance of timbers used in Scottish roofs according to archival research carried out by Newland (2007, 2010, 2011, 2012a, 2012b, 2012c) and Thomson (1991) and dendrochronological analysis carried out by Crone (2001, 2008b, 2008a, 2011) and others (Crone and Fawcett, 1998, Crone and Gallagher, 2008, Crone et al., 2004, Crone and Mills, 2007, Crone and Mills, 2008, Crone and Mills, 2011, Crone and Mills, 2012, Crone and Sproat, 2011, Mills and Crone, 2012)

From 1600 oak is gradually replaced by pine for structural use (Figure 136): the export of oak from Norway is prohibited after 1602 because the remaining supplies are vital for the construction of the Danish-Norwegian fleet (Mills and Crone, 2012, Newland, 2010). Thus seventeenth century is dominated by the import of pine from Norway (Crone and Mills, 2012, Newland, 2010).

In eighteenth century Norway declines as supplier of timber due to the over-exploitation of its natural resources. Imports from Sweden increase dramatically from 1730s and surpass Norway in 1750s (Thomson, 1991). However, because of the difficulty in identifying the specific timber source, roof timbers in eighteenth-century Scottish buildings are often dendro-provenanced as Scandinavian rather than Norwegian or Swedish, as in Duff House (1737) (Crone, 2008a) (Figure 136).

From mid-eighteenth century Scotland starts importing timber from eastern Baltic; the trade is dominated by the import of pine mainly from Prussia and Russia, whose timber is considered to be of better quality than its Swedish and Norwegian rivals (Thomson, 1991). Norway and Sweden keep exporting timber because theirs is cheaper and shorter, therefore more easily manufactured into deals (Thomson, 1991). Baltic pine has been identified in the roofs at Fort George (1761-1767) (Crone and Mills, 2008) (Figure 136). In this period home-grown pine is used as well (Crone and Mills, 2012) (Figure 136). From 1790s timber is also imported from the Americas, as in England (Yeomans, 1992): the West Indies send exotic hardwoods such as mahogany and American Colonies and Canada provide hardwoods such as oak and walnut (Thomson, 1991). These have however not been identified in roof structures: they were probably used for interiors.

3.2.3 The dressing of timbers and the construction process

Norway's dominant position during the sixteenth and seventeenth-century timber trade appears to be due to the use of water-driven sawmills, a new technology which allowed for the mass production of deals and planks (Newland, 2010). Pit saw mills existed in Scotland since early seventeenth century but they were much slower. The water-driven technology reached Scotland by late seventeenth century but it was not so widespread, probably because timber suitable to be processed in this way was very limited or inaccessible (Newland, 2010).

Crone and Mills (2011) and Hanke (2006) state that the earliest surviving Scottish roofs, such as Guthrie Aisle (1464) and 68-74 High street in Brechin (1470), previously mentioned, employ small squared heart baulks, shaped through scoring, hewing and flattening all four faces, often leaving bark on the corners (Figure 137). We have observed the same in the early seventeenth century roofs we have surveyed. Typical cuts of timber bought by the Scottish skippers from Norway included in fact sawn boards for the sarking (deals), and beams for the rafters/collars too small to be further sectioned to obtain more than one beam (Thomson, 1991). It has been suggested that timber elements might have been prefabricated at the source (Hanke, 2006, Newland, 2012c). It is reasonable to think that timbers were roughly dressed at the source in order for them to occupy less space in the ship, but the shrinking effect would not allow to dress timber joints and put them in place after a long period of time (necessary to transport the timber to Scotland).

The earliest evidence of use of saws in Scotland is provided by planks from 1472-6; however, hand sawing does not appear to have become common in Scotland until eighteenth century (Crone and Mills, 2011, Hanke, 2006). It appears earliest in prestigious buildings whose wealthy owners could afford to hire a sawyer (Figure 138) (Crone and Mills, 2011). On the contrary, from eighteenth century technological developments in sawmilling in Scottish ports encourage the import of big squared timber baulks to be further processed by Scottish wrights to meet individual needs

(Thomson, 1991). The balks would be sawn in half, quarters or even more elements: in fact in eighteenth century Scottish buildings timbers have one or more sawn faces. Hewn round-wood is still used up to early nineteenth century but only in lower-status buildings (Crone and Mills, 2011).

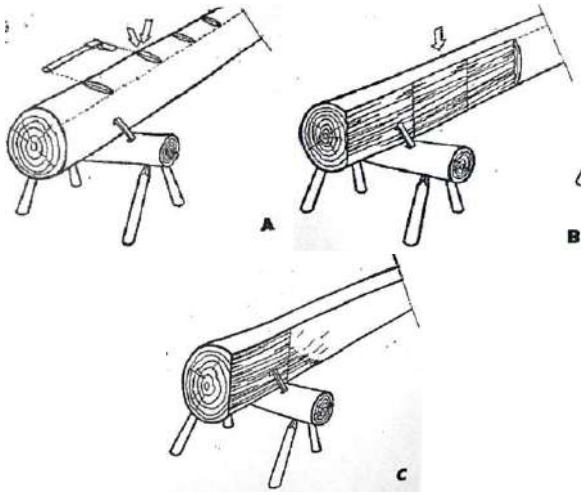


Figure 137: The dressing of timber beams: A. scoring; B. hewing; C. flattening (Drdácký et al., 2006)



Figure 138: Hand-sawn oak collars in the roof of the Mansion House at Drum Castle (1598-1621) (Crone and Mills, 2011)

Hay (1976) hypothesizes that the tools used by medieval and post-medieval Scottish wrights to dress the timber are the same as the ones used by other European carpenters: an axe for felling/squaring/splitting, an adze for smoothing, several types of saw, an auger for boring and a claw hammer. This statement is however quite generic as it is known that different types of axes, adzes and saws were used in the different European countries (Corvol-Dessert et al., 2009). Crone and Mills (2011), based on traces found on historic timbers in 34 buildings, state that until eighteenth century Scottish timbers are dressed with the axe/adze and the minimal use of a pit or frame saw; they are thus hand-axed and hand-sawn. In fact whilst mechanical sawmills exist in Norway since 1530 and in Netherlands since late sixteenth century, the earliest reference to circular saws appears in England in 1767 and in Scotland in 1820 (Crone and Mills, 2011).

Very little is known about the erection process after all the timber elements had been dressed. Hanke (2006) and Crone and Mills (2011) mention the use of roman numerals as assembly marks, but Hay (1976) is the only one discussing their role: he states that the principal members of each frame were marked with the same number, so that they could be correctly assembled; this allowed wrights to prepare the elements away from the site. Frames on site are often not in sequence for this reason: the numbers were used only to match the elements of one frame, then the frames could be placed on the walls in any order.

3.2.4 Wrights and carpentry treatises

Wrights have not been considered worth researching and to date, despite a recent contribution by Newland (2012b), little is known about their relation with architects and their role in the design process. It seems that in seventeenth- and eighteenth-century Scotland there was a sort of hierarchy amongst woodworkers but there is still confusion on the specific terminology since no research has been carried out on this aspect. Whilst literature on English carpentry only mentions the words 'carpenter' and 'joiner', Scottish scholars employ the words 'wright' and 'carpenter' interchangeably. The word 'wright' has disappeared from English construction vocabulary, superseded by 'carpenter' (for heavier structural work) and 'joiner' (for furniture and fittings); in fact Davies and Jokiniemi (2012) say that 'wright' is an outdated or vernacular word for a carpenter. The Concise Scots Dictionary (Robinson, 1999) defines 'wright' as 'a woodwright, a carpenter', the Etymological Dictionary of the Scottish Language (Jamieson, 1808) traces the word back to 'wryhta/wurtha: a workman, one by whom anything is framed' from 'wyrc-an: to work'.

In fact seventeenth-century wrights in Scotland used to deal with all the timber work, from roofs, to flooring, windows, furniture, scaffolding, plasterwork, tools for other craftsmen, etc (Newland, 2010). This clearly required expertise and advanced technological knowledge, which is why their social status improved - unlike in England, wrights had a low social profile in Scotland throughout the Middle Ages (Hanke, 2012). During the transition from direct labour to the contract system they started working as contractors (Dunbar, 1976, Newland, 2012b), as in England (Yeomans, 1992), and some even aspired to the role of architect, as James Baine (Newland, 2010). From seventeenth century their role was increasingly important in the construction site, which is why they soon outnumbered masons in St Mary's Incorporation of masons and wrights in Edinburgh (Newland, 2010). During the eighteenth century some wrights actually became professional architects, as Allan Dreghorn (Lewis, 2015) and city developers, as James Salisbury or John Bourgh (Lewis, 2006).

To become members of St Mary's Chapel Incorporation, wrights had to do an apprenticeship of six or more years and to produce an 'essay' at the end, which normally consisted in creating a piece of furniture (Newland, 2010). They were trained to know the architectural orders, since they were often requested to produce the final essays according to Vignola's (Barozzi da Vignola, 1562), Scamozzi's (1615), or Palladio's (1570) orders. The first mention of Palladio in the wrights' essays occurs in 1692 followed by references to Vignola and Scamozzi (Jones, 1991). This could mean that the Incorporation had a library which included these treatises.

Scamozzi and Palladio show some roofs (Figure 139, Figure 140) and other timber structures (mainly bridges). Other sixteeenth- and seventeenth-century treatises include roof carpentry: Serlio (1545) (Figure 141), Barbaro (1552), Du Cerceau (1576-9) (Figure 142), De l'Orme (1578), Digges (1592),

Baldi (1621), Zanini (1629), De Bray (1631). Very few of them, however, discuss it in detail. This is because these first manuals are either more concerned with the overall architectural proportions and appearance of buildings, or they are aimed mainly at helping tradesmen in measuring and estimating costs, to remedy their education lacking in mathematics (Yeomans, 1986a).

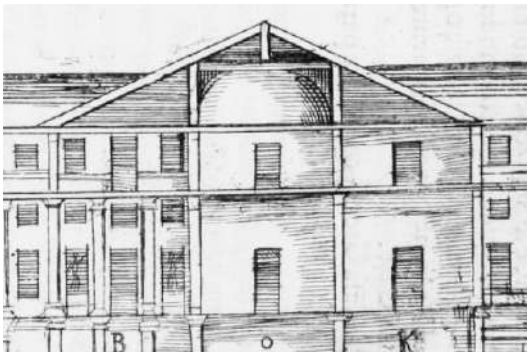


Figure 139: Roof drawn by Scamozzi (1615) at p. 228

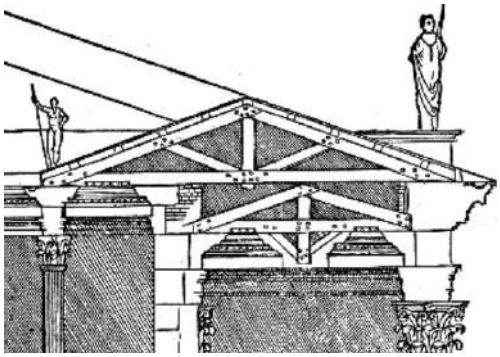


Figure 140: Trussed roof drawn by Palladio (1570) in chapter 12

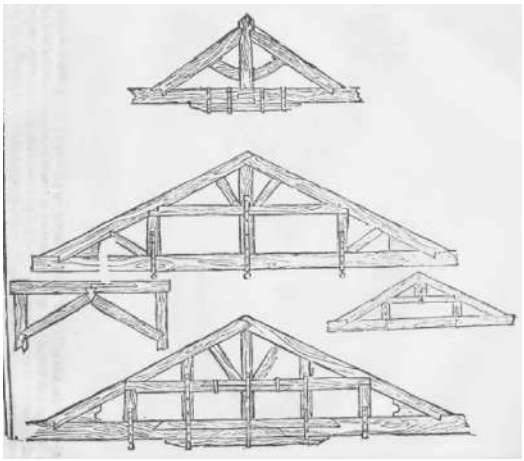


Figure 141: Trussed roofs drawn by Serlio (1545) at p. 197



Figure 142: Roof drawn by Du Cerceau (1576-9), vue 81

These drawings might have been the vehicle for transfer of technological knowledge from continental Europe to Scotland. However, Hanke (2006) argues that, considering the extensive use of simple common rafter roofs up to mid-seventeenth century in Scotland, it is reasonable to think that up to then Scottish wrights did not have access to European carpentry treatises or decided to disregard them and follow the traditional building methods they were comfortable with. He is right in stating that even the complex open structures devised for Edinburgh Tron church (Figure 128) and Parliament Hall (Figure 129) do not resemble any other known roof structure built or drawn - they are very different even from the English hammer-beam roofs - and thus owe little to foreign influences. Besides Hanke's and Newland's contribution (2010), however, little research has been carried out on the role of architects and wrights in the roof design process and on the influence of

contemporary treatises, travels in other countries or acquaintances with foreign professionals. In particular, no investigation has been carried out to understand how these aspects change from the second half of seventeenth century, when Scottish architecture sees an important development driven by the early modern architects Sir W. Bruce and Mr. J. Smith (section 3.1.2).

3.3 Tracing the historic development of seventeenth- and eighteenth-century timber roof structures in Scotland based on our findings

3.3.1 Structural arrangements

As we have seen in the previous section, in Medieval times large spans (>8m) are covered in Scotland by hammer-beam roofs and open purlin structures in line with the English tradition (Figure 143). These structures have been extensively researched because they are visible and quite spectacular. Nevertheless, they represent an exception rather than the rule, because most Medieval Scottish buildings are characterized by reduced spans (<8m), which do not require the use of such complex roof structures, and by decorated ceilings, behind which the roof structures are hidden. These buildings are in fact covered with stone vaults or simple common rafter roofs (Figure 143), as highlighted by Hanke (2006) and confirmed by our surveys: the 15 pre-1670 roofs we have surveyed are all common rafter roofs (Figure 51).

However, things change by the end of seventeenth century, when classical and baroque architecture are introduced in Scotland by the architects Sir W. Bruce and Mr J. Smith: Scottish wrights are forced to develop roof structures able to span increasingly wider spans with shallow pitches and hipped arrangements, whilst supporting heavy plaster ceilings (Figure 143). Eventually, a completely different structure is imported from abroad: the trussed roof (Figure 143). Our surveys have allowed understanding how Scottish wrights face this challenge and how roofs evolve from mid-seventeenth century, which had not been investigated so far.

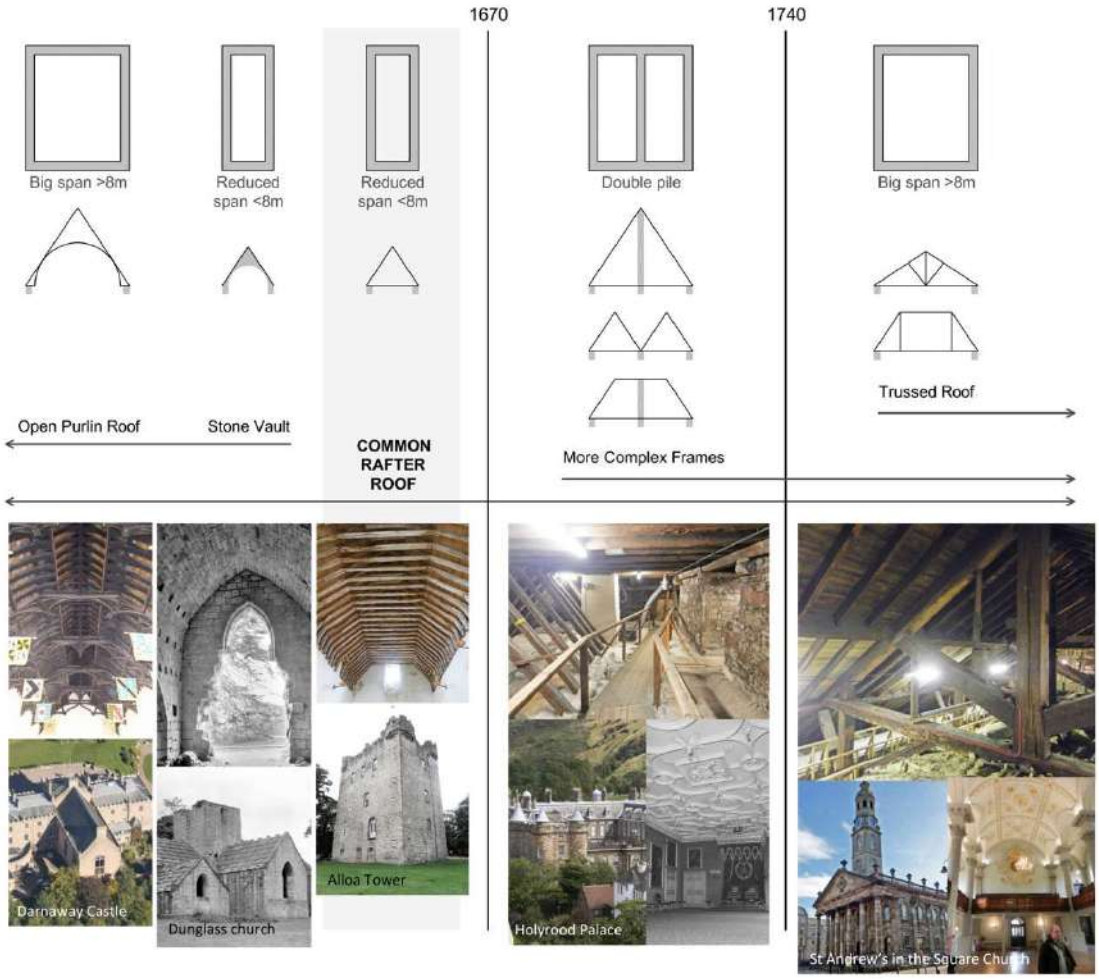


Figure 143: The development of Scottish timber roof structures (Serafini and Gonzalez Longo, 2015b). From left to right: Darnaway Castle, 1387 (RCAHMS DP 161383, 2013, RCAHMS DP 222837, 2015); Dunglass Church, 1423 (RCAHMS SC 1164646, Undated, RCAHMS SC 1171792, Undated); Alloa Tower, 1497 or older; Holyrood Palace, 1670s (RCAHMS SC 1209320, 1922); St Andrew's in the Square Church, 1751-3

3.3.1.1 Common rafter roofs

Our surveys and archival research (Appendix A) confirm Hanke's (2006) statement that up to late seventeenth century Scottish roofs are of simple common rafter form (Figure 51), with no subdivision between load-bearing and non load-bearing rafters and no longitudinal members other than the sarking boards. This is remarkable considering the wider European context, where these features are introduced much earlier, from twelfth century (section 3.2.1). The reason for this extensive use of simple common rafter roofs lies in the development of Scottish architecture of the time (section 3.1) and in the timber trade with North Europe (section 3.2.2), as highlighted by Hanke (2006) and Newland (2011). However, our surveys have allowed identifying certain variations in the

structural arrangements of these common rafter roofs that denote a technological development starting from the end of seventeenth century, as discussed below.

The oldest surviving Scottish common rafter roofs are open roofs, exposed to view: the thirteenth century Glasgow Cathedral (Oldriev, 1916) (Figure 108), the fifteenth century Alloa Tower (Ruddock, 1995) (Figure 113) and Tullibardine Chapel (Fawcett, 2002) (Figure 131). However, painted timber and then plaster ceilings soon become fashionable and roof structures are hidden above them: one of the earliest examples is Guthrie Aisle (1464) (Fawcett, 2002), whose painted timber ceiling has been removed and is now exposed at Guthrie Castle.

The 22 common rafter roof structures we have surveyed from the period between the end of sixteenth century and 1700 (Figure 51) are all hidden behind decorated ceilings. The spans are generally less than 7m and the pitches are quite steep (50°-60°). The typical arrangement can be seen in Figure 144: they are simple gabled roofs composed of rafter couples, spaced 30-60cm apart, each connected transversally by one or two collar beams and longitudinally by sarking boards (Figure 129, Figure 130). The timbers have uniform square/round scantlings of 10/15cm. The rafters are often simply sitting on the wall-head or on a sole piece tenoned into an ashlar post extended downwards on the masonry (Figure 129, Figure 130) - the 'Scottish rafter foot' (Ruddock, 1995) discussed in detail in section 3.3.2.2. No wall-plates, tie-beams, struts or longitudinal elements are used, with the exception of headers supporting the rafter ends above windows and dormers.



Figure 144: Maquettes of Scottish common rafter roofs produced by the attendees of the workshop "Traditional Scottish Timber Frames" held by the author at Glasgow City Heritage Trust on 19/04/2016 (left) and by the Master students of Edinburgh University during a workshop held by the author on 12/02/2015 (right)

During the eighteenth century common rafter roofs are still used, but some innovations are introduced: they retain the basic structural arrangement composed of common rafter couples connected solely by collars and sarking boards, but they are characterized by wider spans (the maximum is 9.8m reached by Duff House, 1737), shallower pitches (the minimum is 34° reached again by Duff House, 1737), different roof geometries (intersected roofs, hipped roofs, M roofs, etc)

and the use of wall-plates and tie-beams, discussed in detail in section 3.3.2.2. Moreover, some roofs we have surveyed testify the introduction of other features that modify their structural arrangement even more significantly: this is why they have been grouped separately, as 'complex frames'.

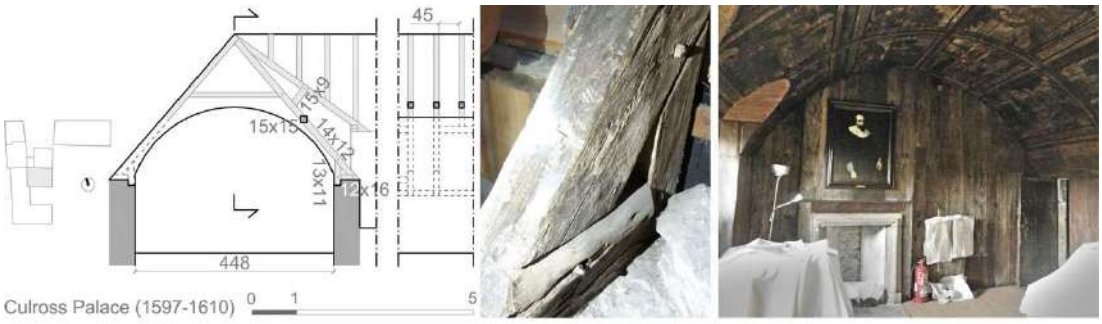


Figure 145: The common rafter roof of Culross Palace (1597-1610): sections (left), the rafter foot (centre), the ceiling underneath (right)

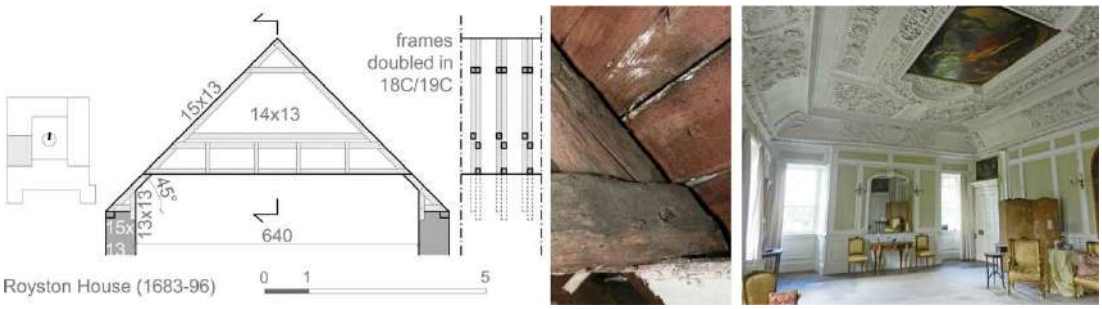


Figure 146: The common rafter roof in the West range of Royston House (1683-96): sections (left), the joint between rafter and collar (centre), the ceiling underneath (right)

3.3.1.2 Complex frames

From 1670s onwards, common rafter roofs had to adapt to the new architecture introduced in Scotland by the architects Sir W. Bruce and Mr J. Smith. Shallower roofs, more in keeping with the requirements of the new facades of buildings such as Holyrood Palace (1671-9) and Melville House (1697-1703), were needed. M-roofs, platform roofs and hipped roofs - known in Scotland as 'Italian roofs' (Innocent, 1971) -, emerged and substituted the high pitched gables of medieval Scottish buildings (Figure 147). The spans became increasingly wide (>8m). Scottish wrights already had the technical knowledge to cover big spans, as proved by Darnaway Castle (Figure 107) and Edinburgh Castle (Figure 109). However, by late seventeenth century heavy plaster ceilings had become fashionable and roof structures were also responsible for supporting them. Roof structures took some time to become efficient enough to do this. At first, intermediate supports were necessary.

Holyrood Palace (1671-9) is the earliest hipped platform roof we have surveyed (Figure 148). The internal structure is still a common rafter roof, since there is no subdivision between load-bearing

and non load-bearing rafters, and there is still no longitudinal bracing other than the sarking boards. However, the roof geometry is innovative as it is hipped and spans above a double pile plan.

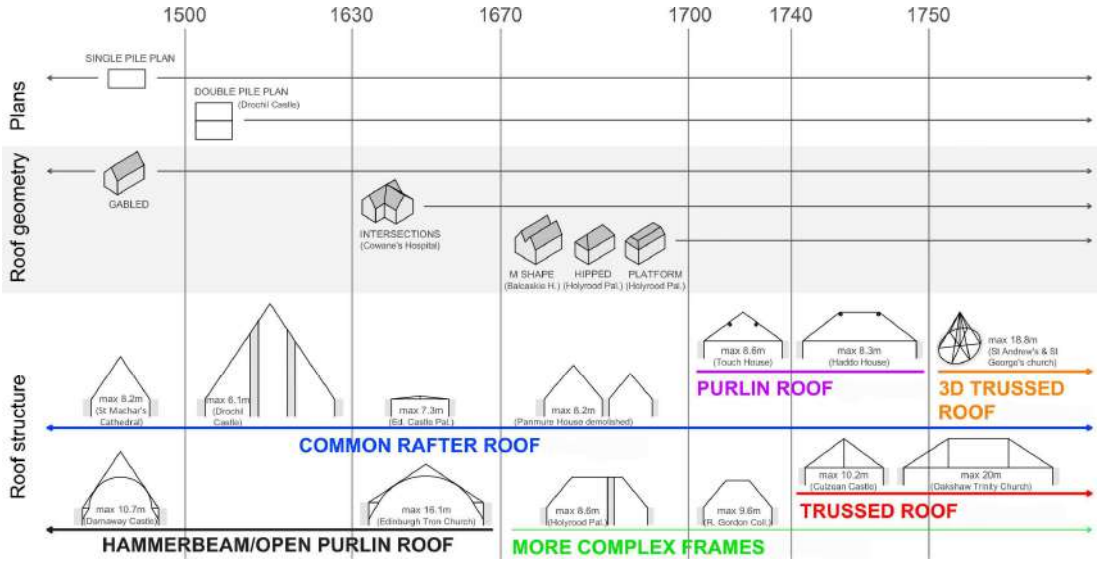


Figure 147: Timeline of the development of structural arrangements of Scottish timber roof structures; adapted from Serafini and Gonzalez Longo (2016)

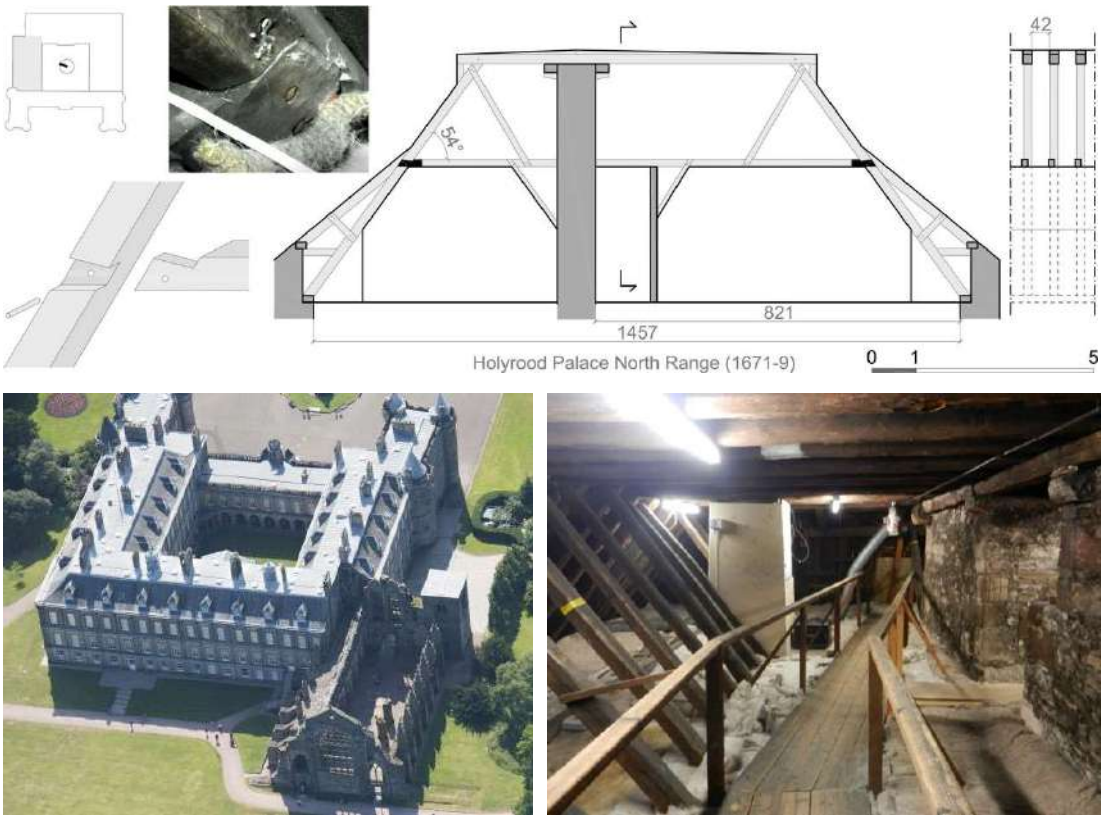


Figure 148: The roof of Holyrood Palace (1671-9): sections with tension-absorbing joints highlighted in black (top), bird's eye view at bottom left (Map data: Google), view of roof space (bottom right)

Double piles had already been introduced by late sixteenth century: Drochil Castle (1578) has one of the very first known double pile plans (Figure 147); the roof has not survived unfortunately, but from what remains we can hypothesize that it was gabled, probably with a common rafter structure spanning over the double pile, supported by the intermediate spine walls (Figure 149). This type of structure was used up to mid-eighteenth century, as testified by Tweeddale House in Edinburgh (1754-56). Sir W. Bruce did the same in Holyrood Palace, but introducing the hipped platform roof and other innovative features, such as tension absorbing joints (dovetail joints, highlighted in black in Figure 148).



Figure 149: Drochil Castle (1578): plan (Macgibbon and Ross, 1887-92) (left), bird's eye view (RCAHMS DP 143824, 2012) (centre), West facade (RCAHMS SC 937335, 1963) (right)

Joints will be discussed in detail in section 3.3.2.1. However, it is important to stress here that whilst dovetail joints were in use in North-West Europe already during early Middle Ages (Bláha, 2006, Corvol-Dessert et al., 2009, Eissing, 2009, Gogolin, 2008, Janse, 1989, Madsen, 2013, Suchý et al., 2008, Szabó and Kulin, 2005, Thelin and Linscott, 2008), they are used in Scotland for the first time in Holyrood Palace and their introduction is important because it testifies the awareness that timber elements can work in tension. In fact, up to late seventeenth century Scottish wrights understood timber elements as behaving in compression only: in structural terms open purlin roofs and common rafter roofs resemble barrel vaults, because all the timber elements are behaving in compression, just like voussoirs in stone arches (Hanke, 2006). The use of tension absorbing joints allowing timber elements to work as ties, in tension, is therefore an important innovation for Scottish roofs.

Holyrood's configuration with an intermediate spine wall might be seen as a consequence of the fact that the Palace had been extended in 1671-9 rather than built ex-novo. This is certainly true but buildings contemporary to Holyrood testify that intermediate spine walls were used even for the new-built. Kinross House (1679-93) and Melville House (1697-1703) (Figure 150), for example, are designed and built ex-novo but they are very similar to Holyrood in terms of roof design: they both

employ hipped platform roofs with intermediate spine walls. This suggests that at the time Scottish wrights still did not have the ability to create shallow roofs over wide spans without intermediate supports.

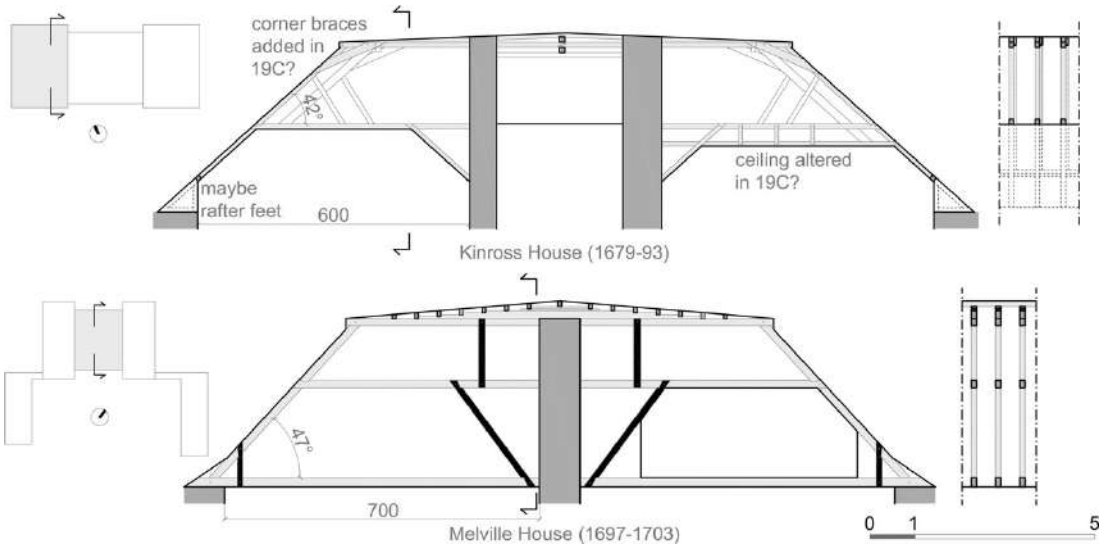


Figure 150: The roofs of Kinross House (1679-93) (top) and Melville House (1697-1703) (bottom)

Another innovative feature is introduced in Melville House's roof: the use of hanging posts and struts (highlighted in black in Figure 150). These tension-absorbing members, just like dovetail joints, were already in use in North-West Europe since early Middle Ages (section 3.2.1.2). Their use in Melville House suggests an awareness of the problem of beam deflection, and can be seen as an antecedent of king/queen-posts in trussed roofs, even though they do not show a full understanding of their role as they create additional load on the collar and upper beam. They later appear in the roofs of Yester House (1699-1748) (Figure 152), Stirling Castle Palace (after 1719) (Hanke, 2008), and Newhailes House (1730) (Figure 153). In some earlier roofs, such as Fountainhall House (early seventeenth century), Pinkie House (1613) and Abbeystrand Buildings (1630), they seem to be later additions, judging from the timber dressing and the joints.

The roofs of Holyrood Palace, Kinross House and Melville House achieve a shallow external geometry, but fail in attaining an undisturbed big span inside, as they still rely on intermediate spine walls as support. Roof structures had to evolve a bit further to be able to get rid of these walls. It was eventually necessary to import from elsewhere a completely different structural type: the truss.

The introduction of the trussed system in Scotland is slow and gradual: many eighteenth-century roofs still show a common rafter form. A good example is Tweeddale House's roof (Figure 151). The house is built in sixteenth century as a small rectangular single pile mansion, with a projecting stair tower, and around 1600 it is extended to the North, transforming it into a double pile (Gifford, 1984a). Throughout the seventeenth century it is renovated several times and in 1750-6 the 4th

Marquess of Tweeddale commissions its reconstruction to John and Robert Adam (Gifford, 1984a). Deacon Thomas Dunlop, who had previously done other works for the Marquess (NRS CS96/2243, 1736-47, NLS MS14665, 1735-53), is the wright and contractor (NLS MS14665/64, 1750-6). The roof is completely dismantled and rebuilt. Some repair works are carried out later in 1779-82 (NLS MS14680, 1779-82) and in 1791 the house is extended to the West (Figure 151) (Gifford, 1984a).

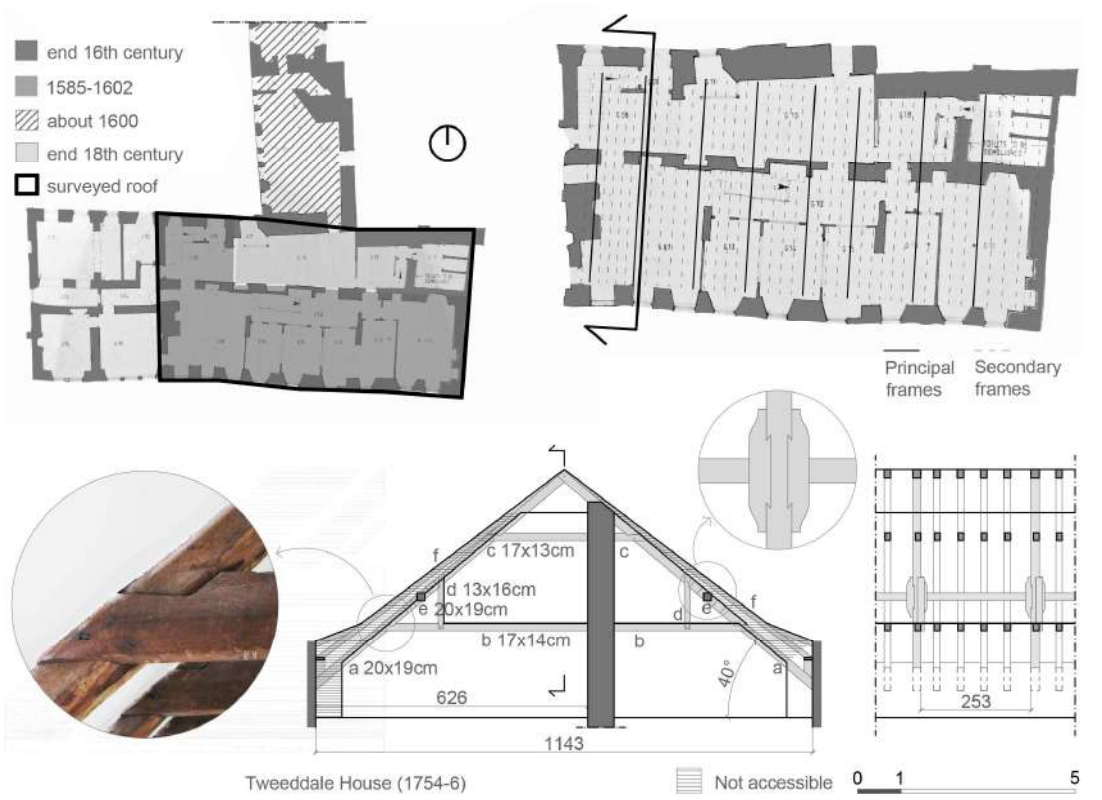




Figure 151: The roof of Tweeddale house (1750-6): reference plans and sections (top), general view from inside (bottom left), cleats reinforcing the rafters' section where the purlins abut (bottom centre), vertical struts supporting the collars (bottom right)

Although only partly visible today, we can appreciate that the structure is the one reconstructed by Dunlop in 1750-6, except for the additional rafters ('f' in Figure 151) later added on top of it, perhaps

as part of the 1779/82 works. Tweeddale's roof retains many features of seventeenth-century common rafter roofs: the pitch is steep (40°) compared to contemporary roofs, such as Oakshaw Trinity church (1754-6) (34°); the frames are very closely spaced (50cm max); neither tie-beams nor wall-plates are employed; though the span is quite wide (11.4m), due to its double pile configuration, the spine wall reduces it to 6.2m, just like in Holyrood Palace (1671-9) (Figure 148).

On the other hand, some features of the roof anticipate the emerging trussed system: vertical tension-absorbing struts ('e' in Figure 151) appear in some frames to give additional support to the collars. More interestingly, there is a subdivision between primary and secondary frames/rafters and the use of butt-purlins as additional longitudinal stiffening elements ('c' in Figure 151). The butt-purlins are tenoned in cleats ('d' in Figure 151) that are in turn dovetailed on the sides of the primary rafters to reinforce their section where the purlins abut. The rafters of the secondary frames are supported by the purlins.

Butt-purlins are actually introduced earlier, together with the subdivision of frames/rafters into principal and common ones, in the roof covering the central hall of Yester House (1729-48), where the primary frames ('a' in Figure 152) are spaced about 2.5m apart and connected by butt-purlins ('b' in Figure 152), which in turn support the common rafters ('c' in Figure 152); an arrangement which significantly reduces the amount of timber needed. The timbers' scantlings and dressing are also different from previous roofs: Holyrood's rafters are bigger compared to previous roofs (21x18cm - height x base), but Yester House's rafters are even bigger and more rectangular (27x17cm – height x base) and some of their faces are hewn rather than axed.

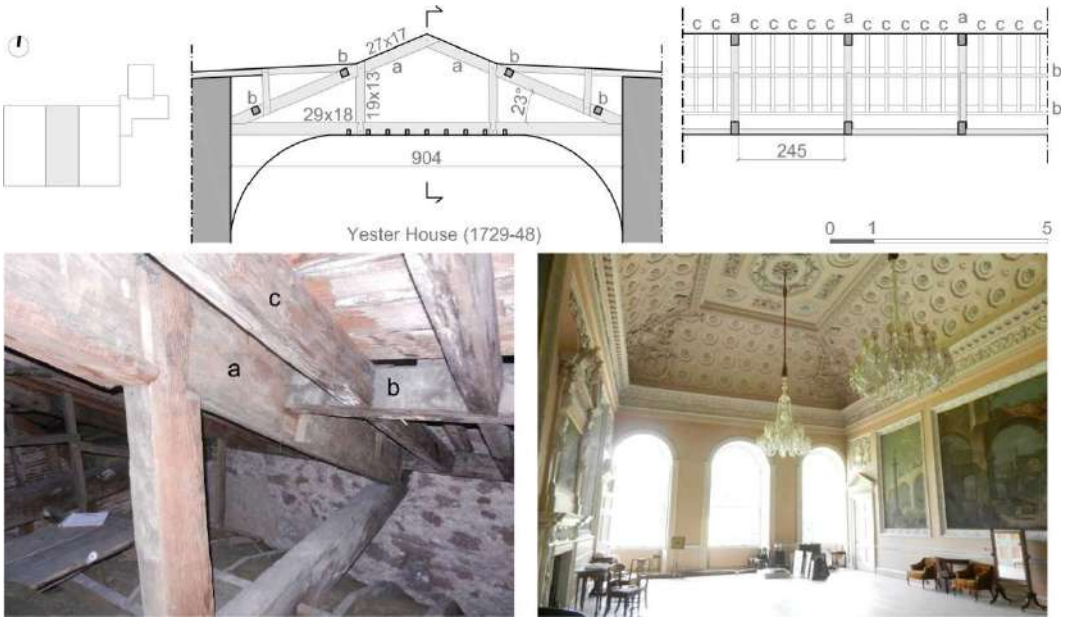


Figure 152: The roof of Yester House (1729-48): sections (top), connection with the lateral walls (bottom left), ceiling underneath (bottom right)

Because of the low pitch, the principal rafters and butt-purlins, as well as the tentative triangulation, Yester House's roof is in structural terms very close to trussed roofs. The same is true for Newhailes House (1730) and Robert Gordon's College (1731-2) (Figure 153), that employ king-posts and struts to counteract the deflection of the raised tie-beam. While in Newhailes the post is designed to work in compression, and the struts in tension, in R. Gordon's it is the other way around. However, both roofs leave the lower part of the rafters unsupported and subject to high bending stresses.

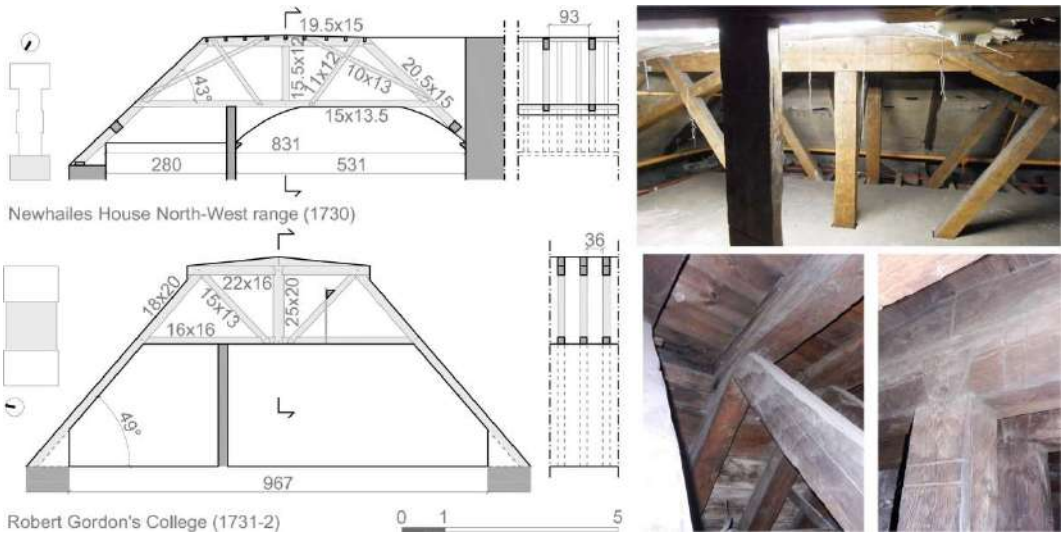


Figure 153: The roofs of Newhailes House (1730) (top) and Robert Gordon's College (1731-2) (bottom)

3.3.1.3 Trussed roofs

In the second half of the eighteenth century trussed roofs are introduced in Scotland (Figure 147): our surveys suggest that from 1750s/60s king-post trusses start being used to cover reduced spans - as in Fort George Museum and Staff blocks (1762-4) (Figure 154) - and princess-post/queen-post trusses to cover bigger spans - as in Fort George Chapel (1763) (Figure 155) and Oakshaw Trinity church (1754-6) (Figure 156). The earliest Scottish trussed roof we have surveyed is the one in Hopetoun House (1721-48) (Figure 157).

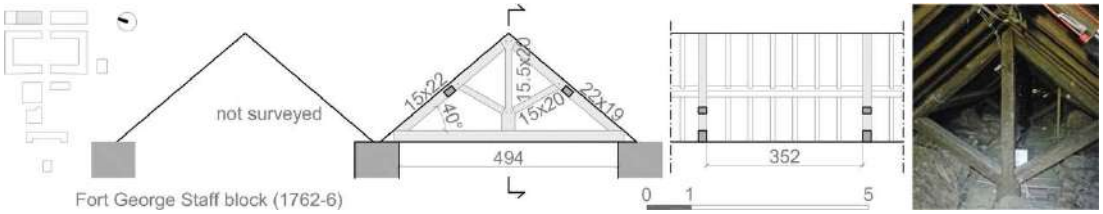


Figure 154: The king-post trusses in the staff block of Fort George (1762-6)

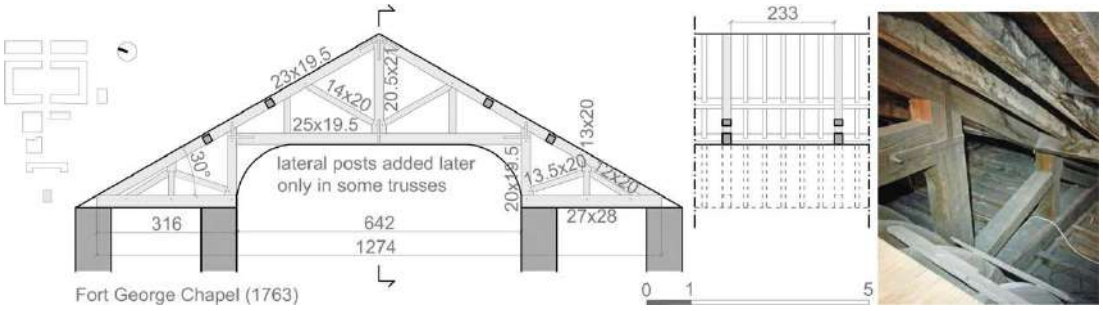
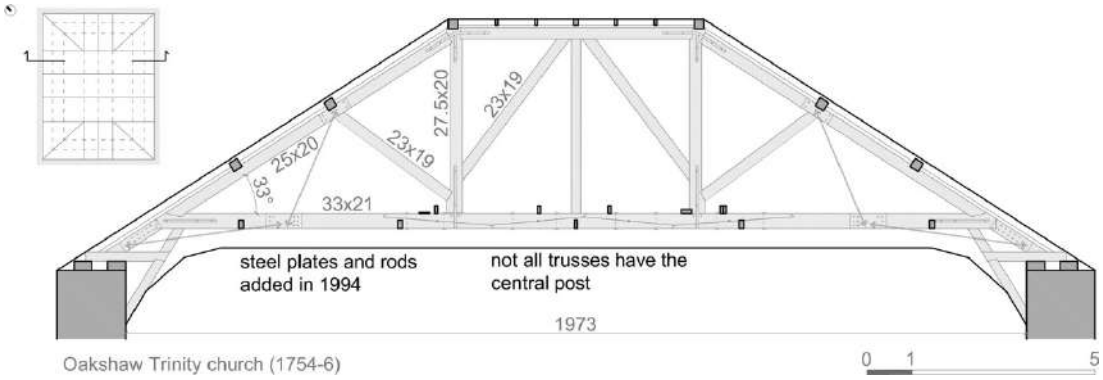


Figure 155: The princess-post trusses in the Chapel of Fort George (1763)



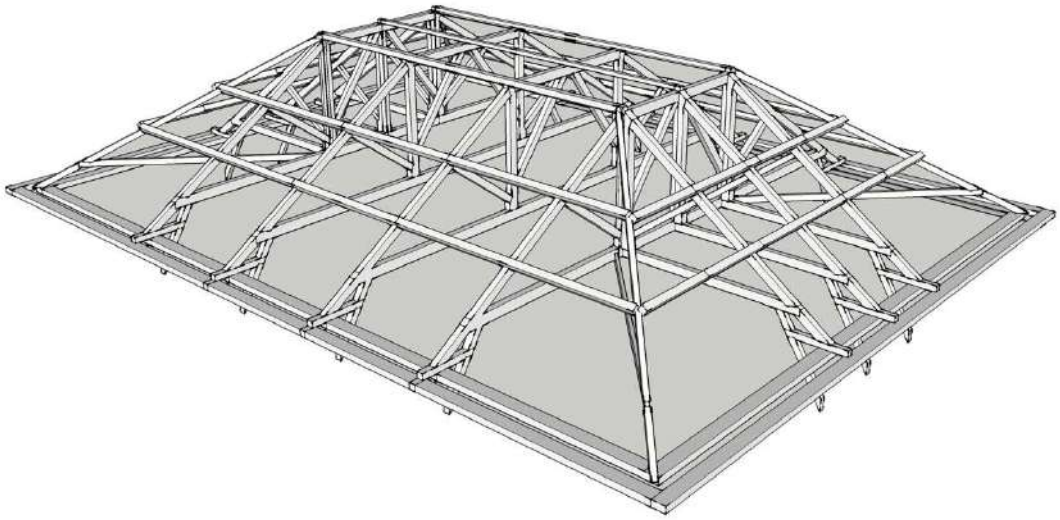


Figure 156: The queen-post trusses in Oakshaw Trinity church (1754-6)

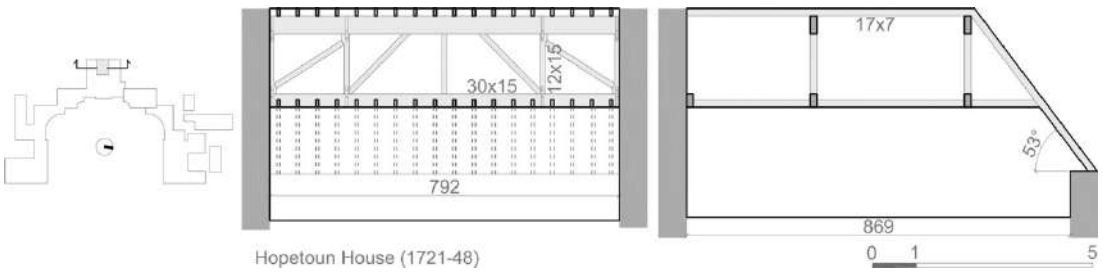


Figure 157: The trussed roof of Hopetoun House (1721-48)

The 14 Scottish trusses we have surveyed have quite different external geometries and internal arrangements, some developing veritable 3D structures, as in St Andrew's and St George's Church (1782-4) (section 4.1) or Glasgow Tron theatre (1793-4). The spans reach their maximum in Oakshaw Trinity church (1754-6) with 19.7m (Figure 156), and pitches vary between 44° and 27°. The characteristic Scottish sarking remains in use, even though butt-purlins are always present too.

The arrangerments of the earliest Scottish trusses show that architects and wrights had only a superficial understanding of how the trussed system works. In Hopetoun House (Figure 157), for example, the truss configures itself as a sort of bridge structure, with two horizontal beams connected by a series of vertical posts and slanted struts. The triangulation is interrupted in the central part, where the post seems to perform no structural function except for keeping apart the two horizontal beams, which can actually be harmful in case of deflection of the upper beam.

The same happens in Oakshaw Trinity church (Figure 156) where the central post is left unsupported and with no apparent function. Another problem of Oakshaw's roof is the asymmetry in the joints between posts and struts: one strut springs from a higher level than the other strut. The purpose was probably to avoid reducing excessively the section of the post by placing two mortice and tenon joints in the same place; however, this arrangement generates unnecessary bending moments in the post. The connection with the wall is also problematic, because the raised tie-beam produces high bending moments at the rafter ends and does not counteract effectively the transversal opening of the roof (as in Newhailes House and Robert Gordon's College, previously discussed). In fact, steel cables and plates have been added in 1994 to try to solve these problems.

The heterogeneity of arrangements of Scottish trusses indicates a transfer of technical knowledge from various sources, as well as a will to experiment and adapt the single solutions to the local tradition. The same had happened one century earlier in England (Valeriani, 2006). The trussed roof of Oakshaw Trinity church (1754-6) (Figure 156), for example, suggests an inspiration from Wren’s St Michael’s Paternoster Royal (1690) (Campbell, 2002), but the connection with the wall is somehow reminiscent of the traditional Scottish rafter foot, with the load transferred to a lower point downwards on the masonry. We will discuss other examples and try to understand which has been the role of architects and wrights in the development of Scottish roof carpentry in section 3.3.4.

3.3.1.4 Purlin roofs

Scottish wrights are acquainted with the purlin roof system at least since early Middle Ages, as testified by the thirteenth, fourteenth and fifteenth century roofs of Darnaway Castle, Stirling Castle, Edinburgh Castle, Holy Rude church in Stirling, and by the seventeenth-century roofs of Tron church and Parliament Hall in Edinburgh (discussed in section 3.2.1). However, the above-mentioned

examples are all open roofs, exposed to view, whilst the ones we have surveyed are all hidden behind plaster ceilings. The only other known example of non-exposed Scottish purlin roof is that of Newark Castle (1597-99), whose arrangement is however not reported in detail (Hanke, 2012).

Melville House (1697/1703) is the earliest purlin roof we've surveyed (Figure 158), followed by Stirling Castle Palace (after 1719) (section 5.2.7), Hopetoun House (1721-48) (Figure 159), Haddo House (1732-6) and Touch House (1757-62) (section 5.2.8). Two of them support pitched roofs, of which one gabled (Stirling Castle Palace) and one hipped (Touch House), two others support platform roofs (Melville House, Haddo House) and one a shed roof (Hopetoun House). The purlins are always supported by masonry walls; additional timber struts are used in Touch House only. The common rafters of Stirling Castle Palace and Touch House are connected by collars and their top ends lean against a thin ridge beam. According to our surveys, ridge beams do not appear in any earlier roof in Scotland (the ones found in Balcaskie House and Gardyne's Land are clearly a later addition judging from their dressing and location). The only other examples we have found date from the second half of eighteenth century and include mainly trusses: Oakshaw Trinity church (1754-6), Auchinleck House (1755-62), St Andrew's and St George's church (1782-4), Glasgow Tron theatre (1793-4). The late eighteenth-century roof in Brunstane House is the only common rafter roof we have surveyed that employs a ridge purlin.

The limited number of surveyed examples and the heterogeneity of their arrangements and details makes it difficult to draw conclusions on their development. However, it is interesting to note that they are often coupled with other structural types in the same building: in Melville House part of the roof structure is composed of complex frames (Figure 150) and the same is true for Touch House, whilst in Hopetoun House part of the roof structure is covered with a truss (Figure 157) and in Stirling Castle Palace most of the roofs are common rafter roofs or complex frames (section 5.2.7). There is no apparent reason driving the choice of one structure or the other. This suggests that either the different timber structures have been constructed in different periods, or, if they appear to belong to the same period (as is the case of Melville House, Hopetoun House and Stirling Castle Palace), that wrights/architects were experimenting.

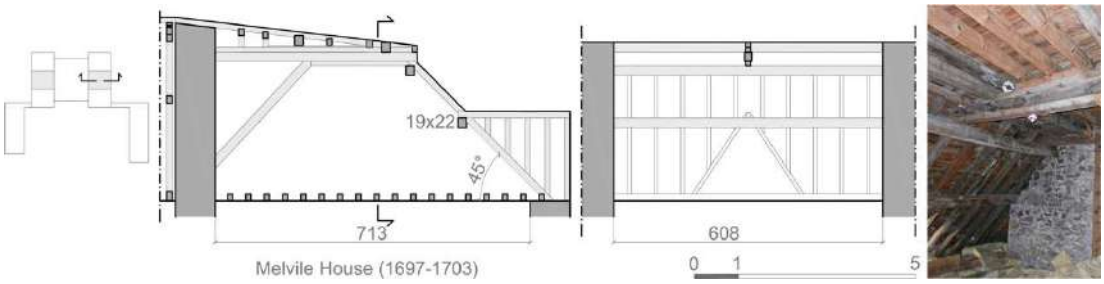


Figure 158: The purlin roof of Melville House (1697-1703)

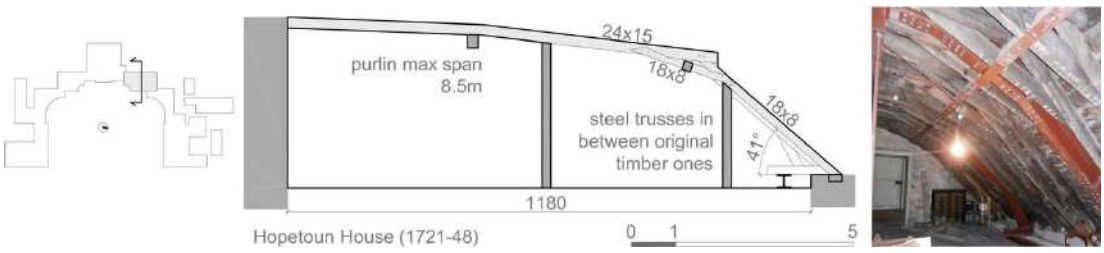


Figure 159: The purlin roof of Hopetoun House (1721-48)

3.3.2 Construction methods and details

3.3.2.1 Carpentry joints

The development of Scottish carpentry joints mirrors that of structural arrangements dicussed above. At first only mortice and tenon joints secured by roughly squared timber pegs (not flush to the surface of the elements) are used to connect all the elements: rafters, collars, sole pieces and ashlar posts (Figure 160 a, b). They are all joints with stopped mortices and stub tenons.

Contrary to what Hay (1976) affirms, lapped/halved joints are introduced already from 1630s (Figure 172) to secure collars to rafters: Malleny House (1635) is the first example (Figure 160 c). These joints are halfway in between lapped and halved joints, as part of the rafter and collar are halved, but the faces are not flush. Soon after, these joints start being secured with a metal nail (Figure 172), rather than a timber peg, and their profile is more refined, 'chamfered' (Figure 160 d).

During the latest part of seventeenth century, when hipped platform roofs and complex frames are introduced, lapped/halved joints start being used at the rafters' apex as well, although mostly secured with timber pegs (Figure 172): the first examples are Geilston House (1666) and Cockenzie House (1683). At the same time, the joints securing collars to rafters become dovetail joints secured with metal nails (Figure 172), as in Holyrood Palace (1671-8), Gardyne's Land (1675-90) (Figure 160 e), Kinross House (1679-93) and Touch House (end seventeenth century). The use of dovetail joints suggests awareness of the fact that timber elements are subject to tension forces, as previously discussed. However, when there are two collars there is no distinction between the upper one, generally working in compression, and the lower one, working more in tension; the joints are treated in the same way and evolve simultaneously from mortice and tenon to lapped/halved to dovetailed. This suggests little understanding of the structural purpose of dovetail joints.

With the introduction of the trussed roof in eighteenth century joints become more diversified. Mortice and tenon joints become common again, although they are now secured with timber round dowels (often two rather than one, rarely square as in Newhailes House) and sometimes timber wedges used to secure the tenon in place (Figure 160 g, Figure 172). Metal straps are seldom used

(Figure 160 f); in some cases they are a later addition, as testified by the Trades Hall truss where the metal straps have been added 50 years after the construction of the building (TDH 1/899, 1856) (Figure 225). In two cases only, the post is connected to the raised tie-beam with a lapped/halved joint rather than a mortice and tenon joint: Auchinleck House (1755-62) and Brodie Castle Stables (end eighteenth century). Double dovetail joints and notched joints are also introduced and used especially for struts (Figure 160 h, i, l, Figure 172). In the second part of the century joints become even more refined and specialised (Figure 160 m, n) (Figure 172).

Scarf joints are rarely used (Figure 172). The roof above King's Old Buildings in Stirling Castle (1557) is a very early example of the use of both the scarf joint and metal nails: the rafters are composed of two elements jointed with a very simple scarf joint secured by metal nails (Figure 160 o). Other scarf joints have been found in Kinross House (1679-93) (Figure 160 p), Duff House (1737), Oakshaw Trinity church (1754-6) (Figure 160 q) and St Andrew and St George's church (1782-4). They are all indented splayed scarf joints that do not develop specific resistance to tension forces.



a) Craigston Castle (1604-7): mortice and tenon joint secured by timber peg (rafter & collar)



b) Methven Castle (1678): mortice and tenon joint secured by timber peg (rafter & sole piece)



c) Malleny House (1635): lapped/halved joint secured by timber peg (rafter & collar)



d) Cowane Hospital (1637-48): chamfered lapped/halved joint secured by metal nail (rafter & collar)



e) Gardyne's Land (1675-90): dovetail joint secured by metal nails (rafter & collar)



f) Hopetoun House (1721-48): mortice and tenon joint with joggle secured by metal strap (post & upper beam)



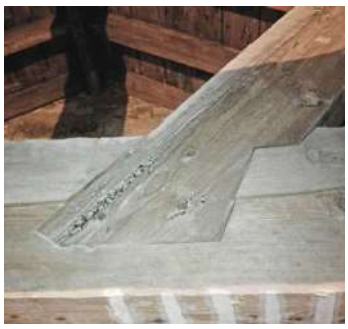
g) Arniston House (1726-55): mortice and tenon joint secured by timber dowel and wedge (rafter & cut post)



h) Yester House (1729-48): notched mortice and tenon joint (rafter & tie-beam)



i) Yester House (1729-48): double dovetail joint secured by metal nail (tie-beam & strut)



l) Auchinleck House (1755-62): notched dovetail lapped joint secured by metal nails (collar & strut)



m) Drum tower of Culzean Castle (after 1791): mortice and tenon joints secured by metal straps and bolts (radial tie-beams & post)



n) Glasgow Tron theatre (1793-4): notched bridle or step joint (rafter & strut)



o) King's Old Buildings in Stirling Castle (1557): scarf joint secured by metal nails (rafters)



p) Kinross House (1679-93): scarf joint secured by metal nail (upper beams)



q) Oakshaw Trinity Church (1754-6): scarf joint secured by timber key and metal bolts (tie-beam)

Figure 160: A representative sample of different types of joints found in the surveyed Scottish roofs structures

Posts in trusses are normally reinforced at their ends by joggles (Figure 160 f, Figure 161 left, Figure 172), a distinctively English feature (Yeomans, 1992) used even in earlier roofs to reinforce joints (Munby et al., 1983) (Figure 161 centre). Scottish wrights could have copied this detail from English examples or from Italian treatises such as Serlio (1545) and Antonio da Sangallo (Munafò, 2002)

(Figure 161 right). The joggles at the top of the post sometimes take the form of a rounded 'bulb', as if to provide further support to the rafters while adding a decorative feature (Figure 163, Figure 172). The origin of this detail remains uncertain so far. Other examples such as Oakshaw Trinity church (1754-6), Glasgow Trades Hall (1791-4), Glasgow Tron Theatre (1793-4) and Brodie Castle Stables (end eighteenth century) show that notches, common in Italy and in the rest of Europe, were used too (Figure 162).

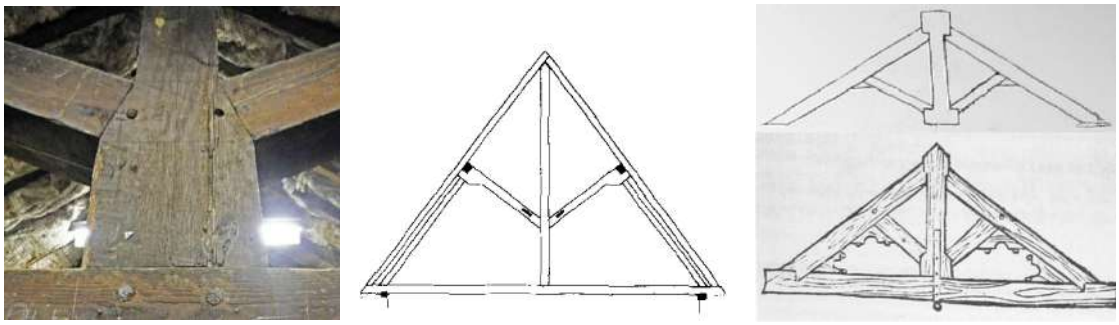


Figure 161: Joggles: the Ordnance Store of Fort George (1759-61) (left), the Chapel of Bishop's Palace in Chirchester (second half of thirteenth century) (Munby et al., 1983) (centre), truss drawn by Antonio da Sangallo il Giovane in his 1539 translation of Vitruvius' treatise (Munafò, 2002), Serlio (1545) (top right), truss drawn by Serlio (1545) (bottom right)

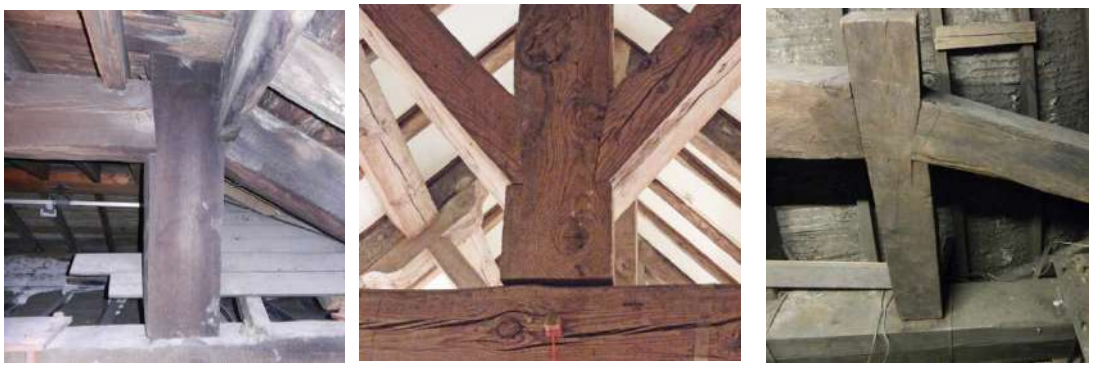


Figure 162: Notches: Glasgow Trades Hall (1791-4) (left), Brodie Castle Stables (end eighteenth century) (centre), Glasgow Tron Theatre (1793-4) (right)



Figure 163: Bulb shaped joggles: Aunchinleck House (1755) (left), Stirling Tolbooth (1785) (centre), Culzean Castle (end eighteenth century) (right) (Serafini and Gonzalez Longo, 2015a)

Another interesting feature is cleats, commonly used in Italy (Figure 164, Figure 165) and found in Scotland in different types of roof structures (Figure 172): the simple frame in Touch House (end

seventeenth century) (Figure 169), the complex frame in Tweeddale House (Figure 151), the truss in Oakshaw Trinity church (1754-6) (Figure 166), the truss in Brodie Castle stables (end eighteenth century) (Figure 167) and the truss in Auchinleck House (1755-62) (Figure 168). These features respond to the same need expressed by joggles in posts: reinforce the mortice and tenon joint.

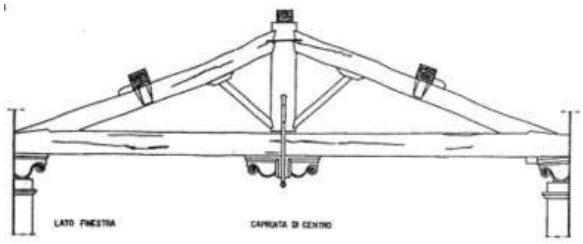


Figure 164: The roof of the church of Sant'Agata di Mugello in Scarperia (Tampone 2001)

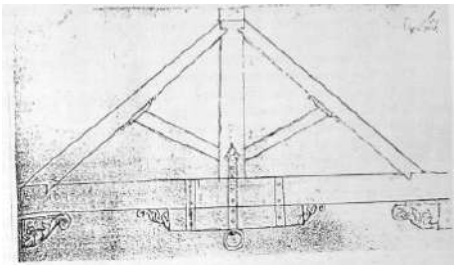


Figure 165: Truss drawn by Mariano di Jacopo (1449 in Munafò 2002)



Figure 166: Cleats used to reinforce the connection between tie-beams and longitudinal purlins in the trussed roof of Oakshaw Trinity church (1754-6)



Figure 167: Cleats used to reinforce the joint between struts and rafters in the trussed roof of Brodie Castle Stables (end eighteenth century)



Figure 168: Cleats used to reinforce the connection between collars and longitudinal purlins in the trussed roof of Auchinleck House (1755-62)



Figure 169: Cleats used to reinforce the connection between rafters and purlins in the common rafter roof of Touch House (end seventeenth century, but the purlins might be a later addition)

Redundant joints with a very particular shape have been found on collars and rafters in the roof of Blair Castle (Figure 170). This roof has probably been reconstructed after a siege in 1745 (personal comment by archivist Jane Anderson) and the redundant joints suggest the reuse of timbers perhaps from the previous roof. Several joints similar to the one in Figure 170 have been identified, but their

shape has not been found anywhere else in literature. A thorough record of their dimensions and positions should be carried out in order to attempt a reconstruction of the original structure. Interesting redundant joints have been found in the North-West corner of Stirling Castle Palace too (Figure 171): these are chase mortice and tenon joints, used to enable the tenon to be slid into position when the morticed member is already fixed.



Figure 170: Redundant lapped/halved joints found in Blair Castle (1745)



Figure 171: Redundant chase mortice and tenon joints found in the North-West corner of Stirling Castle Palace (1719)

The sample of joints we have surveyed is certainly too limited to draw ultimate conclusions, but it allows making some considerations. It seems that Scottish carpentry joints remain quite simple up to end seventeenth century, just as structural arrangements. The introduction of dovetail joints only from the second half of seventeenth century (Figure 172) and the introduction of notched joints only from the first half of eighteenth century (Figure 172) is quite late compared to England and the rest of Europe: these joints are used since twelfth century in North France and Belgium (Corvol-Dessert et al., 2009), Germany (Eissing, 2009) and England (Fletcher and Spokes, 1964). The same is true for metal fasteners, commonly used in Scotland only since mid-seventeenth century (Figure 172) but used in Italy since roman times (Valeriani, 2003) and from late Middle Ages in the rest of North-West Europe: in North France and Belgium, for example, they are used since fifteenth century (Corvol-Dessert et al., 2009). There is the possibility that different types of joints and fasteners were used in earlier roofs, as suggested by the redundant joints we have found in Blair Castle (Figure 170).

Another interesting aspect that emerges is that Scottish wrights do not seem to fully understand the structural purpose of tension-absorbing joints: dovetail joints are used regardless of their position in upper or lower collars, mortice and tenon joints working in tension are seldom reinforced with metal straps and scarf joints remain quite simple, without indentations or specific arrangements to resist tension forces. This confirms the English and Scottish tradition to consider timber elements as working in compression and bending only (Hanke, 2006).

Finally, some eighteenth century features seem to indicate foreign influences: cleats and notches recall the Italian carpentry tradition, while joggles are a distinctive English characteristic. The origin of other details remains uncertain so far, but shows that eighteenth century Scottish roofs combine knowledge and skills from different sources.

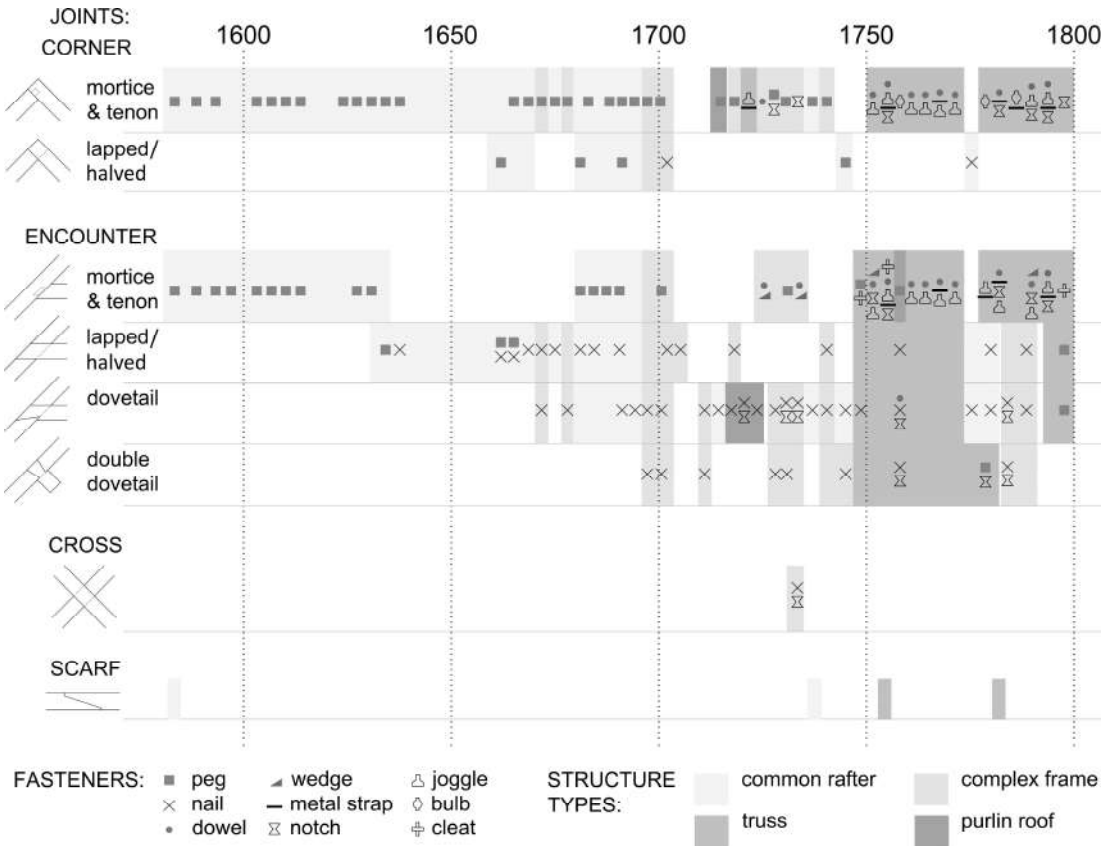


Figure 172: Timeline of types of joints and fasteners found in the surveyed Scottish roofs

3.3.2.2 The connection with the walls

The connection between the timber roof structure and the supporting walls is very important because it is the point where the loads are transmitted and where the horizontal thrust resulting from the roof needs to be neutralized. Unfortunately, in many cases it has been difficult to assess the exact geometry of this part of the structure because of accessibility issues (question marks in Figure 174). Our sample is however wide enough to start tracing a development and give indication of what the typical arrangements look like.

The connection with the lateral walls up to end of seventeenth century is characterized by a simple contact between the rafter ends and the wall-head (Figure 173 left) or by an arrangement known as the 'Scottish rafter foot' (Ruddock, 1995). We have found the latter to be of different dimensions (Figure 173 centre and right) but invariably composed of a sole piece, in which the rafter end is tenoned, and an ashlar post, in which the sole piece is tenoned. The ashlar post is always extended

downwards on the masonry of about 10-15cm. All the joints are secured with roughly squared timber pegs. Rubble masonry is sometimes used to fill the space in-between one foot and the other (Figure 173 right). Hay (1976) states that the rubble infill is used from mid-seventeenth century, but we have found earlier examples too (Figure 174).



Figure 173: Connection with the lateral walls: simple contact between the rafter ends and the wall-head in Sailor's Walk (1670s) (left), rafter feet in Culross Palace (1597-1610) (centre) and Methven Castle (1678) (right)

As previously discussed, the missing wall-plate and the fact that the ashlar post is extended downwards on the masonry differentiate the Scottish rafter foot from the English one (Ruddock, 1995). Wall-plates are introduced in most European countries quite early, during the twelfth century (Bláha, 2006, Corvol-Dessert et al., 2009, Eissing, 2009, Gogolin, 2008, Janse, 1989, Madsen, 2013, Suchý et al., 2008, Szabó and Kulin, 2005, Thelin and Linscott, 2008). On the contrary the earliest Scottish roof with wall-plates we have surveyed is in Holyrood Palace (1671-8) (Figure 175). This is also one of the first Scottish roofs employing hip rafters instead of gable walls: wall-plates are probably introduced to reinforce the longitudinal connection and stability of the roof, previously provided by the gable walls. However, according to our surveys the use of wall-plates becomes common only from eighteenth century (Figure 174). Another interesting feature of Holyrood's roof is the use of sprocket rafters and raised wall-heads to protect the rafter ends: a feature which is not widespread in Scotland (Figure 174) as we have found it only in Stirling Castle Palace and as a later addition in Tweeddale House (Figure 151).

Tie-beams are introduced about 20 years later in Melville House (1697-1703) (Figure 176) and Yester House (1699-1729), reinforced by tension-absorbing ashlar posts and extended beyond the rafter end to create a bell-cast profile. Tie-beams are introduced at this time because the wider spans and thinner walls of late seventeenth century Scottish architecture (section 3.1.2) evidently call for a counteraction of the horizontal thrust more effective than that provided by the traditional rafter feet. In some cases there is a clear will to experiment different arrangements, in order to identify the

most effective: the wright in Melville House (1697-1703), for example, uses traditional rafter feet in the corners of the house, tie-beams with tension absorbing ashlar posts in the central part (Figure 176) and wall-plates on the sides.

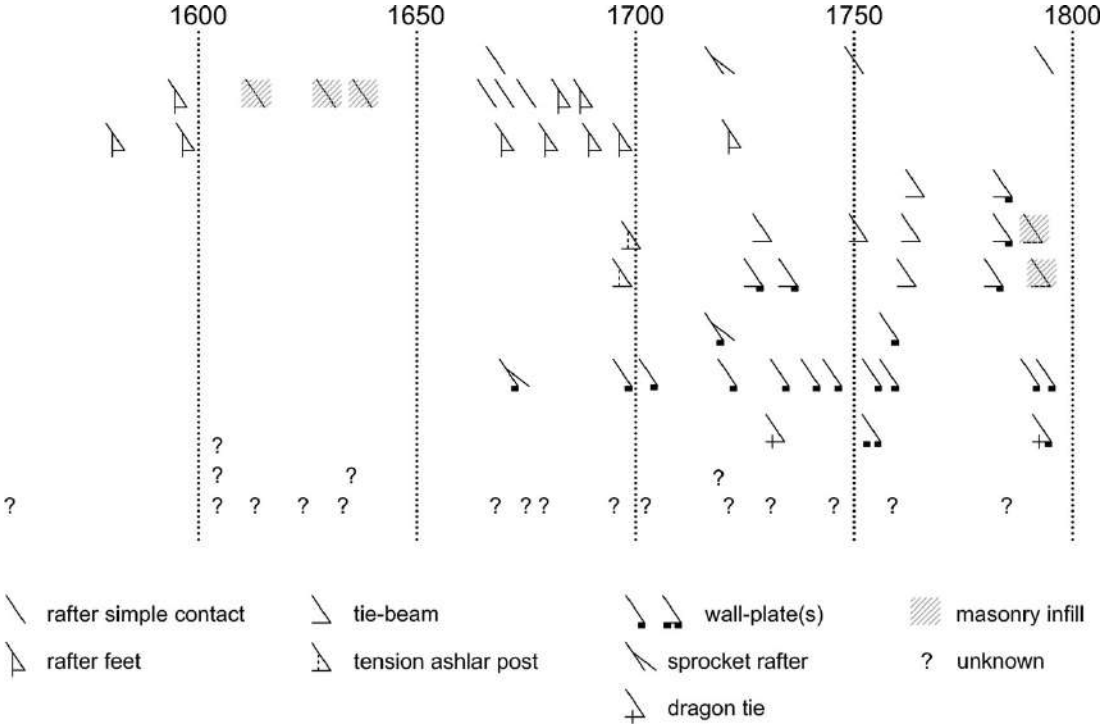


Figure 174: Timeline of different types of connections with the lateral walls found in the surveyed roofs

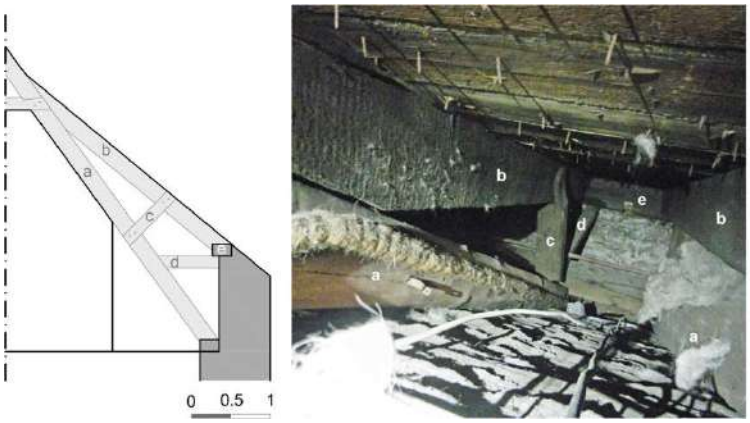


Figure 175: Connection with the wall in Holyrood Palace (1671-8): this is the first Scottish roof to employ wall-plates as well as sprocket rafters and a raised wall-head to protect the rafter ends and create a 'bell-cast' profile



Figure 176: Connection with the wall in Melville House (1697-1703): this is one of the first Scottish roofs to employ a tie-beam and a tension absobring ashlar post

According to our surveys the use of tie-beams becomes common only from mid-eighteenth century (Figure 174), either sitting on wall-plates or embedded in the masonry wall (Figure 177). Nonetheless, we have surveyed quite a few eighteenth century roofs without a tie-beam (Figure

174): even after 1700 raised tie-beams are often employed to increase the height of the room underneath, as in Stirling Castle Palace (after 1719), Blair Castle (1745), Auchinleck House (1755-62) and the previously discussed Newhailes House (1733-51) and Robert Gordon's College (1731-2). Generally rafter ends are left unsupported and become a very weak part of the structure because of the bending stresses concentrated there.

One interesting case is that of Oakshaw Trinity church (1754-6) (Figure 178) where the raised tie-beam is instead supported by a slanted brace springing from lower down on the masonry wall. This brace is kept in place by a sole piece, dovetailed and nailed to the brace. The arrangement is somehow reminiscent of the traditional rafter foot and is in line with the British tradition to bring the load of the roof structure to a lower point down on the masonry, as in hammer-beam roofs. Interesting is also the use of two wall-plates, which we have not found in other Scottish roofs. Another feature we have found in two roofs only (Haddo House 1732-6 and Glasgow Tron theatre 1793-4) is the dragon beam and tie, used to reinforce the corner of the structure (Figure 179).



Figure 177: Connection with the wall in St Andrew's in the Square church (1751-3): the tie-beam simply sits on the ashlar masonry

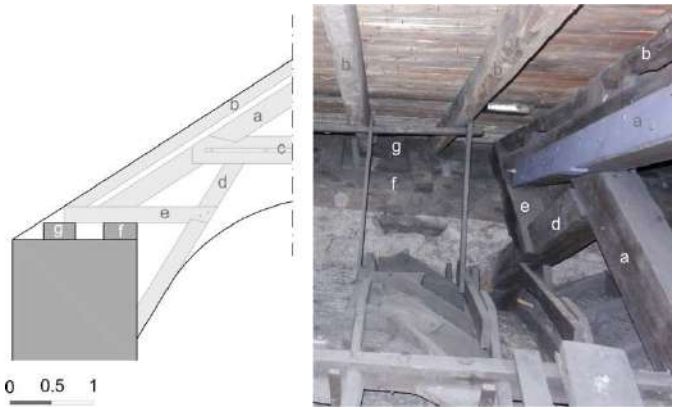


Figure 178: Connection with the wall in Oakshaw Trinity church (1754-6), somehow reminiscent of the traditional rafter foot: the tie-beam is raised and supported by a slanted brace springing from a point lower down on the masonry



Figure 179: Dragon ties in Haddo House (1732-6) (left) and Glasgow Tron theatre (1793-4) (right)

3.3.2.3 Sarking, roof coverings and pitches

One of the distinguishing characteristics of Scottish roof structures is the sarking: horizontal wooden boards (called deals) fixed on top of the rafters and forming a continuous surface which provides longitudinal rigidity and supports the roof covering. Similar wooden boards are used in England, North France and Belgium, Norway, Sweden, Greece, Albania, Italy (Bertolini Cestari et al., 2015, Corvol-Dessert et al., 2009, Janse, 1989, Pompejano et al., 2015, Thelin and Linscott, 2008, Tsakanika, 2007). The extensive use of sarking in Scottish roofs throughout the centuries up to today seems however to be unique: the sarking keeps being used despite the introduction of a foreign structural type, the truss, and is still used today. All the roofs we have surveyed employ the sarking.

The sarking deals we have found in the surveyed roofs are invariably sawn but have different dimensions ranging from 2 to 4cm in thickness and from 25 to 30cm in width. We have not been able to assess the length of the deals, because their ends are hidden behind the rafters (Figure 182). We know, however, that deals were produced in different dimensions and that lengths could vary from 8 to 20 feet (2.5m to 6.3m) (Newland, 2010, Thomson, 1991).

Hanke (2006) states that the sarking is generally composed of two layers of deals that run horizontally and vertically and comprise in-between a sort of fleece for insulation. He mentions as examples the roof in Lauder Parish Church, Black Castle, South Queensferry and Newbattle parish church, which we have not surveyed. The contract for the works in Panmure House (1666, demolished) analysed by Newland (2010) supports Hanke's statement as it specifies that the roof is to be 'double balked' with sarking. However, in all the roofs we have surveyed we have never found evidence suggesting the presence of two layers of deals. On the contrary, we could clearly see one layer of deals in 12 of the roofs we have surveyed, from both seventeenth and eighteenth century, either because the sarking was broken and the slates were exposed to view (Figure 180), or because there were intersecting roof structures from different periods and the sarking was partly continued inside the roof (Figure 182). The 'double balking' mentioned by Newland (2010) might refer to the thickness of the deals, rather than the number of layers.

According to our surveys, the deals are nailed to the rafters (Figure 181, Figure 182) with 1-2cm gap in between one deal and the other. A layer of tar/bitumen (Figure 180) or a modern waterproof sheet sometimes cover the deals outside. Pinkie House's roof (1613) does not have anything between the sarking boards and the slates, allowing for a natural ventilation of the roof space. Perhaps all early Scottish roofs employed this strategy.

We have been able to see how the sarking deals are nailed to the rafters only in a few cases (Figure 182, Figure 181). It is probable that in early seventeenth-century roofs wooden pegs were employed

rather than metal nails, as for joints between elements and for the roofing material (Figure 183). It is not easy to determine when timber pegs are abandoned for metal nails, even because the original sarking and roofing material have often been replaced at a later date. However, we have found wooden pegs securing the slates to the sarking in the West wing of Kelburn Castle, dating to as late as 1722 (Figure 185). We have found them also in Tweeddale House (1750-6), but these might be a remnant of the earlier roof rather than an eighteenth century feature.



Figure 180: A broken sarking deal in Cockenzie House (1680-3) reveals the tar layer on top of the deals and the slates above



Figure 181: Nails on rafter feet of Cockenzie House (1680-3) left after the removal of the sarking boards



Figure 182: Sarking boards in the North range of Touch House (late seventeenth century)



Figure 183: Timber pegs used to secure the slates to the sarking deals in Pinkie House (1613)

The sarking supports the roofing material, which was chosen mainly based on the roof pitch. Figure 184 shows a timeline of the pitches in the surveyed roofs: there is an abrupt change at the end of seventeenth century, when pitches pass from being more than 50° to somewhere between 40° and 50°; by mid eighteenth century they are lower than 40° and at the end of the century they reach 30°. This change corresponds to the introduction of hipped and platform roofs, which start being covered not only in slates, as all previous roofs, but also in lead.

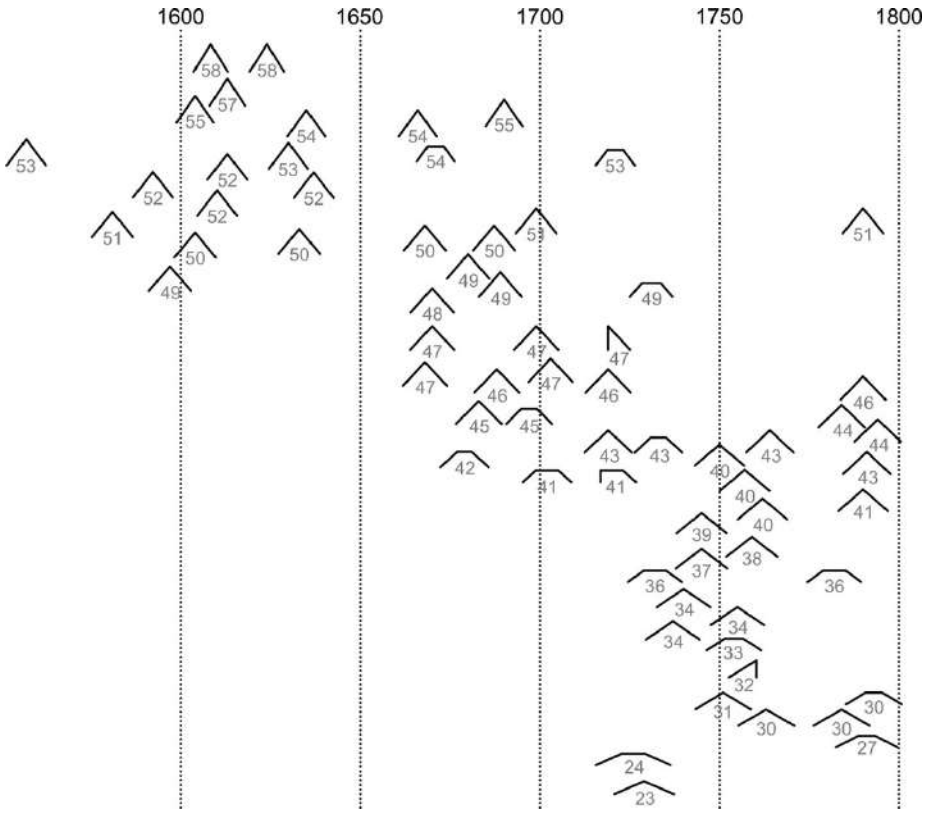


Figure 184: Timeline of the pitches of the surveyed roofs

There is documentary evidence that wooden shingles were used to cover high status buildings before the Reformation (Walker, 2006, Smith, 1870-2), while thatch was used mainly for vernacular architecture (Fenton and Walker, 1981); unfortunately not many examples have survived up to today. Seventeenth and eighteenth centuries are instead dominated by the use of grey/blue slates from Scotland and Wales (Hanke, 2006, Walker, 2006), as confirmed by our surveys (Figure 185) and various archival references (Brown, 1795, NRS E37/24, 1682, NLS MS14551/109, 1742-49, TCH account of materials, Undated). However, it is now very difficult to find roofs with the original slates. The owners of Methven Castle preserved some of the original slates, substituted in 1980s (Figure 186), but in most cases, as in Pinkie House, no records are available (Figure 187).

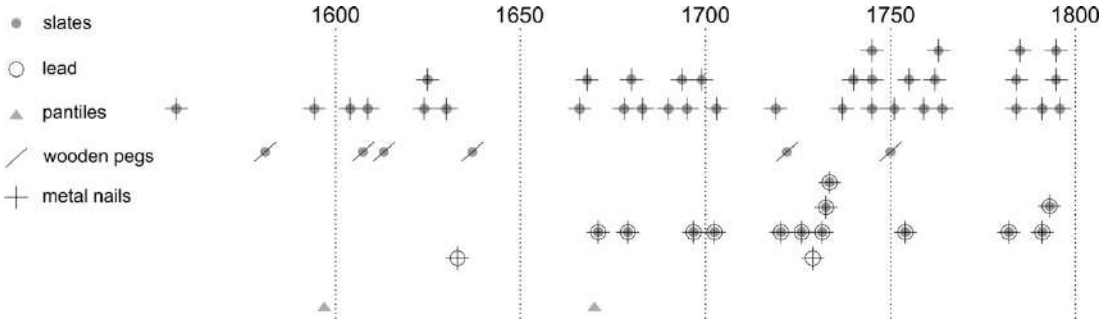


Figure 185: Timeline of the different roofing materials used in the surveyed roofs



Figure 186: An original slate of Methven Castle (1678) with its wooden peg and a piece of sarking



Figure 187: Slate roof at Pinkie House (1613)

George Heriot Hospital (1633-7) (Figure 188) is the first roof we have surveyed where lead is used for the overall covering and not only for the flashings. However, according to our surveys, the use of lead as overall covering material becomes common only from end seventeenth century (Figure 185). George Heriot is an interesting case also because lead is used here to cover a roof with a 50° pitch; in all the other surveyed roofs lead is used on flat parts, while slates cover the slopes, as in Holyrood Palace (1671-8), Kinross House (1679-93), Melville House (1697-1703).

We have also surveyed two roofs covered in pantiles: Culross Palace (1597-1610) (Figure 189) and Sailor's Walk (1670s) (Figure 185). Walker (2006) states that the original roof of Sailor's Walk was covered in slates. We can argue the same for Culross Palace. There is in fact documentary evidence that pantiles are imported from Denmark during late seventeenth century and start being produced in East Scotland at the beginning of eighteenth century (Shaw, 1990); considering that the construction of Culross Palace predates this of more than a century, it is highly probable that its original roofs were not covered in pantiles. Stone flags were also used during this period for low pitches, mainly in churches; we have not, however, surveyed any roof with this covering.



Figure 188: Lead roofs at George Heriot's Hospital (1633-37)



Figure 189: Pantile roofs at Culross Palace (1597-1610)

3.3.2.4 Timber dressing and scantlings

The tool marks we have found on seventeenth-century timbers (Figure 191) confirm Crone and Mills (2011)'s statement that up to eighteenth century Scottish roofs employ small squared heart baulks, shaped through scoring (Figure 190 d), hewing (Figure 190 a, b, f) and flattening all faces (Figure 190 e) (Bláha, 2013), often leaving bark on the corners (Figure 190 c). Such rough dressing results in uniform square/round scantligns rarely exceeding 15cm.



a) Culross Palace (1597-1610), axe marks on rafter



b) Balcaskie House (1668-74), axe marks on rafter



c) Pinkie House (1613), bark left on corners of collar



d) Duff House (1737), scoring marks on collar



e) Tweeddale House (1750-6), flattening marks on collar



f) Glasgow Trades Hall (1791-4), axe marks on strut

Figure 190: Tool marks on hewn timber found in the surveyed roofs

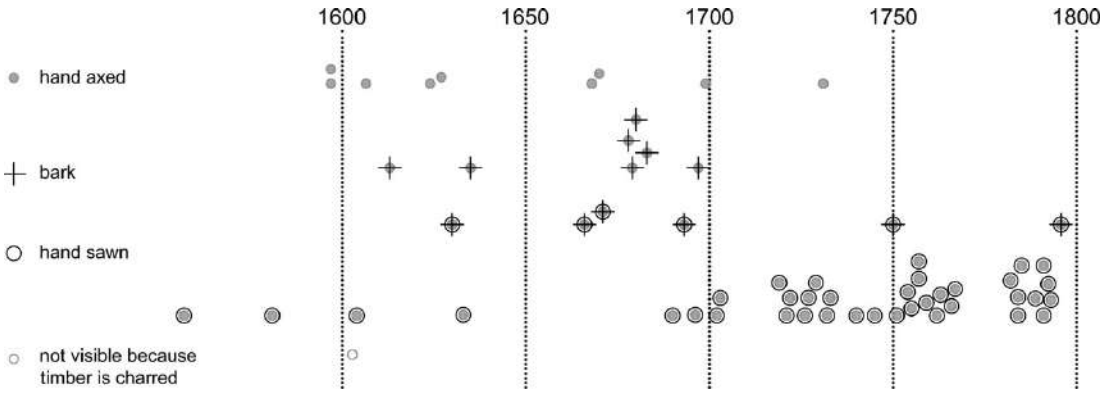


Figure 191: Timeline of the timber dressing found in the surveyed roofs

According to our surveys, the technique of scoring, hewing and flattening is used even during the eighteenth century (Figure 190 d, e, f), but combined with the use of pit and frame saws to further

process the timber into two or more beams. This confirms Crone and Mills (2011)'s statement that saws are used sporadically before 1700, mostly in prestigious buildings, such as King's Old Buildings at Stirling Castle (1557) or Kelburn Castle (1581) (Figure 192 left and centre). On the contrary, from eighteenth century technological developments in sawmilling in Scottish ports encourage the import of big timber baulks to be further sectioned in smaller beams (Thomson, 1991): in fact we have found that eighteenth century timbers often have one or more sawn faces (Figure 192 right, Figure 191), and thus correspond to half balks (usually purlins or principal rafters) or a quarter of a balk (usually common rafters). The scantlings become more rectangular and their height increases, passing from 15cm to the double (*Figure 193*).



Figure 192: Saw marks on collars in King's Old Buildings at Stirling Castle (1557) (left), collars in Kelburn Castle (1581) (centre), struts in Newhailes House (1733-51) (right)

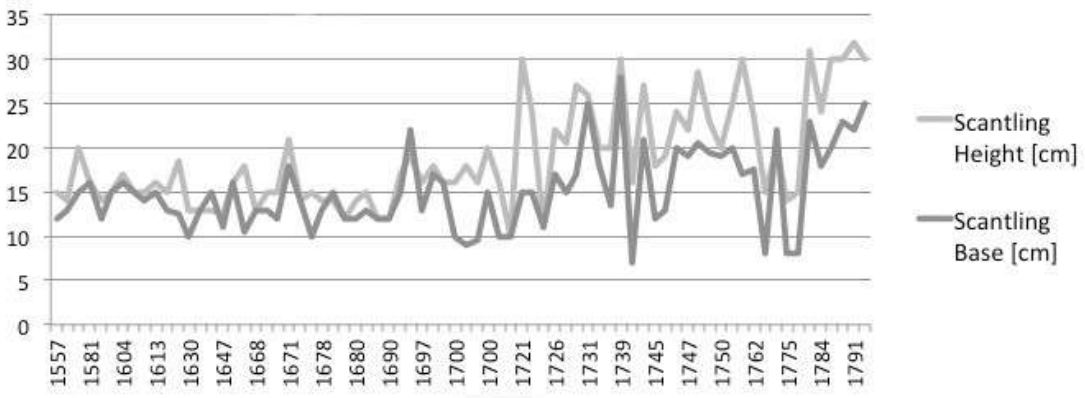


Figure 193: Timeline of the height and base of primary structural timber elements (rafters and purlins) in the surveyed roofs

Other tool marks we have found during our surveys are linked to the geometric tracing for the assembly of the structure. Medieval European carpenters made sketches and even scale models of roof structures; once the design was chosen, they reproduced the sketches full scale and proceeded with the 'staging' process, placing the timber elements on the ground to project the lines of the sketch on the timber surface and trace out on it all the work to be done (Corvol-Dessert et al., 2009). We do not know if Scottish wrights proceeded in the same way, but we have found some marks which show how the joints' geometry was traced on the timber elements (Figure 194).



Figure 194: Marks of geometric tracing in Craigston Castle (1604-7) (left), Oakshaw Trinity church (1754-6) (centre), Glasgow Trades Hall (1791-4) (right)

3.3.2.5 Carpenters' marks

Hanke (2006), Crone and Mills (2011) and Hay (1976) mention the use of Roman numerals as assembly marks in Scottish roofs. These were also used in North France and Belgium (Corvol-Dessert et al., 2009) and in Netherlands (Janse, 1989). Most of the roof structures we have surveyed are in fact numbered with Roman numerals: the members of each frame are marked with the same number, but in most cases the frames are not in sequence. As argued by Hay (1976), this should not be considered as a sign of later alteration because the numbers were used only to assemble the frames and not to place them in order on the wall-head. This is found also in twelfth- and thirteenth-century roofs in Belgium and North France (Corvol-Dessert et al., 2009). However, it does not explain why in some cases the same number is repeated more than once in different frames, in roofs whose homogeneity suggests no later addition or alteration, such as Stirling Castle Palace (after 1719).

The Roman numerals we have found can be grouped in two different categories: big Roman numerals occupying the whole section of the elements (Figure 195) and small Roman numerals (Figure 196). We cannot be sure which tools have been used to trace these marks but their appearance suggests the use of some kind of saw for the big ones and of some kind of chisel or knife for the small ones.



Figure 195: Big sawn roman numerals in Malleny House (1635) (left), Balcaskie House (1668-74) (centre), Brodie Castle Stables (end eighteenth century) (right)

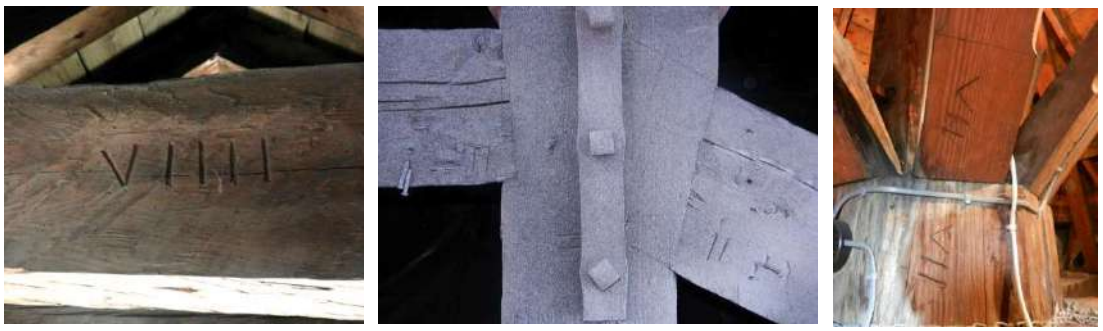


Figure 196: Small chiselled roman numerals in Duff House (1737) (left), Trades Hall (1791-4) (centre), Culzean Castle (after 1791) (right)

We have found the numbers expressed in different ways: number 4, for example, is sometimes marked as 'IIII', sometimes as 'IV' or even with the figure V turned upside down (Figure 197). The figure for 5, V, is sometimes incorporated with the figure for 10, X: number 15 can be 'X/' or 'X\' and the same is true for 25, 35, etc (Figure 197). Tens are normally expressed by multiplying the figure X: XX=20, XXX=30, XXXX=40; we have found the figure L only in Holyrood Palace, to express 40=LX (Figure 197). Another exception is number 11: in Cowane Hospital (1637-48) and Touch House (end seventeenth century) the X and I are incorporated and form a sort of asterisk (Figure 197).

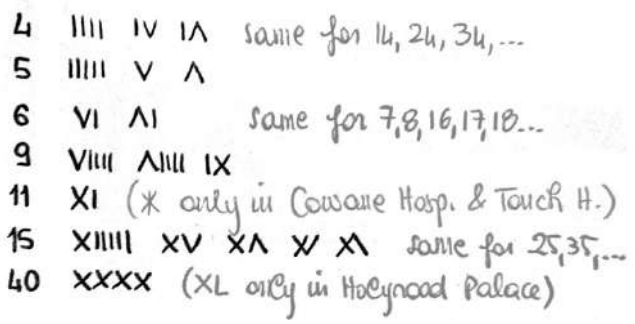


Figure 197: Roman numerals used in the surveyed roofs

The big sawn Roman numerals have been found in roof structures of all ages (Figure 198). On the contrary, the small chiselled Roman numerals have been found only in eighteenth-century roofs, starting from Duff House (1735) (Figure 198). They have also been found in the roof of Craigston Castle (1604-7), but they are clearly linked with eighteenth-century alterations; in fact the early seventeenth-century big sawn Roman numerals are visible too. The same is true for Blair Castle (1745), were both types of Roman numerals are used: this roof has probably been reconstructed after a siege in 1745 partly reusing the timber from the older roof (personal comment by archivist Jane Anderson), as suggested by the double carpentry marks and the numerous redundant joints found on site (Figure 170).

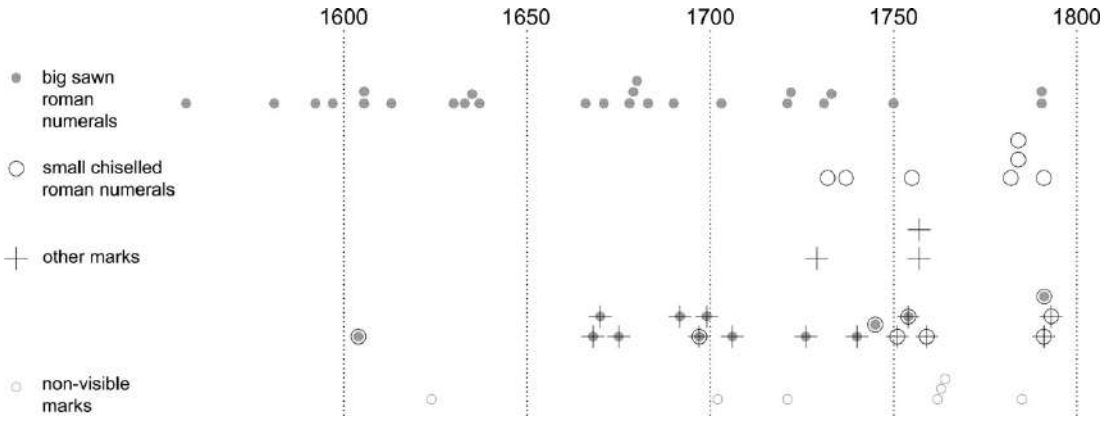


Figure 198: Timeline of types of carpentry marks used in the surveyed roofs

More intriguing is the case of Melville House (1697-1703), already mentioned by Hay (1976), where both types of Roman numerals are used, as well as other types of marks, including Arabic numerals (Figure 199). Some of the Roman and Arabic numerals are in order, but they are too sparse to be able to reconstruct a sequence. Moreover, many timber elements are marked with more than one numeral. This suggests that some of these marks are not assembly marks but perhaps identify the timber merchant, or the harbour of origin, or even the quality of the timber.

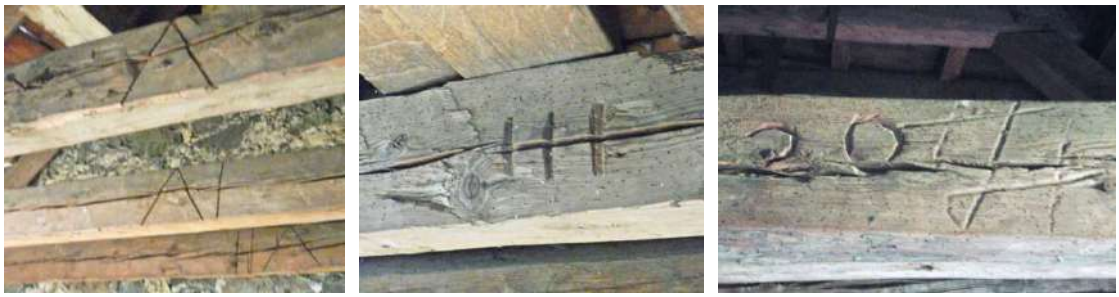


Figure 199: Carpentry marks in Melville House (1697-1703)

We have found marks different from Roman numerals in many other roofs we have surveyed (Figure 200), mostly from 1660 onwards (Figure 198). In most cases these marks are accompanied by Roman numerals which function as assembly marks within the single frames/trusses. Most of them have a 'runic' appearance (Figure 200 b, c, d, e, f, g, h, i, m, n, o), resembling marks found in other North-West European countries, such as Sweden (Figure 201 left). Only a few cases include Arabic numerals and lettering (Figure 200 a, q, Figure 198), which are rare in North-West Europe as well (Corvol-Dessert et al., 2009). In two eighteenth-century roofs (Figure 200 p) we have found Roman numerals combined with small semi-circles, used in Netherlands too (Figure 201 right). The marks in the Ordnance Store of Fort George are also the only ones found which stretch over a joint (Figure 200 p). Circles have been found on a common rafter in St Andrew's in the Square church (Figure 200 l): similar marks were used in North France (Figure 201 centre) and Denmark (Madsen, 2013). Some of them seem to have survived only in part, as if they stretched over a bigger section of timber.



a) Geilston House (1666), collar



b) Balcaskie House (1668-74), rafter



c) Sailor's Walk (1670s), rafter



d) Holyrood Palace (1671-8), upper beam



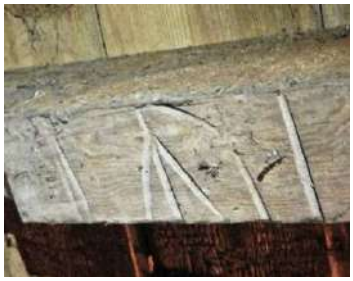
e) Gardyne's Land (1675-90), rafter



f) Stirling Castle Palace (after 1719), rafter



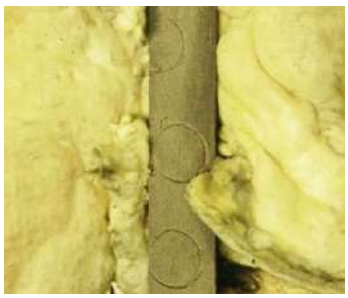
g) Arniston House (1726-55), rafter



h) Yester House (1729-48), upper beam



i) Oakshaw Trinity church (1754-6), rafter



l) St Andrew's in the Square church (1751-3), common rafter



m) St Andrew's in the Square church (1751-3), sarking



n) St Andrew's in the Square church (1751-3), strut



o) Touch House (1757-62), purlin



p) Fort George Ordnance Store (1759-61), rafter and collar



q) Glasgow Trades Hall (1791-4), strut

Figure 200: A representative sample of different types of carpentry marks found in the surveyed roofs

Only for a few of the buildings we have surveyed we know where the timber was sourced:

- Holyrood Palace (1671-8): Norwegian timber was used (NRS E36/30, 1671-1678, EUL LAII87/7, 1686); Holyrood marks (Figure 200 d) are compatible with Norway's (Janse, 1989).
- Gardyne's Land (1675-90): a timber element has been identified as Scandinavian oak by dendrochronologists (Crone, 2001); marks found in Norway (Janse, 1989) and Sweden (Figure 201) are compatible with the ones found in Gardyne's Land (Figure 200 e).
- Touch House (1757-62): we know that Norwegian and Russian timber was used (TCH account by Paterson, 1757, TCH account by Deas & Co, 1757-8); the marks on the common rafters are compatible with Norwegian ones (Janse, 1989) whilst the ones found on the primary structural elements (Figure 200 o) are very different, in both shape and dressing: these might be Russian, although no literature reference can support this hypothesis.
- Fort George Ordnance Store (1759-61): Baltic timber has been identified by dendrochonologists (Crone and Mills, 2008); marks found in Netherlands (Figure 201 right) are compatible with the ones found in Fort George (Figure 200 p).

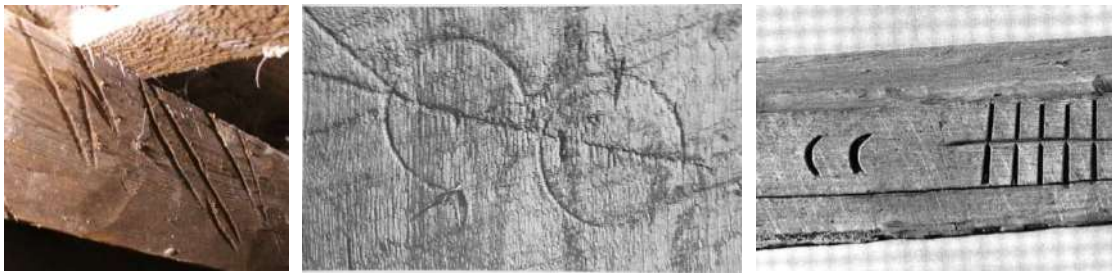


Figure 201: Carpentry marks in Falsterbo church in Sweden (picture by Karl Magnus Melin) (left), in Saint Pierre Cathedral in Beauvais (after 1573) (Corvol-Dessert et al., 2009) (centre), in Bovenkarspel Herv. church in Netherlands (1540) (Janse, 1989) (right)

In conclusion, carpentry marks found in seventeenth- and eighteenth-century Scottish roofs seem to reflect not only local practice but also the intense timber trade with Scandinavian and Baltic regions. If correctly interpreted these marks could provide invaluable information related to the date, origin and quality of the timber, as proved by a research on nineteenth-century Baltic marks (Vandenabeele et al., 2016). Due to the sparseness of literature on the subject, it is still very difficult to interpret these marks; more research is needed in order to fully exploit their potential.

3.3.3 The material

3.3.3.1 Timber Species

The species has been identified visually in all of the reference buildings - except for Maybole Castle (early seventeenth century) whose roof timbers are all covered by a thick layer of char -, and

microscopically in the eight case studies. The reference buildings have been found to be made invariably of softwood except for the old tower at Kelburn Castle (1581), where the timbers have been identified as oak (*quercus sp.*) and only the sarking as softwood. The microscopic identification carried out in the case studies has revealed that most of this softwood is Scots Pine (*pinus sylvestris*), used in all structure types and for all types of structural elements: rafters, collars, beams, struts, purlins, sarking boards, pegs, etc (Figure 202). This confirms the dendrochronological studies carried out in Scotland up to today, which have identified pine in almost all post-1600 analysed structures (section 3.2.2).

The width of the rings in the extracted samples has been found to be quite variable, ranging from 3mm (Figure 202) to invisible macroscopically. Growth rings reflect climatic conditions in which the tree has grown: very narrow rings correspond to more severe temperatures. According to dendrochronologist Anne Crone this suggests that pine with narrow rings might be imported from Scandinavia or Russia, because in those countries the climate is more severe than in Scotland. As previously discussed, timber was imported in Scotland from Scandinavia and later the Baltic area, because it was of better quality than local Scottish timber and more accessible. Nevertheless, the rings' width does not seem to be a reliable criteria to estimate the timber provenance as many of the samples with wider rings have been extracted from elements that have probably been imported rather than being local Scottish; the hypothesis is made based on the presence of unusual carpentry marks on the timbers, discussed in the previous section.

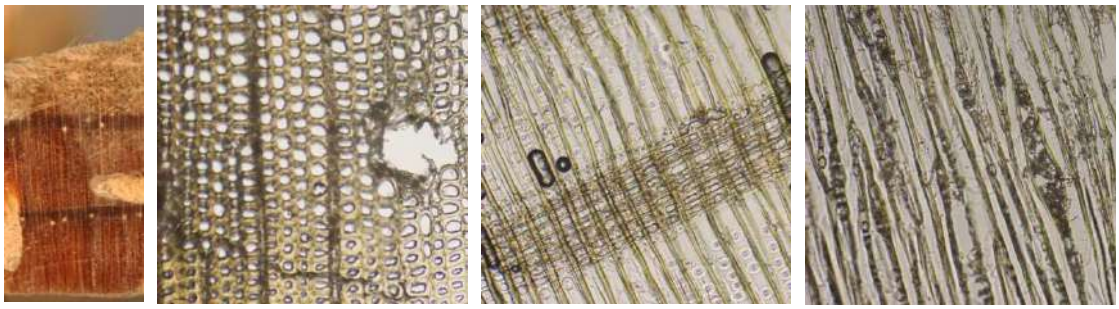


Figure 202: Sample of Scots pine extracted from a sarking board of the roof in Cockenzie House (1680-3): transversal section macro (left); transversal section X100 (centre left); radial Section X100 (centre right); tangential section X100 (right)

We have identified only two other species besides Scots pine: oak (*quercus sp.*) and spruce (*picea abies*). Oak has been used for rafters and collars in the roof of the King's Old Buildings in Stirling Castle (1557), pegs (securing both joints between rafters and collars and slates to the sarking) in Pinkie House (1613), pegs (securing joints between rafters and upper beams) in Holyrood Palace (1671-8) (Figure 203), purlins in the North-West corner of Stirling Castle Palace (after 1719) and pegs (securing joints between posts and collars and upper beams) in Newhailes House (1733-51). This is

not surprising considering the early date of the buildings (the purlins in the North-West corner of Stirling Castle Palace have probably been reused from an earlier structure) and/or their high status. As discussed in section 2.2.2, oak, due to its strength and resilience, was considered the most valuable of timber and used whenever possible for high status buildings (Newland 2010). Local oak was used before sixteenth century, then it started being imported from Norway; oak imports were however restricted due to Norwegian governmental policies, and this is why oak is found mainly in very early roofs or high status buildings.

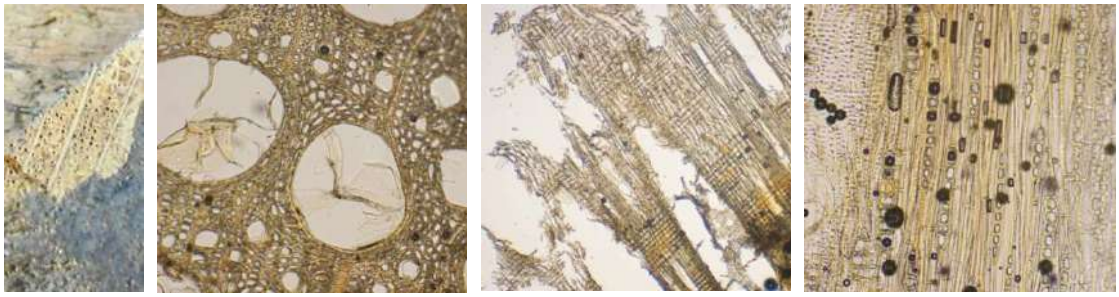


Figure 203: Sample of oak extracted from a peg securing the joint between a rafter and an upper beam in the roof of the North range of Holyrood Palace (1671-9): transversal section macro (left); transversal section X50 (centre left); radial Section X50 (centre right); tangential section X100 (right)

A spruce post has been found in the roof of the North-West wing of Newhailes House (1733-51) (Figure 204), testifying that this species was sometimes used for structural purposes as well. The post in this roof structure is behaving mainly in compression and is thus not highly stressed: this might be the reason why the use of spruce has been considered adequate for this element. All other elements are instead working in tension or bending and are in fact made of Scots pine, while the pegs are made of oak, more durable than pine and less subject to insect attack. The use of different species for different structural purposes in this roof is unique amongst the surveyed roofs and suggests that the wright had a very good knowledge of the material.



Figure 204: Sample of spruce extracted from a post of the roof in Newhailes House (1733-51): transversal section X100 (left); radial Section X100 (centre); tangential section X100 (right)

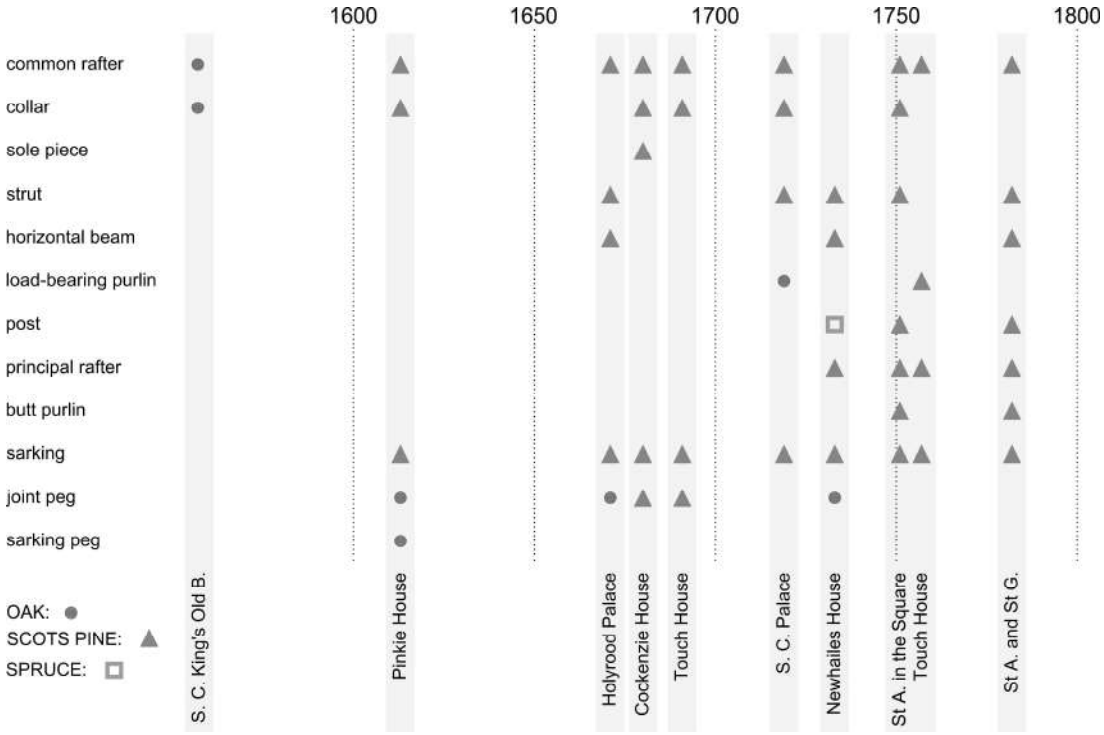


Figure 205: Timeline of the timber species identified microscopically in the case studies investigated

3.3.3.2 Timber Quality

Scottish roofs appear to be composed of timbers of variable quality (Figure 206). This is a consequence of the availability of material and funds and of the knowledge of wrights. The timber was sometimes bought and supplied by wrights - as in Tweeddale House (1750-6) (Dunlop, 1750-1756) -, sometimes by architects - as in Holyrood Palace (1671-8) (NRS E36/30, 1671-1678) - and other times by clients - as in George Heriot's Hospital (1633-7) (Lockhart, 2003). Clients sometimes supplied timber from their own woods, as the Earl of Tweeddale in Yester House (NLS MS14551/24, Undated). It seems that wrights were consulted on the purchase of the material: Thomson (1991) reports that the architect James Baxter working at Gordon Castle in 1770s asked the wrights which was the best quality timber to decide where to buy it from – the wrights replied the Russian one.

In the second half of the eighteenth century timber starts being imported from Russia. Russian deals and balks were of very good quality because in Riga officials sorted and stamped timber balks by quality and length (Thomson, 1991). This was an innovative procedure that allowed to sell and buy products according to their quality in a more efficient way. Timber from Riga had in fact a reputation of being very rigid, regularly squared, very clear of knots, straight in the grain and very durable. VSG has confirmed this reputation in Touch House's purlin roof (1757-62), where the primary structural elements have been found to be of high quality (Figure 207); archival documents record that Riga logs have been used (TCH account by Deas & Co, 1757-8).

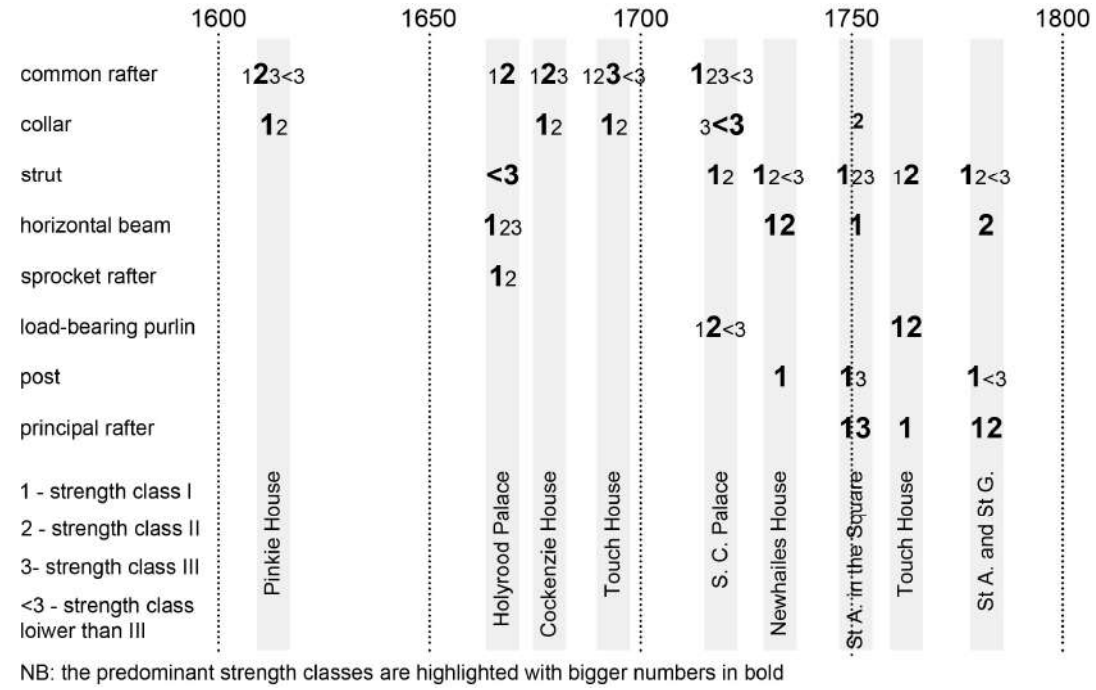


Figure 206: Timeline of the timber quality assessed in the case studies investigated

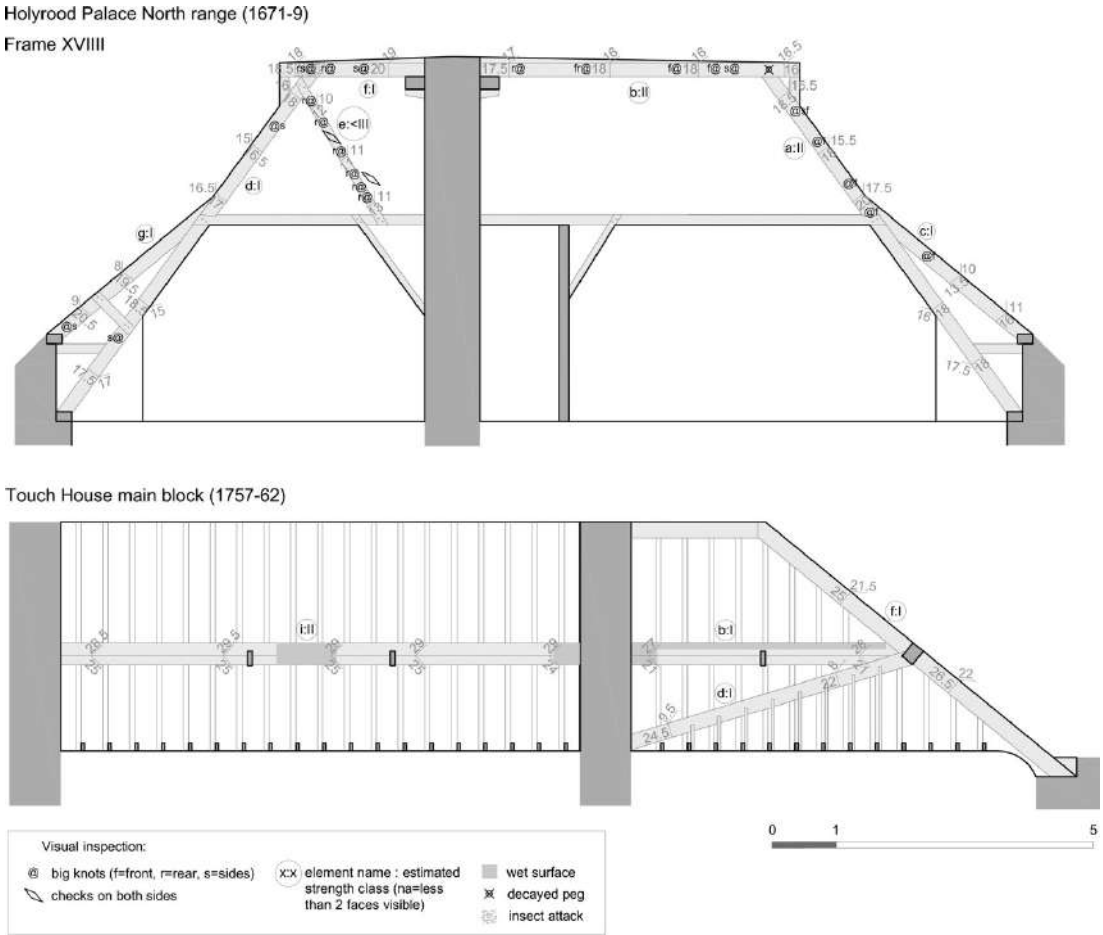


Figure 207: Part of the VSG results of the roofs of Holyrood Palace (top) and Touch House (bottom)

It is interesting however to note that often wrights tried to use the timber they had in the best way possible. Low quality timbers have been used in Holyrood Palace (1671-8), for example, for elements working in compression and thus less affected by defects, such as struts (Figure 207). Rafters in Stirling Castle Palace (after 1719) are sometimes of low quality but the defects are not placed in their critical section, suggesting that wrights were aware of their negative influence on the structural performance of the elements. Timbers in St Andrew's in the Square church (1751-3) do not seem to be distributed according to their quality, but this could be due to the lack of long elements that forced to use a low quality timber as a rafter. Moreover, as already noted, knots in St Andrew's roof are concentrated in elements charged in compression, suggesting that wrights were aware of the knots' negative influence on elements charged in bending and tension.

3.3.4 Wrights, architects and patrons

Figure 208 summarizes the development of Scottish roofs discussed in the previous sections. The end of seventeenth century sees important innovations with the introduction of hipped platform roofs, while different structural solutions are experimented and imported from elsewhere during the eighteenth century. We will now discuss who are the actors that made this development happen, what their relations were and which sources they might have taken inspiration from.

According to previous research, discussed in section 3.2.4, wrights become increasingly important during seventeenth century, working as main contractors (Dunbar, 1976, Newland, 2012b) and some even aspiring to the role of architect, as James Baine (1630-1704) (Newland, 2010). In eighteenth century wrights work as city developers in Edinburgh New Town (Lewis, 2006) and wright Allan Dreghorn (1706-65) becomes an established contractor and architect in Glasgow (Lewis, 2015). However, up to today Baine and Dreghorn are the only wrights whose work has been studied in detail. We do not know if they are an isolated case or if other wrights were following their example.

Based on our archival research (Appendix G) and on the artists' index of the Buildings of Scotland Collection (Cruft, 2005, Gifford, 1984b, 1988, 1992, 1996, 2002, 2007, 2012, McWilliam, 1978, Walker, 2000, Williamson, 1990) we have tracked down wrights involved in seventeenth- and eighteenth-century building works in Scotland, to start understanding who they were working with and if partnerships with other craftsmen and architects had been established. This information has been collected in the ADCRU Microsoft Access database and mapped using ArchGIS (Figure 209). Unfortunately some of the buildings included in Figure 209 are now ruinous (Bernera barracks, Linlithgow Palace, etc) and others could not be visited. Moreover, amongst the ones we have surveyed, some have been heavily altered (Winton House, Brunstane House, etc), leaving little or no trace of the roof structures built by the mentioned wrights. This has precluded a comparison between different structures designed and built by the same wright/architect.

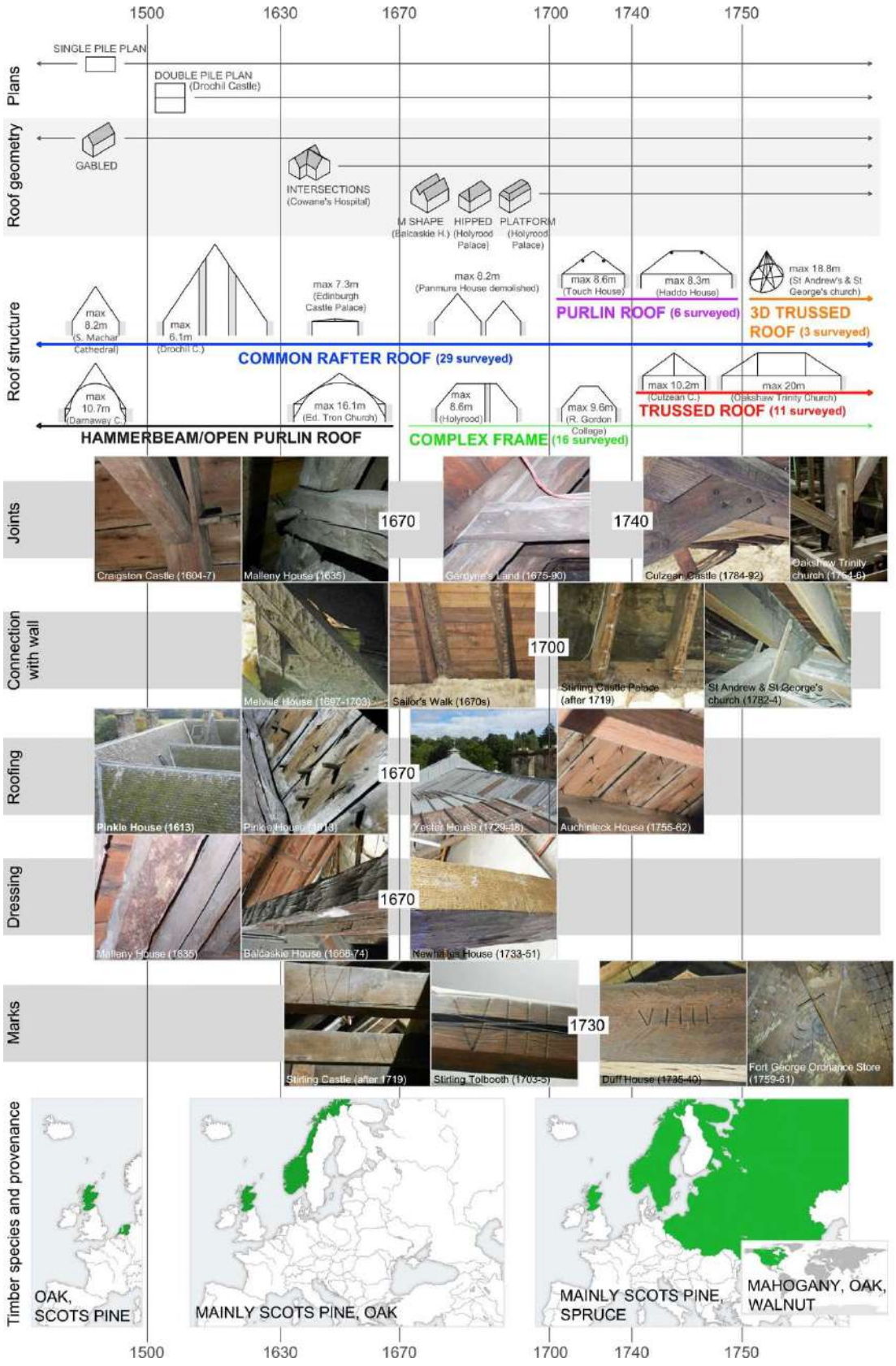


Figure 208: Timeline summarizing the development of Scottish timber roof structures in terms of overall structural arrangements, construction methods and details and timber species and provenance

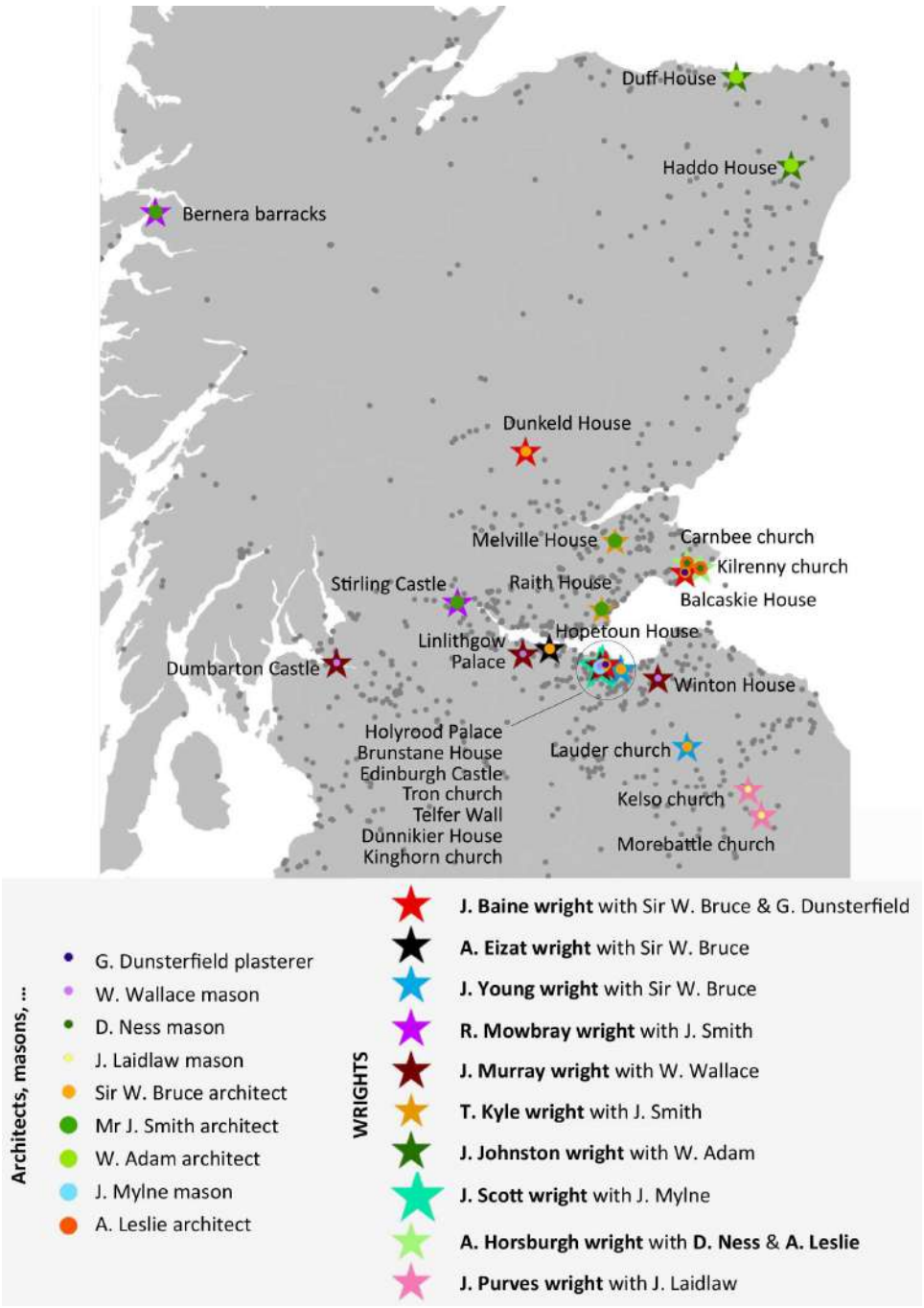


Figure 209: Working teams of wrights, architects, masons and other craftsmen identified during the research; only the teams which have worked together in more than one building have been included

The information collected has nevertheless allowed learning that during eighteenth century partnerships between masons and wrights bring to the design and construction of many churches: Kinglassie Parish church (1773/4) by J. Lawson wright and R. Baxter and R. Black masons, St Andrew's by the Green church (1750/1) by T. Thomson wright and W. Paull and A. Hunter masons, Kilmarnock old high kirk (1732/40) by W. Hunter wright and R. Hunter mason, Tibbermore church (1789) by J. Miller wright and A. Paterson mason, St Cuthbert's church (1771) by W. Watters wright and R. Weir

mason. The fact that an architect was not involved in these projects suggests that either the wright or the mason, or both, were working as designers, following the example of Baine and Dreghorn.

In the following sections we will discuss some examples from both seventeenth and eighteenth century to understand what role the wrights, architects and patrons had in the design of the roof structures and which sources they possibly took inspiration from. Although the sample is not comprehensive and more research is certainly needed to draw ultimate conclusions, this work sheds some light on the competences, input and influences of the different actors involved and represents an important first step in the study of the design process of roof structures of the period.

3.3.4.1 James Baine, the Earl of Panmure and Tobias Bachop

James Baine (1630-1704) was one of the foremost wrights of his time: he worked as wright, plasterer, timber merchant and main contractor for the Crown and some of the most powerful members of the Scottish nobility. His career has been studied in detail by Newland (2007, 2010, 2011, 2012c, 2012b, 2012a) who has identified and analysed his work in twenty major building projects by reviewing a great amount of archival documents.

The only roof we have surveyed which might have been designed by Baine is the one at Holyrood Palace. Other wrights were involved in the building works at Holyrood (NRS E36/30, 1671-1678, NRS GD29/100, 1678, NRS GD29/94, 1679, EUL LAII87/1A, 1684-7), but Baine was the Royal Master Wright, therefore he must have had a major role in the design of the timber structures. Holyrood's roof is innovative for various reasons discussed in the previous section: it is the earliest hipped platform roof we have surveyed and it displays for the first time the use of tension absorbing joints. We know that Baine had invented a new flooring technique to bridge wide spans - the broken joists technique described by Newland (2012a) and used in Panmure House, Holyrood Palace and Brechin Castle -, therefore he could be the author of the innovative design of Holyrood's roof as well. On the other hand, Holyrood's roof is quite similar to the one at Kinross House and the point of contact between the two buildings is Sir W. Bruce, not Baine. This makes us think that the architect might have had an input in the design of the roof structures as well.

Brechin Castle is another building where Baine carried out major works. The seventeenth-century roof has not survived but it is mentioned in several archival documents studied by Newland (2010). Baine worked at Brechin between 1688 and 1694, carrying out repair and renovation works for the Earl of Panmure; these works included the dismantling of the roofs of the South and West ranges and their reconstruction with a wider span, since 3 feet were peeled off the supporting walls in order to widen the rooms (Newland, 2010). The roof structures are not described in the contracts, but they are commented on by the mason Tobias Bachop. Baine had carried out a series of works not agreed

with the Earl, with the ambition to take in the role of architect. The Earl had refused to pay these works and had called in Bachop to assess Baine's work.

Bachop was highly critical of both the workmanship and the materials used by Baine: he stated that the roof was not stable because "*mostlie of old timber & werie few cupll feet & werie manie needless runroofs & too too long bridles but also too flat [...] so small & unsufficient timber not fit for such use [...] a great many of the feits wholly rotten [...] some of the toppings of the cuples as so shaft rotten & wailkie that the mortises have no strength*" (NRS GD45/18/1616/25, 1694 in Newland 2010). According to Bachop, the roof was too flat and made of inadequate timbers (reused, too small, rotten). Baine had inserted many dormers (*runroofs*), therefore many of the rafters did not reach the wall-head but were supported by purlins (*bridles)* ending on the neighbouring rafters; according to Bachop the *bridles* were too long and too many.

In his petition to the Earl Baine replied that he reused many timbers because he could not find suitable timber to buy, but that this was not a problem because old oak timbers look unpleasant but actually last longer than any other timber (NRS GD45/18/1616/21, 1694 in Newland 2010). He also stated that he would have preferred to use the same roof construction as in Panmure House, but the Earl had bound him to put only *upper backs* and not use *nether backs* fastened to the roof with *plum anglets* (NRS GD45/18/1616/21, 1694 in Newland 2010). Unfortunately Panmure House has long been demolished, thus its roof cannot help in understanding what these terms mean. *Back* is the first cut off a tree-trunk (Robinson, 1999); *upper* and *nether* (lower) probably refer to the position of these elements in the structure; a definition for *anglet* could not be found. The *backs* could be upper and lower collars and *anglet* an ashlar post (as suggested by Newland) to connect the lower collar. Perhaps the Earl did not want lower collars because he preferred a higher ceiling. Leaving aside these speculations, what is interesting is that, according to what Baine says, the patron had a say in the design of the roof structure, since he bound him to use only certain elements.

Even more interesting is the fact that a mason is called to assess the work of a wright and that he goes even beyond his task by describing the amount of timber needed to strengthen the roof: "*the supporting & rancing of the Roofe above the dyining roome, drawing roome & chamber will take 50 trees tuo pairt single & third pairt double & to Rance the Gallerie Garrets betwixt 12 & 16 trees tuo pairt single & a third part double*" (NRS GD45/18/1616/25, 1694 in Newland 2010). Thanks to this description he is later contracted by the Earl to re-work the roofs (Newland, 2010).

Bachop includes a sketch of the roof at the end of his comments on Baine's work (Figure 210); it could be either a survey of Baine's roof or his proposal of new design. Given the overall proportions and the four vertical elements it must be a longitudinal section. The four vertical elements could be four gable walls, but the timber structure in between is then difficult to explain. They could also be

four rafter couples, with dormers in between; the small circles at the top of the vertical elements could be the collars - in this case the drawing would be missing the upper part and the other rafters. The drawing is difficult to interpret, but it suggests that timber work was not always a prerogative of wrights.

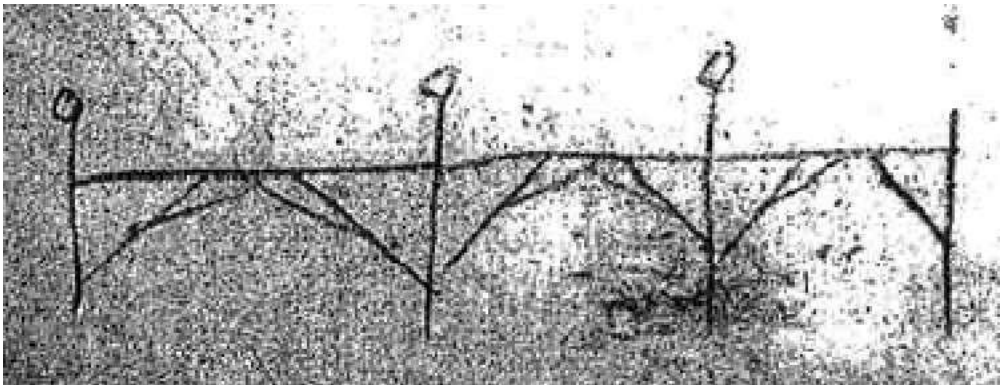


Figure 210: A sketch of Brechin's roof structure included in the assessment of James Baine's work drafted by Thomas Bachop in 1694 (Newland, 2010)

3.3.4.2 John Scott and James Gillespie Graham

The roof structure of the Chapel in George Heriot's Hospital (1628-84) illustrates well the impressive development that Scottish timber roof structures achieved during seventeenth and eighteenth centuries. At first it seems to be a simple common rafter roof, very similar to contemporary Scottish roofs: composed of closely spaced rafter couples (about 30cm space in-between), with two collars connecting each couple transversally and slanted braces supporting the ceiling (Figure 211). The rafters are connected longitudinally by the sarking boards only, forming a continuous surface on which lead sheets are fixed with metal nails. The connection with the supporting walls is not visible, unfortunately. The roof is quite steep (about 50°) but not excessively large (the span is 6.8m). The timbers are hand-axed softwoods connected with mortice and tenon joints secured by roughly squared timber pegs. Big roughly sawn roman numerals mark all the frames, though not in sequence.

Walking through the roof space, it becomes clear that something different happens in the central part of the Chapel: here the roof structure is supported by two additional low-pitched queen-post trusses, inserted in-between the original timbers (Figure 212). The timbers composing these trusses have much bigger scantlings and have been machine-sawn. They are connected again with mortice and tenon joints, but secured with iron straps. The tie-beams are composed of two elements, joined with a scarf joint. Small neatly chiselled roman numerals mark each piece of timber. Two longitudinal purlins sit on top of the trusses and support the upper collar beams of the original roof. Two other purlins hang from the trusses - supported by iron rods and plates - and support the rafters of the original roof, which have been cut.

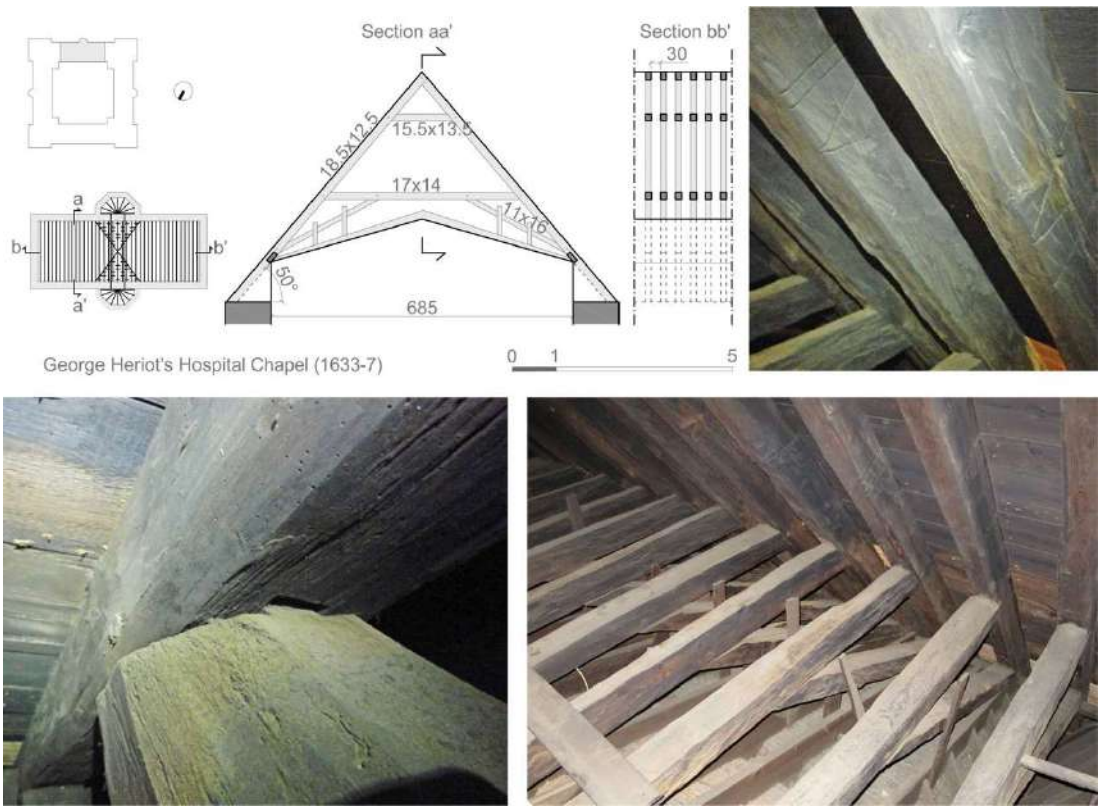


Figure 211: The common rafter roof covering the Chapel of George Heriot's Hospital (1633-7) (Serafini and Gonzalez Longo, 2015b)

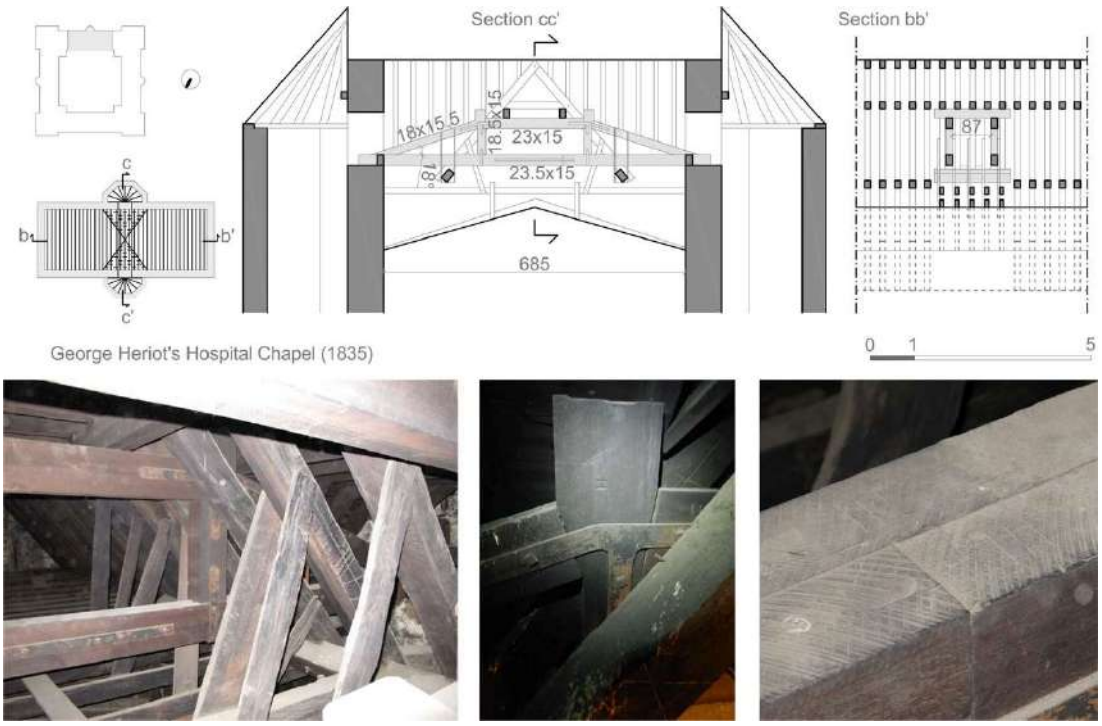


Figure 212: The trusses in the central part of the roof of George Heriot's Hospital Chapel (1835) (Serafini and Gonzalez Longo, 2015b)

Thanks to extensive archive material the original roof structure can be dated to 1633-7. Timber for works at George Heriot's Hospital was brought from Dalkeith, but large timber was imported from Norway (Lockhart, 2003). In December 1633 the mason John Ronald was paid for lintels for the wall-heads of the Chapel; in the same moment the Hospital's governors decided to cover the Chapel with lead and in 1635 the work was contracted to John Bland, an English plumber from Newcastle (Lockhart, 2003). In early 1637 the Hospital's Governors ran out of money and sent Bland back to Newcastle until they needed further lead work (Lockhart, 2003). This makes us think that by 1633 the Chapel walls had reached the roof level and that by 1637 the Chapel had been roofed with lead. However, the first wrights only appear in the Treasurer's accounts of 1638-9 with John Scott as leader of a 6 men team (NRS GD421/5/2, 1633-42).

John Scott (d. 1666) was Master Wright to Edinburgh from 27 January 1637 and Royal Master Wright from 9 June 1641. It is highly unlikely that the Chapel roof structure was built without wrights on-site, but it seems that Scott was not much involved in the design of the Hospital roofs since in 1648 he suggests to dismantle the pavilion roof of the South-West tower for structural reasons, saying that "*it was never his opinione that the said southwest torret should be built in the way that it now standis*" (Lockhart, 2003). Other roofs were platformed as well in those years: the roofs of the North towers in 1642, the North range before 1647, and the South East tower in 1649 (Lockhart, 2003). These alterations, just a few years after the original construction, suggest that Scott had not been much consulted on the roofs' design in the first place.

In that same period Scott was also busy at the Edinburgh Parliament Hall (1631-40) and Tron Church (1636-47) (Figure 128, Figure 129). The two arch-braced open purlin roofs show us that Scott knew very well how to design and construct complex roof structures. Nevertheless he chose to do something very simple in Heriot's Chapel, perhaps because the roof structure was never meant to be visible or because of economic constraints (the Hospital Governors often ran out of money). A further hypothesis is that the reliance on imported timber meant roof construction was rather dictated by standardised lengths; while 'ready-to-build' timber roof 'kits' from Norway would have certainly been a cheaper solution than paying Scott to design a complex roof, and would have allowed the Heriot's architect to bring in wrights only when construction started.

The Chapel interiors remained incomplete until Thomas Sandilands, one of Scott's apprentices, was contracted in 1680s to finish the work (NRS GD421/10/68, 1685). Sandiland's account of work unfortunately does not provide us with details to understand what he did. In this period plaster ceilings were gradually substituting timber ones, but the latter were still in use. The Chapel's roof structure with its slanted braces would have easily accommodated a painted timber ceiling like the 1626 one in Provost Skene's House (Figure 213 a). Nothing as grand as this is mentioned anywhere though, thus it is more probable that a simple ceiling was installed until further funds were found.

In 1787 the chapel was refitted with a new ceiling, called 'adamesque'; Robert Adam might have been involved since he had been consulted previously for other matters (Lockhart, 2003). An undated drawing held in RCHAMS shows a decorated ceiling that matches evidence found in the roof space (Figure 213 b and c). The central part of the roof structure was altered at this time to allow for this new ceiling to be installed. The rafters were cut ('a' in Figure 213 centre and Figure 214), leaving exposed the mortice and tenon joints were the lower collars used to be (Figure 214 right). A purlin was inserted on each side to support the cut rafters ('b' in Figure 213 centre and Figure 214). The purlins were kept in place by a collar ('c' in Figure 213 centre and Figure 214) and two struts ('d' in Figure 213 centre and Figure 214) pushing on the lateral walls. Ceiling joists ('e' in Figure 213 centre and Figure 214) were placed beneath and connected to the rafters with timber struts ('f' in Figure 213 centre and Figure 214).

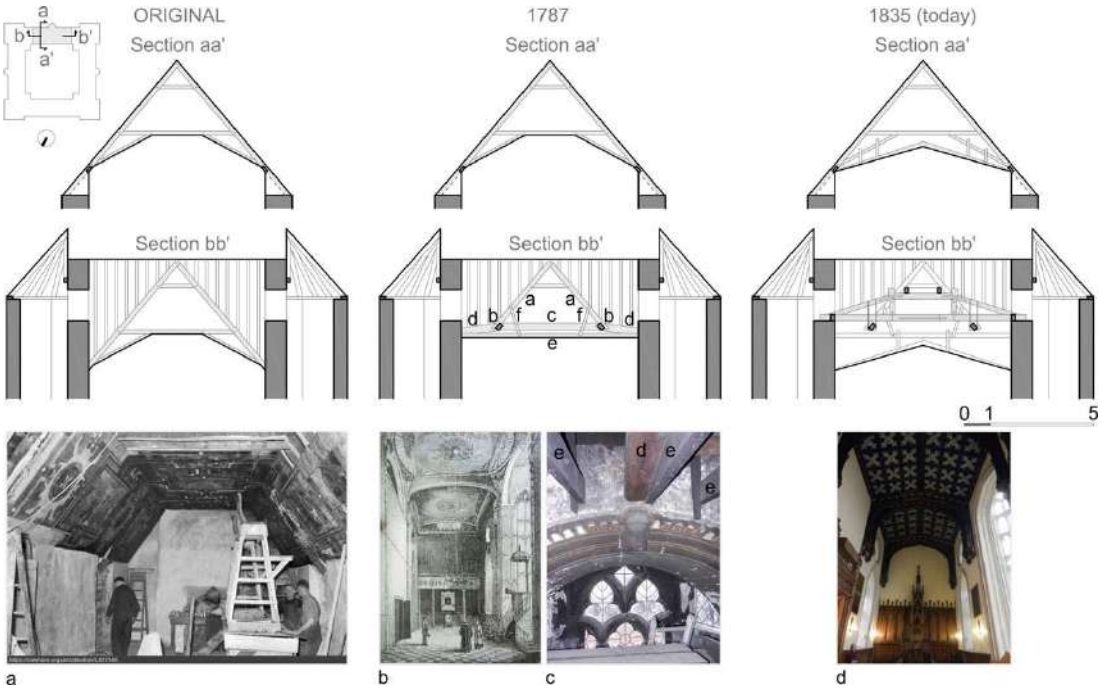


Figure 213: Alterations in time to the roof structure and ceiling of George Heriot's Chapel: a) hypothesis of the original ceiling, that might have been similar to the 1626 one in Provost Skene's House (RCAHMS SC 1327346, 1952); b) an undated drawing probably showing what the 1787 ceiling looked like (Lockhart, 2003); c) remains of the eighteenth century plaster decorations visible in the roof space; d) a view of the ceiling today, as renewed in 1835 (Serafini and Gonzalez Longo, 2015b)

In December 1833 the governors ordered to replace the whole plasterwork, considered unsafe: the work was carried out by architect James Gillespie Graham (Lockhart, 2003). Gillespie's work is what we see today (Figure 213 d). He added two queen-post trusses to reinforce the central part of the roof structure, weakened by the late eighteenth-century interventions. The trusses are clearly of nineteenth-century dating because their pitch (18°) is much lower than that of earlier trusses: the

truss above the Trades Hall in Glasgow (1791-4) is the shallowest with its 27° pitch. Moreover, the elements composing George Heriot's Chapel have been machine sawn - mechanical sawmills started being employed in Scotland only from early nineteenth century (Crone and Mills, 2011).



Figure 214: Alterations in time to the roof structure and ceiling of George Heriot's Chapel; the letters correspond to those in Figure 214 (Serafini and Gonzalez Longo, 2015b)

The use of trusses to cover a reduced span such as the one in George Heriot's Chapel is indicative of how well established the trussed system had become in Scotland by early nineteenth century. The following sections discuss how and by whom the trussed system has been introduced in Scotland.

3.3.4.3 John Robertson and Allan Dreghorn

St Andrew's in the Square church is one of a long series of public buildings designed by the wright and architect Allan Dreghorn (1706-65), who contributed to Glasgow's eighteenth-century flourishment (Lewis, 2015). The roof structure seems to be unaltered and can be confidently assumed to be contemporary to the construction of the church itself (1740-57). The records of the Burgh of Glasgow (Renwick, 1911) report in 16 October 1750 (p. 329): "*Considering that the stone work of the new church in Bells yeard is now done and that it is necessary the church to be rooffed, and to fall therto against the spring, they impower the magistrates, dean of guild and deacon conveener to agree with sufficient workmen to do the same and to furnish the timber thereto upon reasonable terms*". In 20 February 1753 Peter Smith is paid for slating the church (p. 361). All the payments made from 1753 onwards are for interiors, the steeple and lead. This brings to the conclusion that the roof structure was constructed between 1751 and 1753.

Since Dreghorn was a wright, it would be reasonable to assume that he designed the roof structure himself; however, the records of the Burgh of Glasgow (Renwick, 1911) report that in October 1758 (p. 532-533) the wright John Robertson is paid by the client for three different plans and estimates for the roof of the church, which he made in 1751. This does not necessarily rule out an input by Dreghorn in the design of the roof structure but it suggests that, since Dreghorn was acting as

architect, another wright was contracted for the timber work. It also reveals that the client wanted to have his say not only in the cost but also in the design of the roof structure.

As previously discussed, the roof of St Andrew's in the Square church is amongst the earliest trussed roofs extant in Scotland. This raises the question of how Robertson and Dreghorn came in contact with the trussed system. We know that the architect and craftsmen had been asked by the client to follow the model of St Martin's in the Fields, the church designed and built by the architect J. Gibbs in London about 20 years earlier. The roof of Gibb's church is a trussed roof (Figure 215, Figure 216). However, if we compare it with the roof of St Andrew's in the Square church (Figure 217), it is easy to note that St Andrew's structure is a lot simpler. The structure drawn by Gibbs in his Book of Architecture (1728) (Figure 215) is actually a double structure, with more closely spaced trusses and thus employing a greater quantity of timber. The trusses covering the portico are simpler (Figure 216), but still quite different from the ones in St Andrew's in the Square.

Another roof drawn by Gibbs in his Book of Architecture (1728) is more similar to the one of St Andrew's in the Square: that of Marybole Chapel (Figure 218). It might be that Robertson took inspiration from Gibbs' book to draw three different roofs, since he was asked to make three different plans and estimates, and that the client eventually chose the one that employed less timber and was therefore cheaper.

Unfortunately not much is known about Robertson, so it is not possible to say with more confidence if he copied the structure from Gibb's book or another book or came in contact with the trussed system while travelling. However, it is interesting to note that this roof looks like a truss but is not actually behaving as a truss, because of the design of some construction details. The joint between the central post and the raised tie-beam is in fact a simple mortice and tenon joint secured by two timber dowels: such joint can resist very limited tension forces, thus it cannot counteract the deflection of the raised tie-beam, as in a truss. The post is simply sitting on the raised tie-beam and working in compression, as proven by the fact that the joint between the post and the raised tie-beam does not show any signs of distress/opening. In fact the raised tie-beam is supported by the lateral posts and their slanted struts, so it can support the post. What is interesting is that the top of the post is inserted in between the two rafters, as in a truss: the detail would make sense if the post was meant to work as a tie and needed support from the rafters, rather than the other way around.

Clearly, the joint between the post and the rafters has been copied without understanding its meaning. The same detail and misunderstanding has been found in the roofs of Fort George Ordnance Store (1759-61), Fort George Museum block and Staff block (1762-4) and Tron theatre (1793-4). This suggests that many architects and wrights still had a superficial understanding of the trussed system during the eighteenth century, as argued by Yeomans (1984, 1986b, 1992). According

to Yeomans, English architects and carpenters did not fully understand the trussed system because they copied trusses from treatises rather than seeing built examples. Carpenters' manuals of the time had in mind those supervising the work rather than the workmen carrying out the works, so no construction details were included and the structures suggested were often unsafe and difficult to build. The same could be true for Scottish architects and wrights. Other examples of Scottish roofs built during the second half of eighteenth century, discussed below, support this hypothesis.

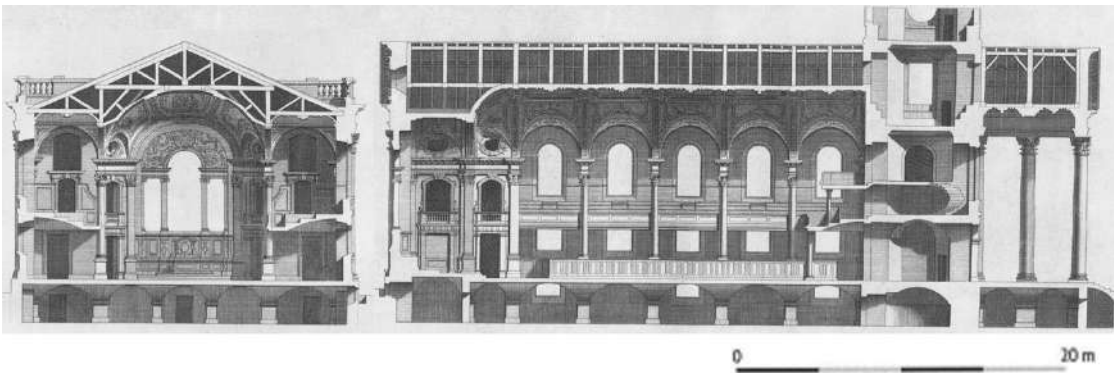


Figure 215: The roof of St Martin's in the fields church as drawn by James Gibbs (1728)

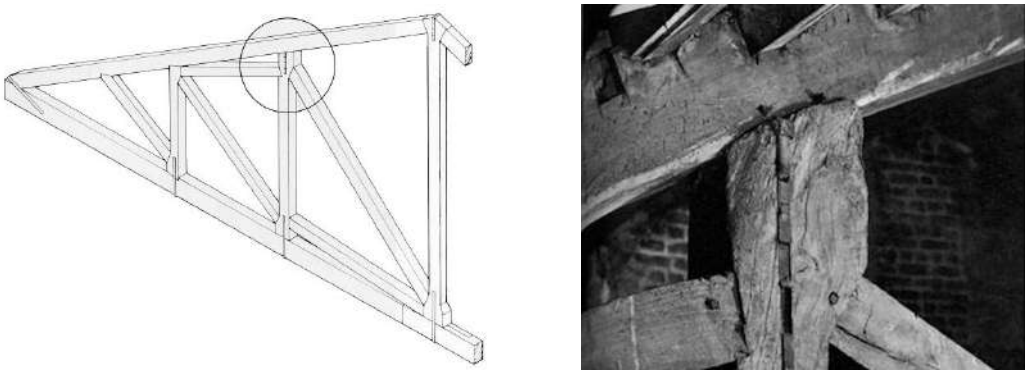


Figure 216: The roof of the portico of St Martin's in the fields church as built (Yeomans, 1987)

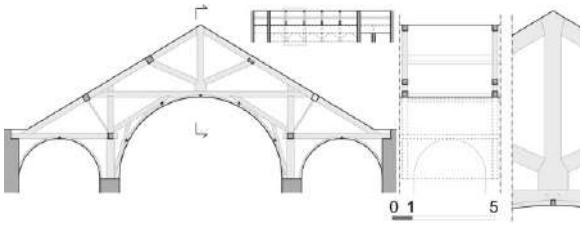


Figure 217: The roof of St Andrew's in the Square church (1751-3)



Figure 218: The roof of Marybole Chapel (Gibbs, 1728)

3.3.4.4 Thomas Dunlop, the Adams and the Marquis of Tweeddale

Tweeddale House's roof is an interesting example of 'complex frame' (Figure 151) built in in 1750-6, during the renovation works carried out by the architects John and Robert Adam (Gifford, 1984a). The Adams were also working at Yester House for the Marquis of Tweeddale at the time (Dunbar, 1972) and this could explain why the wright Thomas Dunlop had a wider commission in the building, as wright and masonry contractor (NLS MS14665/64, 1750-6). Dunlop had been apprentice to John Montgomery in Mary's Chapel, the incorporation of masons and wrights, from 1700 to 1711 (ECA SL34/4/2, 1706-1774). He was probably one of the foremost wrights in Edinburgh at the time: he was Deacon of the incorporation and had eight apprentices through his life (ECA SL34/4/2, 1706-1774). Thus it would be reasonable to think that Tweeddale's roof structure was designed by Dunlop.

A letter written by John Adam to the Marquis (NLS MS14551/126, 1753) suggests, however, that in the case of Tweeddale House the decisions were taken chorally by the architects, wright and mason (Mack), according to specific instructions given by the client: "*we went to your lord's house along with Mess.rs Mack and Dunlop, & concerted every thing with them on the spot, in terms of what your lord directed, so that they are now going on. We are also making out for them Memorandums of the several things with drawings of the particular parts so as they may committ no mistake*".

The Marquis of Tweeddale is known for intervening directly in the design of the roof of another of his houses: Yester House. In a contract between the Marquis and William Adam (NLS MS14551/109, 1742-49), the client asks the architect to change the present M roof (called *happer*) into a platform roof, and gives instructions even for the covering material: "*the present roofe of Yester house being done after the forme commonly called a Happer roof which lodges a great quantity of snow in the winter season to the great prejudice of the said roofe And the said noble marques being designed to alter the same from a Happer roofe to a Plattform to lye betwixt the ridges of the present roof […] The east part of the said house all which to be said with sufficient beams of firr wood and sarking deals and to be covered with lead sufficiently cast and laid with the usual rolls and overlaps at eight pound weight each foot […] As also the said noble marques designing to roofe the middle part of the said house viz- that over the great hall and garden room bounded betwixt the forementioned two principall walls with a pediment roofe to be covered with blue siaillie"*.

Wemyss (2014) underlines the important role that Scottish noblemen had in the design of their houses. The case of the Marquis of Tweeddale suggests that some clients had a say not only in the design of the overall appearance and decoration of their houses, but also in the choice of the construction techniques and materials.

The archival documents related to the works at Tweeddale House reveal another interesting aspect. In the accounts (NLS MS14665/64, 1750-6), both the words 'wright' and 'carpenter' are used. 'Wright' is used more for a person's identification (e.g 'Thomas Dunlop wright'), whilst carpenter is used more to identify the work (e.g. 'carpenter work'). In seventeenth-century accounts of Scottish building works (NRS E36/30, 1671-1678, NRS E37/33, 1699-1703, EUL LAII87/6, 1684-6, NRS GD421/5/2, 1633-42) and in most early eighteenth century accounts as well (EUL LAII88/3, 1721-1805, Rock, 2016, TCH letter to Mr Seton, 1751) the word 'carpenter' does not appear; only 'wright' is used. The fact that 'carpenter' starts being used in Scotland from mid-eighteenth century suggests an English influence, probably prompted by the Union in 1707. This English influence can be traced also in arrangements and construction details of Scottish roofs dating from mid-eighteenth century (discussed in the previous sectios) and in the introduction of the trussed roof, discussed in the next section.

3.3.4.5 John Brown and the Adams

The first Scottish building designed with a trussed roof is the 1720's William Adam's New College Library in Glasgow (Hanke, 2008) (Figure 219). William draws a simple king-post truss whose post has joggles and is dovetailed in the tie-beam. Joggles are a distinctive English feature, although they are also shown by some Italian treatises. Since William did not visit London until 1727, it is likely that his reference was the copy of Serlio's treatise he owned (Rowan, 1990), whose illustration also shows the post dovetailed in the tie-beam (Figure 220). Unfortunately the building has now disappeared so it is not possible to know if his design was implemented. However, other buildings designed by William in the same period, such as Duff House (1735-40) and Arniston House (1726-33), do not have trussed roofs. This brings to the hypothesis that Adam's intention to build trusses clashed with the lack of familiarity of local wrights with the trussed system.

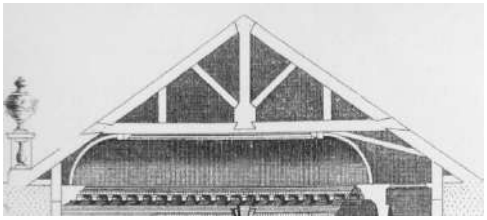


Figure 219: William Adam's design for the roof of Glasgow New College Library, 1720 (Adam, 1812)

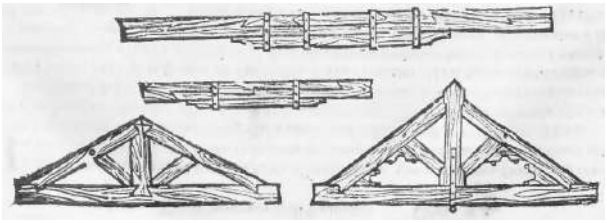


Figure 220: King-post trusses shown by Serlio (1545) at p. 197

Nevertheless, William does build a trussed roof in this period, in Hopetoun House (1721-48) (Figure 157). We do not know who was the wright working with him at Hopetoun, but the fact that he was able to build a truss while his Scottish colleagues still were not, suggests that he might have been a foreigner, or someone who had travelled. Perhaps William brought skilled English carpenters from

his London trip for the very purpose of implementing innovative construction techniques, already used in England. Lewis (2006) noted that in 1760s-70s William's son Robert hired men in London whose names are found in Edinburgh New Town ten years later, thus it might be that William did the same 40 years earlier. Another possible source of information and inspiration could have been the new treatise by Price (1733), a copy of which William possessed in his library (Rowan, 1990).

Further considerations can be made by comparing Robert Adam's design for Glasgow Trades Hall (1791-4) with the structure built after his death in 1792 (Figure 221). Adam's design is chosen by the Trades Incorporations in 1791 through an invited competition between him, James Jaffray and John Craig (ML T-TH 1/1/7, 1787-98). The extra land required by Adam's design is never bought, so the design for a building about 33.5m long must be adapted to a plot only 30.5m long: if we compare Adam's drawings with the present structure (Figure 221) we can see the overall proportions distorted and the diameter of the dome dramatically decreased (Sutherland, 2005). This brings to the assumption that the set of plans used for the construction of the Hall, which has not survived, was not drawn by Adam, but by someone else, after his death in March 1792. This person might be the wright John Brown, appointed as contractor in May 1792, under the supervision of James and William Adam (ML T-TH 1/1/7, 1787-98).

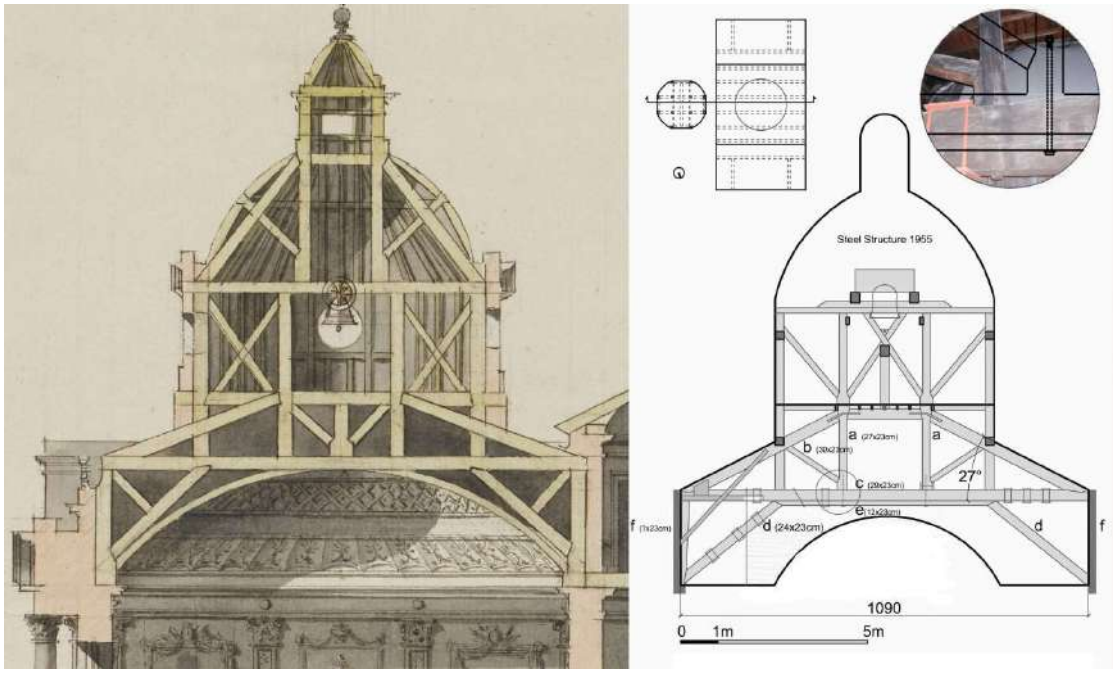


Figure 221: The roof of Glasgow Trades Hall, as designed by Robert Adam on the left (SM Adam 48/25, 1791), and as built on the right; the graphic scale relates to both drawings (Serafini and Gonzalez Longo, 2015a)

The built structure (Figure 221) is composed of 8 parallel queen-post trusses; the 4 middle ones support a drum, dome and lantern above, and leave space for the ceiling below. The span is not excessively wide (10.9m) but the structure is quite tall (10.5m below the lantern). The joints have

joggles and iron straps so that the queen-posts ('a' in Figure 221) hang from the principals ('b' in Figure 221) and support the tie-beam ('c' in Figure 221). The bottom of the post is connected to the tie-beam with a system of cotters and folding wedges passing through the elements (Figure 221 top right): a detail developed in England at the beginning of the nineteenth century, according to Yeomans (1992); it could thereafter be one of the very first uses of this device. The trusses sit on a lower ‘arch’ system, formed by two slanted braces ('d' in Figure 221) and a horizontal beam ('e' in Figure 221). The slanted braces spring from the base of timber posts ('f' in Figure 221) that are partly (on the left) or completely (on the right) embedded in the walls. The tie-beams sit on these posts.

This is one of the two weak points of the structure. The lateral posts and the wall-heads behind them are unable to counteract the horizontal thrust coming from the truss above. The lower ‘arch’ system has partially opened in time and wooden wedges had to be inserted in the joints (Figure 222); the wall-head was reconstructed and steel rods, plates and brackets were added with the same purpose in 1990s (Figure 222). The other weak point is the insufficient longitudinal rigidity. Even though the sarking is still employed, the trusses do not rest on wall-plates and they only have a few purlins connecting one truss to the other. The transversal opening and longitudinal instability are probably the reasons why in 1950s both the dome structure and the ceiling had to be replaced (Figure 223, Figure 224).

The roof structure actually had problems even earlier than in 1950s: in 1856 the buildings’ committee discovered that some of the timbers of the roof had decayed and were unsafe, so architect Charles Wilson was asked to carry out 'considerable' repairs and alterations to secure the roof, which he did from September to November 1856 (Crawford, 1858). From Wilson's drawings we know he added some timber elements and some metal straps and rods (Figure 225).



Figure 222: Repair works to the roof structure of Glasgow Trades Hall (1791-4): a timber wedge inserted between a slanted brace and a horizontal beam (left); steel rods, plates and brackets added in 1990s (right)

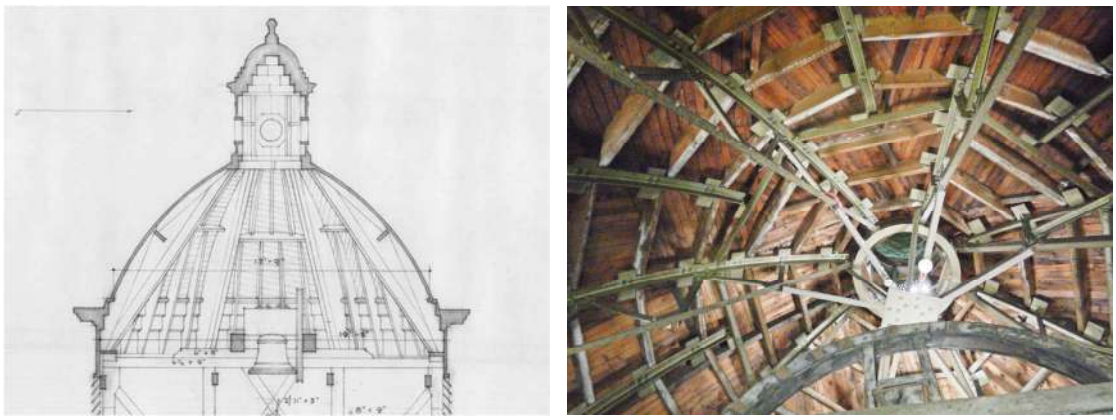


Figure 223: The original timber structure of the dome of Glasgow Trades Hall (1791-4) surveyed by W. Underwood in 1950s (ML Shanks 152/T6, 1955) (left) before the replacement in steel (right)



Figure 224: The ceiling of Glasgow Trades Hall (1791-4): an undated picture probably showing the original ceiling (ML T-TH 1/34/3, Undated) (left) and the present ceiling, installed by W. Underwood in 1950s (right)

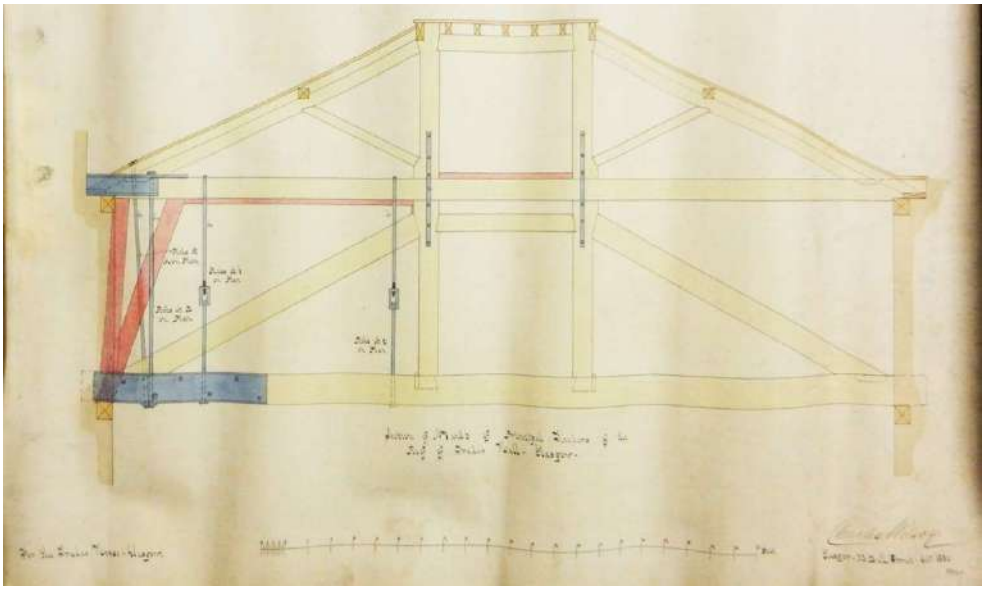


Figure 225: Strengthening of the roof of Glasgow Trades Hall (1791-4): drawing by Charles Wilson architect dated 1856 showing in yellow the original structure, in red new timber elements added by C. Wilson, in blue metal work added by C. Wilson (TDH 1/899, 1856)

The Trades Hall roof as built clearly has some faults, but it shows a better understanding of the trussed system than the structure drawn by Robert Adam (Figure 221). The latter shows an improper design of the joints, which causes the posts to behave in compression, enhancing the tie-beam deflection instead of counteracting it. Moreover, the small central post has no apparent structural function, the lateral walls are too thin to counteract the horizontal thrust produced by the very shallow pitch of the roof, and there is a questionable disposal of rainwater.

There is no evidence of who designed the built roof, whose dome is the very first in Glasgow. Little information could be found on John Brown, the wright/contractor at the Trades Hall, from whom no other building seems to remain. Brown was member of the Glasgow incorporation of wrights from 1790 until his death in 1816 (ML T-TH 9/4/2, 1731-1811, ML T-TH 9/4/3, 1811-70). His appointment as contractor for such a major work as the Trades Hall only one year after becoming a member of the incorporation suggests he was not at the beginning of his career but already had experience. Moreover, the fact that he built a complex dome structure, and perhaps modified Robert's design as well, suggests that he had confidence with the truss system. He might have been brought from London by the Adams, or from elsewhere where the trussed system was already known and used.

The brothers Adam were interested in construction details and in innovative roof structures, just like their father. This is testified by various drawings by Robert, John and James (two examples in Figure 226, Figure 227). Thanks to Rowan's research (1990), we know that William Adam possessed in his library not only Serlio's treatise, but also Vitruvius Pollio (1556), Palladio (1570), Scamozzi (1615), Price (1733) and Salmon (1767), who all show many examples of trussed roofs. His sons might have taken inspiration from these books, just as their father did. Robert and James also travelled to Italy and worked in London (Rykwert, 1985), so they might have seen built trusses too.

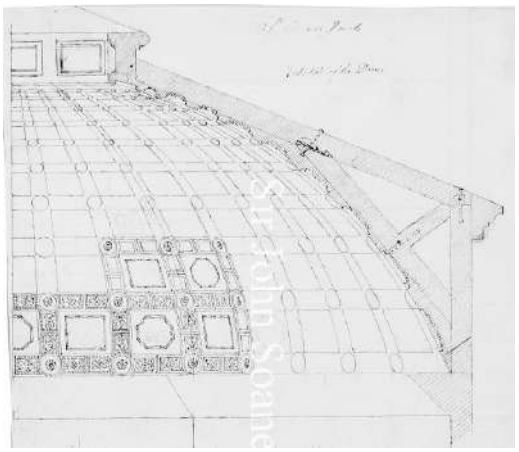


Figure 226: Design for the dome of Edinburgh Assembly Rooms and Musical Society by James Adam (SM Adam 7/225, 1755)

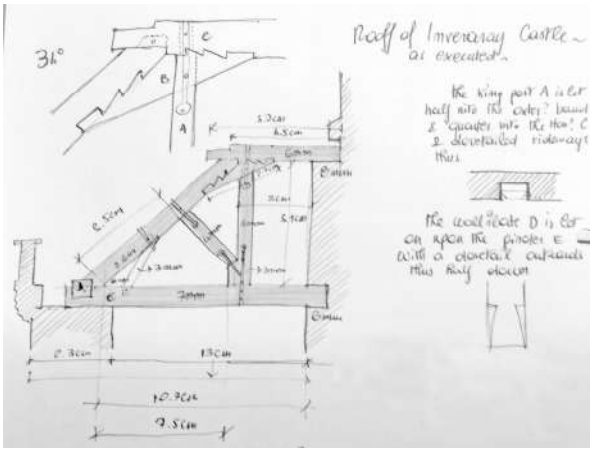


Figure 227: Design for the roof of Invereray Castle (copy of drawing found in John Adam's diary held at Blair Adam House)

These drawings show a superficial understanding of the trussed system, just like Robert's design for Glasgow Trades Hall. This brings to the hypothesis that, since the Adams aspired to build trusses, but they were unable to explain to Scottish wrights how to construct them, they probably sought foreign wrights who were more familiar with these structures and could satisfy their aspirations. And these foreign wrights eventually spread their knowledge to Scottish wrights too. This external influence, from England and/or beyond, necessary for the establishment of the trussed roof in Scotland, is also suggested by the heterogeneity of solutions and details used, previously discussed.

3.4 Conclusions

Our survey of 59 original seventeenth- and eighteenth-century Scottish timber roof structures has allowed identifying different structural typologies, dating them and tracing their development in terms of structural arrangements, construction methods and details, material, know-how and foreign influences. A distinctive Scottish school of roof carpentry has emerged, little influenced by England and Europe up to mid eighteenth century and retaining characteristic features even after.

We can confirm Hanke's (2006) statement that up to late seventeenth century the majority of Scottish roofs is of a simple common rafter form, hidden behind decorated ceilings. Our research also highlights an important development at the end of seventeenth century, when roofs evolve to cover wide spans with shallow pitches and hipped arrangements, whilst supporting heavy plaster ceilings. We noticed that the imported timber products and the know-how of wrights gradually change too. Our investigations also demonstrate that eventually a completely different structural type is imported from elsewhere: the Italian trussed roof, employed from 1740s. Interestingly, we found that some features are maintained and denote a distinctive Scottish tradition, while other details suggest foreign influences. This indicates a transfer of technological knowledge from various sources and a will to experiment and adapt the single solutions to the local tradition, a process in which, according to our research, wrights, architects and patrons all had an important role.

Our research on the work of the Adams architects, in particular, shows that they had an important role in the introduction of the trussed roof Scotland. Although they aspired to build trusses since 1721, when William Adam draws the first Scottish trussed roof, it seems that at first Scottish wrights were unable or unwilling to construct them, probably because they had limited knowledge on the structural behaviour of timber and on the strength and durability of different timber species, as highlighted by our surveys. Our conclusion is that the Adams were forced to bring wrights from abroad in order to implement their designs; this external influence is also suggested by the heterogeneity of solutions and details used in Scottish roofs and highlighted by our surveys.

4 Description of the case studies investigated

This chapter gives a detailed description of the eight case studies investigated (Figure 228), presenting for each of them the architectural and construction history - reconstructed through the literature review, archival research and visual inspection - and the present condition - assessed through visual inspection, VSG and in situ testing. The aim is to show how different assessment methods and tools have been combined together to determine the dating of the roof and evaluate its condition. The overall arrangement of the timber roof, as well as its construcition details and timber species, are described in detail. The accessibility and visibility of the roof structure, as well as the implementation of regular inspections and maintenance works resulting frrom questionnaires to the building owners/managers, are discussed. The measured air temperature/humidity and wood moisture content are then presented along with the results of the visual inspection and in situ testing in terms of present condition. Only the most significant features, documents and test results are here discussed; a thorough report can be found in Appendix F.

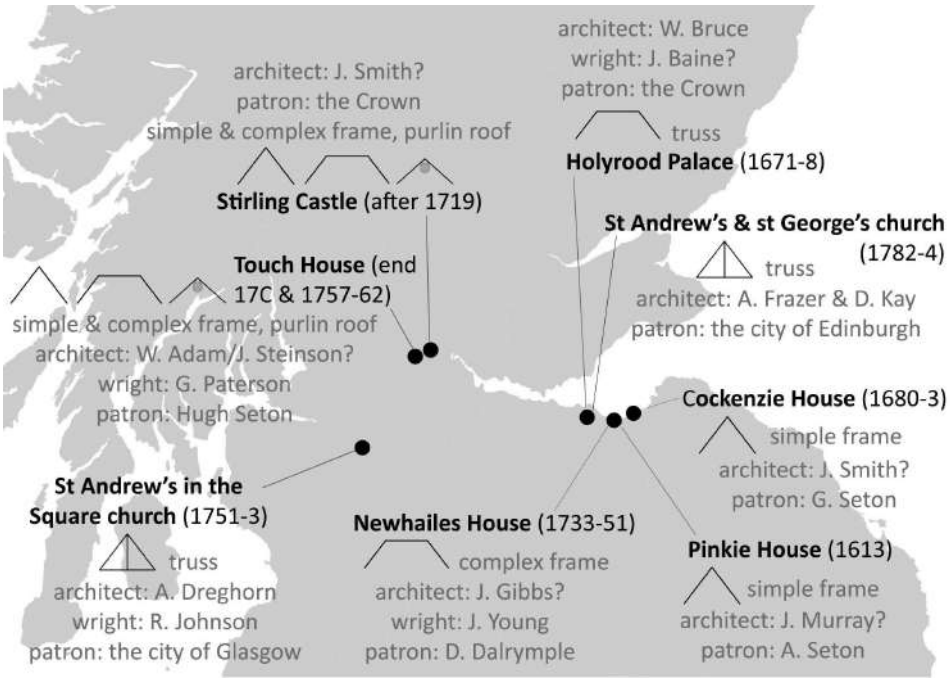


Figure 228: The location, date, structural typology, architect, wright and patron of the roofs of the 8 case studies investigated

4.1 St Andrew's & St George's church

4.1.1 Architecture and Construction

St Andrew's and St George's church is an elliptical church in Edinburgh with a portico topped by a 4-stage steeple on the South side. It was designed and built in 1782-4 by Captain Andrew Frazer, a royal engineer, and the architect David Kay, who might have executed Frazer's designs (Gifford, 1984a). The elliptical plan is one of the very first in Britain and the roof structure is one of the few 3D trusses we have surveyed. We carried out an initial assessment of the church roof (not the steeple) on 3rd July 2015 (accompanied by Dr Daniel Ridley Ellis) and detailed investigations on 3rd February (accompanied by PhD student Clara Gonzalez Manich) and 14th March 2016 (Figure 229).

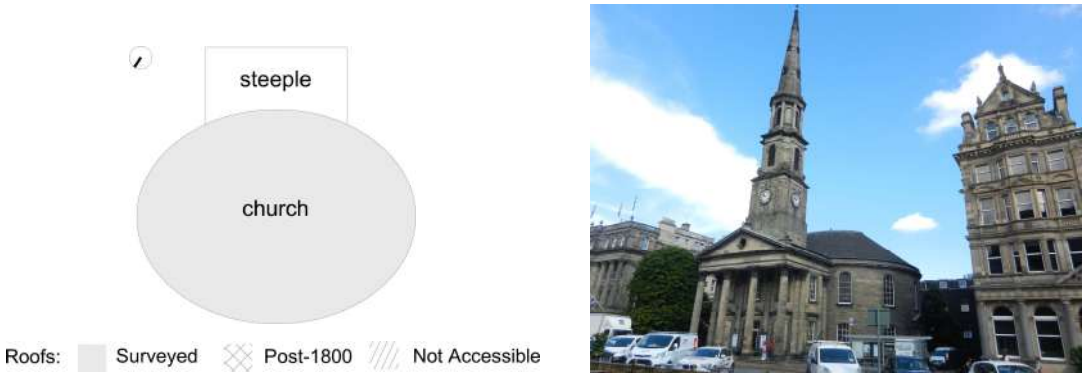


Figure 229: St Andrew's and St George's church (1782-4): plan (left) and view from South-East (right)

The roof is composed of two transversal trusses and radial trusses, linked together by two levels of butt-purlins that follow the elliptical plan (Figure 230). Longitudinal butt-purlins also link the centre top and bottom of the trusses. Sarking boards cover the whole surface of the roof and support lead (on the platform) and slates (on the slopes) secured with metal nails. The transversal trusses are queen trusses with additional central and lateral posts. Slanted struts spring from the posts and support the top of the neighbouriong posts, allowing them to work as ties. The span is almost 19m and the pitch 36°. The radial trusses mirror the arrangement of the transversal ones. The connection with the supporting walls is provided by a wall-plate, on which the tie-beam sits.

The timber elements are all hand sawn to rectangular sections. The rafters and tie-beams are whole logs with big sections (rafters have an average height of 31cm and base of 23cm), the posts and struts are half logs or quarters of logs. The joints are all mortice and tenon. Metal straps are used at the bottom of the posts (except for the posts on the far sides), at the top of the queen posts and between rafter ends and tie-beams (Figure 231 left), to secure the connections and allow them to work in tension. The posts are reinforced by joggles where the struts spring. The tie-beams of the transversal trusses are composed of two elements, joined with a simple scarf joint. Some timbers are numbered with small chiselled roman numerals (Figure 231 centre).

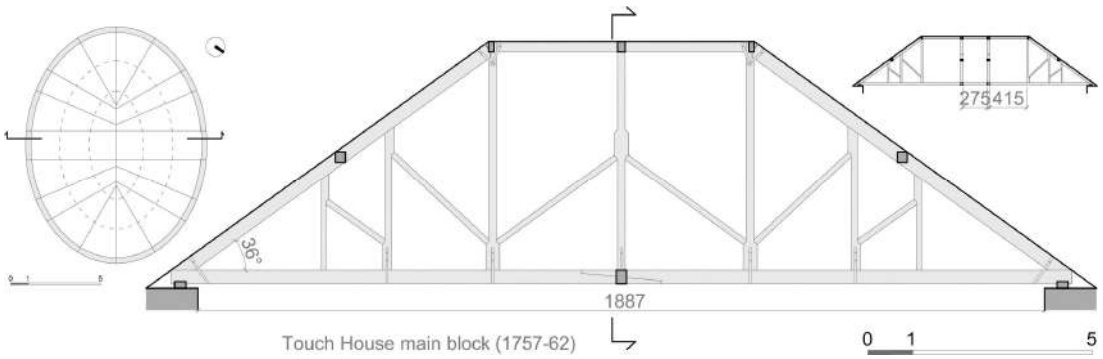


Figure 230: The roof of St Andrew and St George's church (1782-4)

All the timber elements, including the sarking, are made of *pinus sylvestris*. The timbers are of good quality, mostly belonging to Strength Class I and a few to Strength Class II. Three elements on the North side, however, have a Strength Class lower than III: a strut has a really big knot (Figure 231 right) and two posts have shakes all along their length.



Figure 231: The roof of St Andrew and St George's church: the connection with the wall (left), carpentry marks on a post (centre) and a big knot in a strut (right)

The structure is quite homogeneous and looks unaltered. The typology and details all suggest a dating contemporary to the church itself as they resemble other trussed roofs of the second half of the eighteenth century, such as the ones in Culzean Castle (1784 and 1791) or the Trades Hall in Glasgow (1791-4). Unfortunately no records could be found related to the construction works.

4.1.2 Current Condition

St Andrew's and St George's church is property of the Church of Scotland and is inspected regularly, on a yearly basis, although a program of works has not been implemented yet. The roof space is easily accessible, it is well lit and provided with a catwalk for inspections.

The air temperature and relative humidity have been found to be around 13° and 55% in February. These values are very near the optimal range identified by Ridout (2000) and correspond to an equilibrium moisture content of about 11% (Ross, 2010). The measured moisture contents varied from 8% to 15%, but none exceeded 18%, which would allow insects to live (Ridout, 2000); in fact there are no signs of biotic attack.

Some cracks have been identified close to the joint between a post and a strut (Figure 232), on two other posts and in the South rafter. However, the overall performance does not seem to be affected, probably also thanks to the strengthening works carried out in 2003-4, when a Vodafone plant was installed in the roof space: the joints between rafters, posts and upper beams have been strengthened with metal straps and bolts (Figure 233).



Figure 232: The roof of St Andrew and St George's church: compression cracks in a strut and in the joggle of a post

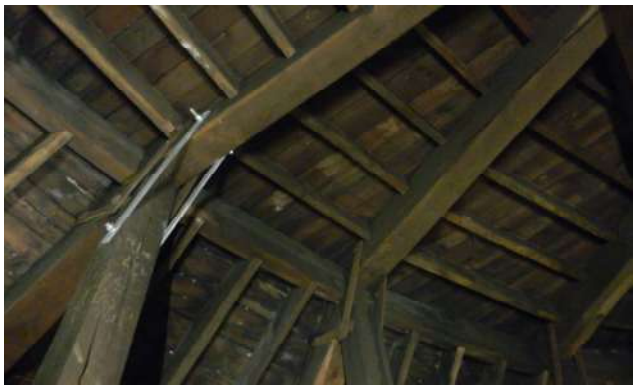


Figure 233: The roof of St Andrew and St George's church: strengthening of a joint between post and upper beam

4.2 St Andrew's in the Square church

4.2.1 Architecture and Construction

St Andrew's in the Square church is a rectangular 3-nave church in Glasgow with an entrance portico topped by a 5-stage steeple (Figure 234). It was designed and built by the wright and architect Allan Dreghorn between 1739 and 1756 (Renwick, 1911). The interiors have been altered during the end of the nineteenth century and the beginning of the twentieth century, but the original plasterwork survives unaltered. In 2000 major repair and restoration works were carried out, including a 4m deep excavation to create a basement café. We have surveyed the church roof (not the steeple): an initial assessment was carried out on 31st August 2015 and detailed investigations on 20th January and 16th February 2016 (Figure 234).



Figure 234: St Andrew's in the square church (1739-57): plan (left) and view from West (right)

The church roof is a double pitched roof sandwiched between two gable walls and supported by two transversal walls and four princess-post trusses, spaced more than 4m one from the other (Figure 235). The tie-beams are interrupted in the central part by the vaulted ceiling, but they are supported by the lateral columns. The posts sitting on these columns support the collars and rafters and have slanted struts on both sides. The trusses are connected longitudinally by two levels of butt-purlins and by sarking boards, on which slates are secured with metal nails. The overall span is 18.2m but it is reduced to 8.1 by the intermediate columns. The pitch is quite low (31°). The tie-beams sit in recesses in the lateral walls. The rafters join the tie-beams before these are supported by the walls, which causes shear stress in the tie-beam, but this does not seem to have created problems so far.

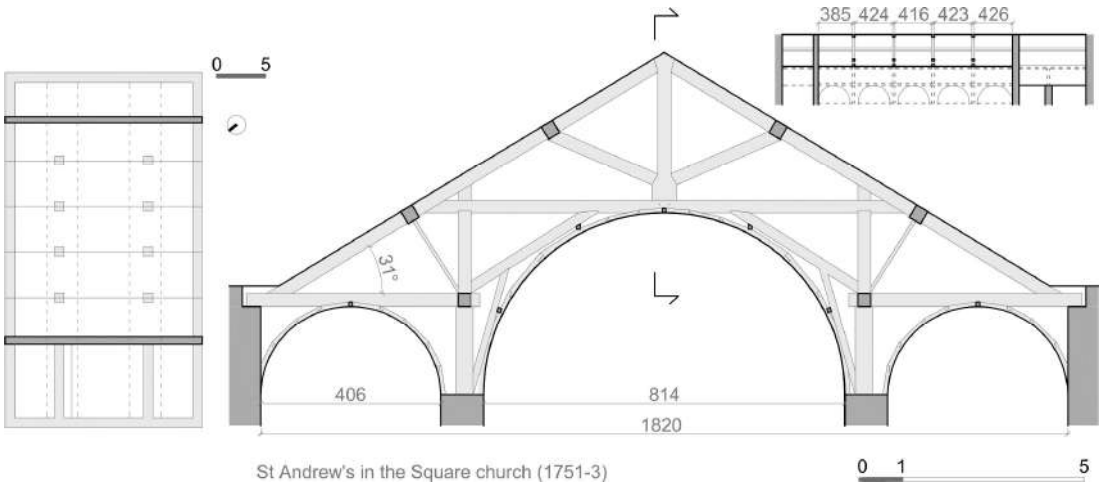


Figure 235: The roof of St Andrew's in the Square church (1751-3)

The timber elements are all whole logs, hand axed (Figure 236 left) and hand sawn to almost square sections, except for the thinner struts. The sections of the rafters are quite big (average height of 30cm and base 28cm). The joints are all mortice and tenon secured by timber dowels and reinforced by joggles in the central post, notched between lateral posts/struts and collar. The elements are all working in compression and bending, even the central post: in fact no metal straps are used

anywhere. The trusses are numbered with small chiselled roman numerals, from I to IIII (from North-East to South-West). Some unusual carpentry marks have been found too (Figure 236 right).



Figure 236: The roof of St Andrew's in the Square church: the dressing of a butt-purlin (left) and unusual carpentry marks on a strut (right)

All the timber elements, including the sarking, are made of *pinus sylvestris*. Most of them have unusually narrow rings, not visible macroscopically (Figure 237). The quality of the timbers ranges from Strength Class I to III, and they do not seem to be distributed in the structure according to their quality. The presence of knots seems instead to be concentrated in less important elements, such as struts and posts, behaving in compression and therefore less affected by defects.

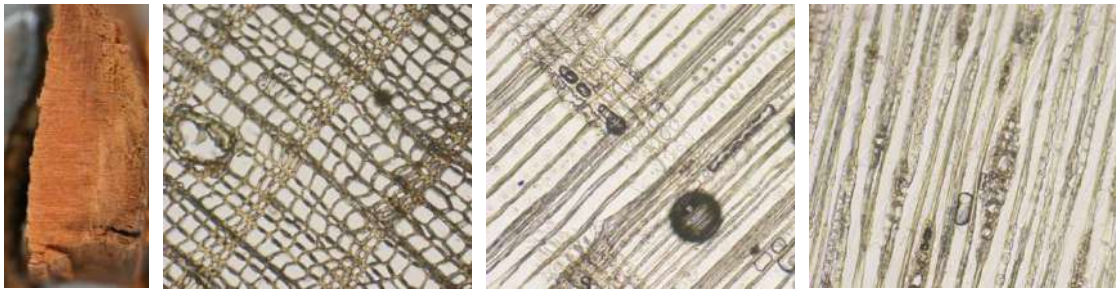


Figure 237: Sample of Scots pine extracted from a strut of the roof of St Andrew's in the Square Church: transversal section macro (left); transversal section X100 (centre left); radial section X100 (centre right); tangential section X100 (right)

The roof structure seems to be unaltered and can be confidently assumed to be contemporary to the construction of the church itself, as discussed in section 3.3.4.3. There are no accounts related to the purchase of the timber but the narrow rings of the pine samples and the unusual carpentry marks found suggest a Scandinavian/Baltic provenance.

4.2.2 Current Condition

The building is owned by Glasgow Building Preservation Trust and is inspected regularly, on a yearly basis, although a program of works has not been implemented yet. The roof structure is easily

accessible, it is well lit and provided with a catwalk for inspections. The air temperature recorded in February was 13° with a relative humidity of 56%, very near the optimal range identified by Ridout (2000) and correspond to an equilibrium moisture content of about 11% (Ross, 2010). The measured moisture contents were a bit higher but none exceeded 18% (Ridout, 2000). In spite of this, there was evidence of insect attack on the corners of the rafters and collars, as well as fungi attack near the North-West gable, affecting the butt-purlins, common rafters and sarking (Figure 238). The cause seems to be water ingress and poor ventilation. Past insect attack has been treated in 1985 by Hunter and Clark Ltd with resin injections (Figure 239), which seem to have been effective, although quite invasive, whilst the fungi attack is currently being treated.



Figure 238: Fungi attack in the North-West gable of the roof of St Andrew's in the square church, affecting the butt-purlin, the common rafter and the sarking



Figure 239: Resin injections used in 1980s to treat insect attack in the roof of St Andrew's in the square church

There are also some cracks (Figure 240), open joints and rotations (Figure 241, Figure 242), but the overall performance and the plaster ceiling underneath do not seem to be affected, perhaps thanks to the strengthening interventions carried out in 1990s: steel brackets and rods strengthening the joints between posts and collars (Figure 242) and the joints rafter/collar and strut/collar (Figure 243).



Figure 240: Cracks in a butt-purlin of the roof of St Andrew's in the square church



Figure 241: A rotation of the principal rafter causing the opening of the joint with the central post in the roof of St Andrew's in the square church



Figure 242: Rotation of the central post causing the opening of the joint with the strut and steel strengthening interventions added in 1990s in the roof of St Andrew's in the square church



Figure 243: A joint between strut and collar with steel strengthening interventions added in 1990s in the roof of St Andrew's in the square church

4.3 Cockenzie House

4.3.1 Architecture and Construction

Cockenzie House is a seventeenth-century laird's house in Tranent (East Lothian). The oldest part is the 3 storeys (plus basement) central block shaded in grey in the plan in Figure 244. We have surveyed the roof above the 1680s central block: an initial survey was carried out on 10th November 2015 and detailed investigations on 22nd January 2016 and 5th February 2016. Due to accessibility and safety issues explained below, the tests have been carried out only partially.

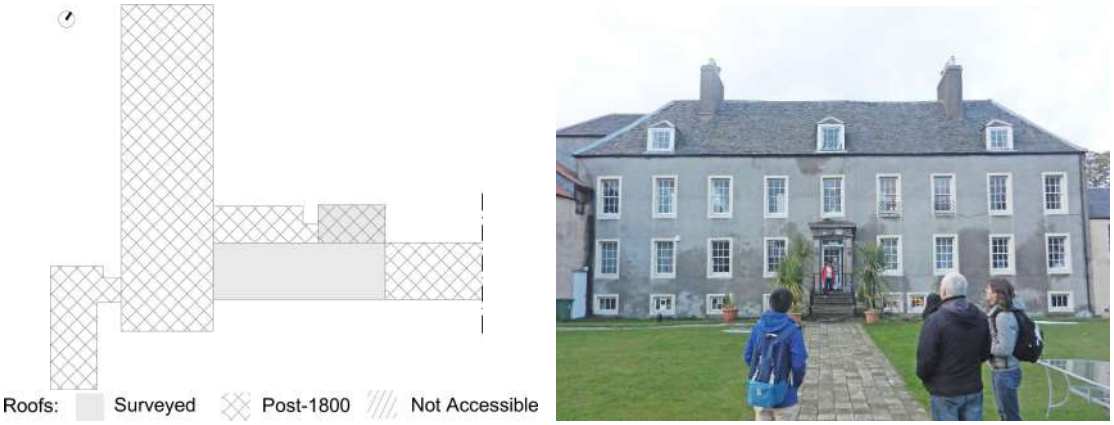


Figure 244: Cockenzie House (1680-3): plan (left) and view from South-East of the central block (right)

The roof is hipped, supported by 4 transversal walls and rafter couples spaced 40cm, connected transversally by one, two or three collars and longitudinally by sarking boards, to which slates are secured with metal nails (Figure 245). Some of the original lower collars have been removed and

others replaced and the ceiling has been lowered and is now supported by new collars. The span is 5.4m and the pitch 49°. The connection with the lateral walls is secured by Scottish rafter feet (Figure 246 centre left).

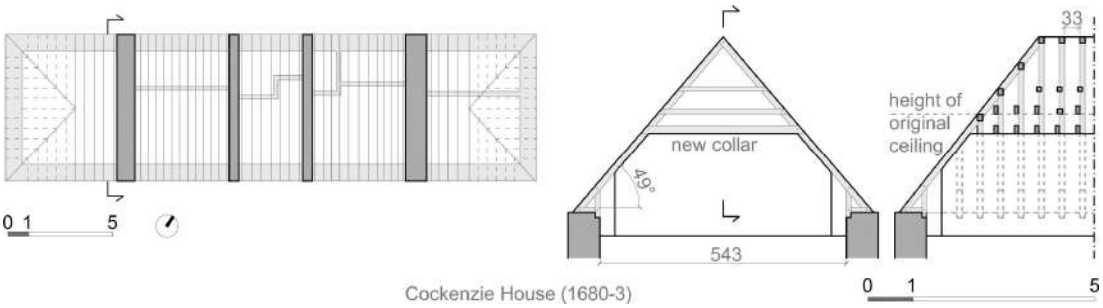


Figure 245: The roof of the central block of Cockenzie House (1680-3)

The timber elements are all whole logs roughly axed to almost square sections, leaving wanes on the corners. The sections are quite variable but small: the maximum height is 13cm and the maximum depth 11.5cm. The joints are mortise and tenon secured with timber pegs in the rafter feet, lapped and secured with timber pegs at the rafters' apex, lapped chamfered secured with metal nails between rafters and collars (Figure 246 right). Some timbers are numbered with roughly sawn roman numerals occupying the whole section of the members (Figure 246 centre right), not in sequence.

The timber elements are all made of *pinus sylvestris*, generally of good quality, belonging mainly to Strength Class I or II. The fact that good quality timber was chosen for Cockenzie House's roof supports the hypothesis that this was a high status building.

Rock suggests that, since the two inner transversal walls are thicker than the outer walls, the core of the house is of earlier date. The roof structure is nevertheless homogeneous in arrangement and construction details: if there was an earlier roof it must have been replaced when the house was extended in 1680-3. Some redundant joints have been found on timbers on site (Figure 246 left), and some timbers seem to have a more rough dressing, with some bark left on the corners. These timbers might have been reused from the earlier roof.

The dating of the roof structure to end seventeenth century rather than earlier is suggested by two details: the use of hip rafters and the use of lapped joints secured with metal nails (section 3.3). In fact, the first hip rafters can be found in the North range of Holyrood Palace (1671-9) and in Kinross House (1679-93) and the use of lapped joints secured with metal nails can be first seen in Cowane Hospital (1637-48). The dating of Cockenzie's roof to end seventeenth century is also endorsed by the comparison with similar roofs such as the one in the West range of Royston House (1683-96) or the ones in Methven Castle (1678).



Figure 246: The roof of Cockenzie House: redundant joint on a collar (left), rafter feet (centre left), big sawn roman numerals on a rafter (centre right), lap joint between collar and rafter secured by metal nail (right)

4.3.2 Current Condition

The roof structure of Cockenzie House is only partly visible and accessible, because the lower part is plastered and occupied by attic rooms. This hinders the inspection and maintenance of the connection with the lateral walls, which is a critical point. The rafter feet are visible only from the North-East roof and in a room in the South-West section of the House, where the plaster boards have been removed. Hatches give access to the upper part of the structure, but lighting and walking boards are not provided and some sections of the roof space are partly occupied by water tanks. The current tenants have occupied the building only since 2012 and are looking for funds to carry out the necessary maintenance and repair works.

The air temperature in January was 9°, with a relative humidity higher than 80%, even in the attic rooms. These values fall well out of the optimal range identified by Ridout (2000) and correspond to an equilibrium moisture content of about 17%, which is very high (Ross, 2010). Nevertheless, the measured moisture contents exceeded 18% in all measurement points except for one, and only 5 measurement points did not exceed 20% (Figure 247). The reasons are more than one: the attic rooms are not in use and so they remain unheated all year long; the sarking is broken in many areas allowing water ingress (Figure 248); the flashings probably have problems as well, since the masonry gables are wet, disintegrating into dust and falling on the timbers and ceiling underneath; some roof spaces are occupied by open-air water tanks (Figure 249). These problems have been identified in the thermographic images as well (Figure 250, Figure 251).

The recorded values of air relative humidity and wood moisture content are quite worrying also because they reduce the timbers' strength (Kasal and Lear, 2010). Considering that the timbers are quite slim and that they are carrying the additional load of the full water tanks it is surprising that no signs of distress or deformation have been found in the roof structure. There is active insect attack on a few rafters (Figure 252) and fungi attack was identified in a rafter foot (Figure 253), but no deflections, cracking or other types of failure have been identified. This does not rule out the

possibility of a brittle failure, which is why it has been advised by a structural engineer to stop the surveys. This is why the assessment of Cockenzie's roof has been only partially completed.

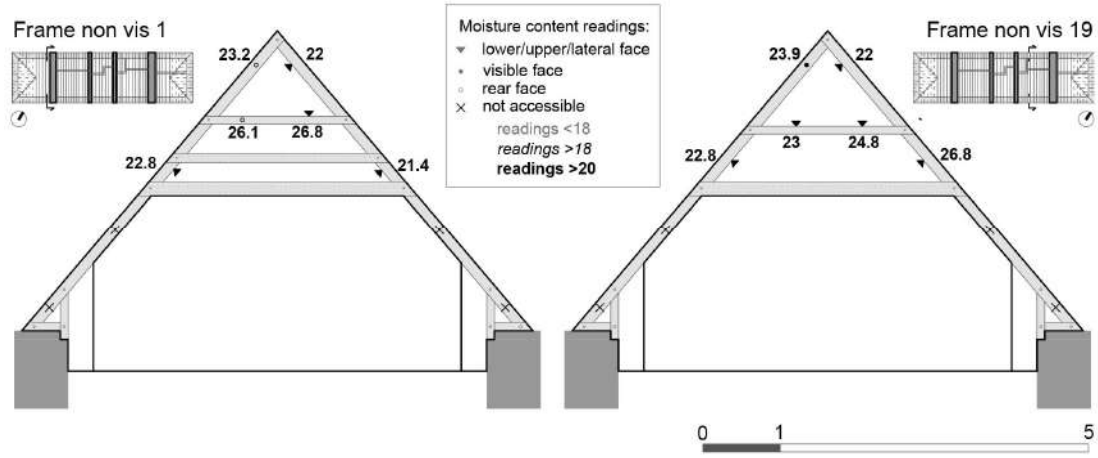


Figure 247: Moisture content readings in two frames of Cockenzie House



Figure 248: Broken sarking in the roof of Cockenzie House



Figure 249: Open-air water tanks in the roof of Cockenzie House

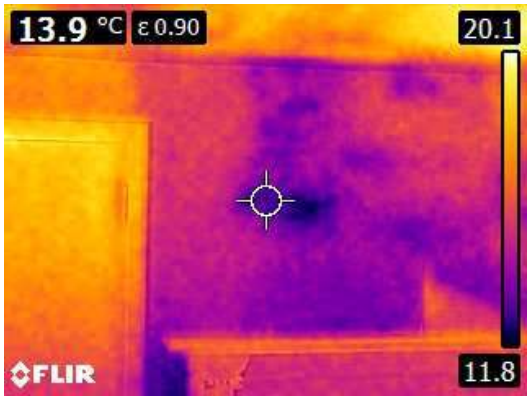


Figure 250: Thermal image showing humidity stains on the inner West gable of the attic of Cockenzie House

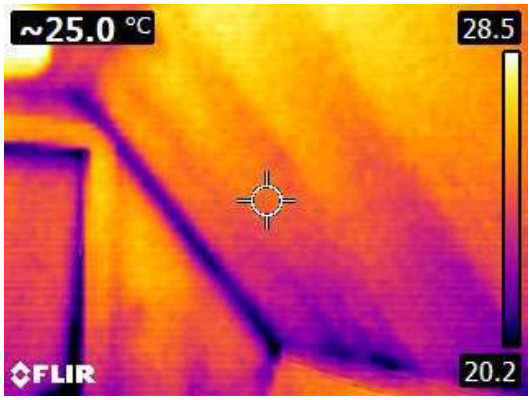


Figure 251: Thermal image showing lower temperatures in proximity of the flashings in the attic of Cockenzie House



Figure 252: Insect attack on a rafter in the roof of Cockenzie House



Figure 253: Fungi attack on a rafter foot in the roof of Cockenzie House

4.4 Holyrood Palace

4.4.1 Architecture and Construction

Holyrood Palace in Edinburgh was born as a monastery in the twelfth century. It became the Royal residence in sixteenth century, when James IV built a palace in the outer court of the Abbey, with a tower, a hall, a chapel and a gatehouse (Gifford, 1984a). What we see today is the result of the renovation works carried out by Sir William Bruce, Robert Mylne and Mr James Smith in 1670s (NRS GD29/94, 1679): they rebuilt the palace with a quadrangle form incorporating the sixteenth century tower to the North-West and mirroring it with another tower to the South-West (Figure 254). The West range is two storeys high and has a flat roof, whilst the other ranges are three storeys high and have hipped platform roofs (Figure 254). Continuous repairs and redecorations were carried out during the eighteenth and nineteenth centuries; in particular, Robert Reid rebuilt the South-West corner tower and refaced the entire South front in ashlar between 1824-34 (Gifford, 1984a).

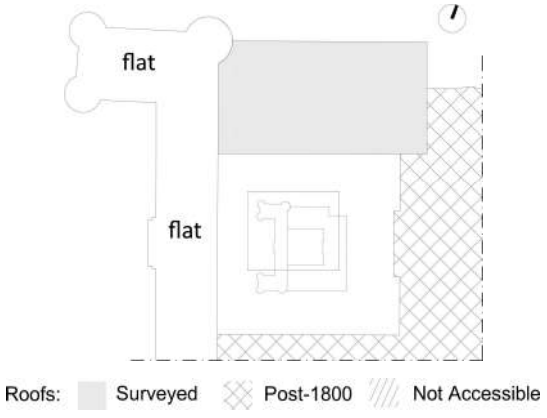




Figure 254: Holyrood Palace (mainly sixteenth century and 1671-9): plan (left) and view from West (right)

Amongst the non-flat roofs of the Palace, the North range is the only one retaining the original seventeenth-century structure. The arrangements and details of the roof structures of the other ranges, as well as various archival references, suggest a later date. Some damage caused by water ingress or fire is in fact recorded in letters of the Duke of Hamilton (Crae, Undated) and accounts of Mr J. Smith (EUL LAII87/1A, 1684-7), and replacements/repairs of roofs are mentioned in many eighteenth/nineteenth century works, although the extent and location are not always clear (Crae, Undated, EUL LAII88/3, 1721-1805, Historic Environment Scotland website - Holyrood Palace, 2016).

On the other hand, there are no records of major works carried out on the North range roof structure after its construction in 1670s. It seems that repair works here were limited to the sarking and slates/lead, which seem in fact to be of later date. Thus we have surveyed only the roof above the North range: an initial survey was carried out on 8th September 2014 and detailed investigations on 12th February 2016, 2nd June 2016, 15th June 2016 and 28th June 2016 (accompanied by Erasmus trainee Giulia Spigarelli during the last three dates).

The North range has a hipped platform roof supported by an intermediate longitudinal wall (Figure 255). The complex frames are composed of horizontal beams spaced 40cm that span transversally and sit on this intermediate wall; at their ends they are joined with the rafters with mortice and tenon joints secured by wooden pegs. The ceiling of the attic rooms is suppoprted by lower horizontal beams that span from the intermediate wall to the rafters, to which they are joined with dovetail lapped joints secured with metal nails. The rafters and upper beams are covered with sarking boards to which slates (on the slope) and lead (on the platform) are secured with metal nails. Slanted struts spring from the lower beams to provide additional support to the roof ridges. The dressing of some of these struts suggests that they have been replaced at a later date. Other slanted struts are used at a lower level to mirror the angle produced by the rafters in the ceiling of the attic rooms. The struts are secured with lapped joints and metal nails. The overall span is 14.6m, but it is reduced by the intermediate wall to 8.2m, and the pitch is 54°.

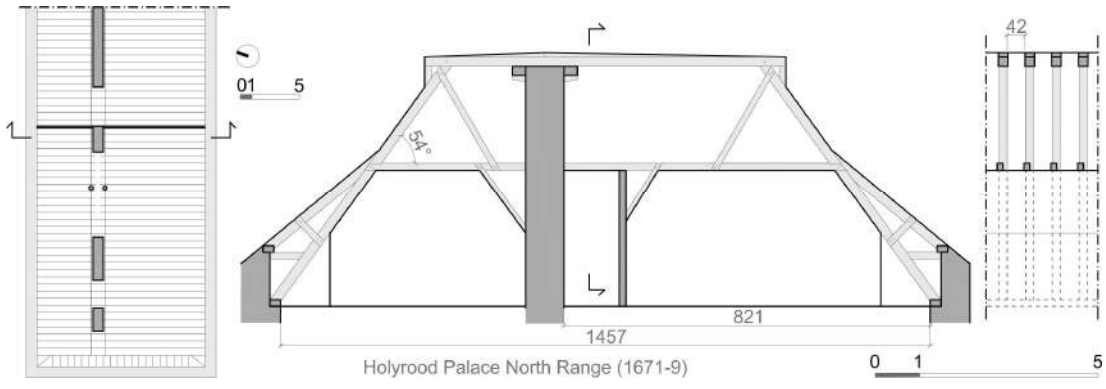


Figure 255: The roof of the North range of Holyrood Palace (1671-9)



Figure 256: The connection with the wall of the roof of the North range of Holyrood Palace seen from the roof space



Figure 257: Strengthening of the rafter ends and floor beams on the South side of the North range of Holyrood Palace

The rafter ends sit on a wall-plate and are protected by the wall-head which rises higher behind them and supports sprocket rafters (Figure 255, Figure 256). This arrangement is quite rare, as discussed in section 3.3.2.2. Some rafter ends on the South side have been partly replaced with prosthesis and strengthened with additional timbers bolted to their sides in order to be able to support the floor beams below (Figure 257).

All timber elements are hand axed whole logs (Figure 258). The sections are more rectangular and bigger than previous roofs (21x18cm - height x base), but they still retain some wane. The struts are smaller and more roughly dressed, with some bark on the corners. All frames are numbered with roughly sawn roman numerals occupying the whole section of the members (Figure 258 left), going from IIII (West) to XXXXX (East). This suggests that four other frames were previsouly in place on the Western side, but no evidence of alterations has been found. The rafters, upper beams, struts and sarking have been identified as *pinus sylvestris*, the pegs securing the joints between rafters and upper beams as *quercus sp*. The use of oak for the pegs highlights the high status of the building as in all other surveyed roof structures of this period pegs have been found to be of pinus sylvestris.



Figure 258: The roof of the North range of Holyrood Palace: the dressing and carpentry marks on two rafters (left), the joint between rafter and upper beam (centre), unusual carpentry marks on a rafter (right)

The dating of the North range roof structure to late seventeenth century is endorsed by the comparison with the roof structures of Kinross House (1679-93) and Melville House (1697-1703), which are very similar to Holyrood's in terms of both overall arrangements and details. The three structures are innovative because they employ tension absorbing joints (dovetail joints) and elements (struts, collars), as discussed in section 0.

The timber used for the renovation works in 1670s/80s was brought from Norway and Linlithgow Mill (NRS E36/30, 1671-1678, EUL LAII87/7, 1686). A few unusual carpentry marks found on site (Figure 258 centre and right) confirm this Scandinavian provenance. The work was carried out by wrights James Baine, Alexander Eizat and James Mcfarland, who also furnished part of the timber (NRS E36/30, 1671-1678, NRS GD29/100, 1678, NRS GD29/94, 1679, EUL LAII87/1A, 1684-7). Even though the roof structure is never mentioned it might have been designed by one of these three wrights, and being Baine the Royal Master Wright he is the number one candidate. James Mccleland and John Hamilton are mentioned too, but only during works in 1680s (EUL LAII87/6, 1684-6). A few timbers might have been reused from the previous roof, as suggested by an archival document (NLS MS14493/37, 1660) and redundant joints found on site (Figure 259).



Figure 259: Redundant joints in purlin on West side of the roof of the North range of Holyrood Palace

4.4.2 Current Condition

Holyrood Palace is property of the Crown but is in care of Historic Environment Scotland since 2000, thus inspections and maintenance works are carried out every 5 years in the roof. The roof structure of the North range is reasonably accessible and visible in all its parts. The lower part of the structure is plastered and occupied by attic rooms, but there are hatches at regular intervals.

The air temperature measured in the roof space varied from an average of 11° in February to an average of 19.5° in June, but the air relative humidity was always lower than 65% (average of 55% in February and of 54% in June). These values fall into the optimal range identified by Ridout (2000) and correspond to an equilibrium moisture content of about 9% in February and of 10% in June, when the moisture content readings were taken (Ross, 2010). Most of the measured moisture

contents were quite higher, but only 6 out of a 119 were higher than 18% and only one was higher than 20%. In none of these points the micro-drill test has highlighted extensive material degradation, but traces of active insect attack have been found in other areas, suggesting that climatic conditions should be monitored regularly.

Most of the identified traces of insect and fungi attack are old and inactive; the roof has been treated in 1960s with insecticides (Figure 260) (personal comment of HES technician John Crae). However, traces of new bore dust in some areas suggest an active attack that should be monitored (Figure 261). In particular, the pegs securing many joints between rafters and upper beams are seriously degraded; some of them have almost disappeared. This can cause the disconnection and slip of these joints, which has already happened in some frames (Figure 262). Different kinds of fungi attack have been identified too, although the type and status (active or not) could not be identified (Figure 263).



Figure 260: Old insect attack treated with insecticides on a purlin of the roof of the North range of Holyrood Palace



Figure 261: New bore dust suggesting active attack on a strut of the roof of the North range of Holyrood Palace



Figure 262: A degraded peg causing the disconnection and slip of a joint between rafter and upper beam of the roof of the North range of Holyrood Palace



Figure 263: Fungi attack - status and type not identified - on a beam of the roof of the North range of Holyrood Palace

The timbers are of variable quality, ranging from Strength Class I to lower than Strength Class III. The latter are all struts whose main problem are deep drying fissures on both sides, which reduce the height of the resisting section. Nevertheless these elements are mainly charged in compression as

their role is to counteract the natural tendency of the joint between rafter and upper beam to fall inwards, thus the effect of defects on their performance is limited (Cruz et al., 2015). It is interesting to note that the worst quality timbers have been used for compression purposes. Other elements fall into Strength Class III or II because of the deviated slope of grain or big knots, but most of these defects are not located in critical areas.

The micro-drill test has identified external and internal section loss in many elements, in particular struts, but also rafters and upper beams. Most of it is limited (>2cm total depth), but in a few cases it is extensive (Figure 264, Figure 265). This does not seem to have caused serious problems so far, probably due to the redundancy of the structure.

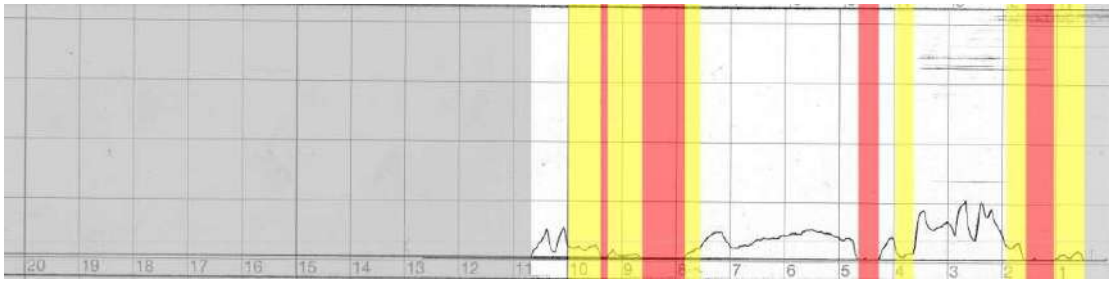


Figure 264: Micro-drill graph of point a in the North strut of frame 42 of the roof of the North range of Holyrood Palace identifying external and internal section loss

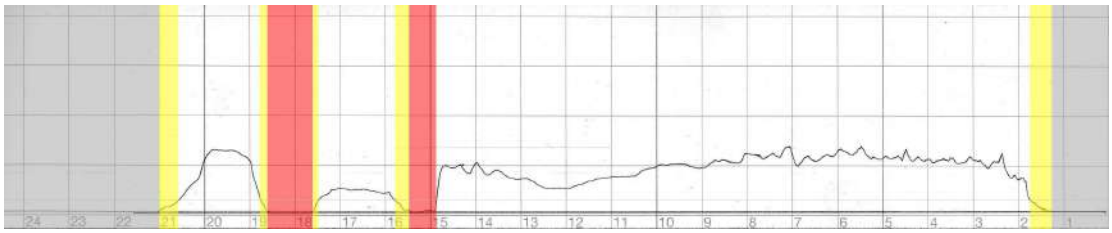


Figure 265: Micro-drill graph of point b in the South upper beam of frame 19 of the roof of the North range of Holyrood Palace identifying external and internal section loss

4.5 Newhailes House

4.5.1 Architecture and Construction

Newhailes House, previously called Broughton and Whitehill, is a 4-storeys oblong country house in Inveresk (East Lothian), whose architectural history has been recently unveiled by Rock (2016) (Figure 266). Rock affirms that James Smith did not build the house in 1686, as previously thought, but only after 1702, probably incorporating the ruins of a Chapel or previous manor house in the lower part of the North-West wing. The South-East wing, where the library is, was added in 1720 and the North-West wing, where the state apartments are, in 1733-51.



Figure 266: Newhailes House (1702-51): plan (left) and view from South-West (right)

The roof of the North-West wing is the only accessible one (Figure 266). We carried out an initial survey on 18th September 2014 and detailed investigations on 3rd June 2016 (accompanied by Erasmus trainee Giulia Spigarelli).

It is a particularly interesting roof as it is not similar to any other roof we have surveyed. It is a platform hipped roof supported by 8 complex frames, spaced about 1/1.3m one from the other (Figure 267). Each frame is composed of two rafters, an upper beam, a collar, a central post and two pairs of struts, crossing each other: two struts connect the rafter to the upper beam and two struts connect the upper beam to the collar. There is no tie-beam, to leave space for the partially vaulted ceiling underneath. The frames support common rafters, small purlins and the sarking, to which lead (on the platform) and slates (on the slopes) are secured with metal nails. The total span is 8.3m, reduced on the Southern side by an intermediate wall, and the pitch is 43°. The connection with the wall is not clearly visible but it seems that the rafters simply sit on a wall-plate (Figure 267).

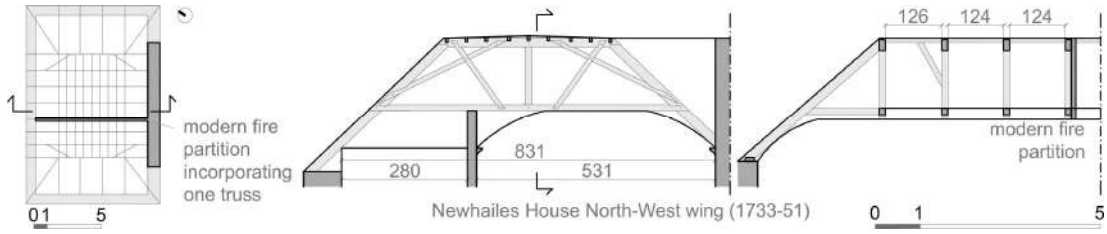


Figure 267: The roof of the North-West wing of Newhailes House (1733-51)

These complex frames could be regarded as the first Scottish trusses. They work in reverse if compared to normal king-post trusses: the struts that link the collar to the upper beam work in tension, pulling up the centre of the collar and allowing the post to work in compression, pushing up the centre of the upper beam. The struts that link the upper beam and the rafters help to counteract the opening of the rafters and to reinforce the joint between rafters and upper beams. The joints are designed according to the forces they have to counteract: dovetail lap joints for the struts and collar (secured with metal nails) (Figure 268 left), working in tension, and mortice and tenon joints for the post (secured with timber dowels and wedges), working in compression. The mortice and tenon joint

at the top of the rafters is notched to prevent them from slipping downwards. The notched lapped cross joint between the struts is the only one we have found in Scotland.

The timber elements have varying scantlings and different dressing: the struts and posts are quarters of a log, with two hand axed faces and two hand sawn faces (Figure 268 centre); the rafters and horizontal beams are instead half logs, with 3 faces hand axed and one face hand sawn. The sections are all rectangular, with no wanes. The upper beams have a varying scantling, bigger in the central part, providing a slope for the disposal of rainwater. The frames are numbered with roughly sawn roman numerals occupying the whole section of the members, from I to VIII, although not in sequence (Figure 268 right).

The rafters, upper beams, struts and sarking are made of *pinus sylvestris*, one post is *picea abies* and a peg securing the joint between the post and the upper beam and collar is *quercus sp*. This is the only example of use of *picea abies* we have found in a Scottish roof. Spruce is in fact considered to be less strong than pine and was usually used for interiors rather than structural purposes. It is interesting to note though that it has been used here for an element working in compression that is not highly stressed. The use of oak for the pegs is unusual for eighteenth century roofs and shows an awareness of oak's durability compared to pine. It also suggests that the works had a good budget allowing to retrieve the required materials since oak was more difficult to source at that time.



Figure 268: The roof of the North-West wing of Newhailes House: a dovetail lap joint between struts and upper beam (left), the dressing of a strut (centre), carpentry mark on a post (right)

The timbers have been found to be generally of very good quality, belonging to Strength Class I or II, with only one strut belonging to Class III because of a very big knot. Thus it seems that not only the species were carefully chosen for this roof but the quality of the timbers as well. Whoever designed this roof structure had a good knowledge about timber species and structural behaviour.

Unfortunately there is no record of who was in charge of the timber works of the North-West wing. The wright John Young could be a good guess since he is mentioned in the accounts starting from 1710 up to 1723 (Rock, 2016). Unfortunately we have not surveyed other roofs that are known to have been designed by John Young so we cannot confirm the attribution by comparison.

4.5.2 Current Condition

Newhailes House is property of the National Trust for Scotland since 1997, thus inspections and maintenance works are carried out every five years. The roof space of the North-West wing is easily accessible from a door in the attic rooms; nevertheless, the timber structure is only partly visible, as the rafters and their connection with the lateral walls are partly hidden by remains of plaster (the roof space was probably part of the attic rooms originally), the collars are partly hidden under floor boards. The roof structures of the rest of the house are instead completely invisible as there are no hatches giving access to any of them. This impedes necessary inspection and maintenance works.

The air temperature was 19° in June and the relative humidity 55%. These values fall within the optimal ranges identifed by Ridout (2000) and correspond to an equilibrium moisture content of about 10% (Ross, 2010). The measured moisture contents were around 14/15%, but none exceeded 18%. There are in fact no signs of biotic attack or water ingress. The ventilation is however quite poor; one of the causes might be the recent replacement of some of the sarking with floor-boards (Figure 269). Recent works include also the replacement of some of the purlins, the insertion of a fire partition and floor-boards for inspections.

The structure shows no signs of distress or deformation either. The joints of the struts are slightly open (1 cm maximum) but this simply proves that they are working in tension (Figure 270). The posts, upper beams and collars are slightly rotated, but this is because the joints of the struts are all on the same side. The lower part of the rafters might have some problems since it is highly stressed and left unsupported, but unfortunately it is not visible.



Figure 269: Recently replaced purlins and sarking boards in the roof of the North-West wing of Newhailes House



Figure 270: Cross joint between struts with an opening of 1cm in the roof of the North-West wing of Newhailes House

4.6 Pinkie House

4.6.1 Architecture and Construction

Pinkie House is an L plan mansion in Musselburgh (East Lothian). It incorporates a late sixteenth century tower house and an earlier fortalice on the North side (McWilliam, 1978). Alexander Seton, Earl of Dumferline, renovated and extended the house in 1613: he added a pair of square pepperpots at the North end of the existing tower house and raised the projecting jamb 2 storeys higher; he also built a 3 storeys long wing to the South (Figure 271 right), decorated with a beautiful painted timber ceiling at the top floor (Figure 75 right). A West wing was added at the end of seventeenth century and extended around 1800 (Figure 271). The other buildings are of later date.

We have surveyed the roof above the old tower house to the North (3 in Figure 271), the roof above the long gallery (1 in Figure 271) and a small roof on the West side of the gallery (2 in Figure 271). These roofs have been accessed for an initial survey on 9th October 2014 (accompanied by PhD student Clara Gonzalez Manich). Detailed investigations have been carried out in the roof above the long gallery on 9th March 2016 (accompanied by PhD student Clara Gonzalez Manich), 31st March 2016 (accompanied by PhD student Bowen Qiu and professor A. Macdonald) and 2nd May 2016.

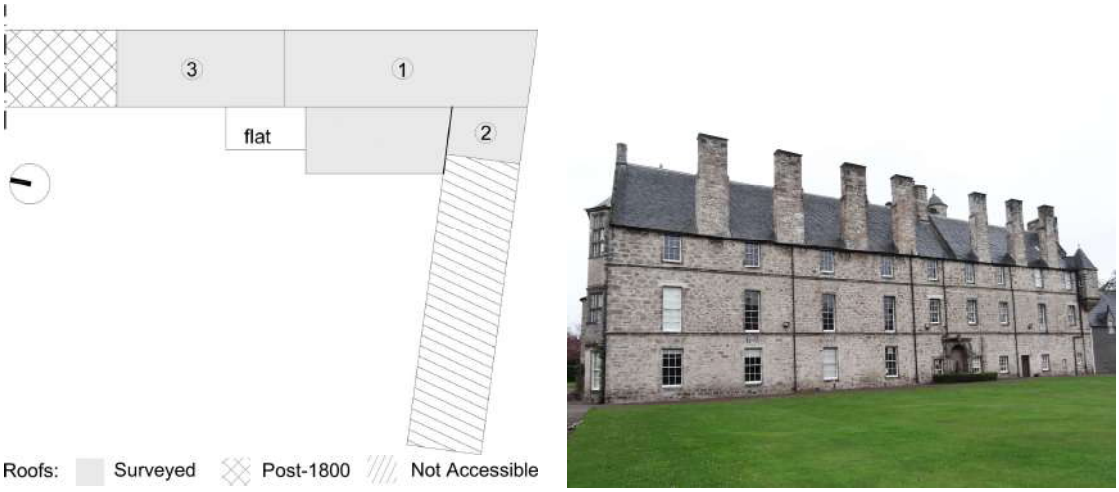


Figure 271: Pinkie House (mainly sixteenth century and 1613): plan (left) and view from East (right)

Unfortunately, as far as we know, no archival document related to the construction works carried out in 1613 remains; only the name of the patron is certain, Alexander Seton, while the design has been attributed to Sir James Murray (MacKechnie, 1994). The structural arrangement and construction details of the roof structures suggest a dating contemporary to the buildings themselves, the only exception being the small roof to the West of the long gallery (McWilliam, 1978): this roof is certainly contemporary to the one above the gallery since the arrangement and construction details are exactly the same (see form in Appendix F). This contradicts previous

statements related to the dating of the West wing: its eastern section is of early seventeenth-century date rather than late seventeenth-century.

The roof above the long gallery is a double pitch roof sandwiched between two gable walls and supported by 50 frames (Figure 272). The frames are composed of rafter couples spaced 35cm, connected trasversally by three collars (the intermediate one is a later addition, as discussed below) and longitudinally by sarking boards. The lower collars support the original painted timber ceiling. The span in not eccessive (6m) but the pitch is quite steep (52°).

The connection with the wall is only partly visible, as it is mostly hidden by the ceiling and the insulation sheets. In an area on the South-West side the rafters simply sit on the wall-head (Figure 273 left). On the East side the space in between the rafters seems to be infilled with rubble masonry up to the start of the timber ceiling; this is confirmed by thermographic images which do not show any differences in temperature below the ceiling (Figure 273 right). In correspondance of windows and chimney stacks the rafter ends are supported by butt-purlins morticed in the rafters.

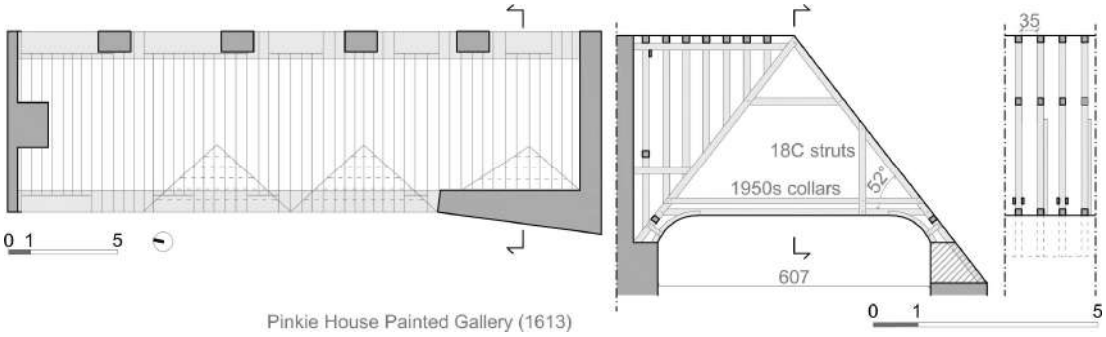


Figure 272: The roof of the long gallery at Pinkie House (1613)

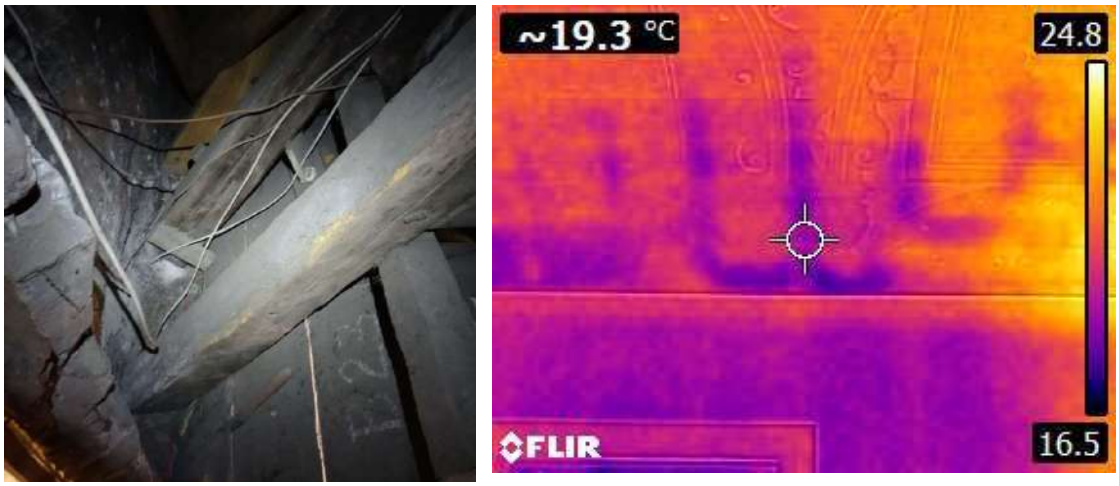


Figure 273: The roof of the long gallery at Pinkie House: the connection with the wall on the West side, with the rafters simply sitting on the wall-head (left), a thermographic image of the wall-head and ceiling on the East side, taken from the gallery below (right)

The timber elements are all whole logs roughly axed to a square section, leaving significant wanes and often some bark on the corners (Figure 274). The sections are quite variable but the height almost never exceeds 15cm and the base 14cm. All joints are mortice and tenon secured with timber pegs, used also to secure the slates to the sarking (Figure 274). The timbers are numbered with roughly sawn roman numerals occupying the whole section of the members (Figure 274). Similar arrangements and details can be found in contemporary roofs such as the one in Craigston Castle (1604) or Culross Palace (1597-1610).

The timber species has been microscopically identified as *pinus sylvestris* for rafters, collars and sarking, and *quercus sp*. for the pegs used for both the joints and the sarking. No unusual carpentry marks have been found. The quality of the timbers is variable, ranging from Strength Class I to lower than Class III. However, the lower class timbers are not many and even though one fourth of the rafters has defects in the central section, the most stressed, most of them are in class I or II.



Figure 274: The roof of the long gallery at Pinkie House: the dressing of the rafters (left), the oak pegs securing the slates to the sarking (centre left), carpentry marks on collars (centre right), mortice and tenon joint between rafter and collar secured with a timber peg (right)

Despite the good quality of the timber, the roof has been strengthened more than once. Some minor works are reported in eighteenth century, but not specified (NLS MS14716, 1768-78). Part of these works might have been the addition of vertical struts connecting the rafters and the lower collars on the East side. Judging from the dressing (sawn rather than axed), the scantling (more rectangular) and the metal nails (rather than wooden pegs) used to join these struts to rafters and collars, they are not part of the original construction. They were probably inserted to provide additional support to the lower collars, burdened by the weight of the timber ceiling underneath.

A report by HES technical officer WR Adams written in May 1954 (HES report by Adams, 1954), together with a drawing by Lorimer (Figure 275), describe and show the strengthening intervention carried out in 1950s to counteract the opening of the roof structure and the consequent cracking of the ceiling underneath. The problem had probably arisen because of the heating started in 1950s, when it became a private school. The structural strengthening intervention is still visible today and

consists of two collar beams added on the two sides of the rafters of one frame every two (Figure 276). The collars are positioned above the original ones that still support the ceiling, thus the former only restrain the opening of the rafters and provide a support for a catwalk for inspections. In addition, some rafters have been reinforced in their lower end with additional timber elements bolted on their sides.

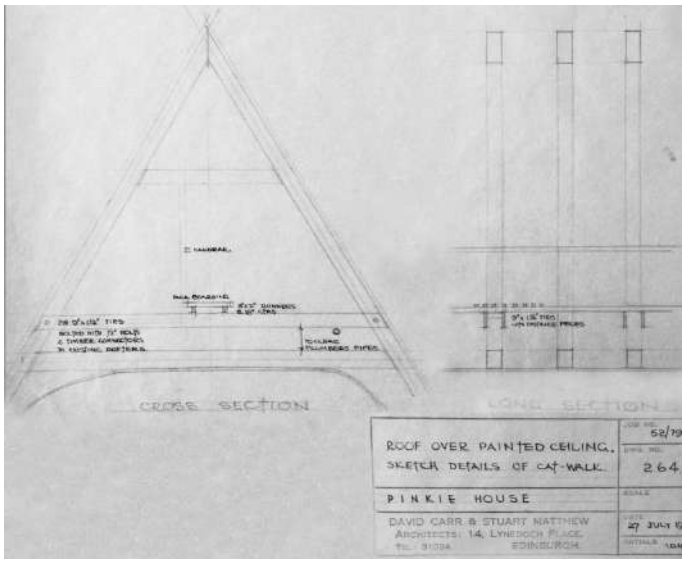


Figure 275: Drawing showing the strengthening intervention carried out in 1950s in the roof of the long gallery at Pinkie House (RCAHMS LOR/M/17/5, 1953)



Figure 276: Struts probably added in eighteenth century and double collars added in 1950s in the roof of the long gallery at Pinkie House

4.6.2 Current Condition

The building is property of Loretto School since 1950s and has a regular inspection regime in place, although a program of works has not been implemented yet. The roof structure of the long gallery is easily accessible and provided with a catwalk and lighting. The only part of the structure that is difficult to assess is the connection with the lateral walls, due to visibility issues discussed above.

The roof space seems to be well ventilated, thanks to the fact that nothing lies in between the sarking and the slates on the East side (the West side has been resarked with the addition of modern waterproof sheets), allowing air to pass in the 1-2cm gap between the sarking boards. In March the air temperature was 15° and the air relative humidity 50%, falling into the optimal range identified by Ridout (2000) and corresponding to an equilibrium moisture content of about 9.5% (Ross, 2010). All measured moisture contents were quite higher, but out of a total of 61 measurements only 17 exceeded 18% and only 1 exceeded 20%. Even though most timbers show diffuse insect exit holes, no fresh bore dust was found. The high moisture contents are evidently due to age (Ridout, 2000).

Some rafters and collars seem to have been treated against insect attacks, and portions of the timber sections have been removed. A letter dated July 1973 (Rentokil, 1973) held by HES details proposed chemical insecticidal treatment of the main roof space and provision of a thermal kilt by Rentokil (Ratsouris Scotland Ltd). It seems that this has been carried out and has been effective.

Since Pinkie's was the first roof where the ultrasonic and micro-drill tests were used some reference measurements were taken on reference frame I, even where the moisture content recorded was low. The micro-drill confirmed that the reduction of the resisting section caused by past biotic attack is in most cases concentrated in the sapwood and very limited (>1cm total depth). In one point only internal damage was identified (Figure 277) - probably a shake - and in one only extensive (>4cm total depth) external damage (Figure 278).

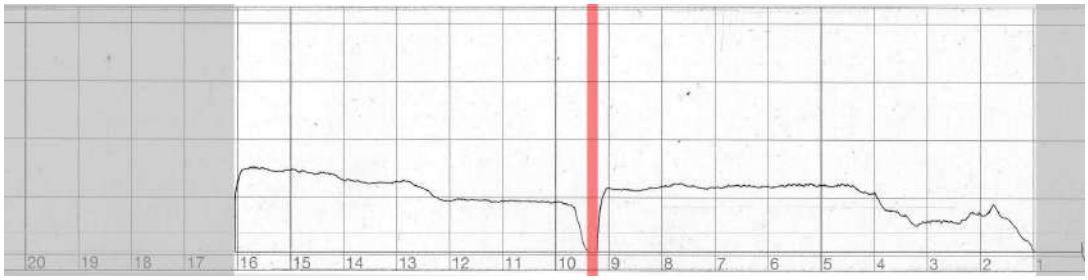


Figure 277: Micro-drill graph of measurement point 10 on frame I of the long gallery roof at Pinkie House

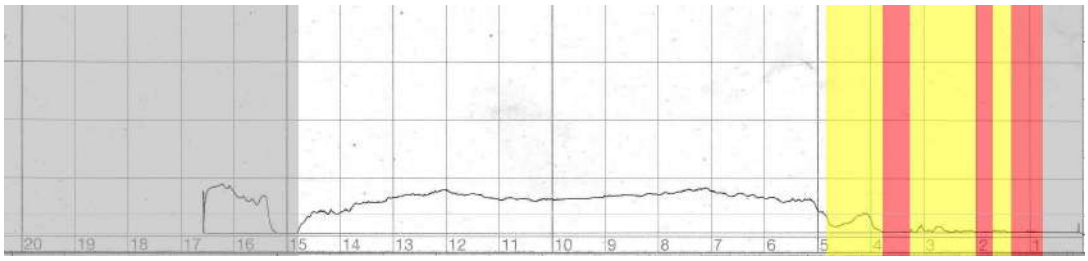


Figure 278: Micro-drill graph of measurement point 1 on frame XVII of the long gallery roof at Pinkie House

On the other hand more than half of the pegs securing the mortice and tenon joints between the rafters and the upper collars are deteriorated, some have almost disappeared (Figure 279). This has not created problems in the upper collar (charged in compression mainly), but it has created problems in the lower collars (charged in tension and bending): more than half of the visible joints have opened, and some of these failures are attributable to broken pegs (Figure 280). Other joints have failed because the part of the rafter covering the peg was too thin (Figure 281). These failed joints are probably the reason why in 1950s additional collars have been added. The strengthening intervention probably solved the problem as the ceiling has not been cracking since then.

A preliminary structural analysis based on all this information has been carried out by Professor Angus Macdonald (Macdonald, unpublished), who has concluded that the connection between the rafters and the lateral walls is the most critical point of the roof structure. The roof structure has in

fact been found to be adequate for all conditions of support, but the factor of safety against strength failure has been found to be minimal if the connection at the wall-head is incapable of producing a significant horizontal reaction. Judging from what is visible from the roof space, the rafters simply sit on the wall-head and the space in between them is in-filled with rubble masonry. As suggested by professor Macdonald, although this arrangement is quite minimal, it is reasonable to assume that it develops a significant horizontal reaction since the overall condition of the roof structure is good. Moreover, the structural analysis has highlighted that the integrity of the joint between the lower collars and the rafters is critical to the overall structural functioning of the roof if no horizontal reaction is present at the wall-head. The fact that some of the connections have failed without causing significant distress to the overall roof is a further indication that the connection at the wall-head is providing a significant horizontal reaction.



Figure 279: A degraded peg in a mortice and tenon joint between rafter and upper collar in the roof of the long gallery at Pinkie House



Figure 280: A failed joint between rafter and lower collar with an opening of 8cm in the roof of the long gallery at Pinkie House; the peg is broken



Figure 281: A failed joint between rafter and lower collar with an opening of 4cm in the roof of the long gallery at Pinkie House; the rafter is broken

4.7 Stirling Castle

4.7.1 Architecture and Construction

The history of Stirling Castle dates back to at least the twelfth century (Gifford, 2002). However, the oldest surviving building inside the Castle is the fourteenth century North gate, followed by the sixteenth century Great Hall (1503), Palace (1530-55), King's Old Buidlings (1557) and Chapel Royal (1594). The remaining buildings and defences are of eighteenth- and nineteenth-century date. The West range of the palace was rebuilt in early seventeenth century, after part of it had collapsed, and the North and East wings of the King's Old Buidlings were rebuilt after a fire in 1855. However,

besides these alterations, these buildings remain largely original. On the contrary, the Great Hall was greatly mutilated when converted into military barracks in the eighteenth century; the roof was lost and recently reconstructed. The Chapel Royal was also reroofed in nineteenth century; therefore we focused our surveys in the King's Old Buildings (Figure 282), Palace (Figure 283) and eighteenth century governor's house and regimental headquarters.

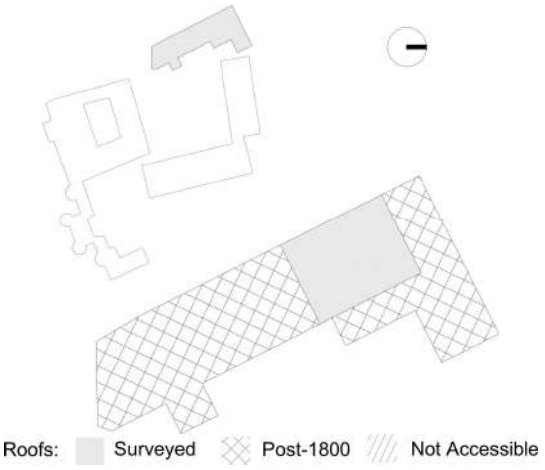




Figure 282: Stirling Castle King's Old Buildings (1557): plan (left) and view from East (right)

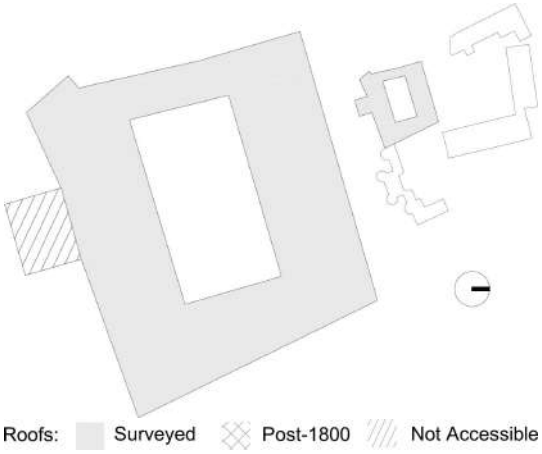




Figure 283: Stirling Castle Palace (1530-55): plan (left) and view from West (right)

We carried out an initial survey on 1st October 2014 and detailed investigations on 10th February, 7th April, 29th April (accompanied by PhD student Bowen Qiu), 20th May and 16th June 2016 (accompanied by Erasmus trainee Giulia Spigarelli on the last two dates). During the initial survey we found out that the governor's house and regimental headquarters have probably been reroofed at a later date, judging from the timber dressing and joints, therefore we have not proceeded with the measured survey in these buildings. The detailed investigations have been carried out in some roofs of the Palace and King's Old Buildings (Table 12). The measurements and tests have been carried out on 3 reference frames per roof and on additional critical elements identified during the visual inspection. The number of reference frames has been limited by constraints imposed by HES.

Table 12: Measurements and tests carried out in the roofs of Stirling Castle

STIRLING CASTLE	Timber Species Identif.	Air Temp. Humid.	Thermal camera - snake camera	Visual Strength Grading	Moisture Content Readings	Visual insp.	Rubber hammer	Ultrasonic test	Micro-drill
Palace North East Range	x	x	x	3 frames	3 frames & critical elements	all roof	3 frames & critical elements	45 points	45 points
Palace South West Range	x	x	x	3 frames	3 frames & critical elements	all roof	3 frames & critical elements	32 points	32 points
Palace North West Corner	x	x	x	all primary elements					
Palace West Range	x	x	x	3 frames					
King's Old Buildings	x	x	x						

The roof structure we have surveyed in the King's Old Buildings is a double pitch roof sandwiched between two gable walls and supported by 18 frames (Figure 284). The frames are composed of rafter couples spaced 40cm, connected transversally by two collars and longitudinally by sarking boards. The lower collars support the ceiling of the attic rooms. The span in about 7m but the pitch is quite steep (53°). Unfortunately the connection with the wall is not visible.

The timber elements have almost square scantlings (15x12cm maximum), hand axed and hand sawn (Figure 285), with no wane. This refined dressing corresponds to the high status of the building: not many patrons could afford to hire sawyers before the eighteenth century, as discussed in section 3.2.3. The joints are all mortice and tenon secured by timber pegs (Figure 285). Big roughly sawn roman numerals occupy the whole section of the elements (Figure 285), although the numbers are not in sequence. The timber elements are all made of *quercus sp*.

The use of oak for the timber elements suggests an early date, since oak is very rarely used after 1600: we have not found it in any other seventeenth- or eighteenth-century roof (except for pegs in Pinkie House, Holyrood Palace, Newhailes House). The arrangement and details are also in line with the earliest Scottish roof structures we know of, such as the one in Alloa Tower (Ruddock, 1995) or in the late sixteenth-century North range at Pinkie House. Thus it seems reasonable to think that this is the original sixteenth century roof structure. One detail is interesting and has not been found in any other roof: the rafters are composed each of two elements joined together with a simple scarf joint secured with metal nails (Figure 285). This suggests that long oak timbers were not available at the moment of construction, which is in line with the scarcity of local and imported oak timbers that we know characterized Scotland from 1500 onwards (Newland, 2010). The use of metal nails is instead

uncommon in such early roofs, as they were normally all made of timber, pegs included, but could be explained by the high shear stresses that these simple scarf joints had to endure.

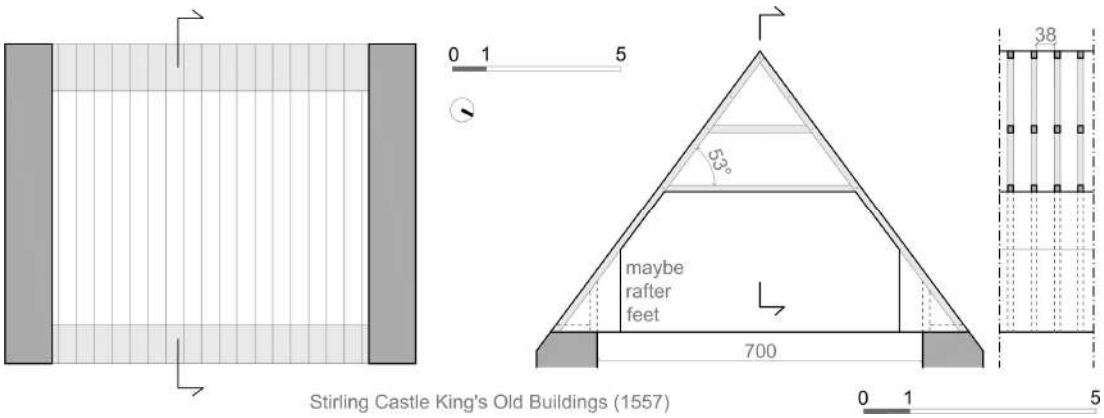


Figure 284: The roof of the King's Old Buildings (1557) at Stirling Castle



Figure 285: The roof of the King's Old Buildings: tool and carpentry marks on collars (left), mortice and tenon joint between rafter and upper collar (centre), scarf joints in rafters (right)

The Palace block, instead, clearly does not retain the original sixteenth century roof structure. The roof structures are all independent, sandwiched between two gable walls, except for the West range, which intersects both the purlin roof in the North-West corner and the common rafter roof in the South range. Although it is a composite roof, as it comprises common rafter roofs, complex frames and a purlin roof, the structures are quite homogeneous, suggesting that they belong to one single operation of re-roofing. Besides the purlin roof in the North-West corner, all the other roofs are composed of rafter couples spaced 40cm, connected trasversally by one or two collars and longitudinally by sarking boards (Figure 286). The spans range from 6.1m to 7.6m and the pitches from 43° to 47°. The rafters simply sit on the wall-heads (wall-plates have been identified only in the North-East range) and their lower ends are protected by sprocket rafters.

The timber elements are half logs, roughly squared with an axe and then sawn in half, with some wane. They have rectangular scantlings (18x8cm maximum). The collars are connected to the rafters with dovetail lap joints secured with metal nails (Figure 287 left); the rafters' apex is secured by

simple lap joints with metal nails. Big roughly sawn roman numerals occupy the whole section of the elements (Figure 287 centre), although they are not in sequence. The timber was probably imported from Scandinavia or the Baltic area since many unusual marks have been found on site.

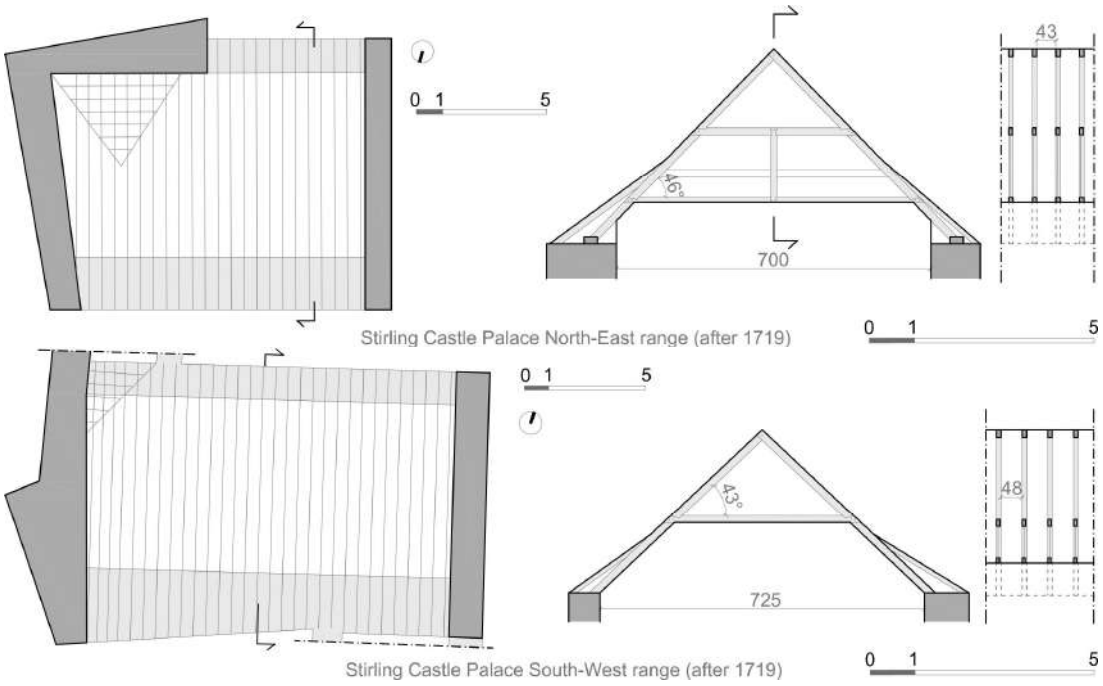


Figure 286: The roofs in the North-East (above) and South-West (below) ranges of Stirling Castle Palace (after 1719)

All the timber elements of the Palace roofs are made of *pinus sylvestris*, of variable quality, ranging from Strength Class I to lower than Strength Class III. Most of them are quite knotty, with shakes and a wavy grain (Figure 287 right). However, in most timbers these defects are not positioned in critical areas, which suggests that although high quality timber was not available or chosen for these roof structures, the wrights tried to use the timber they had in the best way possible.



Figure 287: The roofs of Stirling Castle Palace: dovetail lapped joint securing a collar to a rafter in the South-West range (left), carpentry marks on collars in the North-West range (centre), wavy grain and knots in a collar in the North-East range (right)

The timber species, dressing and details of the Palace roofs suggest a dating from 1700 onwards. The use of tension-absorbing elements (king-struts) in the North-East range (Figure 286 above) and the central part of the South range also suggest a late seventeenth- or eighteenth-century date, as discussed in section 3.2.1.2. The struts do not reach the rafters' apex and therefore fail in counteracting the collar's deflection; thus Hanke (2008) argues that they must predate the more mature king-post truss drawn by William ADam in 1721 (Figure 219). However, we have surveyed many eighteenth century roofs that refute Hanke's argument (section 3.2.1); moreover, the analysis of available archival documents suggests a different dating for the Palace roofs.

The archival documents record minor works carried out in 1671-87 (NRS E37/24, 1682, NRS GD29/92, 1671, EUL LAII87/1A, 1684-7), involving mainly re-sarking and pointing of the slates, and works carried out in 1699-1703, involving re-sarking, cutting of the rafter couples to insert windows and reinforcement of the rafters with additional timbers (NRS E37/33, 1699-1703). These reinforcement timbers are not visible today, suggesting that the existing roof structures are post-1703. Moreover, there are letters dated 1700-7 that report the efforts made to collect money to repair Stirling Castle (NRS GD124/15/216/2, 1701, NRS GD124/15/506/23, 1707, NRS GD124/15/567, 1707, NRS GD124/15/207/3, 1700) and a 1707 letter by J. Smith describing the 'dismail' condition in which the roofs of Stirling Castle are (NRS GD124/15/471, 1707). Finally, there is a survey by Thomas Moore dated 1719 which shows the roofs of the Palace with a different arrangement compared to what we see today (Figure 288). Considering that the roof of the King's Old Buildings in Moore's survey is instead very close to what we see today, it seems reasonable to think that the Palace roofs have been replaced after 1719. Unfortunately, as far as we know, there are no records of these works in the archives. Thus, it is only a hypothesis that the Royal Surveyor General J. Smith might be the responsible for the design of the new roof structures, considering that he had already employed tension-absorbing elements in both Melville House (1697-1703) and Yester House (1699-1715).

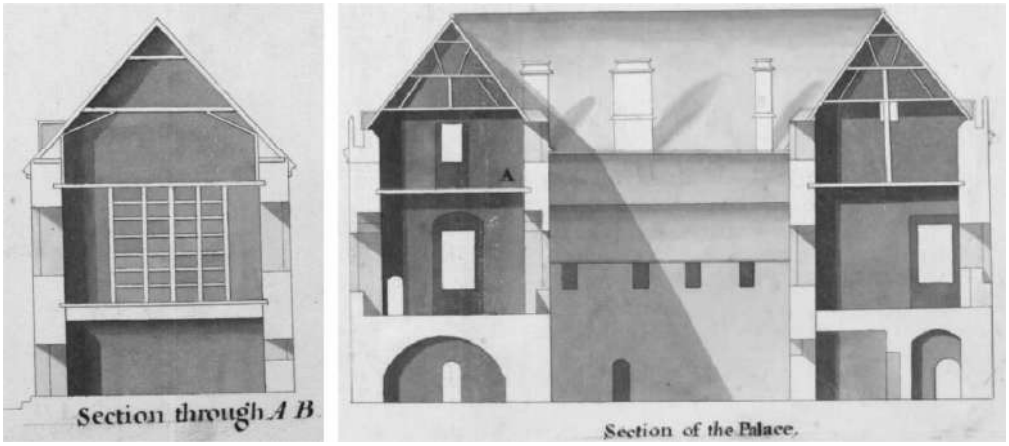


Figure 288: The roofs of Stirling Castle surveyed by Thomas Moore in 1719: the King's Old Building (NLS MS1646 Z.02/18b, 1719) and the Palace (NLS MS1646 Z.02/18b, 1719)

The North-West corner of the Palace is different from the rest of the quadrangle: it is covered with a purlin roof (Figure 289 left). The purlins are in oak and have redundant mortice and tenon joints with chase mortices (Figure 171), suggesting their reuse from another structure (perhaps the original roof). The common rafters are instead in pine and with similar scantlings and dressing to the rafters used in the other roofs of the Palace. This suggests a dating contemporary to the rest of the Palace roofs. The difference in type of structure can be explained by the fact that the longitudinal span covered in this corner is smaller than in the other ranges and therefore suitable for the use of four oak purlins that were readily available. The span is in fact reduced by a gable wall spanning North-South that is positioned only 3.7m East of the external gable. The East gable probably used to be the external one, as testified by a blocked mullion window (Figure 289 right).

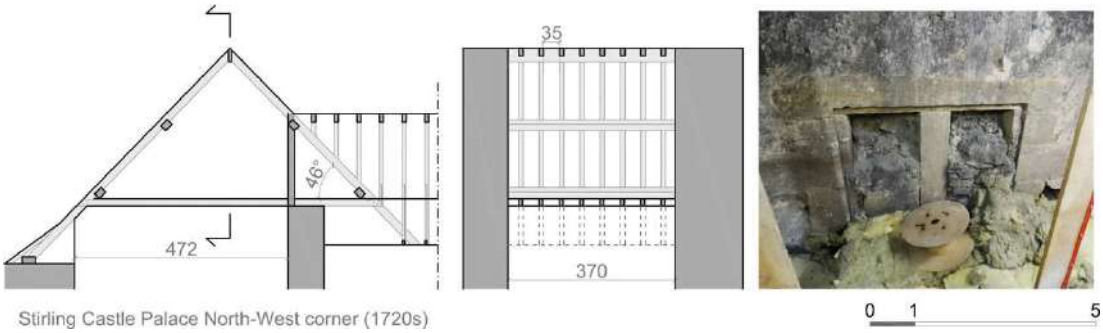


Figure 289: The roof of the North-West corner of Stirling Castle Palace (after 1719) with a picture of the blocked mullion window in the East gable

4.7.2 Current Condition

Stirling Castle is in care of Historic Environment Scotland. The roof spaces are easily accessible through hatches in the ceilings. The connection with the walls is however only partly visible and in the case of the King's Old Buildings completely invisible.

The air temperature measured in the roof spaces varied from an average of 12° in February to around 19° in June, but the air relative humidity was always lower than 67%. The West range of the Palace is the only one where the air temperature dropped to 10° in February with an air relative humidity of 73%. The West gable is in fact quite wet and the masonry is disintegrating to dust and falling on the timbers and ceiling underneath. The same is happening in the North-East range even though the values of air temperature and relative humidity were within the acceptable limits here.

The moisture content was measured in the North-East range in April (air temp. 17°, air humid. 61%) and in the South-West range in May (air temp. 18.3°, air humid. 53.7%). The corresponding equilibrium moisture content was of about 11% for the North-East range and 10% for the South-West range (Ross, 2010). All measured moisture contents were quite higher in the North-East range,

whilst they were mostly near the equilibrium one in the South-West range. Only in 8 measurement points out of a total of 109 the hygrometer measured a moisture content higher than 18% and only in 3 points the moisture content was higher than 20%. Five of these points are on king-struts in the North-East range, the other three are on rafters in both ranges.

Traces of new bore dust suggesting an active insect attack have been found mainly in rafters in the North-East and West ranges (Figure 290Figure 291) and purlins in the North-West corner (Figure 27), where possible fungi attack has been identified as well (Figure 292). The South-West range showed instead traces of an old insect attack that had already been treated (Figure 293).



Figure 290: Insect attack on a rafter in the North-East range of Stirling Castle Palace



Figure 291: Insect attack on a purlin in the North-West corner of Stirling Castle Palace



Figure 292: Fungi attack on a purlin in the North-West corner of Stirling Castle Palace



Figure 293: Old insect attack on rafter in the South-East range of Stirling Castle Palace

The micro-drill test identified external and internal section loss in some rafters and collars. Most of it is limited (>2cm total depth), but in a few cases it is extensive (Figure 294, Figure 295). This does not seem to have caused serious problems so far, probably due to the redundancy of the structure. However, since traces of active attack have been identified, the condition of the structure should be closely monitored and the water ingress problems in the West range and the North-East range should be dealt with.

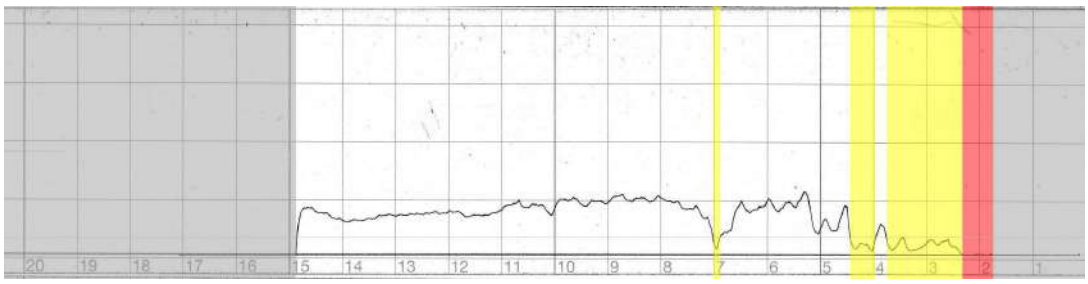


Figure 294: Micro-drill graph of point a' in the South rafter of frame 3 in the North-East range of Stirling Castle Palace identifying extensive external section loss and limited internal section loss

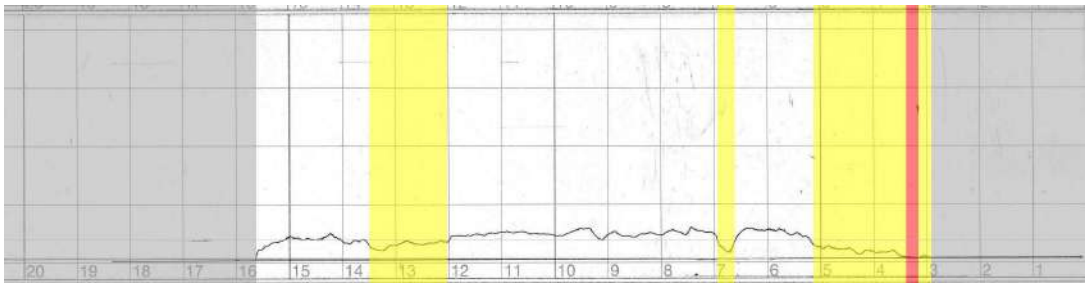


Figure 295: Micro-drill graph of point a' in the South rafter of frame 12 in the South-West range of Stirling Castle Palace identifying extensive external and internal section loss

4.8 Touch House

4.8.1 Architecture and Construction

Touch House is a country house near Stirling incorporating structures from different periods. Of the original sixteenth century building only the South-East tower and the lower portion of the North-West tower remain. The central block was replaced in 1757-62 (Gifford, 2002). The architect is not known but William Adam is often associated to this work; others hypothesize John Steinson (Gifford, 2002), not known for other works. The wright George Paterson is instead mentioned in two documents, one of 1751 (TCH letter to Mr Seton, 1751) and one of 1757 (TCH account by Paterson, 1757), where he is called 'Mr George Paterson' and buys timber for the commissioner, Hugh Seton. The fact that he is called 'Mr' suggests he had an important role in the works and that he might have been responsible even for the design of the central block. The range of offices to the North-East are instead of nineteenth-century date.

We have surveyed the roof structures of the central block (1 in Figure 296), of the North-West range (2 in Figure 296) and the roof in-between the two (3 in Figure 296). An initial assessment was carried out on 12th August 2015 and detailed investigations on 17th February 2016 in the central block and North-West range (accompanied by PhD student Clara Gonzalez Manich on both dates).

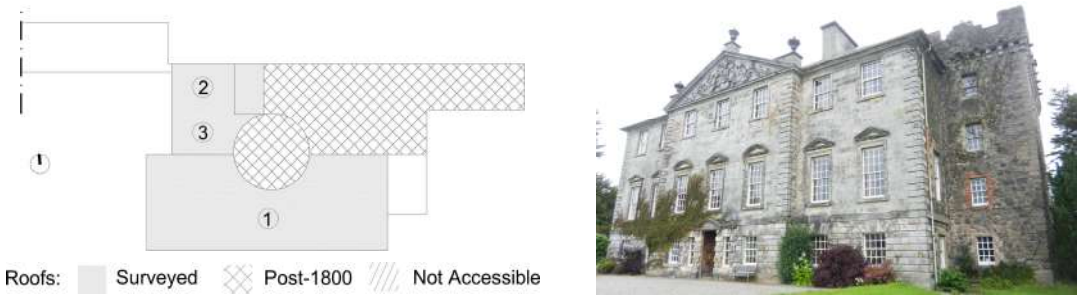


Figure 296: Touch House (sixteenth century and 1757-62): plan (left) and view from South-East (right)

The roof structure covering the central block is a composite structure supported by two transversal gable walls (Figure 297). The central part is covered with a purlin roof while complex frames are used on the sides. The purlin roof is supported by two purlins, one on each side, that span 8.1m from one gable wall to the other. The purlins are kept apart by two horizontal struts in the centre. Common rafters are tenoned into the purlins (with double tenons) and connected transversally by a lower collar that supports the roof of the attic rooms. Additional slanted struts connect the collar and the rafters. A thin ridge purlin sits between the rafters' apex and wall-plates are used at the rafter ends, protected by sprocket rafters. Sarking boards connect the common rafters and support slates, secured with metal nails. In 1930s Sir Robert Lorimer carried out some repair works (Gifford, 2002): he is probably responsible for the two steel beams that support the purlins in the central part.

On the sides of the central block the arrangement is the same but the main supporting elements are three primary rafters, two placed on the hips and one in the centre (Figure 297). Here the purlins are butt-purlins, tenoned into the primary rafters. The central primary rafter is supported by a slanted strut that springs from the gable wall. The span is 8.6m, the pitch is the same as the purlin roof (40°).

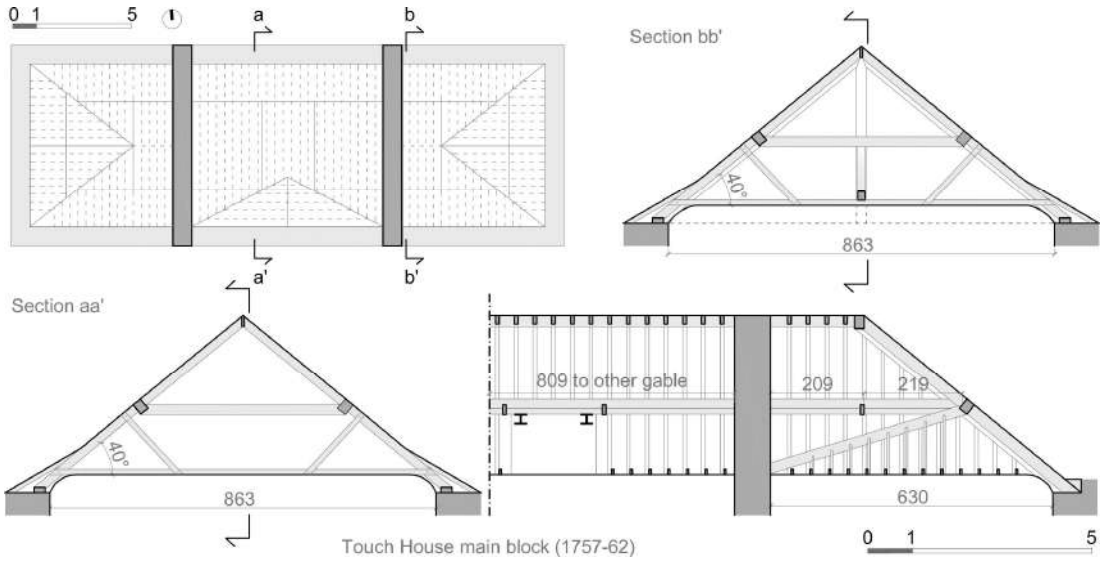


Figure 297: The roof of the central block of Touch House (1757-62)

The purlins and primary rafters are whole logs axed to a rectangular section, leaving no wanes. The purlins are 27x21cm maximum, the rafters 29x22cm. The struts and common rafters are instead half logs, axed and then sawn in two. The joints are all mortice and tenon secured with timber pegs, but the common rafters have double tenons (Figure 298 left), a feature that we have not found in other roofs. There are unusual carpentry marks on many timbers (Figure 298 right).



Figure 298: The roof of the central block of Touch House: double mortice and tenon joint securing a common rafter to a purlin (left) and unusual carprenty mark found on a common rafter (right)

The timber elements are made of *pinus sylvestris* of high quality, mostly belonging to Strength Class I or II, except for one short purlin affected by shakes. Judging from details such as dressing, scantlings, etc, the roof structure above the central block is the original eighteenth-century one, although the use of purlin roofs seems to have been limited in Scotland (section 3.3.1.4). George Paterson, the wright mentioned in Touch Hous's accounts, is known to have worked at Kinghorn Parish Church (Gifford, 1988) and Marlefield House (Cruft, 2005) as well, but unfortunately their roof structures have not been surveyed.

The archival documents held at Touch House tell us that high quality timber was brought from Norway (Copenhagen) and Russia (Riga) in the form of logs, deals, planks, of different measures (TCH account by Paterson, 1757, TCH account by Deas & Co, 1757-8), and that the logs were then cut on site for the specific uses (TCH letter to Mr Seton, 1751). The import of timber is also suggested by several unusual carpentry marks found on site. The Riga logs, known for their higher quality (Thomson, 1991), have probably been used for the primary structural elements, e.g. the purlins and principal rafters, which in fact have been found to be of very good quality.

The roof above the North-West range is a double pitch roof sandwiched between two gable walls and supported by 18 frames (Figure 299). The frames are composed of rafter couples spaced 35cm connected transversally by two collars and longitudinally by sarking boards, to which slates are

secured with metal nails. The lower collars support the attic ceiling. The span is only 5m and the pitch is quite steep (49°). Some frames have vertical struts connecting the two collars, but their dressing (machine sawn) and jointing (simple lap with metal nails) suggest a recent dating. Unfortunately the connection with the lateral walls is not visible.

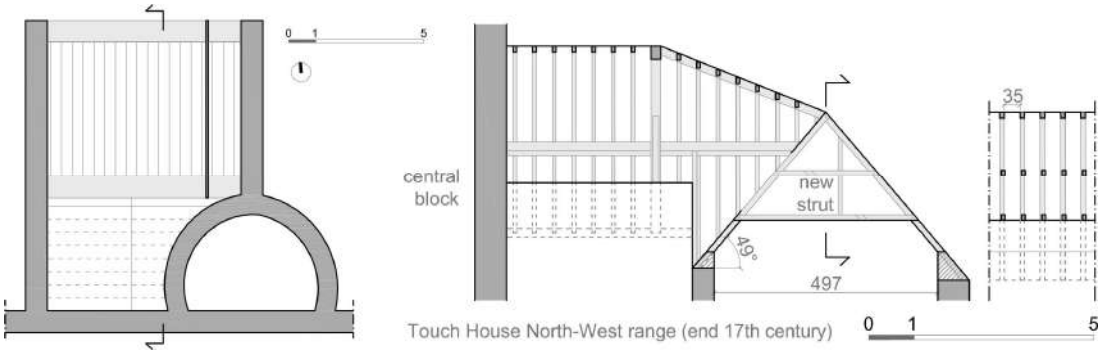


Figure 299: The roof of the North-West range of Touch House (end seventeenth century)

The timber elements are all half logs, axed and then sawn in two; however, some of them are more roughly dressed, leaving wanes and sometimes bark on the corners. The difference in dressing can be clearly seen in Figure 300. Some collars also have redundant joints, suggesting that they have been reused (Figure 302). The sections are quite variable but the height never exceeds 15cm and the base 13cm. The rafters' apex is secured by mortice and tenon joints with timber pegs, while collars are secured to the rafters with dovetail lapped joints with metal nails (Figure 300). In an area on the North side a butt-purlin, used to support the rafters in correspondance of a dormer, is reinforced by cleats (Figure 301). The timbers are numbered with big roughly sawn roman numerals, not in sequence (Figure 302); some unusual carpentry marks have been found too.

The timber elements are made of *pinus sylvestris* of variable quality, ranging from Strength Class I to lower than III. The low quality timbers have big knots or a deviated slope of grain, but none of them have defects in their critical section.

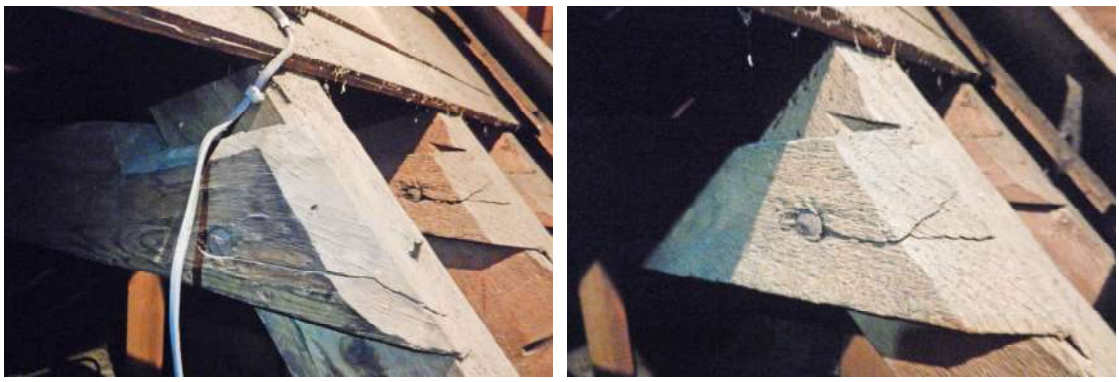


Figure 300: two collars with a different dressing in the roof of the North-West range of Touch House



Figure 301: A cleat reinforcing the joint between a rafter and a butt-purlin in the roof of the North-West range of Touch House



Figure 302: Carpentry marks and redundant joints on collars in the North-West range of Touch House; recently added struts are also visible

The North-West tower was rebuilt and extended to the East in seventeenth century (Gifford, 2002). This would be today's North-West range, whose roof structure does indeed resemble other late seventeenth-century Scottish roofs, such as Panmure House in Edinburgh (1690). This dating is also suggested by the timber dressing and the dovetail lap joints, first used in Holyrood Palace (1671).

There is an undated account of materials which could be related to these seventeenth-century works: it lists 458 yards of roofing and sarking for £117 (TCH account of materials, Undated). This does not seem sufficient to cover the whole North range but some of the timbers have redundant joints, thus they might have been reused from elsewhere or the previous roof. Other timbers have a more refined dressing that suggests an eighteenth century dating. They might have been replaced when the central block was completely replaced and linked to the North range, whose sarking is still visible on this side (Figure 303). This dating is corroborated also by a few strange marks found on the timbers on site, which might indicate their provenance from Scandinavia or Russia. Recent works have also included the replacement of the sarking on the North side, the reinforcement of some lower collars with additional timber elements and the introduction of vertical struts (Figure 304). These works might date to 1930s when the roof of the main block was strengthened by Sir Lorimer and the East side of the North range roof was replaced (RCAHMS LOR/T/1/5, 1928).



Figure 303: Remains of sarking on the North side of the roof of the North-West range of Touch House



Figure 304: Additional collars and struts reinforcing the roof of the North-West range of Touch House

4.8.2 Current Condition

Touch House is privately owned. The current owner has carried out some repair works, but the lack of funds prevents him from keeping a good inspection and maintenance regime in place. The roof of the main block is accessible through a hatch in the ceiling in the Eastern section. However, the Western section is only partly visible and not accessible. Moreover, there are some bats in the roof space. The roof of the North range can be accessed from a door in the attic rooms, but inspection is hindered by the lack of lights and walking boards.

The air temperature and relative humidity in February were around 10.5° and 68% respectively in both roof spaces. These values are not far from the optimal range identified by Ridout (2000) and correspond to an equilibrium moisture content of about 13% (Ross, 2010). The measured moisture content was a lot higher than the equilibrium one in many areas: it exceeded 18% in 32 measurement points in the North range roof and in 13 measurement points in the main block roof; it exceeded 20% in 16 measurement points in the North range roof and 7 measurement points in the main block roof. The highest moisture contents in the North range roof concentrated near the East gable, which is in fact visibly wet: the masonry is disintegrating to dust and falling on the timbers and ceiling underneath (Figure 305). There is probably a problem of water ingress; in some areas the sarking is in fact broken (Figure 306). Moreover, the ventilation is very poor.



Figure 305: The dampness disintegrating the East gable in the roof of the North range of Touch House



Figure 306: Broken sarking in the roof of the North-West range of Touch House

A few areas of the central block roof seem to be affected by biotic attack. The highest moisture contents in the main block concentrate near the gables and the roof-light, where the timbers are visibly wet, but also on the West side strut, which is affected by insect attack too (Figure 307). One purlin also shows signs of possible fungi attack near the gables (Figure 308). In fact, repair works have been carried out in in 2003 in the South-East corner where dry rot was found.



Figure 307: Insect attack on the West side strut of the roof of the central block of Touch House



Figure 308: Fungi attack on a purlin of the roof of the central block of Touch House, near a gable wall

4.9 Conclusions

The chapter describes in detail the historical and condition assessment of the eight case studies investigated, showing how different assessment methods and tools have been combined together to estimate the construction date and identify later interventions, as well as to give an initial evaluation of the structure's condition, identifying the need for urgent interventions and further monitoring. The eight case studies represent well the great variety of roof structures found amongst the 53 surveyed buildings. Despite having classified the roofs in just a few groups according to their structural typology, it is clear that each one has its own peculiar arrangement and details, and that their value also resides in their singularity. This singularity, however, complicates the assessment of these roofs. The available information for each roof is quite different, both in terms of accessibility/visibility and in terms of archival documents. Moreover, the same test can work in one roof but not in another one, which is why, although all tests have been carried out in each case study, not all test results, but only the useful ones, have been presented in this chapter.

5 The assessment of the condition of seventeenth- and eighteenth-century timber roof structures in Scotland

This chapter reviews current conservation practice of historic timber roof structures in Scotland and discusses the assessment of their present condition, with the aim to contribute in improving conservation practice. Current conservation practice is examined by looking at the approach of building owners/managers and professionals and discussing how they are affected by the lack of specific standards and training. Published and unpublished conservation projects, past interventions found during the surveys, existing available training as well as interviews to three conservation engineers, have been used to understand the approach of professionals, while questionnaires have been used to assess the approach of owners and managers. The present condition of Scottish roofs is then discussed based on the results from the preliminary surveys carried out in the 53 reference buildings and the in-depth investigations carried out in the 8 case studies. Typical pathologies and possible causes are identified for each structural typology. The assessment techniques used during the research are then evaluated and compared in terms of effectiveness, reliability, costs and training needed, in order to inform specific training for conservation professionals, which is proposed in the last section.

5.1 Current conservation practice of timber roof structures in Scotland

5.1.1 Standards, Regulations and policies

The availability of specific regulations and standards affects conservation practice because it ensures that professionals follow a standardized procedure during the assessment. Since there are no standards in UK related to the inspection and survey of in situ structures, Scottish professionals use Eurocode 5 (Eurocode 5, 2004) and British National Standards (BS ISO 13033, 2013, BS 5268-2, 2002), as suggested by the interviewed engineers (section 5.1.3). E5 and BNS provide rules on how to correctly design a new timber structure, but these are only partly applicable to in situ structures and even less to historical ones, because they do not consider the accessibility and visibility problems,

the irregular geometries and arrangements, the difficulty and sometimes impossibility to determine the timber species and the mechanical properties. Some BNS give recommendations for the survey and measurement of decay and material degradation caused by fungi/insects (BS EN 1311, 1997), but the purpose is visual strength grading, not repair. There are standards for preservation treatments (BS EN 15228, 2009, BS 8417, 2014), but not for disinfestation. Even visual strength grading rules (BS 5756, 2011a, BS 5756, 2011b) do not take into consideration the difficult conditions of in situ timber, where elements are only partly accessible/visible. All test methods suggested to determine the mechanical properties are to be carried out on samples (BS ISO 13910, 2014, BS EN 408, 2012), which cannot always be taken from historic structures. In situ testing techniques are not mentioned.

Guidelines for recording Scottish historic buildings (Dallas, 2003) and designing interventions on them (Urquhart, 2007) are provided by Historic Environment Scotland (HES), the lead public body researching, taking care of and promoting Scotland's heritage. Unfortunately these guidelines do not include anything specific on timber roof structures. Only two INFORM guides, addressed to traditional building owners, are focused on rot and insect attack to timbers (Jenkins, 2008, 2016).

TRADA, the Timber Research and Development Association, provides more speficic publications on the assessment and repair of historic timbers (Slavid, 2011, TRADA, 2012, Williams, 2015), where visual inspection and non-destructive and semi-destructive testing, such as thermography and micro-drilling, are discussed. However, the topic is not extensively addressed and no standardized procedure is suggested. Moreover, only members of the association have access to these publications.

Protection policies are another important tool that greatly influences conservation practice. HES is responsible for making and maintaining lists of nationally important historic buildings and monuments. The lists include conservation areas and listed A, B or C buildings, to which different levels of protection correspond. Regrettably, most designations are based on surveys carried out decades ago that often do not include an appraisal of the interiors; roof structures, in particular, are very seldom mentioned. This clearly poses a limit to the level of control that can be enforced on interventions altering these elements.

The control over interventions is also hindered by the fact that applications for interventions are seldom approved or rejected by experts in conservation. In fact HES provides guidelines on what kind of interventions can be carried out on listed buildings (Scotland, 2010), but the task to check if these guidelines are implemented is left to local authorities, whose technical office does not always include an expert in conservation, as confirmed by NHTG (2013). HES is involved only in case of major alterations to an A listed building. The local authorities can consult voluntary associations such

as the Architectural Heritage Society of Scotland (AHSS), although the members are not necessarily conservation experts and the local authority is not obliged to comply with their opinion.

The lack of specific standards and the unresolved issues in the designation process and in the process of approval/rejection of proposed interventions do not create the optimal conditions for the conservation of historic timber roof structures. As discussed in the following sections, building users and professionals are in fact lacking the necessary guidance and tools to take care of this heritage.

5.1.2 Building owners, users, managers and professionals in charge of the maintenance

An online questionnaire was sent to all building owners, managers, tenants, architects and other professionals, whom we came in contact with during our surveys, to understand what knowledge and approach they employ in taking care of their buildings. The questionnaire included questions on the ownership, available documentation, accessibility to the roof structure, current condition of the roof structure and maintenance regime (Appendix B). It was partly filled by 40 respondents, mostly owners, managers or architects in charge of the building maintenance (Figure 309).

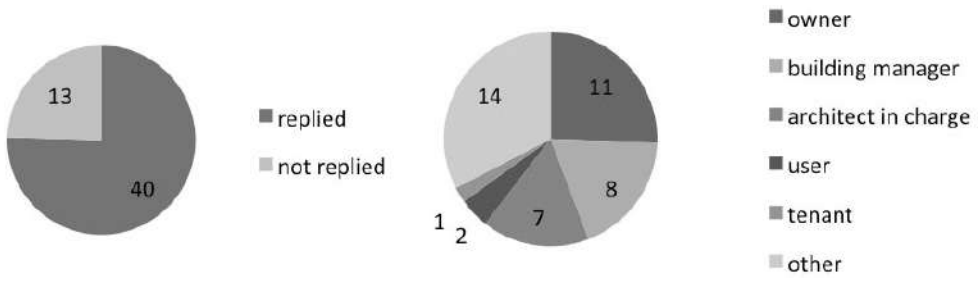


Figure 309: Respondents to the online questionnaire: number (left) and types (right)

Not all of the people responsible for the maintenance of these buildings are fully aware of the accessibility and visibility problems that their roof structures have. About half of the respondents think that the roof space of their building is easily accessible and that the timbers are clearly visible, the other half thinks that this is true only partly, but there are some dicrepancies with what we have found during our surveys (Figure 310): in one case the structure was completely inaccessible and invisible and in other cases the roof was accessible only through very small openings and with no lighting and no walking boards provided.

Inspections, especially of the roof timber structure, are not carried out regularly (Figure 311). Regular inspections are mainly implemented by HES and NTS. The other respondents specified that inspections are made only after a storm or when there seems to be a problem (Figure 311). The roof covering and flashings are inspected mainly by roofing specialists, or the respondents themselves, whilst the roof structure is mostly inspected by architects, followed again by roofing specialists and

the respondents themselves; very few call an engineer (Figure 312). This is probably the reason why some of the respondents are not aware of current problems that their roofs have (Figure 313).

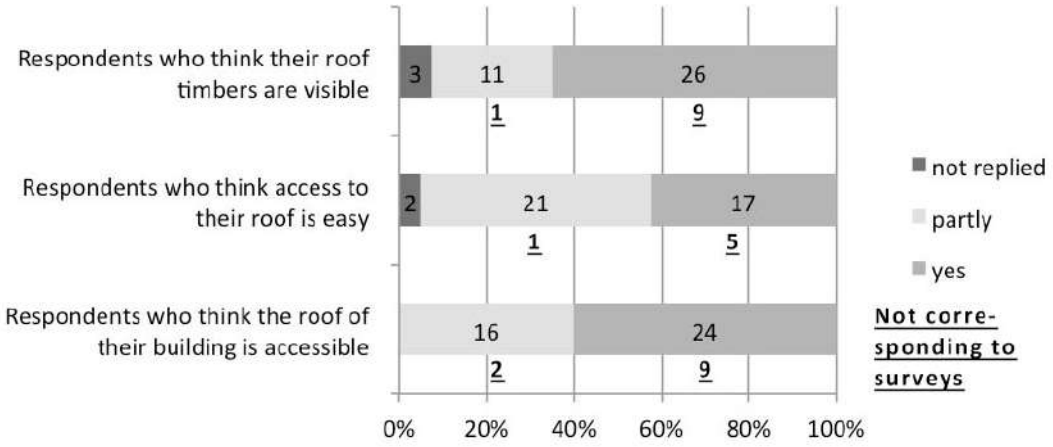


Figure 310: Accessibility and visibility of the surveyed roofs according to the respondents of the online questionnaire and compared to what we have found during our surveys

Programmed works are even less implemented than regular inspections. Only about half of the respondents have regular works programmed for the roof covering and flashings and less than 30% have programmed works for the structure (Figure 311). Programmed works are again mainly implemented by HES and NTS. The rest of the respondents specified that works are carried out ad hoc, when needed (Figure 311).

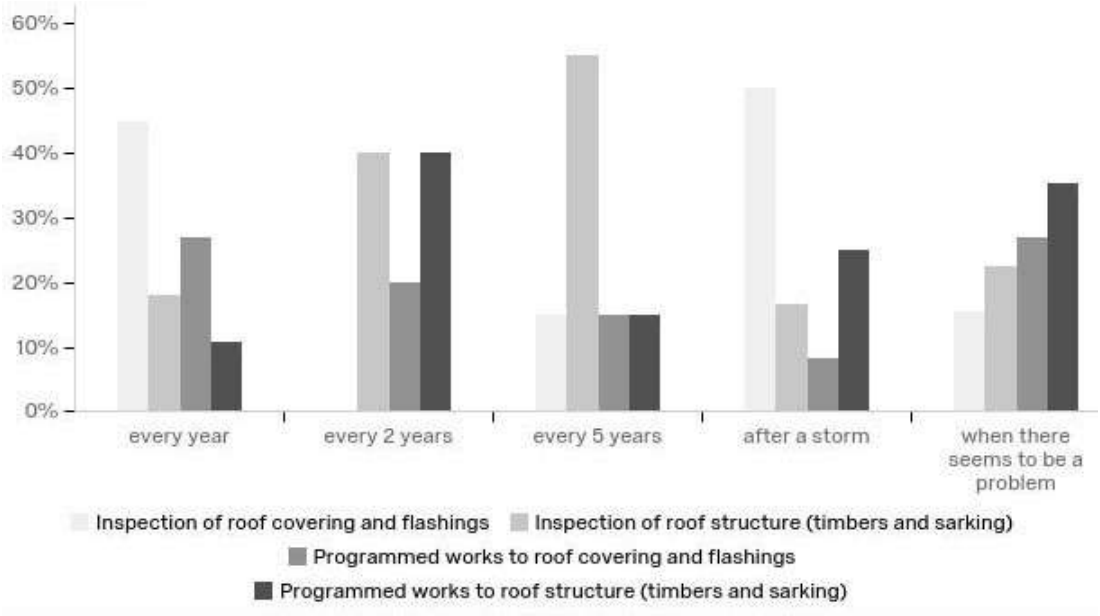


Figure 311: Frequency of inspections and programmed works to the roof structure, covering and flashings according to the respondents of the online questionnaire; 35/40 respondents replied

Moreover, most of the inspections and works are not recorded nor adequately documented. Only about half of the respondents receive a report after the inspection or works have been carried out (Figure 314). This is why they have difficulties keeping track of past repairs. 70% of the respondents claim to have some information about past interventions (Figure 314), but most of this information is not detailed (Appendix B). Furthermore, very few respondents have information on works carried out before they became responsible for the building (Figure 315).

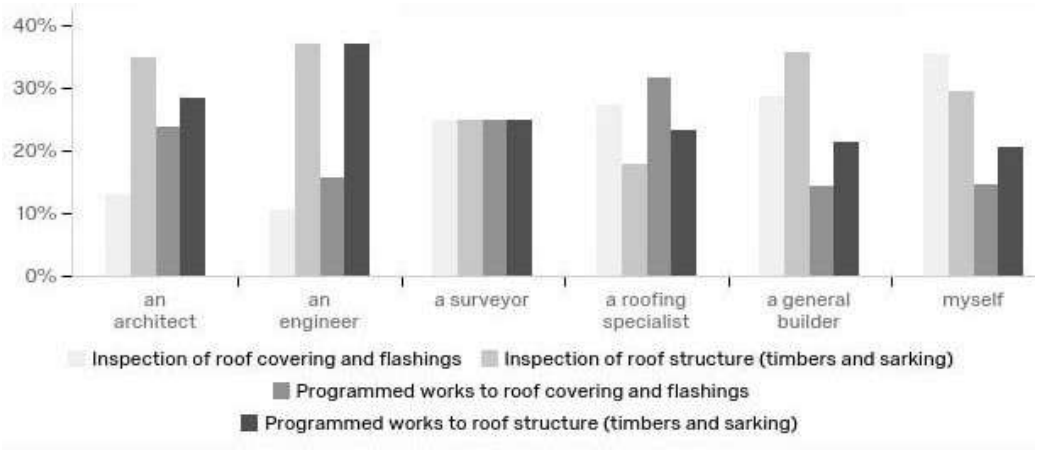


Figure 312: Professionals called to carry out inspections and programmed works to the roof structure, covering and flashings according to the respondents of the online questionnaire; 33/40 respondents replied

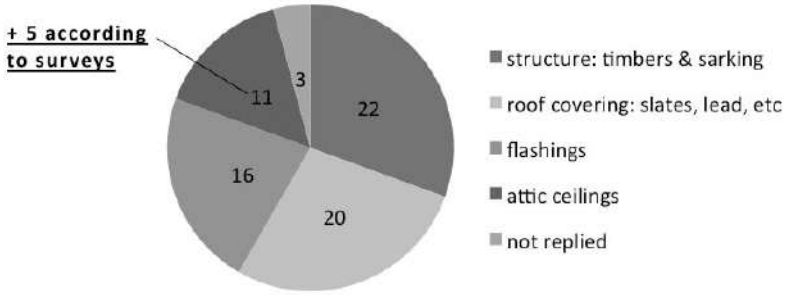


Figure 313: Current problems to the roof structure, covering, flashings and attic ceilings according to the respondents of the online questionnaire and compared to what we have found during our surveys

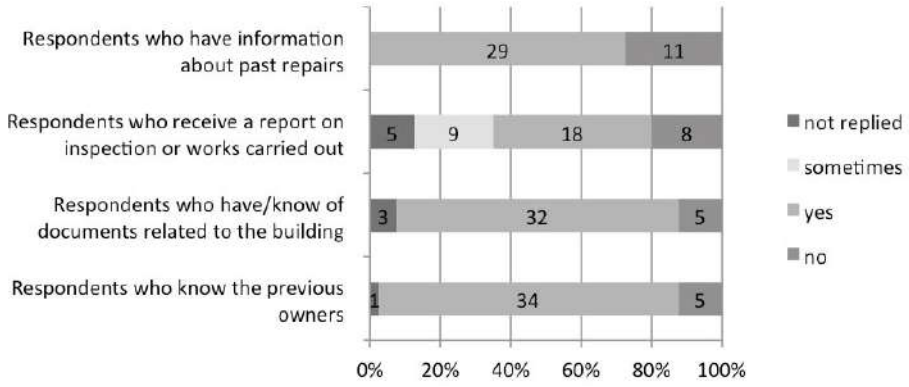


Figure 314: Building documentation according to the respondents to the online questionnaires: information on past repairs, inspection reports, historic documents, name of previous owners

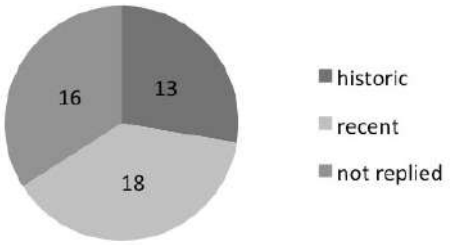


Figure 315: Types of documents related to the building that respondents to the online questionnaire know of

It must be kept in mind that the sample of respondents is not comprehensive and that 11 of them work for HES or NTS, which obviously follow certain established standards for the documentation and care of the buildings. Nevertheless, the overall picture is not reassuring as it highlights a distorted view of accessibility and visibility requirements, lack of regular inspections and programmed works and poor documentation.

5.1.3 Conservation professionals

The information gathered through the questionnaires has been integrated by interviewing three conservation engineers working in Scotland, to understand what kind of knowledge, skills and approach they have when assessing the condition of a timber roof structure and how they choose, design and carry out the necessary repair works. They have been selected amongst the engineers most frequently mentioned in association with interventions to timber roof structures. Engineer 1 works for HES, engineer 2 has his own engineering firm and engineer 3 is a director in an engineering firm. The interviews included questions regarding their education, present and past professional experience, method of assessment of historic timber roof structures, and criteria followed to design the necessary repair works (Appendix C).

Neither of the three has attended specific courses on conservation in University, because these were not offered. Engineer 2 underlines that in his experience the engineering course was all about mathematics and calculations and no aspect of design, architecture or history was considered. Engineer 3 is the only one who had specific training in conservation after University, thanks to a SPAB scholarship that allowed him to take a year off work to visit conservation sites and country houses across the country, guided by conservation practitioners. He is also the only one of the three accredited for conservation (CARE).

Carrying out a historical research prior to the inspection is not considered a priority: they rely on clients or architects to provide it. Engineer 2 is the only one stressing the importance to integrate this research by investigating the history of loads/problems/repairs, which is fundamental to understand the present condition of a historic structure.

They are never called to carry out a routine inspection, as already highlighted by the questionnaires discussed in the previous section; they are called to inspect a roof space only when the client sees an evident problem or when there is a change of use. Even HES relies on its architects to identify structural problems during their quinquennial inspection; HES engineers are not involved in the routine inspections of the buildings in their care. In fact, engineer 1 says that he never dealt with timber structures since he first started working for HES seven years ago.

During the inspections they mostly look out for water ingress and rot, because they think these are the most common problems. According to engineer 1 and 3 deflections, cracking and deformations are less common, although engineer 2 thinks otherwise. All three mention past alterations as another common issue.

Although there are various testing techniques that can help estimating the mechanical properties of timber, its resisting section and other unknowns that strongly influence the results of calculations, the interviewed engineers rely chiefly on traditional surveying techniques, visual inspection and past experience. The only tools employed are moisture meters, used by engineer 2, and coring, sometimes used by engineer 3 to test the inner condition of timber. If the timbers have big sections, or are heavily punctured, or there are signs of an active attack, they all call a timber specialist.

They sometimes carry out simple hand calculations, but not always because extensive analyses are expensive and seldom provide useful results, due to the big number of unknowns involved. Engineer 2 and 3 think it is important to identify the timber species for the calculations, so they often call a timber specialist for this purpose. Once the species is known they look up for reference properties and then adjust the calculations based on the first results they get. Engineer 1 thinks the timber species is important only if the timber element is of historical value, otherwise he makes assumptions for both the species and the properties.

Despite recognizing the importance of the minimum intervention criteria, the impossibility to reach a confident structural assessment forces engineers to 'stay on the safe side' and carry out interventions even when they are not sure it is necessary, as explained by engineer 3. When it comes to deciding what repair works are needed and how to design them, engineer 3 underlines that the availability of a skilled carpenter is not less fundamental than the philosophical criteria of minimum intervention and distinguishability. Unfortunately, it is difficult even for carpenters to acquire specific expertise in conservation, as discussed in the next section.

5.1.4 Existing training in conservation

A review of academic and training courses offered to professionals such as engineers, architects, and craftsmen to acquire specific knowledge about conservation of timber structures (Figure 316)

highlights a lack of courses related to conservation engineering and timber structures in Scotland and North England, as confirmed by the interviewed engineers. Postgraduate courses in architectural conservation are offered at the moment in Scotland at the University of Edinburgh (for all professionals), the University of Strathclyde (for architects and engineers) and Heriot Watt University (for building surveyors, builders and construction managers). In North England masters in conservation are offered at the University of York (Department of Archaeology), at the University of Central Lancashire (Faculty of Science and Technology) and at the University of Sheffield (School of Architecture).

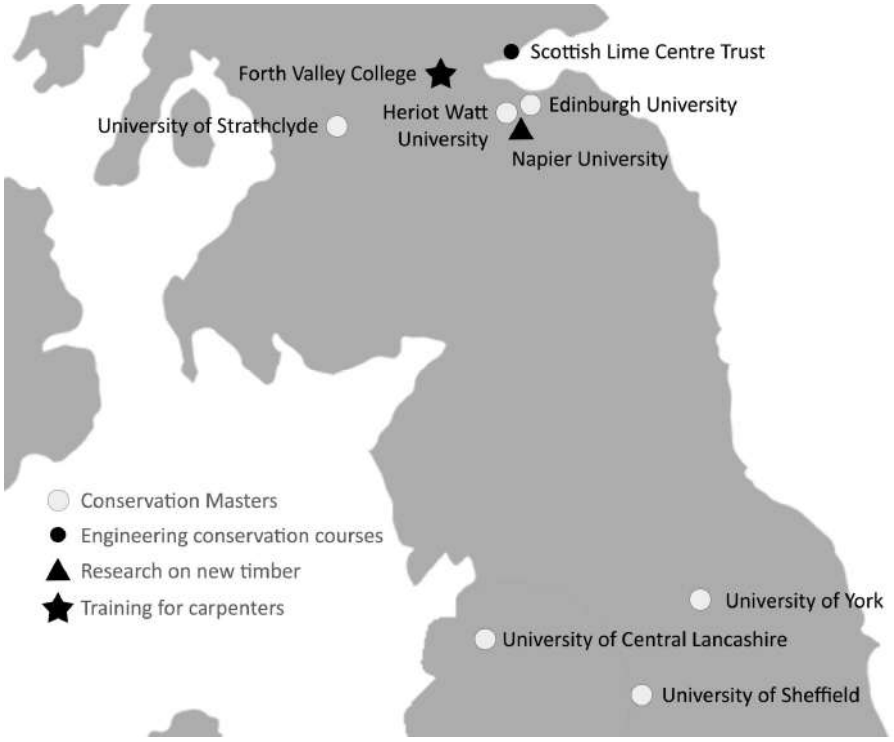


Figure 316: Available academic and training courses offered to conservation professionals dealing with historic timber structures in Scotland and North England

The only specific training in engineering conservation is a two-days seminar offered yearly by the Scottish Lime Centre Trust, entitled 'the structural repair of historic buildings' and held by Ian Hume, a conservation accredited engineer based in England. Napier University has two centres of research on timber engineering and technology, but they focus chiefly on new timber structures. This lack of training is confirmed by a research carried out by NHTG (2013) and explains why the three interviewed engineers say they have learnt most of what they know about conservation during their professional experience rather than through academic training. Experience is considered more important than training and accreditation (NHTG, 2013): in fact only one of the three interviewed engineers has attended specific training and is accredited in conservation (CARE). The register for

conservation accredited engineers (CARE) includes, at the moment, 48 members of which only 4 based in Scotland.

The same is true for carpenters. Forth Valley College is the only one in Scotland offering courses on maintenance and repair of structural timbers. The only other option, even for carpenters working for HES, is to go to the Oak Frame Training Forum School near Bristol through the Carpenter's fellowship. Therefore, just as engineers, most carpenters tend to learn 'on the job' rather than through formal training (NHTG, 2013).

5.1.5 Dissemination of conservation projects

In Scotland it is unusual to publish conservation projects, therefore it is necessary to look at unpublished professional reports to find examples of current conservation practice. This means that successful conservation projects are not available to the wider public and thus cannot inform other conservation projects and contribute in improving conservation practice.

A striking example is that of Historic Environment Scotland. HES has published many technical reports and papers, but most of them focus on upgrading and improvement of historic buildings (Fabian and Dobbie, 2014) rather than their condition assessment. Moreover, they often analyse historical and stylistic aspects (Historic Environment Scotland, 2014) or very technical ones (Baker, 2008), lacking of a more comprehensive and interdisciplinary approach. Most importantly in our case, no HES publication discusses timber structures.

If we look at unpublished work we can find an example of how HES maintains and repairs the roofs in its care. The unpublished final report on the timber roof of Newark Castle, produced by an English company to whom the assessment has been appointed by HES (Demaus Building Diagnostics Ltd, 2007), includes a thorough historical and condition assessment based on visual inspection and the use of a micro-drill and a hygrometer. The timber species is specified, although the method of identification is not stated. The document reports that decay was found at most rafter feet and other areas in contact with the damp masonry, which in turn showed some cracks and deformations linked with the roof overall movement. Based on this assessment it is suggested to reinforce the connection between the rafter feet and the wall-head with steel brackets and to connect these brackets transversally with steel wires, to counteract the roof opening (Figure 317, Figure 318). It is also recommended to dry out the masonry, improve ventilation and monitor the repairs afterwards.

The fact that this work was contracted to an English company suggests that timber specialists were not available in Scotland ten years ago. On the other hand, the report is very detailed and the proposed interventions reveal a sensible approach: they are reversible, they do not involve losing

the original material and they are relatively low-cost. It is thus a pity that such a good example is not shared and published in order to inform similar projects.

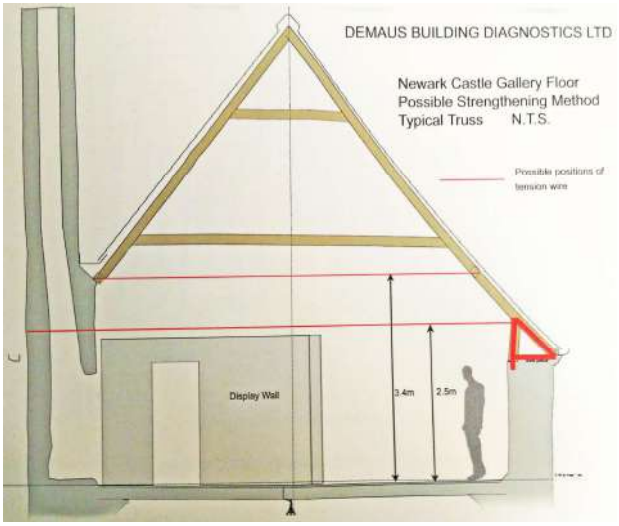


Figure 317: Proposed repairs to the roof of Newark (in red): steel brackets reinforcing the rafter feet and steel wires connecting them transversally (Demaus Building Diagnostics Ltd, 2007)

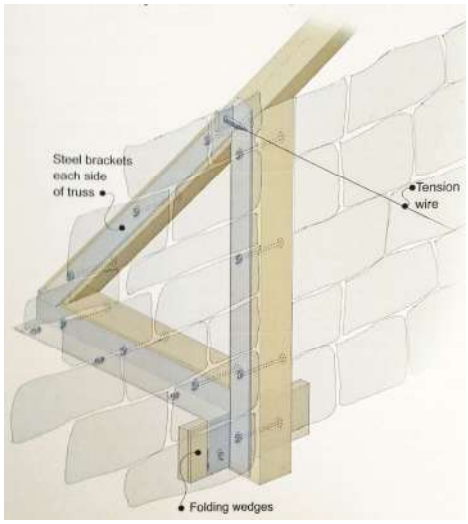


Figure 318: Detail of the steel brackets proposed as reinforcement for the rafter feet of the roof of Newark Castle (Demaus Building Diagnostics Ltd, 2007)

There are only a few contributions on the subject published by professionals: Oldriev (1916), Ruddock (1995) and Murdoch (2010) discuss the condition assessment and repair of four early Scottish timber roof structures. These studies are all quite dated since they discuss works carried out at the beginning of the twentieth century and in 1980s, but they all embrace a sensible approach to conservation, aiming at conserving the original fabric as much as possible and minimizing the impact of interventions.

Oldriev (1916) discusses the assessment and repair of the roof of Glasgow Cathedral (thirteenth century), Ruddock (1995) that of the roofs of Alloa Tower (1497 but maybe older) and a house in Kirkcaldy (1600), Murdoch (2010) explains the research and conservation works carried out at his own house, Methven Castle (1678-81). They all proceeded with a thorough historical research, aimed at assessing past problems and repairs as well, and a detailed in situ inspection. During the condition assessment they employed mainly visual techniques; in fact they had to remove parts of the roof covering and sarking boards, as well as the plaster ceiling, in order to be able to assess the condition of hidden parts of the structure. Oldriev (1916) also employed the plumb line to measure the out of plumb of the masonry walls and columns. In fact, whilst Ruddock (1995) and Murdoch (2010) found out that the main problem of their roofs was material degradation, concentrated at the rafter ends, the horizontal thrust produced by the roof of Glasgow Cathedral had created a dangerous out of plumb in the masonry walls and columns.

In Alloa and Kirckaldy it was sufficient to replace some of the rafter ends with new pieces of timber, joined to the original ones with scarf joints secured by steel bolts (Figure 319). In Methven Castle it was instead necessary to replace most of the rafters entirely and to reinforce the joints between rafters and collars with steel plates (Figure 320). The rafters were replaced with nineteenth century timbers recovered from the demolition of an industrial building nearby. Likewise, in Glasgow Cathedral most of the timbers had to be entirely replaced and other invasive interventions were needed to reduce the horizontal thrust exerted by the roof on the walls: the overall structural behaviour had to be changed by adding tie-beams and a secondary steel structure; the roof covering was also changed in order to reduce the weight on the roof structure.

The interventions described above, although partly invasive, are justified by the poor condition in which the roofs were. However, during our surveys we have seen many past repairs and interventions resulting from a less sensible approach, as discussed in the next section, suggesting that the above discussed published examples are not necessarily representative of the current approach in Scotland to the conservation of historic timber structures.



Figure 319: Repairs carried out in the roof of Alloa tower: some rafter ends, sole pieces and ashlar posts partly replaced with new timber and connected to the original timber with scarf joints and steel bolts



Figure 320: Repairs carried out in the roof of Methven Castle: many original rafters substituted with reused nineteenth century timbers, but many original collars retained and steel plates used to reinforce the lap joints between them

5.2 An overview of the typical pathologies found in the surveyed buildings

Our literature and archival research and on site surveys have highlighted a high percentage of seventeenth- and eighteenth-century Scottish buildings whose original timber roof structure has been replaced. Out of the 53 buildings we have surveyed, one had no accessibility to the roof structure and 8 had all the visible roof structures dating to post-1800 (Figure 321). In addition to

these, thanks to information given by the owners/building managers/architects contacted, 6 other roofs have been identified as having the roof structure completely replaced after 1800 (Figure 321). Therefore, out of the 80 roofs whose owners/mangers/tenants/architects have replied, 14 roofs (almost 20%) have been reroofed after 1800. 20% is quite a high percentage and is probably higher since many owners/managers could not tell if the roof structure was original or not. It suggests either a conservative approach on the professionals' side, leading to the replacement of structures even when not necessary, or poor maintenance on the owners' side, leading to damage/degradation beyond repair. The results from our interviews to conservation engineers and questionnaires to building owners confirm that both things happen: engineers are often unable to reach a confident structural assessment and are thus forced to carry out unnecessary or over-dimensioned interventions to 'stay on the safe side'; on the other hand, owners and managers do not program regular inspection and maintenance works.

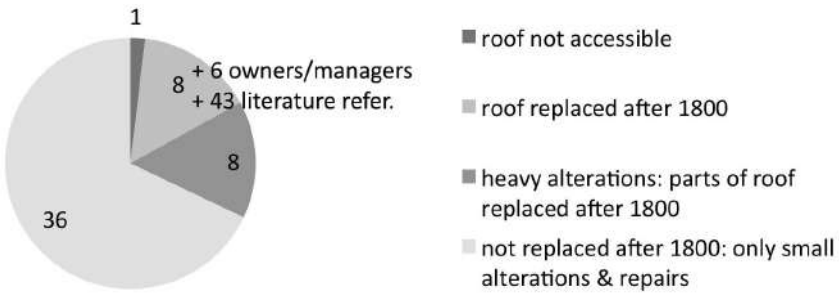


Figure 321: Replacements and alterations to surveyed roofs

It is clear that the value of these structures is not recognized and that good conservation practice is hindered by lack of information, training and method. Our surveys have allowed us to start addressing these issues, by identifying typical pathologies in each roof structure type and estimating the possible causes, summarized in Table 13 and Figure 322 and discussed in the following sections.

Table 13: Pathologies identified in the roofs surveyed, and estimated causes; the damage types are as represented in Figure 64. The roofs with no pathology have not been included. For details see Appendix E and F

Building name and roof location	Type of roof	Fungi attack	Insect attack	Mechanical damage	Estimated cause
Balcaskie House	simple frame		probably *Anobium Punctatum*		inadequate environmental conditions
Blair Castle	simple frame + complex frame	type not identified	probably *Anobium Punctatum*		inadequate environmental conditions

Cockenzie House	simple frame	Brown rot	probably *Anobium Punctatum*		poor maintenance, inadequate environmental conditions
Cowane's Hospital	simple frame		probably *Anobium Punctatum*		poor maintenance, inadequate environmental conditions
Craigston Castle	simple frame		probably *Anobium Punctatum*	stacking up of frames	poor design
Culross Palace	simple frame		probably *Anobium Punctatum*		inadequate environmental conditions
Edinburgh Panmure House	simple frame		probably *Anobium Punctatum*		inadequate environmental conditions
Edinburgh St Andrew's and St George's Church	truss			cracks	not identified
Fountainhall House	simple frame		probably *Anobium Punctatum*	stacking up of frames	poor design
Gardyne's Land	simple frame		probably *Anobium Punctatum*	permanent deformation of frames	past interventions, inadequate environmental conditions
Geilston House	simple frame		probably *Anobium Punctatum*	stacking up of frames	poor design/ maintenance
George Fort Chapel	truss		probably *Anobium Punctatum*		inadequate environmental conditions
George Fort Store	truss			disconnection of joints	poor design
Glasgow St Andrew's in The Square Church	truss	type not identified	probably *Anobium Punctatum*	cracks and disconnection of joints	inadequate environmental conditions
Glasgow Trades Hall	truss			transv. opening of roof, cracks and disconnection of joints	poor design
Glasgow Tron Church	truss			cracks and disconnection of joints	past interventions
Holyrood Palace	complex frame	type not identified	probably *Anobium Punctatum*	disconnection of joints	poor design, inadequate environmental conditions
Kelburn Castle tower	simple frame	Dry rot	probably *Anobium Punctatum*		poor maintenance, inadequate environmental conditions

Kelburn Castle W wing	simple frame	type not identified			poor maintenance
Kinross House	complex frame	type not identified	probably *Anobium Punctatum*		inadequate environmental conditions
Malleny House	simple frame		probably *Anobium Punctatum*		inadequate environmental conditions
Maybole Castle	simple frame	Dry rot	probably *Anobium Punctatum*		external action (fire), inadequate environmental conditions
Melville House	complex frame + purlin		probably *Anobium Punctatum*	permanent deformation of elements	poor design
Oakshaw Trinity Church	truss			transversal opening of roof, cracks, permanent deformation of elements, disconnection of joints	poor design, past interventions
Pilmuir House	simple frame		probably *Anobium Punctatum*		inadequate environmental conditions
Pinkie House tower	simple frame		probably *Anobium Punctatum*		inadequate environmental conditions
Pinkie House long hall	simple frame		probably *Anobium Punctatum*	transversal opening of roof, disconnection of joints	poor design
Sailor's Walk	simple frame		probably *Anobium Punctatum*	disconnection of joints	poor maintenance
Stirling Castle Palace	simple frame + complex frame + purlin	type not identified	probably *Anobium Punctatum*		inadequate environmental conditions
Stirling Castle King's Old Buildings	simple frame		probably *Xestobium Rufovillosum*		inadequate environmental conditions
Touch House main block	complex frame + purlin	type not identified		cracks	poor design, inadequate environmental conditions
Touch house in between	complex frame			permanent deformation of elements and cracks	poor design
Touch House N range	simple frame	type not identified		splitting of joints	poor maintenance, inadequate environmental conditions

Tweeddale House	complex frame		probably *Anobium Punctatum*		inadequate environmental conditions
Yester House central	complex frame		probably *Anobium Punctatum*	cracks and disconnection of joints	poor design, inadequate environmental conditions
Yester House sides	complex frame	type not identified	probably *Anobium Punctatum*		inadequate environmental conditions

Building name and roof location	Type of roof	**Fungi attack**	**Insect attack**	**Mechanical damage**	Estimated cause
simple frames (tot 29)		5 = **17%**	18 = **62%**	7 = **24%**	see Figure 322
complex frames (tot 18)		5 = **28%**	8 = **44%**	4 = **22%**	
purlin roofs (tot 5)		2= **40%**	1 = **20%**	2= **40%**	
trusses (tot 14)		1 = **7%**	2 = **14%**	6 = **43%**	

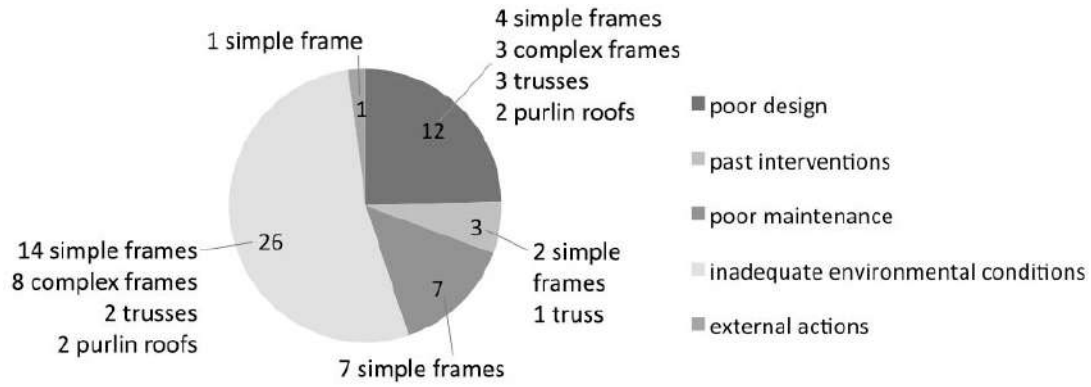


Figure 322: Estimated causes of the pathologies identified in the surveyed roofs

5.2.1 Poor initial design of the overall structural arrangements and details

Although two of the three engineers we have interviewed think that deflections, cracking and deformations are not common issues in Scottish roofs (section 2.3.4), we have found quite a few of these pathologies during our surveys and we have estimated that many of them are caused primarily by a poor initial design of the overall structural arrangement, the joints, and the timber dressing (Figure 322), as discussed below. It is not unusual for poor initial design to play a key role in causing damage in roofs (Tampone, 2007).

Simple frames sometimes show joint disconnections and splitting that can be associated with an overall transversal opening of the roof (Figure 323 left), caused mainly by the absence of tie-beams and of tension-absorbing joints. As previously discussed, tie-beams are not used in Scottish roofs before the end of seventeenth century, and even after 1700 they are not common. When there is no tie-beam the transversal opening of the roof is restricted only by collars and rafter feet. When there

are two collars, as in Pinkie House (1613), the upper one is working mainly in compression and the lower one mainly in bending and tension (even because it often supports the ceiling underneath). The problem is that up to about 1670 simple lap or mortise and tenon joints are used, secured with timber pegs, for both lower and upper collars (section 3.3.2.1). These joints are capable of resisting very limited tension forces (Jasienko et al 2014): the timber pegs fail easily (also because of biotic attack) and the joints open, as in Sailor's Walk (1670s) and in Pinkie House (1613) (Figure 323 centre and right); in both cases additional collars have been recently added to counteract the roof opening.



Figure 323: Mechanical damage in common rafter roofs: schematic of the transversal opening of roofs (left), joint disconnection in a rafter foot of Sailor's Walk (1670s) (centre), an open joint between lower collar and rafter in the roof of the long gallery at Pinkie House (1613) (right)

This problem is visible even in later roofs, when the tie-beam is not used, as in Oakshaw Trinity church (1754-6) (Figure 324 left) and the Trades Hall in Glasgow (1791-4) (Figure 324 right), because Scottish wrights never develop efficient tension-absorbing joints, as discussed in section 3.3.2.1.



Figure 324: The transversal opening of eighteenth century roofs without a tie-beam: open scarf joint in a tie-beam of the roof of Oakshaw Trinity church (1754-6) (left), wooden peg inserted in an open joint between a slanted strut and a horizontal beam in the roof of Glasgow Trades Hall (1791-4) (right)

Other common rafter roofs have a problem in the longitudinal direction, with the frames stacking up and losing stability, as in Craigston Castle (1604-7), Fountainhall House (early seventeenth century) and Geilston House (1666) (Figure 325). This becomes a serious problem when the distance between the frames is more than the common 50cm, since the longitudinal rigidity is provided only by the sarking boards. It is the case of Geilston House, where the frames are spaced around 90cm and the out of plumb reaches up to 60cm at their top. In fact, additional timber frames and a steel structure have been added to support the original roof.

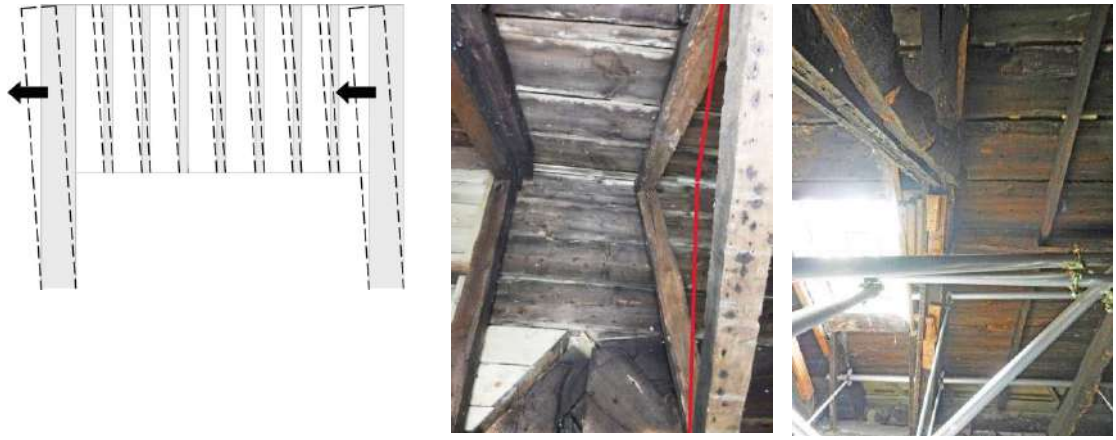


Figure 325: Mechanical damage in common rafter roofs: schematic of the stacking up of frames (left) and pictures of the roof of Geilston House (1666) (centre and right); the black line in the central picture represents the position that the frame should have if there was no out of plomb

Trusses with reduced spans are generally in good conditions, whilst those covering bigger spans sometimes have deflected elements, joint disconnections and cracks, which suggest high stresses and possibly an overall deflection and opening of the roof structure. The causes are certainly more than one and difficult to determine, but the improper design of arrangements and joints is clearly one of them. Timber elements are sometimes too slender and long and do not have sufficient propping provided, as the hip rafter in Oakshaw Trinity Church (Figure 326: the posts and struts have been added later). The same roof is also a good example of problematic asymmetrical arrangements: the fact that the struts do not encounter the posts at the same height creates unnecessary stresses in the post (Figure 326).

The Ordnance Store in Fort George is another example of insufficient propping: the long tie-beam has no supports. The lateral posts (Figure 327 right) are probably a later addition since they do not appear in a survey carried out one year after completion of the building (Figure 327 left). In any case, they do not help the tie-beam because they are jointed with mortice and tenon joints secured by timber dowels, which, as already discussed, can work mainly in compression (Figure 328 top right). In fact, additional steel reinforcements have been recently added to try to counteract the tie-beam deflection.

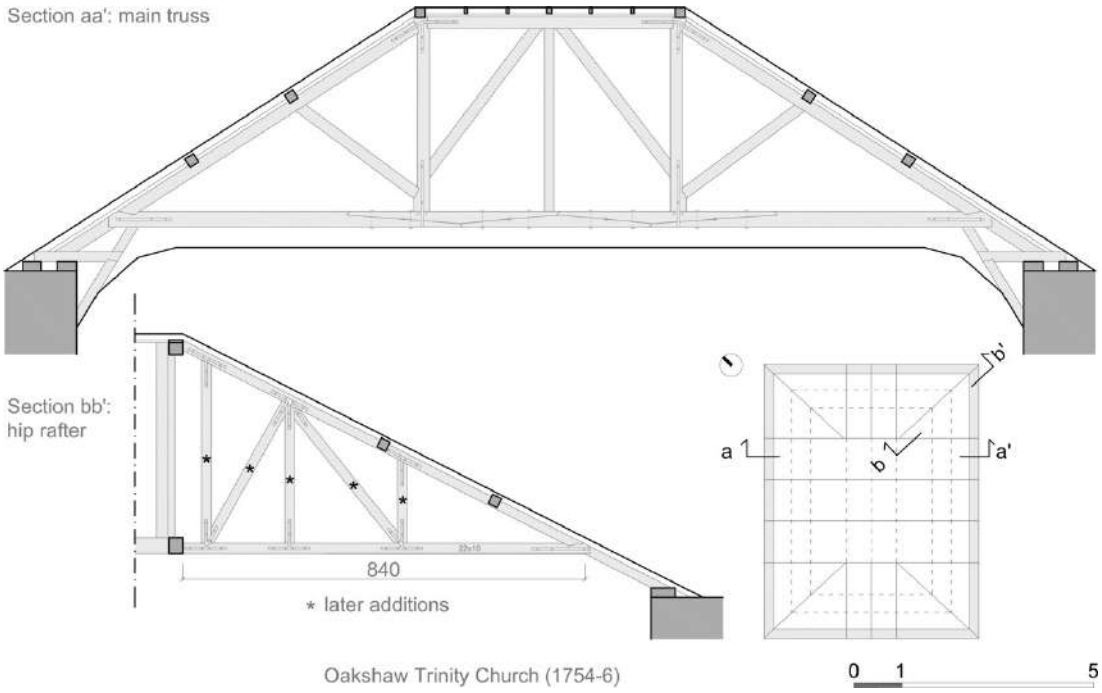


Figure 326: The roof of Oakshaw Trinity Church (1754-6)

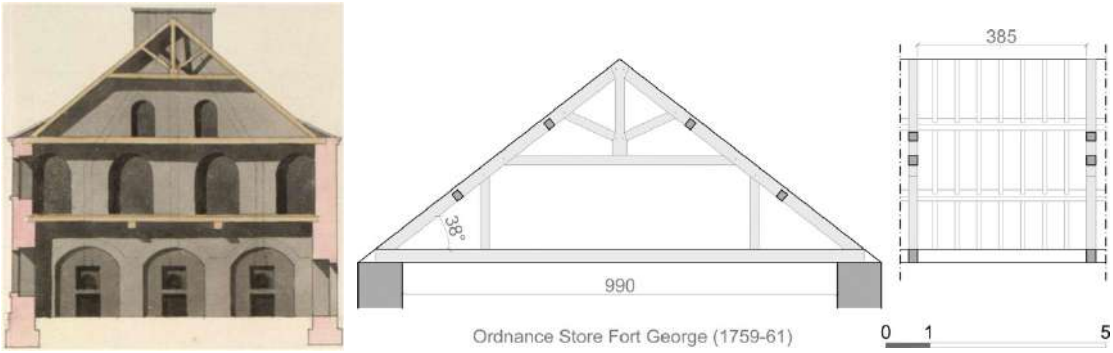


Figure 327: The roof of the Ordnance Store in Fort George (1759-61): as drawn by engineer William Skinner in 1762 after completion (NLS MS1647 Z.02/55a, 1762) (left), as surveyed by the author (right)

As previously discussed, Scottish wrights do not develop efficient tension-absorbing joints and in fact most trusses employ exclusively mortise and tenon joints secured with timber dowels or wedges. Metal straps are very seldom used and sometimes they are a later addition, as in Trades Hall in Glasgow (1791-4) where they have been added in 1856 (Figure 328 left). Scarf joints, when used, are very simple and unable to absorb tension forces, as the one in Oakshaw Trinity Church, which has opened up to 4.5cm breaking the wooden keys (Figure 328 bottom right).

Complex frames and purlins roofs also have deflected elements and cracked supports (Figure 329) caused by insufficient dimensions and insufficient number of supports, as in trussed roofs. Touch House is a good example: the original purlin roof has purlins more than 8 meters long, running from one gable to the other, with only two slender horizontal struts as intermediate supports. In 1930s

two steel beams were added as additional support to avoid further deflection of the purlins (Figure 330). Another part of the roof has not been intervened on and is visibly suffering (Figure 329).

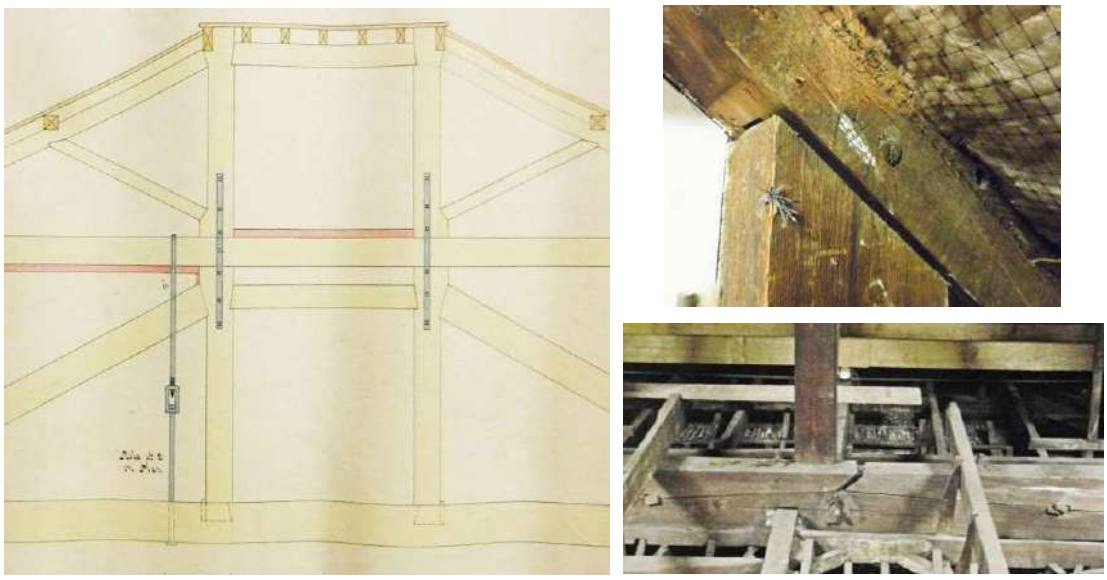


Figure 328: Mechanical damage in trussed roofs: drawing showing in red and blue the timber and steel added to the roof of the Trades Hall in Glasgow (TDH 1/899, 1856) (left), joint disconnection in the roof of Fort George Ordnance Store (1759-61) (top right) and in the roof of Oakshaw Trinity Church (1754-6) (bottom right)



Figure 329: Mechanical damage in purlin roofs and complex frames: deflected purlin in Melville House (1697-1701) (left), deflected purlin in Touch House (1757-62) (centre), crack in strut supporting the purlin in Touch House (1757-62) (right) (Serafini and Gonzalez Longo, 2016)

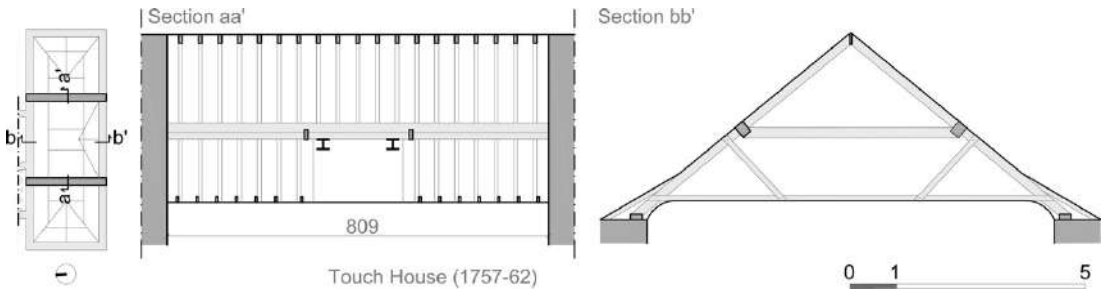


Figure 330: The central part of the roof of the main block of Touch House (1757-62)

Many common rafter roofs and almost half of the surveyed complex frames, have material degradation problems caused by biotic agents (Table 13), as stressed by the interviewed engineers as well (section 5.1.3). The optimal conditions for these agents to proliferate are generally provided by water ingress problems, as suggested by the interviewed engineers and our surveys (Table 13). However, the rough dressing of the timber elements is also a cause, since bark and sapwood are more vulnerable to insect attack (Ridout, 2000). This would explain why trussed roofs, according to our surveys, are less vulnerable to biotic attack (Table 13): the timber elements for these more complex structures were more carefully squared and finished, leaving no bark and less sapwood.

In some cases the insect attack has been treated and is not active anymore (Figure 331 left), but in other roofs new bore dust indicates active infestation (Figure 331 centre) (Figure 332). Fungi attack (Figure 331 right) is less common (Table 13) and more difficult to identify and evaluate.



Figure 331: Material degradation in common rafter roofs: old insect attack in Malleny House (1635) (left), active insect attack in Cockenzie House (1680s) (centre), fungi attack in Kelburn Castle (1581) (right)

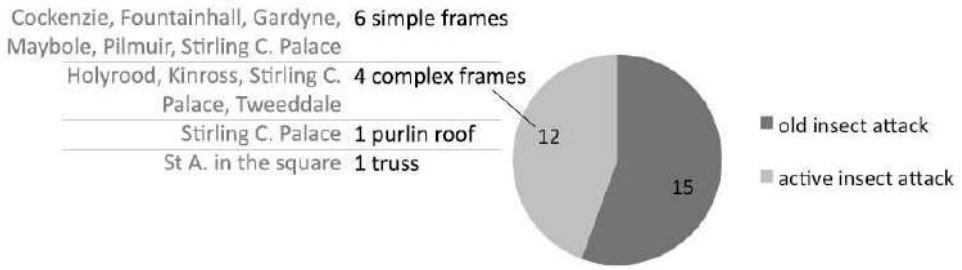


Figure 332: Estimated status of the insect attack affecting the surveyed roofs

Even when it is not active anymore, insect attack might have caused a considerable reduction of the resisting section of the elements, as highlighted by the micro-drill test. Most of the micro-drill graphs resulting from our in situ testing campaign show healthy wood or external degradation limited to the sapwood, up to 2cm deep (green circle in Figure 333, top two lines) (Figure 334). However, in a few measurement points extensive external degradation has been found, up to 4cm deep (only one deeper than 4cm) (Figure 335) and in rare occasions internal degradation, mainly in the sapwood but occasionally in the heartwood as well (Figure 336), especially in Holyrood Palace (red circle in Figure 333). Extensive degradation can cause serious mechanical damage and brittle failures.

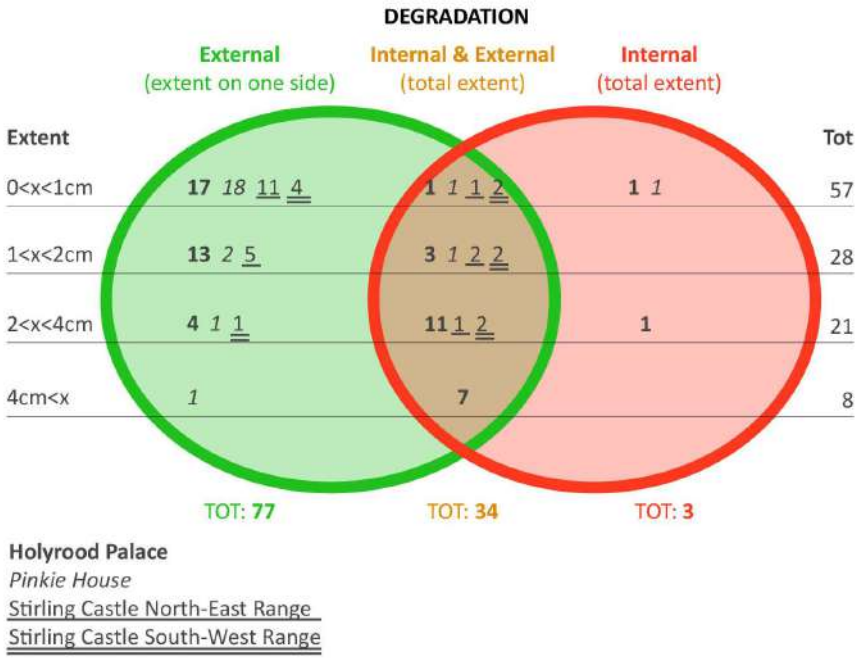


Figure 333: Number of micro-drills carried out in the roofs of Stirling Castle Palace, Holyrood Palace and Pinkie House, organized according to the position and extent of the degradation detected

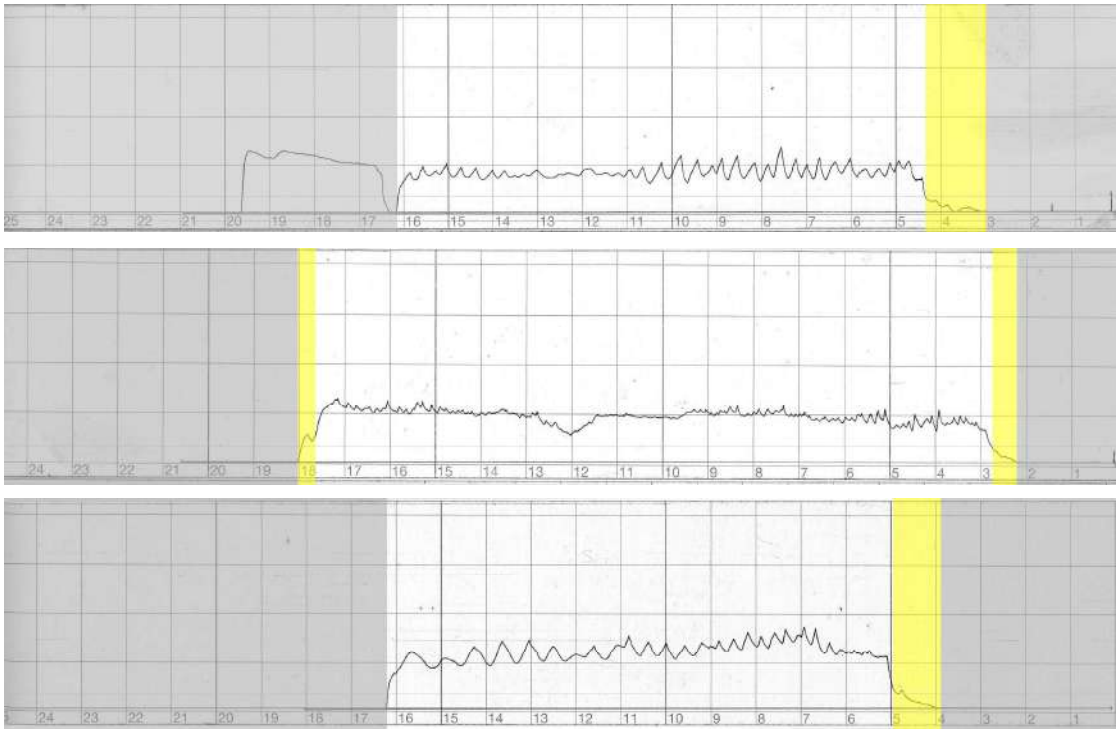


Figure 334: Examples of micro-drill graphs that show external degradation limited to the sapwood, up to 2cm deep. From the top:

- measurement point b in the Upper Beam on the North side of frame XX of Holyrood Palace

- measurement point 5 in frame I of Pinkie House

- measurement point 2 in frame 7 in the North-East range of Stirling Castle Palace

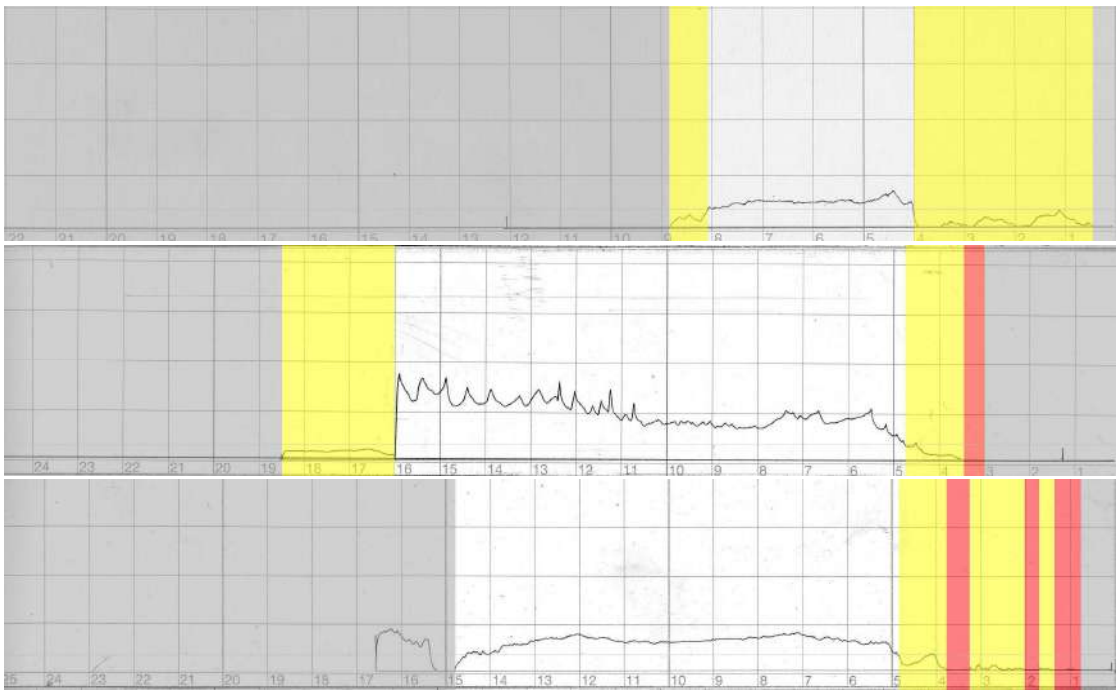


Figure 335: Examples of micro-drill graphs showing extensive external degradation (more than 2cm deep).

From the top:

- measurement point d in the Upper Beam on the Sorth side of frame X of Holyrood Palace

- measurement point b rear in frame 7 in the South-West range of Stirling Castle Palace

- measurement point 6 in frame XXVII in Pinkie House (with more than more than 4cm degradation on one side)

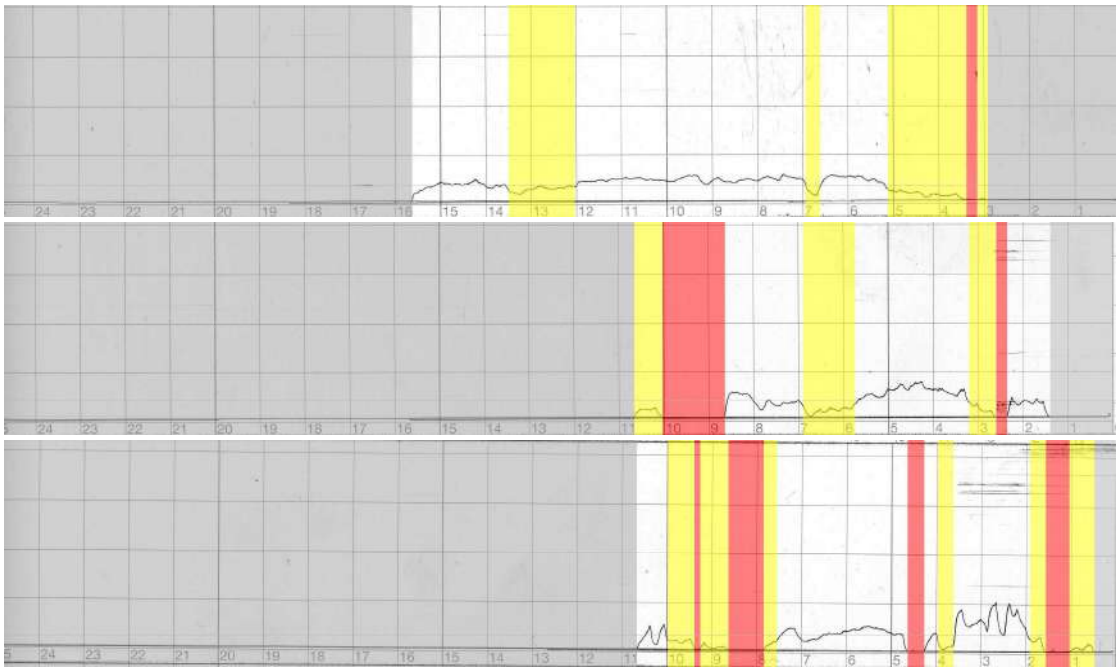


Figure 336: Examples of micro-drill graphs showing internal degradation. From the top:

- measurement point a' rear in frame 8 in the South-West range of Stirling Castle Palace

- measurement point a in the Strut on the North side of frame XLII of Holyrood Palace

- measurement point b in the Strut on the North side of frame XLIII of Holyrood Palace

5.2.2 Past repairs, alterations and interventions

Past alterations and repairs can contribute to creating or accelerating damage in some cases. Although we have estimated past interventions to be a direct cause of damage and degradation only in three of the surveyed roofs (Figure 322), the three conservation engineers we have interviewed confirm that this is a common issue in Scottish roofs (section 5.1.3). Gardyne's Land (1675), for example, has deflected collars in the central part of the roof, because a pediment was added here in early eighteenth century; the problem has been solved with a temporary steel beam placed under the collars and pulled up by cables (Figure 337 left). Another example is Oakshaw Trinity church (1754-6), where the heavy plaster ceiling was probably added or replaced in nienteenth century, causing, together with the improper design of the structure previously discussed, deflections and joint disconnections due to the additional dead load (Figure 324 left and Figure 328 bottom right).



Figure 337: Past interventions: steel beam and ties counteracting the collars' deflection in Gardyne's Land (1675) (left), steel truss supporting the roof of Geilston House (1666) (centre), eighteenth century and twenty-first century timbers strengthening the original seventeenth-century timbers in Panmure House (1680s) (right)

There is often no documentation on past and recent repairs and why they have been done, as previously discussed. Temporary interventions often become permanent, and their effect on the structure is not monitored: the interventions in Gardyne's Land and Geilston House were supposed to be temporary but they've been there for about 20 years now (Figure 337 left and centre). The steel truss in Geilston House, in particular, is very bulky and hinders accessibility to the attic.

Whilst in eighteenth and nineteenth centuries timber was used to either replace the whole roof or double its structure (Figure 337 right), in twentieth and twenty-first centuries steel became more fashionable. The weight of steel can however be a problem for the masonry and the plaster ceilings. For example, timber posts and steel beams were added in Oakshaw Trinity Church to support the hip rafters that were deflecting (Figure 338 left, Figure 326); this intervention actually increased the loads on the tie-beams, incrementing their deflection and the joints' opening (Figure 328 bottom right), and the loads on the masonry, causing cracks. Moreover, secondary elements were savagely

cut to make place for the steel reinforcement, causing further problems to the plaster ceiling directly attached to these secondary beams (Figure 338 centre).



Figure 338: Past interventions: timber and steel elements counteracting the hip rafters' deflection in Oakshaw Trinity church (1754-6) (left), a secondary beamcut to make place for the steel reinforcements in Oakshaw Trinity Church (1754-6) (centre), filled checks in the roof of the Ordnance Store at Fort George (1759-61) (right)

Checks and cracks are often filled with resin (Figure 338 right). Checks are natural cracks that develop along the radius of a log, when the timber dries. They rarely are a structural problem, unless they are deep and on both sides of the timber. Filling them actually weakens the timber preventing it from swelling when the temperature and humidity change, causing further cracks to develop.

5.2.3 Inadequate environmental conditions, accessibility issues and poor maintenance

As already stated, many common rafter roofs, as well as almost half of the surveyed complex frames, have material degradation problems (Table 13). Besides the timber dressing, other factors contribute as causes. While the roof spaces of trussed roofs are bigger and more airy, common rafter roofs and complex frames generally cover dwelling houses, where the lower part of the roof spaces is plastered and occupied by attic rooms - there are only 7 exceptions where this does not happen, out of 47 roofs. This lower part of the structure, and in particular the connection with the lateral walls, is often not visible nor accessible (Figure 339), which hinders its inspection and maintenance. Moreover, the upper part can be quite small, with poor ventilation (Figure 340) and sometimes over insulation, as in Stirling Castle's King's Old Buildings (Figure 342 left).

Modern waterproofing sheets added in-between the sarking and the slates often hinders ventilation too. In Pinkie House there is nothing in-between the sarking boards and the slates, and the sarking boards are laid with 0.5-1cm space between one another allowing for air to pass through. The water can pass through as well, but air dries out the timber quickly. This 'breathable' roofing, together with the fact that the room under the roof space is heated, provides Pinkie's roof space with very good environmental conditions.

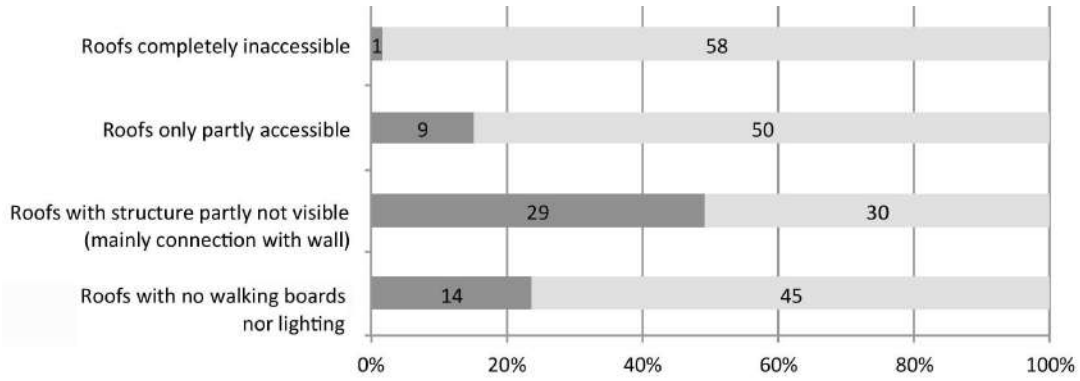


Figure 339: Accessibility and visibility issues found in the surveyed roofs

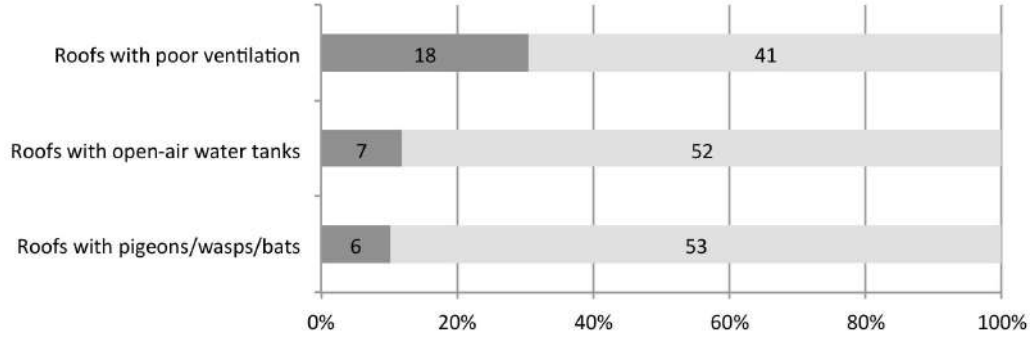


Figure 340: Surveyed roofs affected by inadequate environmental conditions

Most attic spaces are, however, not heated, especially in private houses, and this does not help in reducing humidity. In particular, the air relative humidity and the wood moisture content measured in the simple frames in Touch House and Cockenzie House have been found to have very high values, surpassing 18% in almost all of the measured points and surpassing 20% in most of them (Figure 341). High values have been measured in Cockenzie House both on rafters and collars, near or far from the gable walls, whilst in Touch House mainly in collars and rafters near the East gable wall (Appendix F). The masonry gables in both roofs are wet, disintegrating into dust and falling on the timbers and ceiling underneath. This suggests problems in the flashings, which, together with the fact that the sarking is broken in some areas, causes water ingress. This situation, together with the fact that the timbers are very slim, has forced us not to proceed with further surveys, for safety reasons. The main problem in both cases is the difficult accessibility to the roof spaces coupled with economic aspects, which makes it difficult for owners to carry out the necessary maintenance works.

Many roof spaces are also used to host uncovered water tanks (Figure 340) that increase humidity and thus foster biotic attack, as in Kelburn Castle (Figure 342 centre). Moreover, the presence of pigeons, wasps, and bats hinders accessibility and maintenance (Figure 340): access to many properties has been denied because of the presence of bats or wasps, and a few of the surveyed roofs proved to be problematic because of pigeons' droppings (Figure 342 right).

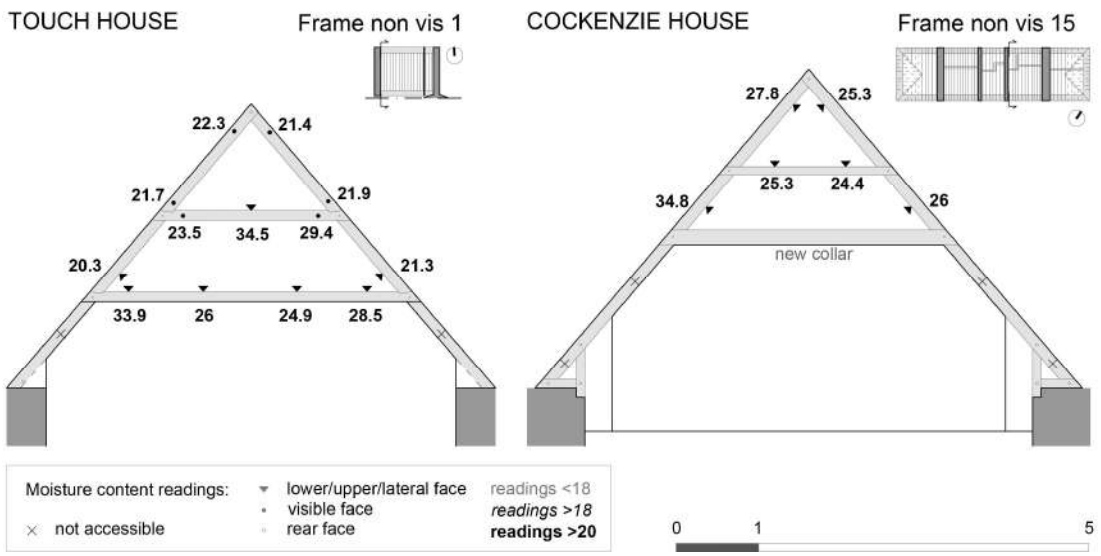


Figure 341: Moisture content readings in one frame in the roof of the North range of Touch House (left) and in one frame in the roof of Cockenzie House (right)



Figure 342: Unfavourable conditions in simple frames: over-insulation in the roof of King's Old Buildings in Stirling Castle (1557) (left), uncovered water tank in Kelburn Castle (1581) (centre), pigeons' droppings in George Heriot School (1630s) (right)

Finally, owners, tenants, estate managers and professionals in charge of the building's maintenance do not always know how to access roof spaces and do not always have the necessary equipment to do it (ladders, torches, etc). As discussed in section 5.1.2, most of them do not feel that accessibility is a problem, also because they do not carry out regular inspections and maintenance works. The extreme example is that of Prestonfield House were the roof structure is completely invisible (Figure 339), hidden behind plaster, as no hatch has been provided for the inspection of the roof space.

5.3 Evaluation of the assessment techniques used

The previous section discusses the condition of the surveyed roofs based on the results of the assessment methods used. The results of visual inspection, VSG and various tests have been combined to give the best evaluation possible of the safety of the roof structures. However, it is

interesting to consider the performance of the techniques used, in order to provide a detailed evaluation of each of them, so to inform future training for conservation professionals. This section will discuss the adopted techniques in terms of: 1) effectiveness and reliability; 2) knowledge and skills required; 3) costs. This discussion will clarify which of the assessment techniques have actually provided valuable information, which of them have been practical to implement, what expertise and skills is required to use each particular technique and what are the costs involved.

5.3.1 Effectiveness and reliability of the assessment techinques used

The foremost requirement for an assessment technique is to provide useful results, in other words to be effective. In addition, the results have to be reliable, to allow for a confident evaluation of the structure's condition. It is therefore important to classifiy the techniques in terms of effectiveness and reliability, according to the survey conditions. To do so we identified the specific requirements that have to be in place for each technique to be effective and reliable, as summarized in Table 14.

Visual assessment techniques, such as visual identification of pathologies and VSG, are highly effective if the roof structure is accessible and visible. It must be kept in mind, however, that the reliability of their results is limited to the surface: internal degradation, damage and natural defects cannot be assessed visually. Moreover, in case of fungi attack we have found that it is often difficult to identify the type of fungi and evaluate its status (active or not) based only on other examples and guidelines provided by the literature. With regard to VSG, it is necessary to observe all the faces of the timber elements in order to classify them in specific a stregnth class. The results of VSG are consistent with those obtained from the visual identificaiton of pathologies. However, it would be interesting for future research to validate VSG results against laboratory measurements of mechanical properties for the timber structures examined here.

When the roof structure was accessible only through small apertures, we used a snake camera to perform endoscopic imaging and observe the timbers. However, the effectiveness of our snake camera was limited by the short length of the probe, its low resolution and by the fact that insulation sheets between the timber elements often hindered the probe movements.

The identification of the timber species can be done macroscopically in situ or microscopically in the lab after collecting a sample. The macroscopic identification of the timber species requires the transversal section of wood to be visible (e.g. the end of a beam), otherwise a sample must be collected and cut transversally. The macroscopic identification is challenging even for experts, as it is often not possible to distinguish between the different softwoods. Conversely, the microscopic identification of the timber species is much more reliable. In fact, in one occasion we were able to distinguish pine from spruce only after analysing the sample with the optical microscope.

The measurement of the environmental conditions using an air thermometer and a hygrometer does not pose any specific issues in terms of effectiveness and reliability. Measuring the air temperature/humidity with an air thermometer clearly requires access to the roof space but it does not necessarily require visibility of the roof structure. Measuring the wood moisture content with a hygrometer does not require full visibility of the roof structure either, but it does require access to the wood surface. Both techniques are considered reliable and robust as they promptly provide a quantitative measurement of punctual properties of the wood structure, such as local temperature or water content.

Table 14: Summary of the effectiveness and reliability of the assessment techniques used during the surveys. The effectiveness column details on the requirements needed to obtain useful results, such as accessibility, visibility, sampling, environmental conditions, instrumental resolution, and timber thickness. The reliability column specifies wether the results obtained from each technique can be considered reliable and to what extent.

Assessment technique		Effectiveness	Reliability
Visual identification of historically relevant features and pathologies		requires accessibility and visibility of the roof structure	reliable, but limited to surface and difficult to identify type and status of fungi
Visual Strength Grading (VSG)		requires accessibility and visibility of all faces of the timber elements	results consistent with visual identification of pathologies
Timber species identification	Macroscopic	requires visibility of the roof structure and in particular of the transversal section of wood *or* wood sampling	reliable but it is difficult to distinguish among softwoods
	Microscopic	requires visibility of the roof structure *and* wood sampling	reliable
Measurement of environmental conditions	Thermometer	requires access to roof structure	reliable
	Hygrometer	requires access to wood surface	reliable
Other non-destructive and semi-destructive testing	Rubber hammer	requires access to wood surface	no useful information obtained
	Ultrasonic test	requires access to wood surface and timbers with limited thickness	inconsistent with micro-drill results
	Micro-drill	requires access to wood surface	reliable
	Snake Camera	requires accessibility through slits/holes and good resolution camera	no useful information obtained
	Thermal Camera	requires heated environment	reliable

The same consideration does not hold for timber sounding with a rubber hammer, as it was arduous to perceive differences in sounding. This method, therefore, appears prone to subjective biasing depending on the surveyor's experience. On the other hand, literature reports that sounding is effective only for extensive degradation/damage (Ross et al., 1999). As the published studies do not

report quantitatively on the degree of damage that can be assessed with rubber hammer testing, we cannot exclude that we never encountered such extensive damage. The effectiveness and reliability of the thermal camera, the ultrasonic device and the micro-drill are discussed separately in the following sub-sections.

5.3.1.1 The effectiveness and reliability of the thermal camera

We have used the thermal camera both in roof spaces and attic spaces underneath, to identify damp areas and water ingress problems, as well as thermal bridges, and to investigate the connection between the roof structure and the lateral walls hidden behind timber or plaster panelling. Unfortunately, we have obtained interesting results only in some heated attic spaces.

As detailed in chapter 2 (section 2.1.3.1), thermal imaging, or infrared thermography (IRT), allows visualizing and quantifying temperature variations across surfaces by detecting infrared radiation emitted by objects: the warmer the object, the more infrared radiation it emits (Riggio et al., 2015b, Young, 2014). This means that for useful thermal images to be recorded there needs to be a temperature contrast: without heat to drive evaporation, a damp patch on a wall will have the same temperature as an adjacent dry surface.

Unfortunately all of the roof spaces where we carried out thermal imaging were not heated and owners never allowed heating because of fire safety reasons. Outdoor temperatures never allowed a natural heating of the roof spaces either (as, for example, in Colla and Gabrielli, 2015): our in situ campaign was carried out between January and June 2016, when temperatures in Scotland seldom surpassed 15°. Therefore, none of the thermograms we have taken in roof spaces show any relevant feature, even after increasing the thermal contrast by reducing the visualised temperature range in the post-processing. Some examples are visible in Table 15 (B, C, E, I, O, T): the temperature differences are easily identified as air coming through ridges and eaves, gaps in the insulation sheets, or other features not useful to assess the geometry or condition of the roof structure.

On the contrary, most attic spaces where we carried out thermal imaging were heated and thermography provided valuable results. The only exceptions are: the attic of Newhailes House (Table 15 L), where no temperature difference was identified despite the attic being heated; the attic of Touch House (Table 15 S), where the attic spaces where not heated and no temperature difference was identified; the attic of St Andrew's in the Square church (Table 15 D), where the thermograms only revealed gaps in the insulation sheets above the ceiling.

In Abbeystand Buildings (Table 15 A), Holyrood Palace (Table 15 H), Pinkie House (Table 15 M) and Stirling Castle Palace (Table 15 P) thermal images allowed assessing the position and geometry of the structure hidden behind the plaster/timber panelling. In fact, in all four roofs the position and

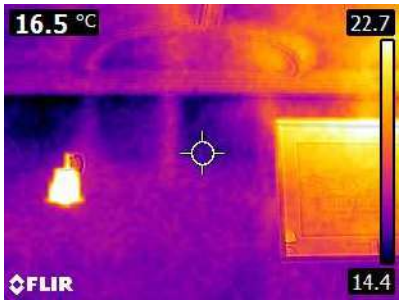
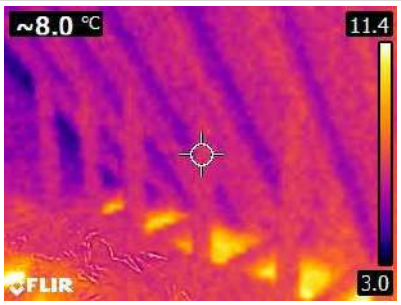
dimension of the rafters, and sometimes collars, hidden behind the panelling is visible in the thermographic images taken in the attic spaces.

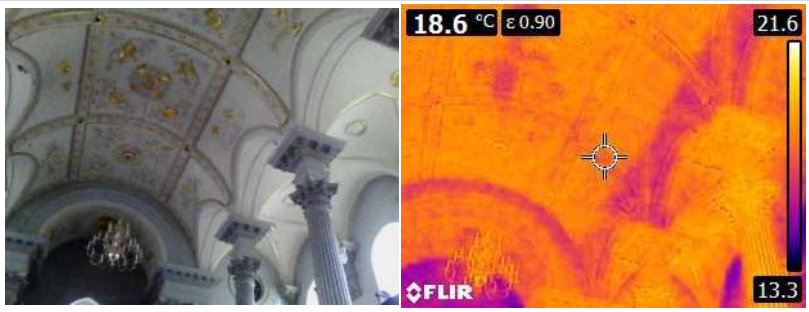
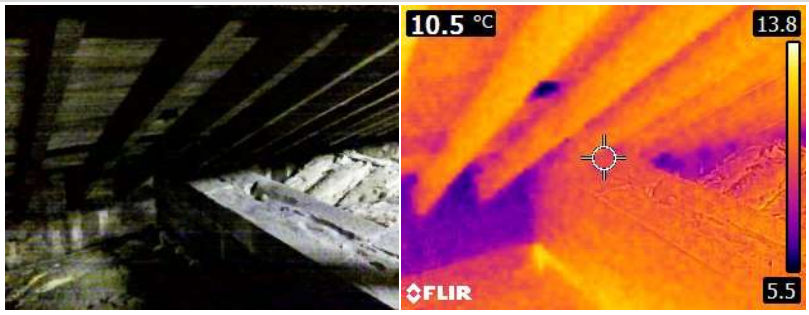
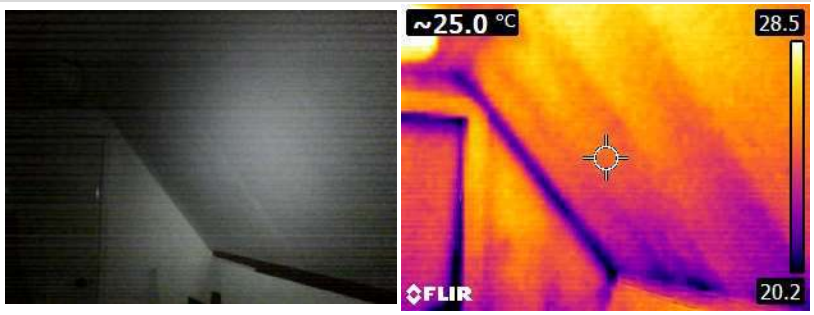
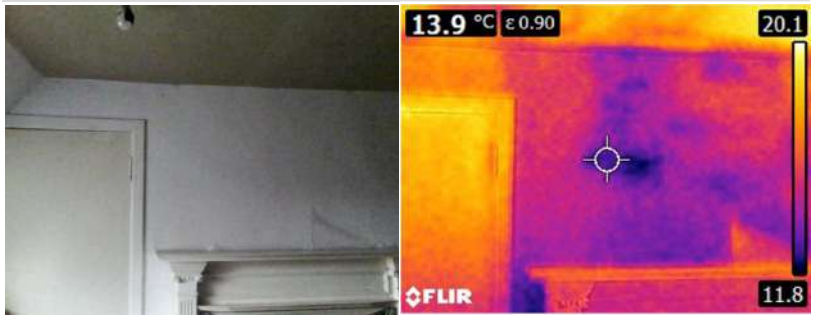
In Pinkie's roof (Table 15 M), in particular, it has been useful to assess the geometry of the connection with the wall: the fact that no timbers are visible in the lower part of the thermographic image, below the timber ceiling, suggests that no ashlar posts are present and that the lower part of the rafters is embedded in rubble masonry. This hypothesis is confirmed by the comparison with the thermographic images taken in the attic of Abbeystrand Buildings, where the ashlar posts are instead clearly visible (Table 15 A) .

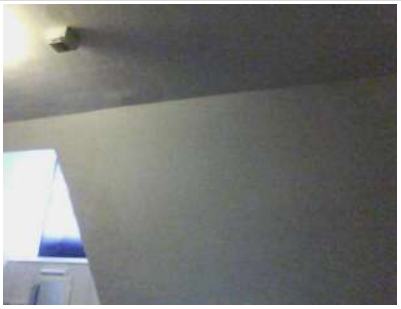
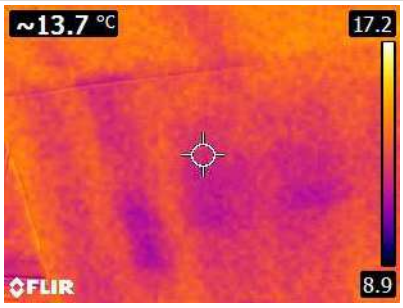
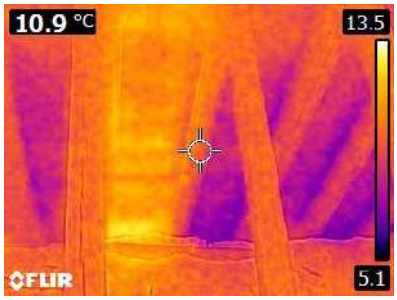
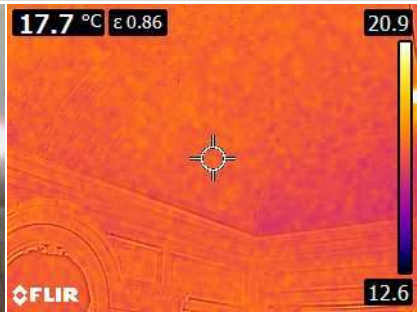
In other heated attics thermography has allowed identifying damp areas where water ingress might be causing damage, as in Cockenzie House (Table 15 F, G), Pinkie House (Table 15 N), Stirling Castle Palace (Table 15 Q) and the King's Old Buildings in Stirling Castle (Table 15 R). Cockenzie House's attics are not heated but since the rooms are quite small it has been possible to heat them with a small electric heater. After one or two hours, depending on the room's dimensions, the thermographic images showed good results. In Cockenzie House and Stirling Castle Palace the damp areas revealed by thermography confirmed what was found in the roof spaces: very damp gable walls disintegrating into dust and falling on the timbers and ceiling. In the King's Old Buildings it was not possible to assess the condition of the timbers and gable wall because the roof could only be accessed from a small hatch on the North side and no walking boards were provided. In Pinkie House's case it was also impossible to assess the masonry's condition because the connection between the roof structure and the lateral wall was not accessible nor visible from the roof space.

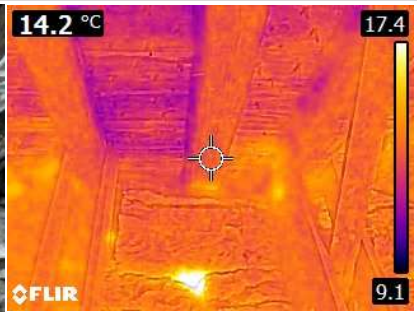
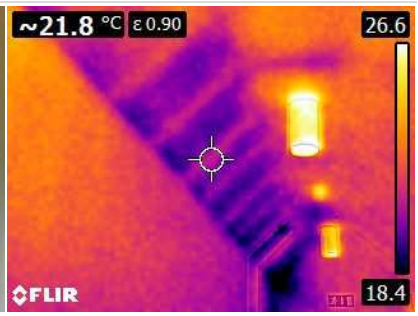
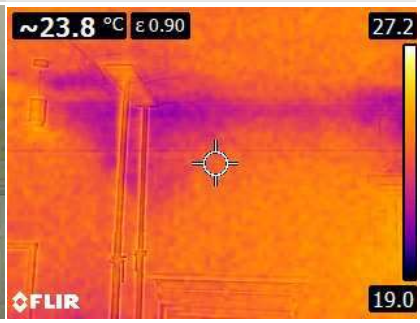
Therefore it can be concluded that, in environmental conditions such as the ones found in Scotland, thermal imaging is effective only in heated spaces. With regard to the reliability of thermal images, it only depends on the ability of who takes the images and interprets them, as discussed in section 5.3.2.

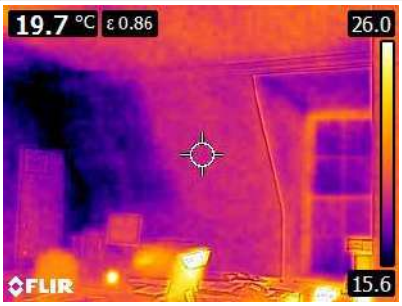
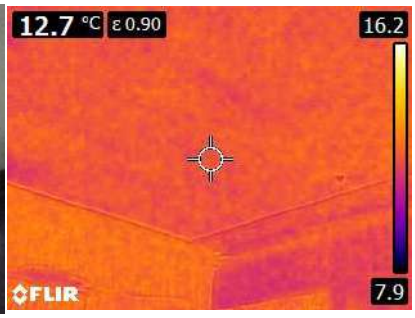
Table 15: The most significant thermograms taken in the attic and roof spaces of the case studies, with at least one example (when available) for both the roof space and the attic space of each case study. The measured air temperature/humidity and wood moisture content are also reported to show the environmental conditions in which the thermograms have been taken

Building		Air temp. hum.	Photographic image	Thermogram
Abbey strand 12/02/ 2016	attic	*17°* *51%*		
			A) *higher temperatures identify the position of the timber roof structure hidden behind the wall and the ceiling: the presence of an ashlar post, typical of the Scottish rafter foot, is highlighted*	
	roof	10° 65%		
			B) *higher temperatures identify the heat coming from the attic space underneath (wood MC not recorded)*	
St Andrew's and St George's church 03/02/2016	attic		*not accessible at time of test*	
	roof	13.2° 54.4%		
			C) *lower temperatures at the eaves identify deficiencies in the flashings allowing air to come in from outside (wood MC=14.1%)*	

St Andrew's in the Square church 16/02/2016	attic	18.4° 35.2%	 ***D)*** *lower temperatures at the top of the columns and in the central part of the vaults identify missing insulation sheets above the plaster ceiling; the masonry parts in the bottom left corner are also identified by lower temperatures*
	roof	13.3° 56.2%	 ***E)*** *lower temperatures identify the masonry and a gap in the sarking boards between the rafters allowing air to come in from outside (wood MC=16%)*
Cockenzie House 22/01/2016	attic	9.7° (14° after heating) 77.3%	 ***F)*** *lower temperatures at the junction between the roof structure and the gable wall identify deficiencies in the flashings*  ***G)*** *lower temperatures on an intermediate gable wall identify damp masonry*

	roof		*not accessible at time of test*
Holyrood Palace	attic 02/ 06/ 2016	19.6° 52%	  ***H)*** *higher temperatures identify the position of the timber roof structure hidden behind the plaster panelling*
	roof 12/ 02/ 2016	11° 55%	  ***I)*** *higher temperatures between two rafters identify a gap in the insulation sheets allowing heat to come up from the attics (wood MC=16.5%)*
Newhailes House 03/06/2016	attic	17.7° 56.5%	  ***L)*** *no differencies in temperature highlighted*
	roof		*not accessible at time of test*
Pinkie House 09/03/2016	attic	18.7° 38%	  ***M)*** *lower temperatures identify the position of the timber roof structure hidden behind the painted timber ceiling*

			  ***N)*** *lower temperatures on a lateral wall identify damp masonry*
	roof	14.8° 48.7%	  ***O)*** *lower temperatures identify gaps between the sarking boards and the rafters allowing air to come in from outside, while higher temperatures identify gaps in the insulation sheets allowing heat to come up from the attic space (wood MC=15.6%)*
Stirling Castle Palace 10/02/2016	attic	17.1° 52%	  ***P)*** *higher temperatures identify the position of the timber roof structure hidden behind the plaster panelling*   ***Q)*** *lower temperatures identify damp masonry and plaster*
	roof		*not accessible at time of test*

Stirling Castle King's Old Buildings 10/02/2016	attic	17° 45%	  ***R)*** *lower temperatures on an intermediate gable wall and external wall identify damp masonry*
	roof		*not accessible at time of test*
Touch House 17/02/2016	attic	13.8° 55.2%	  ***S)*** *no differencies in temperature highlighted*
	roof	10.3° 69%	  ***T)*** *lower temperatures on an intermediate gable wall identify a gap in the masonry allowing air to pass (wood MC=18.3%)*

5.3.1.2 The effectiveness and reliability of the ultrasonic waves test and the micro-drill test

The ultrasonic waves test and the micro-drill test have been used to investigate the internal condition of the timber elements. As detailed in chapter 2 (section 2.1.3.4), the ultrasonic waves test emits sound waves with high frequencies into the material and measures how much time is needed for the waves to pass through the object; once the distance between the two sensors on the opposite sides of the objects is known, the velocity can be calculated and compared with reference velocities for sound materials, in order to assess the presence or not of internal flaws. As detailed in chapter 2 (section 2.1.3.1), the micro-drill test measures the resistance of wood to the penetration of a drill at a constant rotational speed and penetration rate. A graph representing this resistance is

traced by the device during the test and provides a density profile of the section of the timber element.

The two tests are quite different: the micro-drill is semidestructive while the ultrasonic waves test is non-destructive, therefore preferable; the ultrasonic waves test has a numerical output while the micro-drill has a graphical one, easier to interpret. Most of all, the ultrasonic waves test has been designed to be used on concrete structures and its application to timber structures is quite recent. On the contrary, the micro-drill test has been designed specifically for timber and has been used for a longer time; the available literature is vaster and the implementation of the test has been studied in more detail. Therefore, the results of the micro-drill test can be considered reliable (from a qualitative point of view, as detailed in section 2.1.3.5) and can be used to "verify" the reliability of the the ultrasonic test results. In order to do so, the ultrasonic test and the micro-drill test have been performed in the same measurement points.

The results of the micro-drill test have already been presented in section 5.2.1 (Figure 333, Figure 334, Figure 335, Figure 336). The results of the ultrasonic test are summarized in Figure 343. Most of the measured velocities do not show a decrease higher than 10% compared to the reference velocity 1470 m/s. This, according to Dackermann et al. (2014), should correspond to healthy wood (green circle in Figure 343). Some of the measurements in Holyrood Palace have been taken with a higher Voltage and Gain (light blue circle in Figure 343), because the signal was not strong enough. The increase of these parameters is not recommended as it increases the noise in the signal. These measurements have all recorded good velocities. In other measurement points in Holyrood Palace, even after having increased the Voltage and Gain to the maximum levels, the signal was still unstable and it was therefore impossible to record a measurement (Purple circle in Figure 343). Only 12 measurements recorded a decrease in velocity higher than 10% compared to the reference velocity 1470 m/s (intersection between red and green circles in Figure 343), and 3 of them recorded a decrease in velocity higher than 10% compared to the reference velocity 1200 m/s (red circle in Figure 343), which should correspond to unhealthy wood (Rodríguez Liñán et al., 2015).

The results of both the ultrasonic waves test and the micro-drilling test depend on the original quality of the timber and on its present condition (e.g. the extent of material degradation and damage). In the case of the ultrasonic waves test it is not possible to determine the contribution of these two factors in the final result. The micro-drill, on the contrary, produces a graphic result based on which we can qualitatively estimate the original quality of the timber and the amount of degradation/damage affecting it.

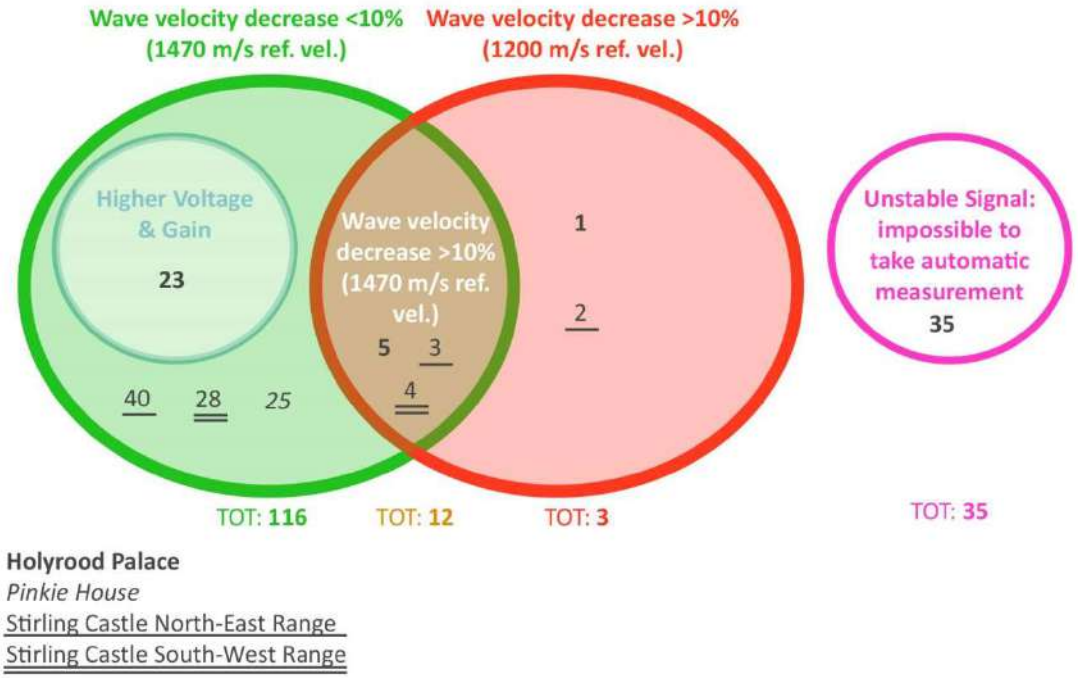


Figure 343: Results of the ultrasonic measurements taken in the roofs of Stirling Castle Palace, Holyrood Palace and Pinkie House

The original quality of the timber can be estimated by looking at the white part of the micro-drill graph, corresponding to non-degraded timber (example in Table 16). The graph shows the energy consumed by the drill to penetrate the timber at a constant rotational speed and penetration rate. It can be assumed that timber with a higher resistance to penetration has a better quality (Nowak et al., 2016). Thus an average height (representing the energy consumed by the drill = the resistance to penetration) has been calculated for each graph and three categories (high quality, medium quality, low quality) have been estimated based on the highest height divided by 3.

The extent of material degradation has been quantified according to the following procedure:

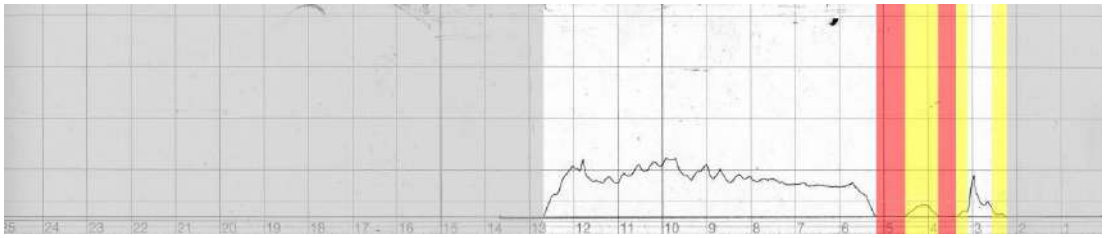
- An ideal graph has been calculated considering only the non-degraded wood: the area under the curve in the white part of the graph (85282 pixels in the example in Table 16) has been divided by the corresponding depth (8,09 cm in the example in Table 16) and then multiplied by the total depth (10.47cm in the example in Table 16);
- The real area has been measured (87418 pixels in the example in Table 16);
- The extent of material degradation/damage has been calculated in percentage:

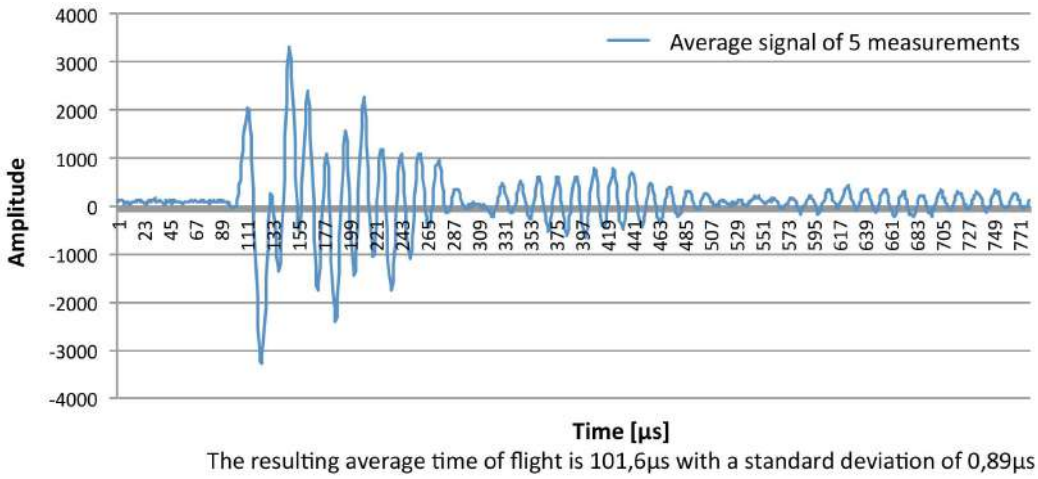
$$\mathrm{Md} = \frac{\mathrm{A_{id}} - \mathrm{A_r}}{\mathrm{A_{id}}}\ 100\ [\%]$$

(Md = material degradation extent; Aid = ideal area; Ar = real area)

Table 16: Example of measurement taken in the roof of Holyrood Palace: comparison between density loss calculated based on the ultrasonic results and extent of material degradation identified by the micro-drills. The density loss has been calculated based on the measured time of flight of ultrasonic waves, from which their velocity has been calculated, corrected based on grain orientation and moisture content and compared to reference velocities, as detailed in chapter 2 (section 2.4.3.4)

Location	Visible Decay	Moisture Content [%]	Velocity [m/s]	Relative Velocity Decrease [%]		**Density Loss Ultrasonic [%]**	**Material degr/damage Resistograph [%]**
				Reference 1470 m/s	Reference 1200 m/s		
Holyrood Palace Frame XVIIII North Strut Point a	no	15.7	1340	8.9	-11.5	**0.3**	**20.8**





The micro-drills have then been grouped in six categories, based on the combination of original quality and extent of material degradation:

- High quality and low degradation/damage: 8 micro-drills;
- High quality and high degradation/damage: 0 micro-drills;
- Medium quality and low degradation/damage: 36 micro-drills;
- Medium quality and high degradation/damage: 4: micro-drills;
- Low quality and low degradation/damage: 5 micro-drills;
- Low quality and high degradation/damage: 3 micro-drills.

The extent of material degradation/damage has been considered to be low if less than 10% (Tannert et al., 2014). The micro-drill has been used in the same measurement points where the ultrasonic device has been used, thus the micro-drilling graph shows density variation along the path we assume the ultrasonic wave took. Figure 344 shows the ultrasonic wave velocities grouped according to the category to which the corresponding micro-drill belongs. Only the ultrasonic wave velocities measured without increasing the default values of voltage and gain have been considered.

High and low wave velocities are evenly distributed in all 5 categories. A different arrangement would have been expected: timber with high quality and low degradation/damage should have higher wave velocities than timber with low quality and high degradation/damage.

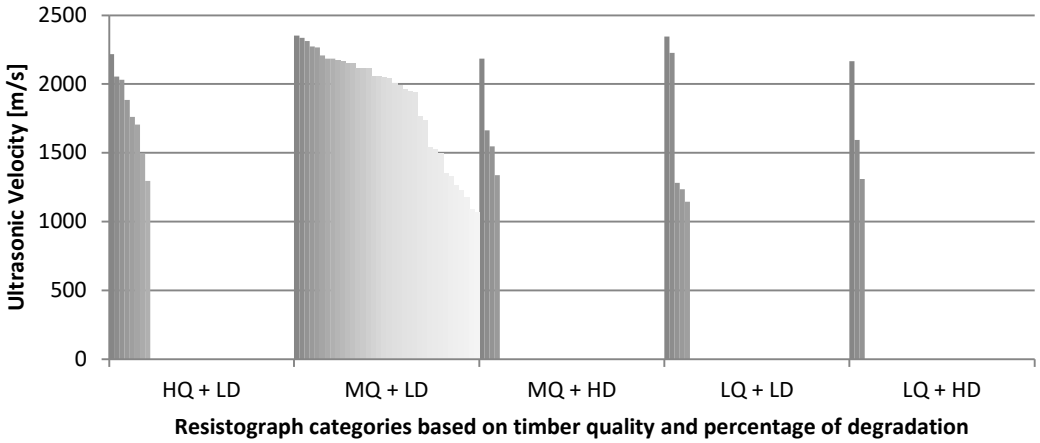


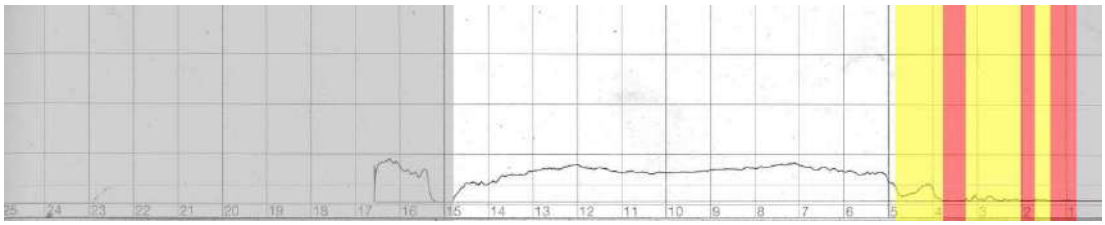
Figure 344: Ultrasonic wavs velocities grouped according to the categories of the corresponding micro-drills: HQ = High Quality, MQ = Medium Quality, LQ = Low Quality, LD = Low Degradation, HD = High Degradation

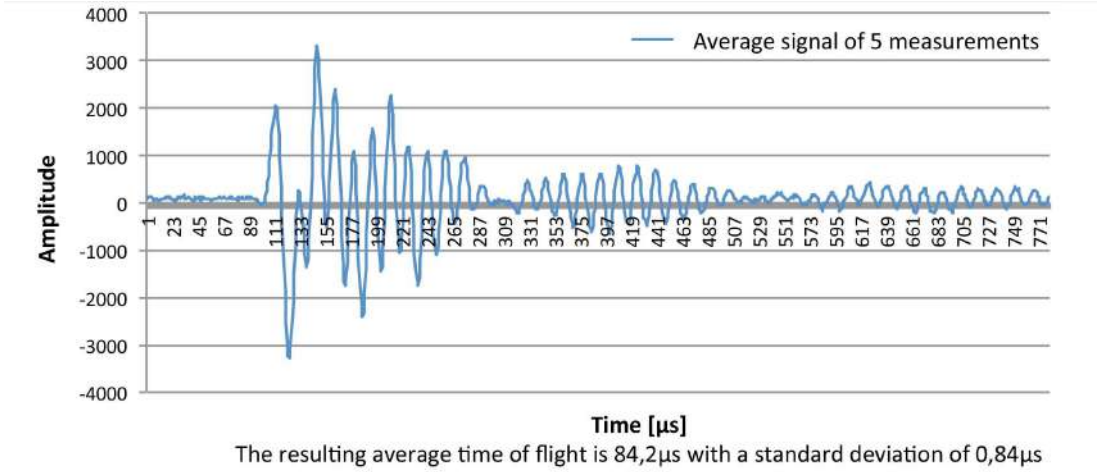
This means that in some cases the ultrasonic device measured a high velocity (supposedly corresponding to good quality/healthy wood), whilst the micro-drilling test highlighted a low quality timber with extended degradation (example in Table 17). In other cases the ultrasonic device measured a low velocity (supposedly corresponding to low quality/unhealthy wood), whilst the micro-drilling test showed a high quality timber with very limited degradation (example in Table 18).

In those measurement points where the ultrasonic device was not able to record a measurement automatically due to the unstable signal (Purple circle in Figure 343), at first it was thought that there might be extensive degradation/damage that caused the instability of the signal. However, the hypothesis was incorrect, as the micro-drilling device often reported the wood to be healthy in the same measurement points (Figure 345).

Table 17: Example of measurement taken in the roof of Pinkie House, where the ultrasonic test results do not correspond to the results of the micro-drill test: the ultrasonic test measured a high velocity, while the micro-drilling test highlighted internal decay

Location	Visible Decay	Moisture Content [%]	**Velocity [m/s]**	Relative Velocity Decrease [%]		Density Loss Ultrasonic [%]	**Material degradation Resistograph [%]**
				Reference 1470 m/s	Reference 1200 m/s		
Pinkie House Frame XVII Point 1	no	18.1	**2165**	-47.3	-80.5	-32.5	**26.3**

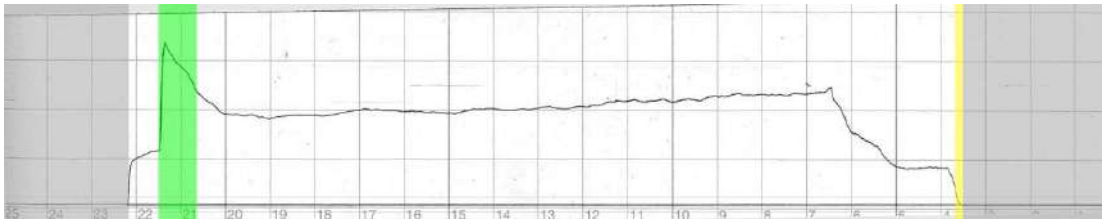


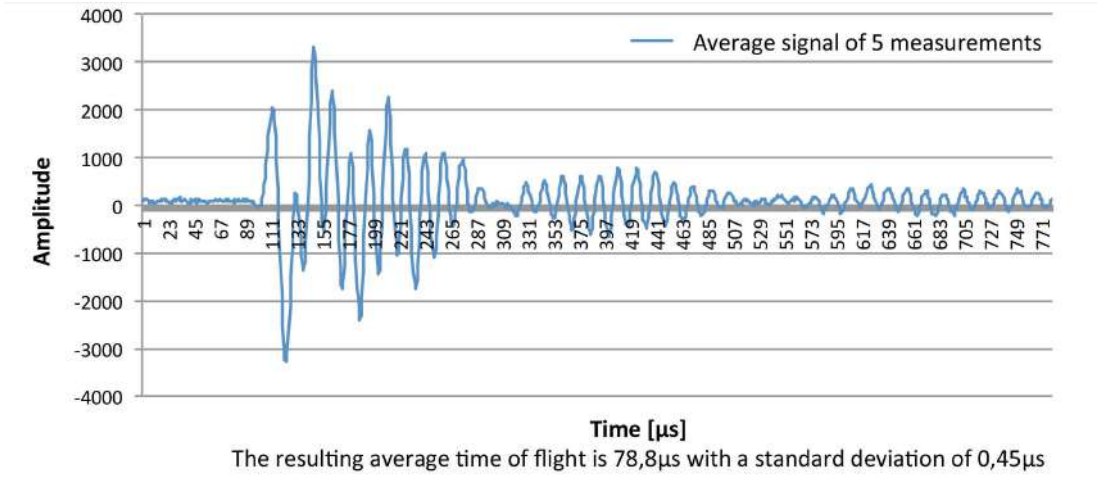


The discrepancies between the uiltrasonic results and the micro-drill results could be linked to problems with the setup of the ultrasonic test. In fact, due to the rough dressing of the timbers, the coupling of the transducers was problematic since the very beginning of the survey campaign and it hindered an effective transmission of the wave energy into the wood. However, once silicone polymer putty was used as coupling agent, it was possible to record automatic measurements in most measurement points, with the only exception of most points in Holyrood Palace (Figure 343). Holyrood Palace's roof is the only one where it has been necessary to increase the Voltage and Gain in all measurement points except for 6. In 23 measurements points it was possible to record automatic measurements after icnreasing the Voltage and Gain, while in 35 measurement points it was not sufficient, as the signal remained unstable.

Table 18: Example of measurement taken in the roof of Stirling Castle Palace, where the ultrasonic test results do not correspond to the results of the micro-drill test: the ultrasonic test measured a low velocity, while the micro-drilling test highlighted healthy wood

Location	Visible Decay	Moisture Content [%]	**Velocity [m/s]**	Relative Velocity Decrease [%]		Density Loss Ultrasonic [%]	**Material degradation Resistograph [%]**
				Reference 1470 m/s	Reference 1200 m/s		
Stirling Castle Palace North-East range, Frame 1, Point 16	no	17.1	**1295**	11.8	-8	1.9	**1**





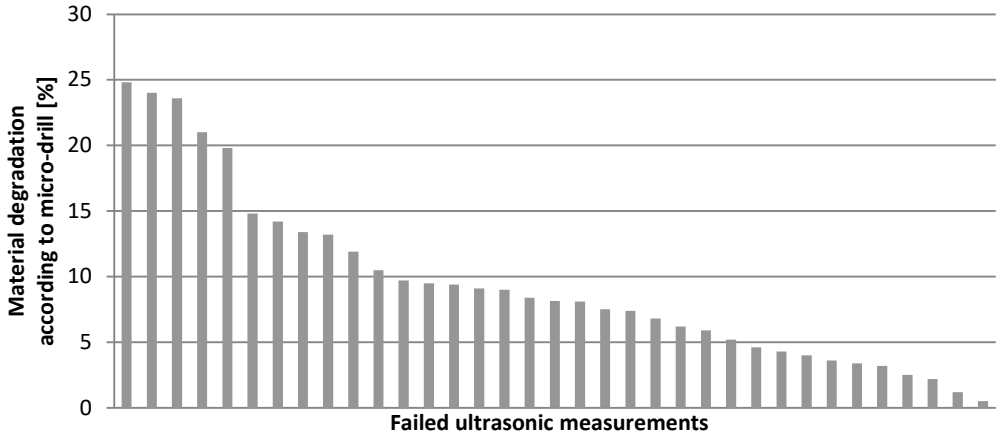


Figure 345: Extent of material degradation estimated for the micro-drill graphs in the measurement points where the unstable signal has not allowed recording the ultrasonic wave velocity

There is one important characteristic that differentiates Holyrood Palace's roof from those of the other case studies: its timbers have bigger sections. Stirling Castle's timbers range from sections of 6.5cm to 10.7cm, Pinkie House's timbers from 11.5cm to 15cm, but Holyrood Palace's timbers have sections up to 23cm. As detailed in chapter 2 (section 2.1.3.4), the attentuation of sound waves increases with the distance they travel, especially in case of high frequencies. This is because higher frequency waves have shorter wavelengths that are able to detect more subtle interior defects, but attenuate more quickly. The graph in Figure 346 highlights that it was impossible to take measurements due to the unstable signal only in sections equal to or bigger than 10cm. Moreover, the graph in Figure 347 highlights that the ultrasonic results that agree with micro-drill results have been obtained mainly for small timber sections, while the results that do not agree have been obtained bigger sections.

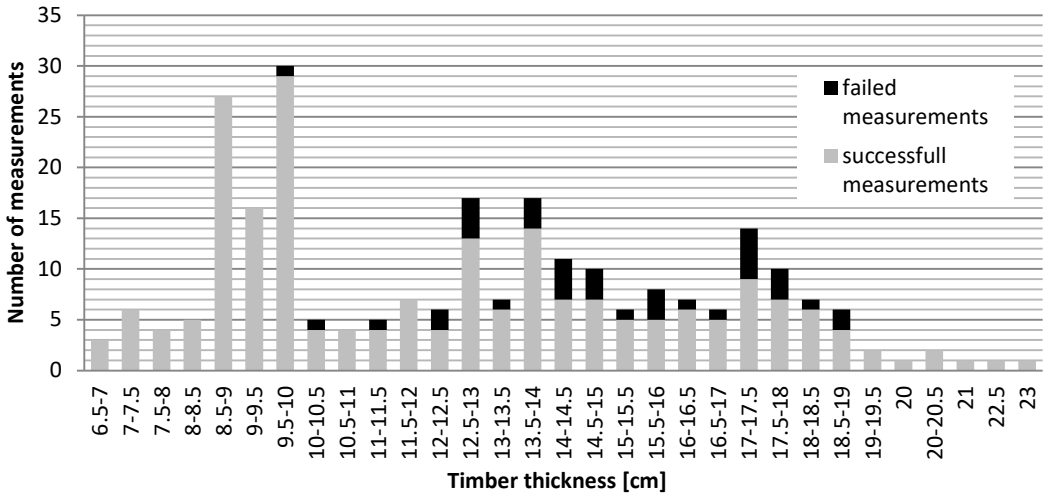


Figure 346: Graph showing the failed ultrasonic measurements, that could not be recorded due to the unstable signal (highlighted in black) distributed according to the thickness of the timber elements tested

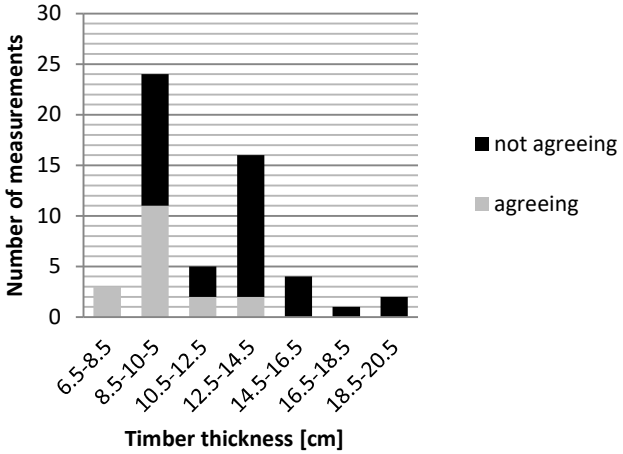


Figure 347: Graph showing the correspondance between the ultrasonic results and the micro-drill results distributed according to the thickness of the timber elements tested

The number of measurements taken is not sufficient to draw ultimate conclusions, but it does highlight that the ultrasonic waves test is not effective for timbers with big sections, in spite of recent research stating otherwise (Cescatti et al., 2014, Morales Conde et al., 2015, Rodríguez Liñán et al., 2015). On the contrary, it is not possible to make considerations on the reliability of the ultrasonic waves test, because the number of micro-drill measurements taken on small sections of timber is too low (Figure 347).

5.3.2 Knowledge and skills needed to implement the assessment techniques used

Expertise is a key parameter that can affect the effectiveness and reliability of any assessment techinque, as stressed by many publications (Dackermann et al., 2014, Hasníková and Kuklík, 2014, Feio and Machado, 2015). **Error! Reference source not found.** summarizes the specific knowledge and skills needed to correctly implement the different assessment techniques used, according to our experience during the surveys campaign.

The visual identification of historically relevant features requires knowledge related to types of historic structural typologies and construction techniques and details such as joints, timber dressing, fasteners, etc. Likewise, the visual identification of pathologies requires knowledge related to the different types of degradation and damage that might affect timber and the possible causes. Literature is full of classifications and examples, but it is not rare to find new features or variations of a type of joint or structure that are present only in a certain geographical area. These variations often produce types of damage different to that of other already known structures. It is therefore important to have a deep understanding of the structural behaviour of timber in order to be able to understand how a structure, even of a new type, is working, and what might be the cause of its pathologies. To do so it is also fundamental to know which features, details and parameters need to be measured and how.

Visual Strength Grading requires knowledge related to wood anatomy and timber natural defects, as well as knowledge of the VSG standards that can be applied depending on the timber species, age and survey condition. Each VSG standard, in fact, requires certain parameters to be measured in a specific way, and its guidelines must be closely followed during the survey in order to have reliable results.

According to our experience, the knowledge and skills needed to carry out visual assessment techniques are not hard to acquire. Conversely, while it is relatively easy to acquire through literature the necessary knowledge needed to carry out different in situ tests, operating the corresponding equipment involves practical procedures that we have sometimes found hard to learn and implement.

The timber species identification, both macroscopic and microscopic, requires a deep knowledge of the wood anatomy of different timber species. It is in fact necessary to know which features must be looked for and where, as well as being able to identify them. While the macroscopic identification only involves using hand lenses, the microscopic identification requires being able to take samples, cut slices for the microscope and operate the microscope, all quite difficult operations.

The measurement of the environmental conditions involves using an air thermometer and a hygrometer. The use of a thermometer is not at all difficult, but the use of a hygrometer with pins, as the one we used, can be quite arduous: it is fundamental to acquire knowledge about wood anatomy, to understand in which point and direction the measurements must be taken, and the pins must be hammered inside the wood with precision and care, otherwise they bend and break. Some practice is needed to become confident in the procedure. Knowledge related to the optimal environmental conditions for wood is then needed to interpret the results.

Timber sounding with a rubber hammer, although operatively simple, is very difficult to interpret: it is in fact impossible to learn simply through literature which sounds are associated with which features (defects, damage, degradation). Unfortunately, we have not obtained any meaningful results from this test, perhaps because we did not have the chance to learn from an expert how to interpret the different sounds.

The ultrasonic test and micro-drill test require knowledge related to wood anatomy, timber defects/damage/degradation and the working principles of acoustic waves, to understand in which point and direction the measurements must be taken and be able to interpret the results correctly. All of these can be acquired through literature. Operating the ultrasonic device is however not straightforward; in our case, if it hadn't been for an expert's suggestion to use silicon polimer putty instead of the gel mentioned in literature and provided by the device's manufacturer, we would have obtained no results at all. It is also difficult to postprocess the results and interpret them. The post-processing, in particular, is not fully exaplained in literature, especially the phase related to the calculation of the time-of-flight: as explained in chapter 2 (section 2.1.3.4), the time-of-flight automatically provided by the device is not accurate.

Endoscopy with a snake camera, on the contrary, does not pose any specific issues in terms of knowldge and skills needed, except that the interpretation of the acquired images might be difficult because of their scarce resolution, as in our case. Thermography requires instead knowledge related to timber defects/damage/degradation, to interpret the results, and the working principles of electromagnetic waves, to operate the thermal camera correctly. The post-processing of the thermal images with the software provided bny the camera's manufacturer is instead quite easy.

Table 19: Knowledge and skills needed to implement the assessment techniques used

Assessment technique		Knowledge	Skills
Visual identification of historically relevant features and pathologies		historic structural typologies and construction techniques and details; types of timber damage/degradation and causes; timber structural behaviour	identifying and measuring overall geometry, construction details, damage and degradation
Visual Strength Grading (VSG)		timber defects, wood anatomy, VSG standards	identifying and measuring timber defects
Timber species identification	Macroscopic	wood anatomy of different timber species	using hand lenses
	Microscopic	wood anatomy of different timber species	taking samples, cutting timber slices, using a microscope
Measurement of environmental conditions	Thermometer	optimal environmental conditions for timber	using a thermometer
	Hygrometer	optimal environmental conditions for timber, wood anatomy	using a hygrometer
Other non-destructive and semi-destructive testing	Rubber hammer	wood anatomy, timber damage/degradation/defects, sounds associated with different featrures	operating the equipment
	Ultrasonic test	acoustic waves working principles, wood anatomy, timber damage/degradation/defects	using an ultrasonic device, post-processing the results and interpreting them
	Micro-drill	wood anatomy, timber damage/degradation/defects	operating the equipment and interpreting the results
	Snake Camera	timber damage/degradation/defects	operating the equipment and interpreting the results
	Thermal Camera	electromagnetic waves working priciples, timber damage/degradation/defects	operating the equipment, post-processing the results and interpreting them

The above-mentioned knowledge and skills have been acquired by the author through a critical literature review, but mostly by interacting with experts, researchers and professionals in the field. Some previous experience in the visual identification of historically relevant features and damage/degradation and in the use of in situ testing techniques was acquired during the MSc studies at the ITAM Institute in Prague (Serafini, 2013). The MSc dissertation consisted in the historical and structural assessment of a seventeenth-century timber roof in Prague Old Town, surveyed through visual inspection and the use of NDTs and SDTs: humidity recordings, stress waves test, resistance microdrilling, pin pushing and loading jack. The presence of two experts during two out of five days of the surveying campaign was crucial to the learning process of the author.

Further expertise was gained during the PhD thanks to the participation in COST Action FP1101 and to short visits to Napier University (Edinburgh), HES Conservation Science Team and Padova University (Italy). Specific knowledge on timber damage/decay/defects, guidelines and different testing techniques was acquired during a training school in Portugal and a Short Term Scientific Mission in Italy, organized and funded by COST FP1101. During the 4 days training school the author had the chance to learn more about natural defects of timber, VSG and related regulations, carpentry joints as well as some in situ and laboratory testing techniques, whose use was demonstrated on several full-scale timber joints and a complete truss, tested to failure in the laboratory. The two weeks STSM at IVALSA Institute in San Michele All'Adige (Italy), supervised by Dr. Mariapaola Riggio, was instead focused on learning about different typologies of historic timber roof structures and different types of degradation/damage affecting them.

The contact with Dr. Daniel Ridley Ellis, associate professor and head of the Centre for Wood Science and Technology at Napier University, allowed gaining knowledge about wood anatomy and Visual Strength Grading of new timber as well as practical skills on the use and interpretation of results of the ultrasonic test and tomography. The University was visited on two occasions, during which Dr. Ellis demonstrated the use of the above-mentioned testing devices, while Dr. Ellis joined on one occasion the preliminary survey in St Andrew's and St George's church.

Dr. Maureen Young, conservation scientist at HES, gave useful advice on the use of thermography, both in person and by e-mail. A two days visit at the Forestry Faculty of the University of Padova allowed instead learning about wood anatomy and timber species identification techniques. Researcher Alan Crivellaro provided the knowldge, supervision, sample and laboratory instruments necessary to learn how to identify different timber species, macroscopically and microscopically.

The close contact with these experts was fundamental. The most useful learning sessions were the practical ones, especially in situ, because the author could directly benefit from the experts' past experience. These sessions made it clear that expertise cannot be gained through literature only, it must be passed on through mentoring.

5.3.3 Costs involved and overall evaluation of the assessment techniques used

The use of testing devices involves additional costs associated with their purchase and maintenance. In addition, the tests can be semi-destructive, which clearly limits their use. Other parameters such as physical effort demanded, time needed, possibility to implement the test alone, as well as the fact that the test is only specific for wood or can be used in other parts of the building, need to be considered. In order to fully evaluate the assessment techniques used, all of the parameters discussed above have been grouped in 3 topics (costs, on-site procedure, results) and graded on a

one-to-four scale, where 1 is the best (Table 20). The effectiveness and realiability requirements and the knowledge and skills needed have been considered in the evaluation but are not detailed in the table since they have already been discussed in sections 5.3.1 and 5.3.2.

The on-site operation has been evaluated considering accessibility and visibility requirements (section 5.3.1), also related to the equipment dimensions, knowledge and skills needed to implement the technique and operate the equipment correctly (sections 5.3.2), the possibility of carrying out the technique/test alone, the physical effort demanded and the time needed. The results have been evaluated considering the knowledge and skills needed to interpret them, the amount of processing required and the reliability of the final results, discussed in the previous section.

Visual surveying techniques (visual inspection and VSG) do not have the drawbacks associated with the use of instruments: they allow gathering a wide range of information without disruption to the structure nor any additional cost, they can be carried out by one person alone with no particular phisical effort, and the time needed depends only on the dimensions of the roof structure and on the level of detail in which the investigation needs to be carried out. Visual strength grading is however specific for wood only.

The same is true for timber sounding with a rubber hammer: it is very cheap, non-destructive, easy to use on site. However, as detailed in the previous section, an experienced ear is needed (and is not easy to acquire), otherwise the results will not be valuable, and it is specific for wood only.

The timber species identification is a semi-destructive assessment technique (unless a macroscopic evaluation can be carried out on the end face of the timber element where the transversal section is visible, but this rarely happens). It can be carried out by one person alone but the preparation of the timber slices for the microscope slides is manually demanding; however, many slides can be made from one single sample. The use of a microtome is not necessary but obviously simplifies the procedure. Portable light transmission microscopes are now on the market for very low prices, allowing for the identification to be done directly on site. Moreover, light transmission microscopes can also be used to analyse samples from other construction materials.

Thermography is a non-destructive test; it can be carried out by one person alone and the processing and interpretation of results is not difficult, but the purchase cost is medium-high. On the other hand, the thermal camera can be useful in the assessment of other parts of the building, since it is not a test specific for wood.

The snake camera is a cheap and straightforward test that can be carried out by one person alone. The cost is however proportional to the results: images from a low-cost camera will have a lower

resolution and will thus be more difficult to interpret. The test can be non-destructive or minor-destructive, depending on the need to make small holes to introduce the probe. Unfortunately insulation sheets in-between the timbers often hinder accessibility and visibility, making the test unsuccessful. On the other hand, just like the thermal camera, the snake camera can be used to assess other parts of the building.

Table 20: Evaluation of the testing equipment used during the surveys based on the costs involved, the test implementation and the results; the effectiveness and realiability requirements and the knowledge and skills needed have been considered in the evaluation but are not detailed in the table since they have already been discussed in sections 5.3.1 and 5.3.2. The grades' scale is 1=best, 4=worst.

Equipment	Costs	On site procedure	Results
Visual Inspection	**1** £0 (0€)	**2**	**2**
Visual Strength Grading	**1** £0 (0€)	**2** specific for wood	**2**
Rubber Hammer	**1** ~ £4 (5€)	**2** specific for wood	**3**
Microscope	**2** ~ £60 (70€)	**2** semi-destructive; preparation of the timber slices for the microscope slides is manually demanding	**2**
Thermal Camera	**3** ~ £660 (750€)	**2**	**1**
Snake Camera	**2** ~ £40 (50€)	**2** insulation sheets often hinder accessibility and visibility	**2**
Thermometer	**1** ~ £15 (20€)	**1**	**1**
Hygrometer	**3** ~ £800 (900€)	**3** requires physical effort; is time-consuming; difficult to hammer without deflecting pins; semi-destructive	**1**
Micro-drill	**4** ~ £8000 (9000€)	**3** heavy and bulky; drill sometimes deviates; specific for wood; semi-destructive	**2**
Ultrasonic	**4** ~ £7800 (8800€)	**4** difficult to have good coupling and good signal; difficult for one person to operate alone; not effective for timbers with big sections	**4** long and difficult data-processing

Air thermometers are very cheap, easy to use and with straightforward results. Hygrometers can instead be of different types (Riggio et al., 2014), with variable purchase costs. The cost is medium/high in the case of resistance type hygrometers adequate for different materials, able to measure the moisture content inside the timber rather than on its surface only, and incorporating

automatic corrections for the air temperature and the timber species, such as the one we used. The GANN Hydromette RTU 600 is not easy to operate. It incorporates a hammer used to insert and extract the pins from the wood. A bit of training is necessary to understand how to hammer correctly without deflecting the pins, which need to be replaced whenever this happens. The cost for the replacement pins is also to be considered. The physical effort is quite high and the test is time-consuming. The results are however straightforward. Both thermometers and hygrometers can be operated by one person alone.

The micro-drill device is quite heavy and bulky, thus it is sometimes difficult to bring it in the roof space and carry out the test. The test can, however, be carried out by one person alone. The drill sometimes deviates but the results can be interpreted straight away and if there are doubts the test can be repeated as it is quite quick. The purchase cost is nevertheless high and the test is semi-destructive.

The ultrasonic device is also expensive but it is non-destructive. It is difficult to operate because the coupling between the transducers and the surface of the wood is often not optimal, and this can create unstable signals. Moreover the test requires two people, one keeping the transducers and one operating the touch screen. The test is effective only for timbers with small sections and the data processing is quite long.The grades given to each assessment technique are summarized in Figure 348. This evaluation is not comprehensive as there are many other non-destructive and semi-destructive tests that can be used in situ to assess historic timber structures, as detailed in chapter 2 (section 2.1). Moreover, the tests compared are not interchangeable, but complementary, as they give information on different aspects of the timber structure. However, as detailed in chapter 2, these devices have been selected based on availability and cost, thus they are representative of what is available to Scottish professionals.

Looking at Figure 348 it can be noted that: besides visual techniques which are obviously costless, the thermometer and hammer are the cheapest (1), followed by the snake camera/microscope (2), the thermal camera/hygrometer (3), and finally the micro-drill and ultrasonic device which are the most expensive (4). The thermometer is also the test that requires less training and effort on site (1), followed by most of the other techniques (2), the microscope/micro-drill (3), and the ultrasonic test that is the most difficult (4). This work highlights that further research is needed in order to overcome the problems in the setup and results processing of the ultrasonic test and make it appealing to professionals working with historic timber structures. On the contrary, the micro-drill test is minor-destructive, expensive and needs training, but it is reliable and it gives information on the internal condition of timber elements, which no other considered technique does.

This research also highlights that not every test is suitable for all survey conditions and every type of roof structure: the thermal camera, for example, requires a heated environment; the use of the snake camera is hindered by the presence of insulation sheets; the micro-drill is quite bulky and thus requires a comfortable hatch to access the roof space; and finally, the ultrasonic device is not suitable for structures made of timbers with big sections. It is therefore important to design each assessment according to the techniques that can be effective for the particular roof space and structure that needs to be investigated.

Costs involved	4			**<u>Microdrill</u>**	**Ultrasonic**
	3		**<u>Hygrometer</u> Thermal Camera**		
	2		**Snake Camera <u>Microscope</u>**		
	1	**Thermometer**	**Visual Inspection VSG**	**Hammer**	
	0	1	2	3	4
	On-site procedure and interpretation of results				

Figure 348: Comparison between assessment techniques used during the surveys; the best grade is 1; x=non destructive test, <u>x</u>=minor destructive test

5.4 Proposal of specialising course for conservation professionals

This research has highlighted that Scottish building owners, users, managers and professionals would benefit from targeted training providing them with the necessary skills and knowledge to value, conserve and maintain historic timber roof structures. Regular maintenance rather than extraordinary repairs should be implemented and, when repairs are necessary, trained professionals should be available and able to implement the state-of-the-art tools and methods. Owners often adduce lack of funding as the main reason preventing them from carrying out the necessary inspections and repair works. However, it is clear that if trained professionals inspected roof spaces regularly, damage could be detected in its early stages, when it could be solved in an easier, quicker and cheaper way.

Based on our findings and on examples of training schools organized by COST Action FP1101 on similar topics (D'Ayala et al., 2015), we outline the aims, learning outcomes, structure and contents of a course on the assessment of historic timber roof structures which could be proposed to start addressing the lack of training of professinals in this specific field. Separate training courses should be designed for buildings owners/users/managers and for craftsmen. Since the author is an architect

and has focused the research on the assessment of roof structures that architects and engineers carry out, the designed course is addressed to participants with this profile only.

The aim of the course would be to raise awareness amongst engineers and architects about the importance of conserving historic timber roof structures and to equip them with the knowledge and skills necessary to address the issues and challenges involved in the first phase of any conservation project: the assessment. Professionals would learn how to read and analyse a timber roof structure, gaining a thorough understanding of which aspects need to be investigated and how they can be investigated, in order to reach a critical evaluation of the structure both from a historical and a structural point of view.

The assessment of historic timber structures involves different disciplines (construction history, structural engineering, material science, etc) therefore the course would be necessarily multidisciplinary. Ideally, a team of experts, professionals and researchers with different backgrounds and expertise should be invited to give the lectures; this would allow attendees to understand the main focus of each discipline and would underline the need for close collaboration and interaction between different professionals such as engineers, architects, historians and wood technologists.

The contents would review a wide range of topics, based on the present research:

- The historic development of Scottish timber roof structures, with a glimpse to the wider European context, looking at different typologies, structural arrangements and details such as types of joints, timber dressing, tool marks, carpentry marks. The analysis of these aspects can help in estimating the structure's date and value, but also in understanding its structural behaviour.
- Basics of wood anatomy and techniques to identify timber species: macroscopic analysis with hand lenses and microscopic analysis using a light transmission microscope. Particular attention will be paid to Scots pine and oak, the two main species used in Scottish timber roof structures. Basic knowledge on wood anatomy is necessary to understand the structural behaviour of timber and to be able to identify the timber species, which is one of the most important parameters when carrying out structural tests and calculations.
- Visual assessment techniques: detailed visual inspection, to assess the geometry and condition of the structure, with particular attention to the different types of degradation and damage that can affect timber, and Visual Strength Grading (VSG), to assess the natural defects of the structure and estimate the elements' strength and stiffness. Typical damage and decay of Scottish timber roofs will be reviewed as well, pointing out weak points to which special attention should be paid during the inspection.

- In situ and laboratory testing techniques for structural timber to further investigate the structure condition and mechanical properties. Specific testing techniques to estimate the mechanical properties would be included, although they have not been discussed in the present study.

Although this topic has not been covered by the present research, the course should also review different methods of structural analysis of historic timber roof structures, both as assessment and verification tool: traditional hand calculations, numerical modelling, physical modelling. This would be restricted to attendees with an engineering background and would allow them to understand how the data gathered during the survey can be used to verify the structure's safety.

Following the example of COST Action FP1101 training schools (D'Ayala et al., 2015), of which the author has had first hand experience during the training school in Minho in May 2015, the course could be organized in 5 one-day modules, with each module corresponding to a topic: the mornings used for ex-cathedra lectures and discussion and the afternoons for site visits and practical sessions directly related to the mornings' topics. Edinburgh would be the best location since many examples of roof structures from different periods would be available in a restricted geographical area.

The learning outcomes would include the ability to:

- estimate the structure date and value based on the analysis of its typology and construction details;
- identify different timber species;
- carry out an effective visual inspection, knowing where to look for faults, and being able to identify the type and extent of damage/decay and estimate its causes;
- grade timbers visually, according to current standards;
- use testing techniques to further assess and estimate the condition and mechanical properties of the structure;
- use the gathered data to evaluate the structure safety.

In order to make the course appealing to professionals, accreditation could be sought from professional bodies such as the Institute of Historic Building Conservation (IHBC). The course could then be completed by another training on the design and implementation of repair interventions, which are beyond the scope of this study.

5.5 Conclusions

The review of current conservation practice in this chapter highlights the lack of specific standards, regulations, training and published projects. This lack is reflected in the approach of building owners, managers and conservation professionals. There are no standards in UK related to the inspection and survey of in situ timber structures and neither HES nor TRADA address the subject extensively. Listings by HES mention roof structures very rarely and applications for interventions are seldom judged by experts in conservation. Owners and building managers seldom program regular inspections and maintenance works and often they do not provide basic accessibility and visibility conditions. There is also a lack of academic and training courses in conservation engineering in Scotland and North England and most professionals do not publish and share their conservation projects. The result is that professionals still rely mainly on traditional methods and past experience, which entails making several assumptions, and sometimes replacing the whole structure or implementing unnecessary or over-dimensioned interventions, as confirmed by our surveys.

In order to contribute in improving current conservation practice we have investigated the condition of seventeenth- and eighteenth-century timber roof structures in Scotland and evaluated the assessment tools and methods employed. We have identified typical pathologies and possible causes for each type of structure. We found that about one fourth of the surveyed roofs show pathologies caused by flaws in their initial design, while in a few cases past alterations and repairs contributed to creating or accelerating damage because of inadequate materials used, loads increased or the overall structural behaviour modified. We also noticed that poor environmental conditions and poor accessibility are a major issue, mainly causing biotic attack in common rafter roofs incorporating attic rooms, but also hindering the inspection and maintenance of many roofs.

The pathologies and causes have been assessed with state-of-the-art techniques that we have evaluated in terms of effectiveness, reliability, skills and knowldge needed to implement them and costs involved. Not all assessment techniques employed have given results, and in some cases it has not been possible to assess their reliability, but the particular environmental and testing conditions in which each test can be useful have been identified. This has highlighted that it is fundamental to design each assessment according to the techniques that can be effective for the particular roof space and structure that needs to be investigated. Moreover, expertise has been identified as a key parameter, to be acquired through mentoring, not literature only. This is why, based on our findings, we have also outlined the aims, learning outcomes, structure and contents of a course on the assessment of historic timber roof structures which could be proposed to start addressing the lack of training of professinals in this specific field.

6 Conclusions

This thesis researches the conservation of seventeenth- and eighteenth-century timber roof structures in Scotland, largely forgotten up to now. Previous studies fail in characterizing the extent, nature and condition of these structures, especially post-1650, mainly because of the shortage of measured surveys. This missing body of knowledge, together with the absence of specific standards and training, hinders good conservation practice. The result is that many roofs are heavily altered or replaced, and thus lost, depriving future generations of a substantial part of this important heritage.

In order to address these issues, a database with a related mapping of 1500 Scottish buildings of the period has been created and a representative sample of roofs has been studied through in situ surveys and archival research. Preliminary surveys have been carried out in 53 buildings and thorough, in-depth investigations have been performed in eight case studies, using state-of-the-art tools, methods and standards. This has allowed gathering data on 59 original timber roof structures.

Thanks to this data, we have characterized the surviving family of seventeenth- and eighteenth-century Scottish timber roof structures and traced their historic development, demonstrating that they form a heritage of great extent and quality. The collected data has also been used to identify typical pathologies and possible causes for each roof structural typology. Moreover, the assessment techniques used have been evaluated in terms of effectiveness, reliability, costs involved and training needed, in order to understand when they can be useful during the assessment. Based on the findings, a specialisation course for conservation professionals has been proposed.

6.1 Research outcomes

Our research has allowed tracing the historic development of seventeenth- and eighteenth-century Scottish timber roof structures. For the first time, structural arrangements, construction methods and details, materials, know-how and foreign influences have been comprehensively described and classified. From this evidence, a distinctive Scottish school of roof carpentry has emerged, little influenced by Europe up to mid eighteenth century and retaining characteristic features even after.

We can confirm Hanke's (2006) statement that up to late seventeenth century the majority of Scottish roofs is of a simple common rafter form, hidden behind decorated ceilings, with no

subdivision between load-bearing and non load-bearing rafters, no longitudinal members other than the sarking boards, no tie-beams nor wall-plates. This is remarkable considering the wider European context, where these features are introduced much earlier. Thus, Scottish common rafter roofs might give an indication as to how very early North-West European roofs looked like. While previous research has relied mainly on archive material, we have surveyed 29 roofs with such characteristics while also finding more than 50 drawings of them in archival documents and unpublished work.

Previous research had highlighted that the extensive use of simple common rafter roofs is due to the limited spans and thick walls that characterized Scottish architecture of the time, and to the timber trade with North Europe, which provided short small beams and deals in great quantity (Hanke, 2006, Newland, 2011). Our research demonstrates that Scotthish roofs evolve when these conditions change at the end of seventeenth century, with the introduction of classical and baroque architecture in Scotland. Scottish wrights are forced to develop roof structures able to span increasingly wider spans with shallow pitches and hipped arrangements, whilst supporting heavy plaster ceilings. Our work has allowed highlighting and understanding this important development that had been disregarded by previous literature, mainly due to the lack of measured surveys.

The analysis of our surveys and archive material also highlighted that the imported timber products and the know-how of wrights gradually change to meet the structural requirements of the new architecture, where gable walls disappear, walls become thinner and spans wider. We observed that: (i) the traditional rafter feet are substituted by tie-beams, wall-plates and butt-purlins, to reinforce the longitudinal and transversal connection and stability of the roof; (ii) tension-absorbing elements and joints are introduced to counteract the elements' deflection and the roof opening; (iii) the subdivision between load-bearing and non load-bearing rafters is introduced to better distribute the loads; (iv) timber scantlings become more rectangular and are differentiated based on the elements' structural role, confirming Thomson's (1999) statement that sawmilling in Scottish ports develops to process imported timber. These characteristics have emerged in 18 roofs we have surveyed.

However, our investigations also demonstrate that these innovations are not sufficient to attain undisturbed wide spans and that it is eventually necessary to import from elsewhere a completely different structural type: the Italian trussed roof, that we have found starting from 1740s in 14 public buildings and country houses, used even for reduced spans. In fact, only with the use of trussed roofs Scottish wrights are able to get rid of the intermediate supporting walls used up to then. We have also surveyed 5 purlin roofs, showing that wrights experimented using different solutions.

Interestingly, we found that despite the introduction of ~~a~~ new type of roof structure (the trussed roof) some distinctive Scottish features are maintained: the sarking, the raised tie-beams, the idea of bringing the load down on the masonry, the predominant use of Scots Pine, slates as roofing

material and roman numerals as assembly marks. At the same time, we recorded details that suggest instead foreign influences: joggles, a distinctive English feature (Yeomans, 1992), cleats and notches, typical Italian features (Munafò, 2002, Serlio, 1545), bulb-shaped joggles and unusual carpentry marks, whose origins remain uncertain. Moreover, our archival research has highlighted that the English influence, probably prompted by the Union in 1707, is traceable in the language too: the English word 'carpenter' partly substitutes the Scottish word 'wright' during the eighteenth century.

Our research also sheds new light on the role that wrights, architects and patrons played in importing technological knowledge from various sources and in adapting it to the local tradition. According to previous research, wrights become increasingly important during seventeenth century, some even aspiring to the role of architect (Dunbar, 1976, Newland, 2012b). However, our studies on the seventeenth-century roofs of George Heriot's Hospital (NRS GD421/5/2, 1633-42) and Brechin Castle (NRS GD45/18/1616/25, 1694 in Newland 2010) suggest that the reliance on imported short timbers, and the consequent extensive use of simple roofs, partially obliterated the wrights' role in the roof design in this period. We also found evidence that a mason is called to judge the quality of the wright's work in Brechin's Castle and to repair it. This suggests that wrights did not always have a prerogative on timber-work at the end of seventeenth century.

Our investigations on St Andrew's in the Square church (1751-3) suggests instead that when wrights start working as professional architects, as pointed out by Lewis (2006, 2015) and highlighted by our research (we have found many teams of wrights and masons that design churches in the eighteenth century), they hand over the timber-work to another wright. The wright Allan Dreghorn works at St Andrew's as architect, but the client asks the wright John Robertson to make three plans and estimates of the roof (Renwick, 1911). This entails that it was the wright's responsibility to design the roof structure, even if the architect was a wright.

The request to see three plans of the roof of St Andrew's in the Square also shows that the client wanted to have a say not only on the budget but also on the design of the roof structure. Other patrons, from both centuries, give specific instructions for the design of their roof: James Baine says that the Earl of Panmure binds him at Brechin Castle to make the roof in a certain way rather than how he would have done it (NRS GD45/18/1616/21, 1694 in Newland 2010); the Marquis of Tweeddale asks the architect William Adam to change the present roof of his house at Yester, which is an M-roof, into a platform roof (NLS MS14551/109, 1742-49).

Our research on the work of the Adams shows that architects were also influentieal in the design of roof structures: they play an important role in the introduction of the trussed roof in Scotland. William is the first to draw a trussed roof for a Scottish building in 1720, as suggested by Hanke (2006), but, according to our surveys, only one of his buildings of the period has a trussed roof:

Hopetoun House (1721-48). This makes us think that, although William aspired to build trusses, Scottish wrights were unable or unwilling to construct them, at least at the beginning, probably because they had limited knowledge on the structural behaviour of timber and on the strength and durability of different timber species. In fact, our surveys highlight that Scottish wrights: (i) introduced tension-absorbing joints and elements very late compared to the rest of Europe; (ii) often used them incorrectly and did not develop them fully; (iii) used the same species for all of the elements of the structure; (iv) often did not distribute elements of different quality according to the stresses they had to endure. Our conclusion is that the Adams were forced to bring wrights from abroad in order to implement their designs; this external influence is also suggested by the heterogeneity of solutions and details used in Scottish roofs and highlighted by our surveys.

Since our work is based on a limited sample of surveyed roofs and consulted archive material, many questions remain unanswered. Nevertheless, the work succeeds in demonstrating that seventeenth- and eighteenth-century Scottish roofs form a heritage of considerable extent and interest, worth studying in more detail and worth conserving as adequately as possible, in order to secure the knowledge of future generations and to ensure long life to the buildings they are part of. Unfortunately, this is not always the case. In fact, we have found that these structures are not always adequately conserved, not only because their value is not recognized, but also because there is a lack of specific standards and training for the assessment of historic timber structures, as emerged from a critical literature review, questionnaires to building users and interviews to conservation engineers. Indeed, the assessment of historic timber structures is challenging, as timber is an organic material with variable properties. Recent research has started addressing this issue (Dackermann et al., 2014, Kloiber et al., 2015b, Riggio et al., 2014, Tannert et al., 2014), but the lack of specific standards and training forces Scottish professionals to rely mainly on traditional methods and past experience, that are often inadequate as they entail making several assumptions.

UK has no standards for the survey of in situ timber structures and Eurocode 5 and BNS are only partly applicable. HES guidelines do not include anything specific on the subject and TRADA's publications partially address the topic, but do not suggest a standardized procedure. Protection policies also have flaws: listings by HES mention roof structures very rarely and applications for interventions are seldom judged by experts in conservation. This situation is worsened by the fact that owners and building managers seldom program regular inspections or maintenance works and often do not ensure basic accessibility and visibility conditions. On top of that, there is also a lack of academic and training courses in conservation engineering in Scotland and North England and most professionals do not publish or share their conservation projects.

The result is that professionals are not provided with the specific knowledge, guidance and tools to take care of historic timber roof structures. Thus, they sometimes replace the whole structure or

implement unnecessary or over-dimensioned interventions, because they are unable to reach a confident structural assessment. In fact, we have found a high percentage of seventeenth- and eighteenth-century Scottish buildings whose original timber roof structure has been replaced.

In order to address these issues and to contribute in improving conservation practice, we have investigated the condition of seventeenth- and eighteenth-century timber roof structures in Scotland, identifying typical pathologies and possible causes for each type of roof structure. We found that about a fourth of the surveyed roofs show damage and material degradation caused by poor initial design of the structural arrangements and details. Common rafter roofs and trusses have problems of transversal opening due to the absence of tie-beams and to the use of joints unable to resist tension forces. Common rafter roofs also have problems of longitudinal instability, due to the absence of longitudinal bracing; trusses and purlin roofs show instead deflections and cracks due to the use of slender timbers, insufficient propping and problematic asymmetrical arrangements.

Our surveys highlighted that in a few cases past alterations and repairs have contributed to creating or accelerating damage because of inadequate materials used, loads increased or the structural behaviour modified. Moreover, we noticed that most past interventions are poorly documented and some that were meant to be temporary have become permanent, without being monitored.

We observed that common rafter roofs are the most affected by biotic attack. The causes are the rough dressing of the timbers, poor maintenance and poor environmental conditions. Since most of these roofs are plastered and used as attic rooms, the lower part is often not visible nor accessible, hindering inspection and maintenance. At the same time, the roof's upper part is generally small and poorly ventilated, due to modern waterproofing sheets added in-between the sarking and the slates and excessive insulation. Finally, many roofs host uncovered water tanks that increase humidity.

The lack of inspections and maintenance certainly increases all of these problems and is mainly due to accessibility problems that characterize many of the roofs we have surveyed: the presence of bats or wasps, pigeons' droppings, lack or hatches or hatches with very limited dimensions, absence of walking boards. We found some roofs or substantial parts of roofs completely inaccessible. Moreover, our questionnaires to owners, users and managers highlighted that they do not always know how to access their roof spaces and do not always have the necessary equipment to do it.

The pathologies and causes summarised above have been identified using state-of-the-art assessment techniques that are available to Scottish professionals, such as: visual inspection to identify historically relevant features and pathologies; VSG to assess the quality of timbers; a thermometer to measure the air temperature/humidity; a hygrometer to measure the wood moisture content; a light transmission microscope to identify the timber species; a snake camera and

a thermal camera to investigate hidden parts of the structure and identify damp areas; a rubber hammer, an ultrasonic device and a micro-drill device to assess the internal condition of timbers.

These methods have been evaluated in terms of effectiveness and reliability. Our research highlights that not every test is suitable for all survey conditions or all types of roof structures. It is therefore important to design each assessment according to the techniques that can be effective for the particular roof space and structure that need to be investigated. We found that the snake camera is ineffective if it has low resolution and in presence of accessibility issues, such as insulation sheets between timbers. At the same time, the thermal camera does not provide valuable results unless the space is properly heated. We did not obtain useful results from the rubber hammer either, because of the lack of an experienced ear. Finally, thanks to the comparison with the results of the micro-drill, we proved the ultrasonic device to be ineffective for timbers with big sections, in spite of recent publications stating otherwise (Dackermann et al., 2014, Llana et al., 2016, Machado et al., 2009).

We have also ranked the assessment techniques used according to the costs involved, the physical effort demanded, the time needed, the possibility to implement the test alone, the fact that the test is non-destructive or semi-destructive and if it is specific for wood or can be used in other parts of the building. The thermometer has been graded best, followed by (in order of cost) visual techniques, the snake camera and microscope, the hygrometer and thermal camera: these are either semi-destructive, not easy to use, not always effective or require more training. The hammer is as cheap as the thermometer and visual techniques but the expertise required for it to be effective is hard to acquire. Next comes the micro-drill: it is very expensive; it requires training and specific knowledge and it is not easy to use on site because of its dimensions and weight. It is however extremely effective and reliable and it gives information on the internal condition of timber, which no other considered technique does. Lastly, the ultrasonic device: it is as expensive as the micro-drill but it is more difficult to operate and interpret and it is not effective for timbers with big sections.

This evaluation highlights the importance of combining different testing techniques to enhance the assessment of timber structural elements and to evaluate the reliabilty of the tests' results. Our geometric survey has benefitted not only from visual techniques but also from the use of the thermal camera to see hidden parts of the structure. We have assessed the timber quality both through VSG, which consider the visible natural features, and by analysing the micro-drill graphs, that show density variations. We have identified water ingress problems with a thermometer, a hygrometer and a thermal camera, each providing information on the non-optimal environmental conditions, high wood moisture contents and damp areas. The combined use of the rubber hammer, the micro-drill and the ultrasonic device to assess the internal condition of timber has allowed to understand which of these tests is more effective and reliable and in which survey conditions.

6.2 Our work also confirms that expertise is a key parameter and that it must be acquired through mentoring. In fact, the knowledge and skills necessary to implement the assessment techniques used have been acquired by the author mostly by interacting with experts, researchers and professionals in the field. This is why, based on our findings, we have also outlined the aims, learning outcomes, structure and contents of a course on the assessment of historic timber roof structures which could be proposed to start addressing the lack of training of professinals in this specific field.Final remarks

In heritage conservation, values are critical to decide what to conserve and how to do it. Values give some things significance over others and thereby transform some objects and places into "heritage". The ultimate aim of conservation is not to conserve material for its own sake but, rather, the values embodied by heritage: "The value of architectural heritage is not only in its appearance, but also in the integrity of all its components as a unique product of the specific building technology of its time" (ISCARSAH, 2003). A monument is authentic because it provides identity to cultures, regions and towns, because it's a document on ancient knowledge, culture, technology, and a witness of cultural and technical achievements from whose study and use we can still learn and improve today.

Historic timber roof structures must be conserved because they are precious witnesses of the efforts and inventiveness of mankind in search of new shapes and steadier configurations, using available materials. These structures have cultural significance: they help understanding the past, enrich the present and will be of value to future generations (ICOMOS, 1999a). Timber elements carry traces of the tools used to work them, of marks made to transport/assemble them, of past problems and interventions. All these traces help us understanding the past and conserving crafts knowledge that is linked to the values, history and identity of the communities in which it is practiced. Crafts involve a particular kind of learning process that needs to be rediscovered and documented to be able to reuse it. The perpetuation of this knowledge allows conserving the traditional building characteristics of the area and using the most appropriate materials and techniques in conservation (Donkin, 2004).

This thesis represents a fundamental first step in recording the important heritage of seventeenth- and eighteenth-century Scottish timber roof structures. Prior to this work very few measured surveys and documents were available. Now various surveys and transcribed archival documents can be analysed, interpreted and built upon by future researchers and conservation and government bodies to build the skills and knowldege needed to conserve the Scottish timber built heritage.

In order for future generations to be able to keep learning from the past, the government must take immediate action to conserve this heritage. Grant funding should be made available even for privately owned buildings, given that certain conditions are met: regular inspections carried out at least on a bi-annual basis - following the example of Monument Watch (Vandesande and Van Balen,

2016)-, interventions approved by a committee of conservation experts and buildings accessible to the wider public on certain dates, in order to allow everyone to benefit from the knowledge of the past. This would hopefully solve some of the problems we have met during our surveys: poor accessibility and visibility conditions, no regular inspections or maintenance in place, and sometimes even no interest in the history of the building itself, since access was denied for no particular reason.

We have focused on timber roof structures but certainly the same conservation policies are applicable to all other structural components of a building, equally important. The methodology we have employed can and should be applied to assess roofs of other periods, in other regions, or to assess other parts of the building. The relational database we have created is already being used by other members of ADCRU and the digital form developed with COST Action FP1101 is being used by other members of WG1 for this purpose.

The coordination between the archival research, historical documentation, in situ inspections, measurements and experimental phases has proven to be fundamental not only to constitute this data bank useful for future research and conservation policies, but also to evaluate the structures' safety. As proven by our surveys, historical and archival research allow finding out about problems that the structure had in the past, interventions or repairs that were carried out; sometimes even the timber species is reported, a key parameter to carry out a structural analysis and evaluate the structure safety. The assessment of the history of loads and problems is fundamental to understand the present condition of a historic structure and to evaluate the adequacy of past interventions.

Once professionals have made a diagnosis of problems and causes based on all the available information, they should design interventions with the primary aim to maintain as much as possible the original fabric in place, improving the legibility of its historical integrity (ICOMOS, 1965). The interventions should preferably use compatible techniques and materials, be reversible, not impede future conservation work nor access to evidence incorporated in the structure (ICOMOS, 1999b).

According to our surveys the interventions that have shown to be more in line with this approach are, for example, those that add timber elements next to the damaged ones: the biotic attack is stopped by improving the environmental conditions but the damaged elements are left in place, simply adding a new element next to it (as in Panmure House). This approach ensures the safety of the structure, by placing a new healthy member able to take the loads, and conserves the original fabric, allowing to read the original structure, its past problems and repairs. However, in some cases it might be preferable to replace parts of the structure with prosthesis (as in Brodie Castle Stables), in order not to crowd up the structure, or to make other punctual interventions such as improving connections with steel elements (as in St Andrew and St George's Church). What should not be done in any case is to damage the original timbers as in Oakshaw Trinity Church or to leave temporary

interventions un-monitored for years, as in Geilston House. Moreover, contrary to what we have found during our research, interventions should be fully documented, in order for future generations to know what has been done and why. When successfull, interventions should also be published and shared, in order to inform similar projects.

Specific training must be provided to professionals in order for them to acquire the necessary skills and knowledge to apply this approach. It is also necessary to train experts that can form a committee suitable for the evaluation and approval of interventions. The specialisation course we have proposed should be organized in collaboration with all the active conservation researchers and bodies (HES, NTS, NHTG). Funds could be raised by these bodies and a contribution could be asked to participants in exchange of accreditation and inclusion in a list of timber experts. The translation of this work into actual training would ensure that the created data bank is not only a repository but an innovative way of building skills for the conservation of Scottish timber built heritage.

6.3 Recommendations for future research

Although our research represents an important first step in the study of historic timber roof structures in Scotland, it is based on a limited sample of surveyed roofs and consulted archival documents compared to the number of identified buildings. Future research should therefore focus on widening this sample. This will help finding out more about the design and construction processes and the role of architects, wrights and patrons. Archive material could also be useful in interpreting the unusual carpentry marks we have found. If correctly interpreted, these marks could complement dendrochronology in providing information on the timber date and provenance. Since some of the marking found clearly represents trading companies, the cooperation with experts from Belgium, Netherlands, Germany, Baltic regions and Scandinavian countries would be extremely helpful.

Moreover, it must be kept in mind that the construction date of most of the surveyed roofs has been estimated. In order to progress with more precise construction history analyses it would be necessary to proceed with the dendrochronological dating of more roofs of the period.

Our research findings could also be used to trace guidelines for the assessment of each type of roof structure and to derive vulnerability factors to predict failure mechanisms and identify urgent interventions. With this aim, future research should also focus on the assessment and estimation of mechanical properties and on the use of structural analysis, two topics not addressed by this thesis.

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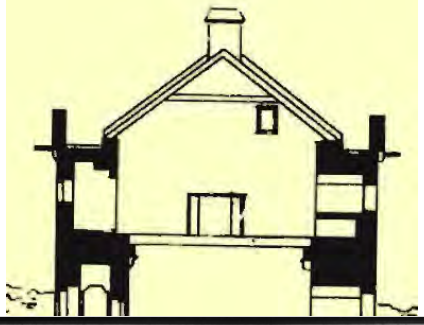
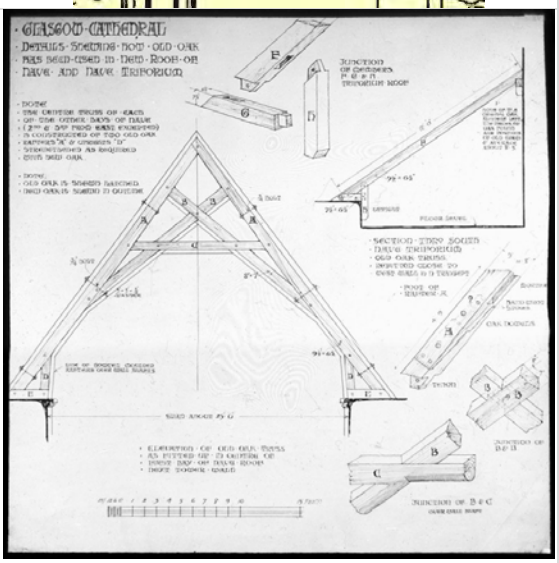
VOLUME 2

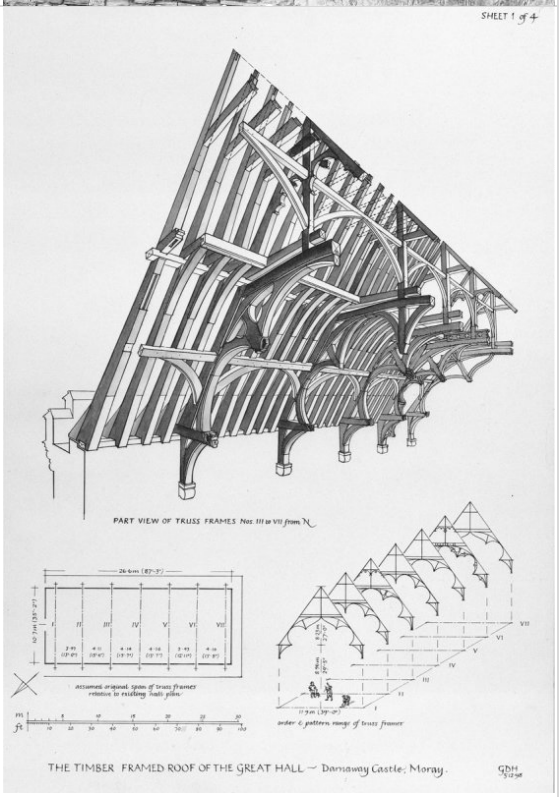
APPENDIX A

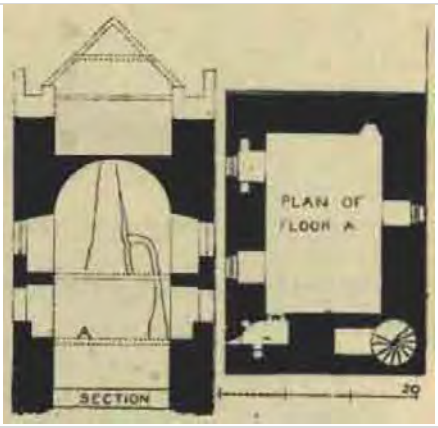
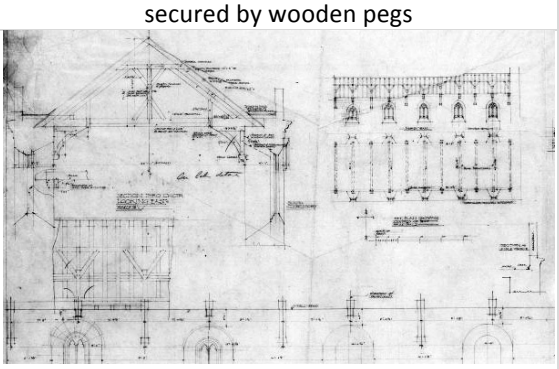
INFORMATION ON PRE-1800 SCOTTISH ROOFS OTHER THAN THE REFERENCE BUILDINGS

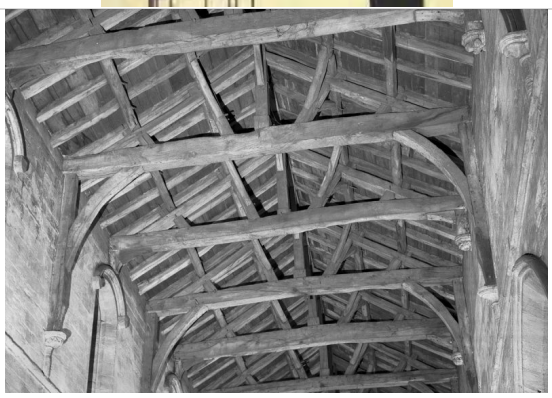
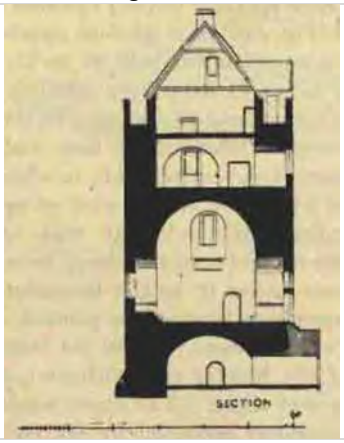
The roofs are in chronological order

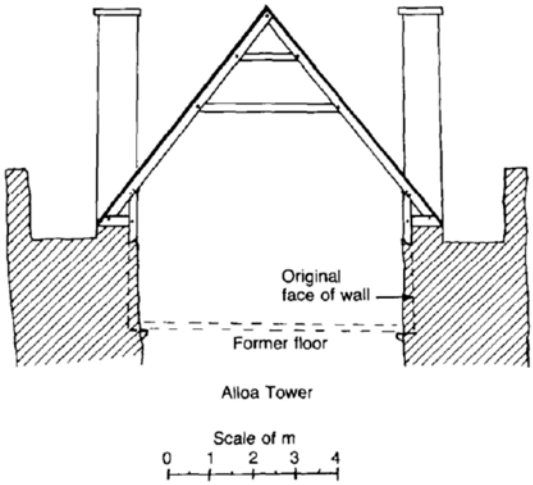
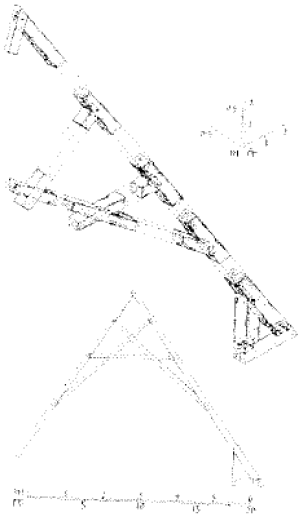
The first reference is the one referring to the drawing/picture

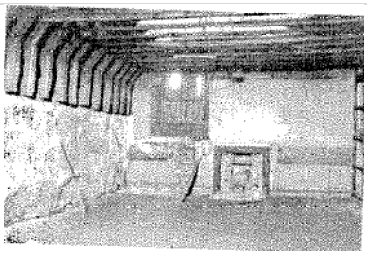
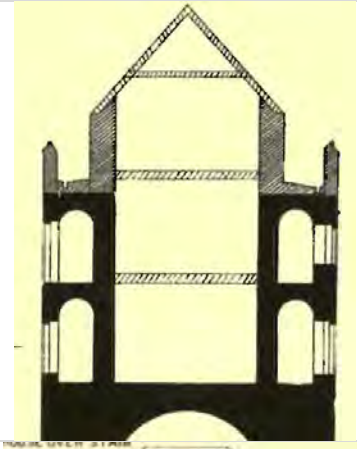
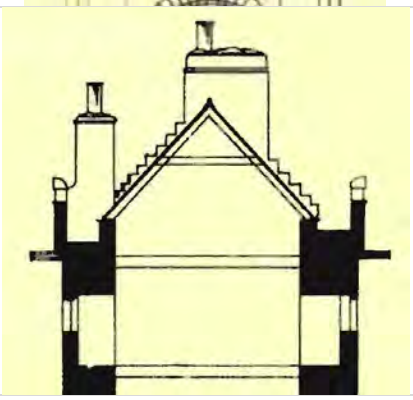
Building name	Roof construction date (estimated)	Retains pre-1800 roof?	Drawings/Pictures/Information	References
Temple Old Parish Church	12C	no		Hanke (2006)
Gullane St Andrew's Church	12C	no		Hanke (2006)
Holyrood Abbey	12C	no		Hanke (2006)
Cockpen Old Parish Church	13C	no		Hanke (2006)
Hailes Castle	13C	no		Hanke (2006)
Skipness Castle	13C			Macgibbon and Ross (1887-92)
Glasgow Cathedral	1256 choir roof, late 13C nave roof (1909 drawing)	yes	 Scottish oak (dendroanalysed), span 7.56m and 8.25m, common rafter roofs (choir and nave) with	RCHAMS DPM 1900/67/2 Oldriev (1916) Fawcett (2002) Hay (1976) Hanke (2006) Crone and Mills (2012)

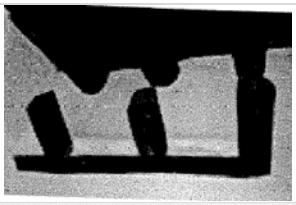
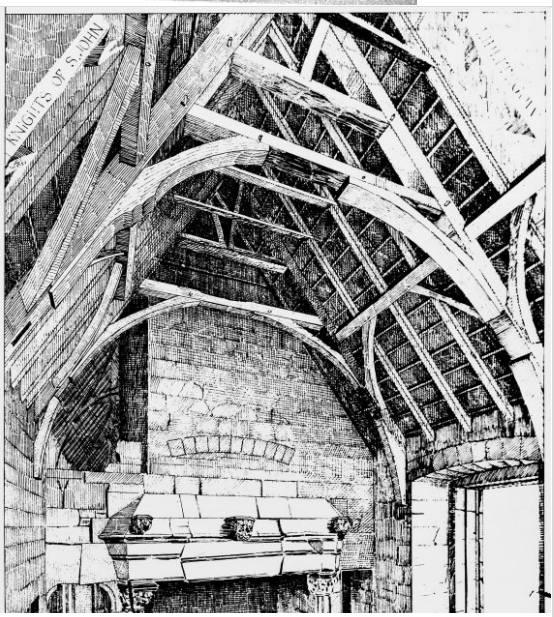
			one collar, scissor braces and rafter feet, mortice and tenon joints secured with wooden pegs	
Ormiston St Giles Church	13C	no		Hanke (2006)
St Andrew's Cathedral	1318	no		Hanke (2006)
Tantallon Castle (ruinous)	1360 (1923-30 picture)	no		RCAHMS SC 1201453
Darnaway Castle Hall	1387 but possibly dismantled and reassembled in 1802	yes	 Scottish oak (dendroanalysed), span 10.7m, 53° pitch, hammerbeam roof, roman numerals	RCAHMS SC 433080 Stell and Baillie (1993) Gomme (2002) Hanke (2006) Hay (1976) Crone and Mills (2012) Macgibbon and Ross (1887-92)
Dunfermline Palace	14/15C	no		Hanke (2006)

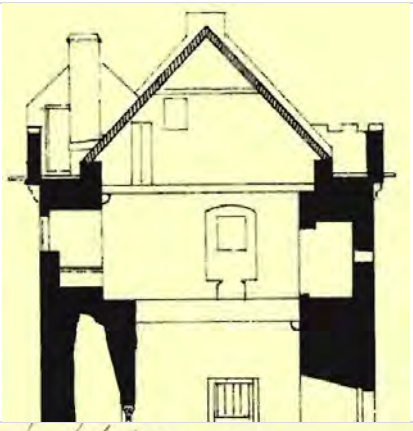
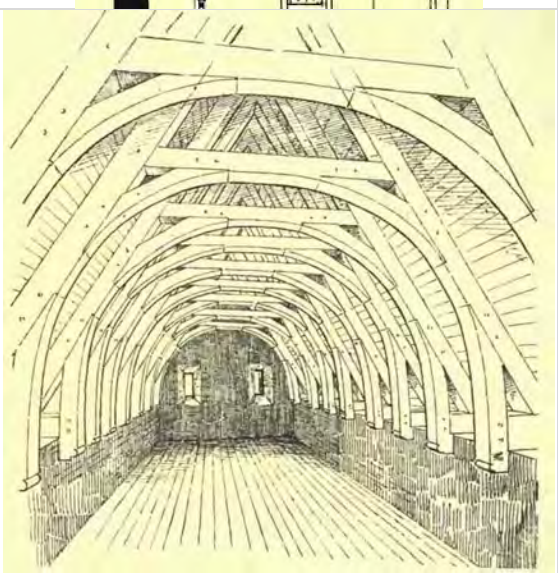
Craigneil Castle	14/15C			Macgibbon and Ross (1887-92)
Craigmillar Castle	14C to 17C	no		Hanke (2006)
St Andrew's Castle	1400	no		Hanke (2006)
Tullibardine Chapel	1446	yes	 oak, span 5.6m, common rafter roof with two collars and rafter feet, mortice and tenon joints secured by wooden pegs	picture by Author Hanke (2006) Fawcett (2002)
Perth St John Church	1448 (1927 drawing)	yes	 span 7.2m, open purlin roof with longitudinal bracing	RCAHMS SC 830680 Hanke (2006)
Threave Castle	mid 15C	yes	Scottish oak (dendroanalysed)	Crone and Mills (2012)

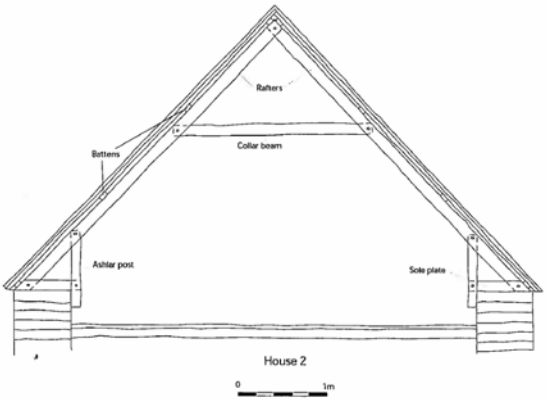
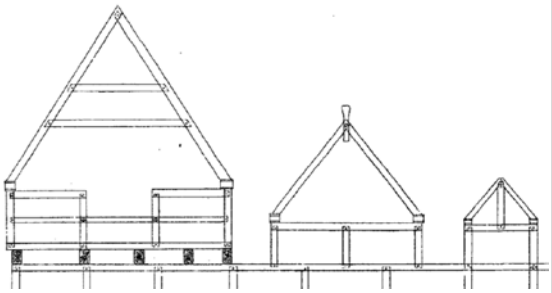
Cawdor Castle	1454			Macgibbon and Ross (1887-92)
Holy Rude Church Stirling	1455 (1959 picture)	yes	 span 6.3m, open purlin roof supported by principal frames with a central post and struts, posts and arched braces bringing load down on masonry wall, longitudinal bracing	RCAHMS SC 738897 Hanke (2006)
Guthrie Aisle	1464	yes	 Scandinavian oak (dendroanalysed), span 4.3m, common rafter roof with one collar and rafter feet, originally supporting vaulted painted timber ceiling underneath	picture by Author Hanke (2006) Crone and Mills (2012) Fawcett (2002)
The Dean Castle	1468-9			Macgibbon and Ross (1887-92)

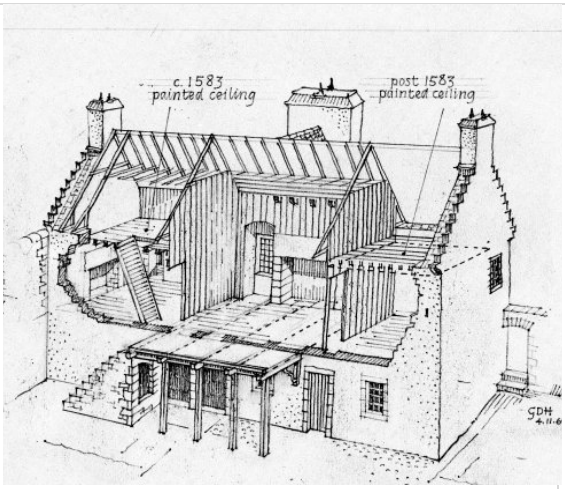
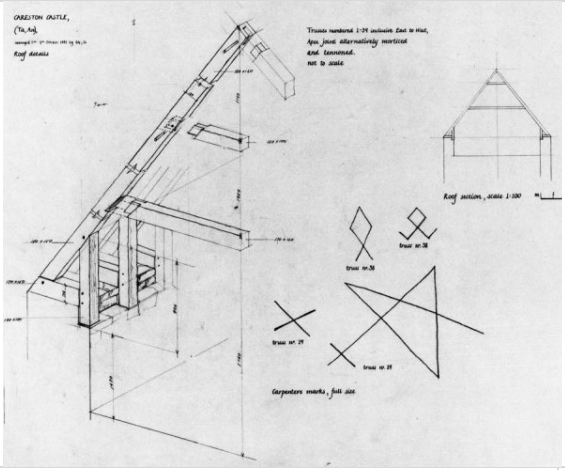
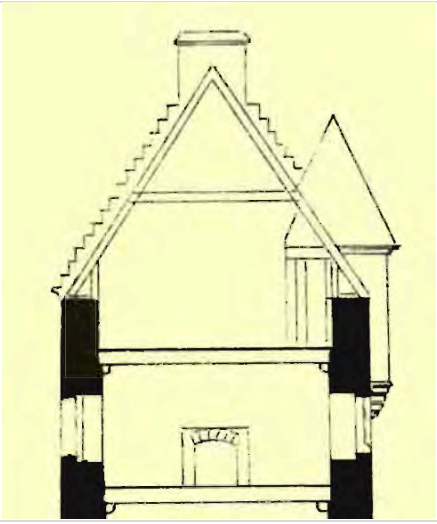
Provand Lordship Glasgow	1471	yes		picture by Scott Bain HES
Alloa Tower	1497, maybe earlier (1995 drawing)	yes	 oak, span 6.15m, 50/52° pitch, common rafter roof with two collars and rafter feet, mortice and tenon joints with timber pegs	Ruddock (1995) Hanke (2006)
Barns Tower	1498	no		Macgibbon and Ross (1887-92)
Ardchattan Priory	15C	yes	 common rafter roof with scissor braces	Hanke (2006) Fawcett (2002) Hay (1976)
Linlithgow Palace	15C	no		Hanke (2006)

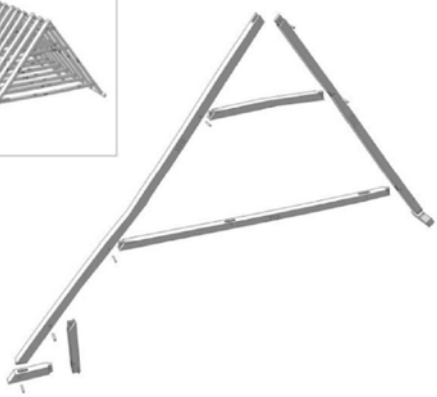
Merchiston Castle	15C	yes	 span 6.9m, common rafter roof with rafter feet	Hanke (2006)
Ackergill Tower	15C			Macgibbon and Ross (1887-92)
Inverquharity Castle	15C			Macgibbon and Ross (1887-92)
Cranshaws Castle	15C			Macgibbon and Ross (1887-92)
Innerwick Castle	15/16C	no		Hanke (2006)
Old townhouse in Dunbar	1509	yes	Norwegian oak (dendroanalysed)	Crone and Mills (2012)

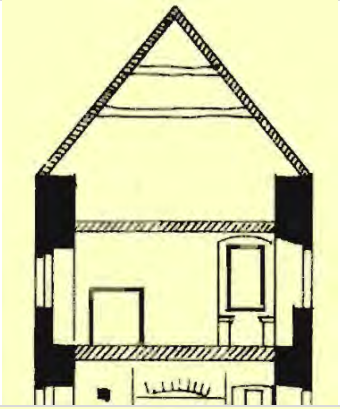
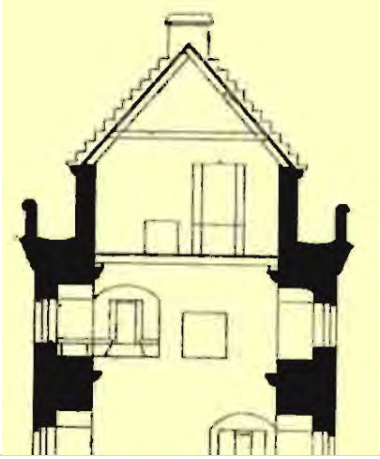
Edinburgh Castle Great Hall	1510 but heavily restored in 19C (1888 picture)	yes	 Scandinavia oak (dendroanalysed), span 10.1m, 45° pitch, false hammerbeam roof, roman numerals, maybe John Drummon wright	RCHAMS SC 1201162 Crone and Gallagher (2008) Hanke (2006) Hay (1976) Macgibbon and Ross (1887-92)
Dysart St Serf church	1511	yes	Scandinavian oak (dendroanalysed)	Anne Crone
Edinburgh 146 Canongate	early 16C	no (replaced in 20C)		Hanke (2006)
Linlithgow Town House of the Knights of St John (demolished)	early 16C (1886 drawing)	no	 span 5.7m, common rafter roof with primary and secondary frames and longitudinal bracing	RCAHMS SC 1047690 Macgibbon and Ross (1887-92) Hanke (2006) Hay (1976)
St Andrews St Leonard's Chapel	early 16C	no	reroofed in 1910	RCAHMS

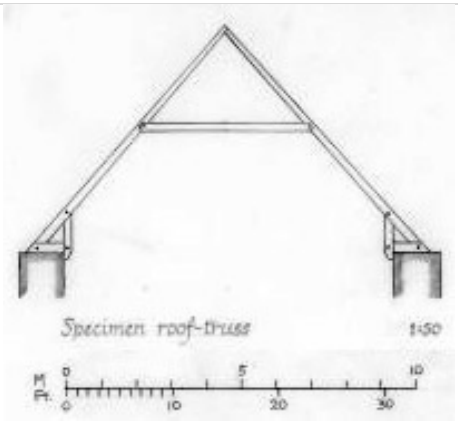
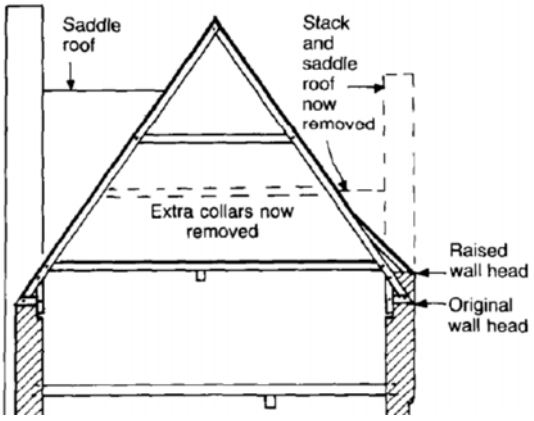
Castle Grant	1540	yes	 Scottish pine (dendroanalysed), common rafter roof with two collars and vertical struts between lower collars and rafters	pictures by John Addison engineer Crone and Mills (2011)
Oakwood Tower	1541	no		Macgibbon and Ross (1887-92)
Rusco Castle	1565			Macgibbon and Ross (1887-92)
Bardowie Castle	1566		 span 4.35m, common rafter roof with one collar and arch braces forming rafter feet	Macgibbon and Ross (1887-92) Hanke (2006) Hay (1976)

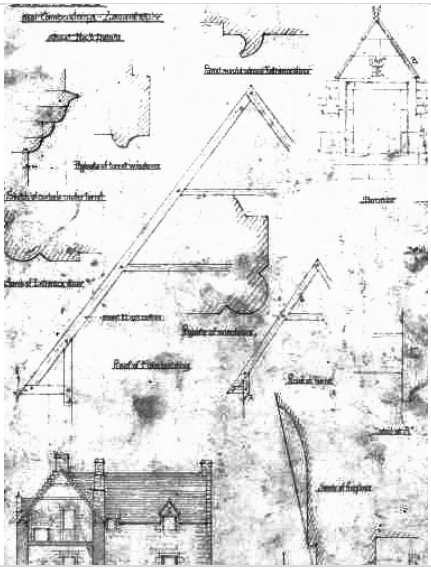
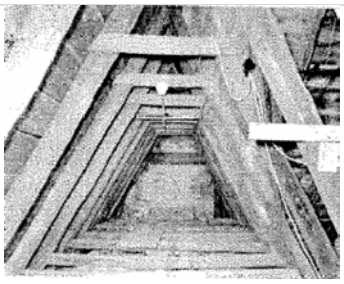
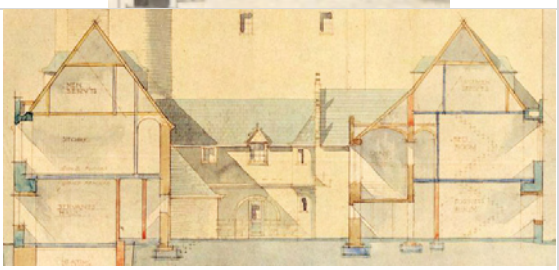
Claypotts Castle	1569-88	yes	 common rafter roof with a collar and rafter feet	RCAHMS AN 755 Hanke (2012)
Kinneil House (ruinous)	1570 (1929 picture)			RCAHMS SC 1214591
Brechin 68-74 High street	1575 with reused 1470 timbers	yes	 Scandinavian oak (dendroanalysed), common rafter roof with one collar and rafter feet, mortice and tenon joints secured by wooden pegs, big roughly sawn roman numerals	Crone et al. (2004)
Edinburgh Lawnmarket	1580	no (demolished before 1884)	 Oak, common rafter roofs on half timbered walls	Peddie (1883) Hanke (2006)

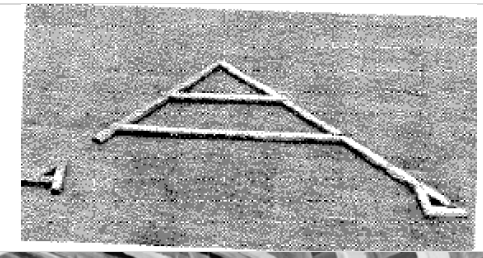
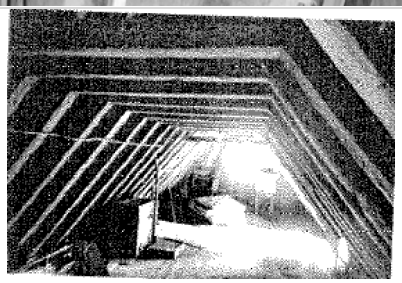
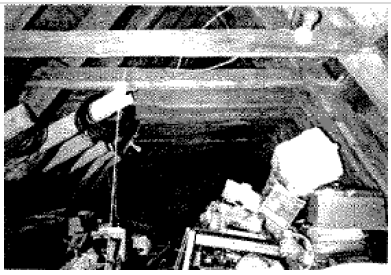
Dysart 1 pan ha	1583 (1969 drawing)	yes	 span 4.4m, common rafter roof with one collar and rafter feet	RCAHMS SC 989070 Hanke (2006)
Careston Castle	1586 (1992 drawing)			RCAHMS DC 290 22
Riddle's Court in Edinburgh	1587	yes	Norwegian oak (dendroanalysed)	Crone and Mills (2012)
Crathes Castle	1589-96	yes	Scottish oak (dendroanalysed), common rafter roofs with one collar, joints secured with wooden pegs, half baulks (timbers axed and then sawn in half)	Crone and Mills (2007)
Fourmerkland Tower	1590			Macgibbon and Ross (1887-92)

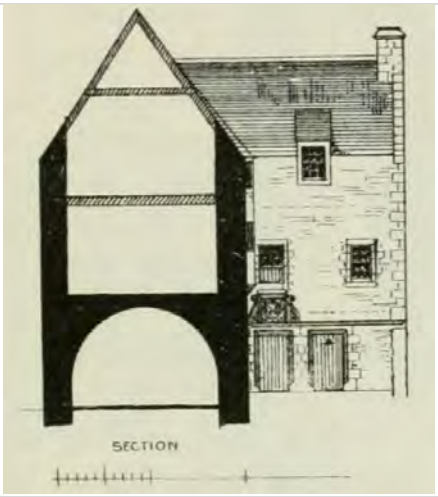
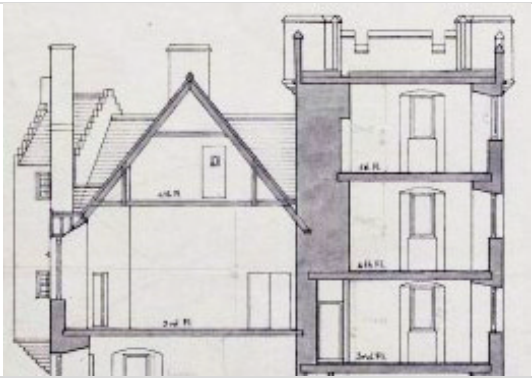
Newark Castle	1598	yes	  Scottish oak (dendroanalysed), common rafter roofs and a purlin roof, mortice and tenon joints secured by wooden pegs, square scantlings	Hanke (2012) Crone (2008)
Crichton Castle	16C	no		Hanke (2006)
Elcho Castle	16C	no	reroofed in 1830s	Graeme Bell HES
Grandtully Chapel	16C (1942 drawing)			RCAHMS SC 1451511

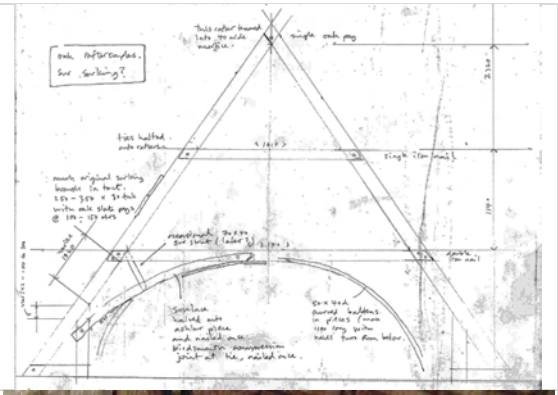
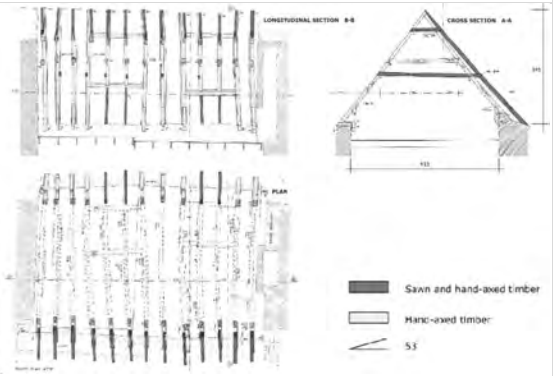
Stirling Castle Great Hall	16C but reconstructed in 20C	yes	 span 14.3m, hammerbeam roof, maybe John Drummon wright	Picture by Author Crone and Fawcett (1998) Gomme (2002) Hanke (2006)
Penkill Castle	16C			Macgibbon and Ross (1887-92)
Minto Tower or Fatlips Tower	16C			Macgibbon and Ross (1887-92)
Scotstarvit Tower	late 16C	no		Graeme Bell HES

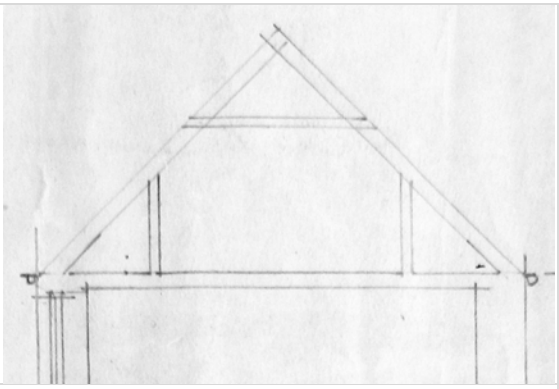
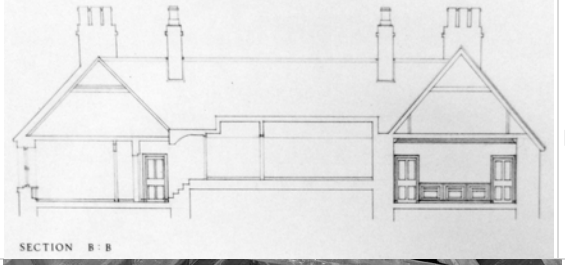
Tranent Tower	late 16C (1979 drawing)	yes	 span 9.3m, common rafter roof with one collar and rafter feet	RCAHMS DP 039231 Hanke (2006)
Drum Castle	1598-1621	yes	Scottish oak (dendroanalysed), common rafter roof with one collar	Shannon Fraser NTS Crone (2011)
Kirkcaldy 339-343 High Street	1600 (1995 drawing)	yes	 Baltic pine, span 7.3m, 53/55° pitch, common rafter roof with two collars and rafter feet, mortice and tenon joints with timber pegs	Ruddock (1995) Hanke (2006)
Moniack Castle	1600-10	no	reroofed in 1807-8	Gifford (1992)
Bruntisfield House	1605	no	unroofed	Steven Robb HES
Lamb's House in Leith	1608	yes	Scandinavian pine and Norwegian oak (dendroanalysed)	Anne Crone

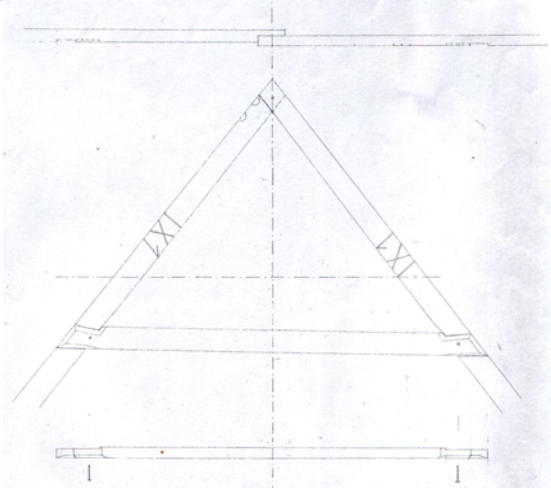
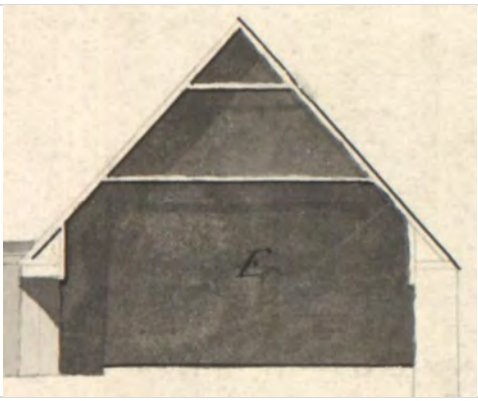
Gilbertfield Castle	1607 (1900 drawing)	no (ruinous)		RCAHMS DP 225199
Craigievar Castle	1610-26	no	reroofed in 1826	Crone and Mills (2011)
Northfield House	1611	yes	 common rafter roof	Hanke (2006)
Dirleton Church	1612	yes		HES
Edinburgh Castle Chapel	1615 (1719 drawing)	no		NLS Military Maps MS.1645 Z.02/01e Macgibbon and Ross (1887-92)
Fraser Castle	1615-30, stables late 18C (1980 drawing)	yes	 pine, common rafter roofs with two collars and attic rooms in between, collars are half baulks (timbers axed and sawn in two), rafters are full	RCAHMS ABD/18/14 Shannon Fraser NTS Crone and Mills (2011)

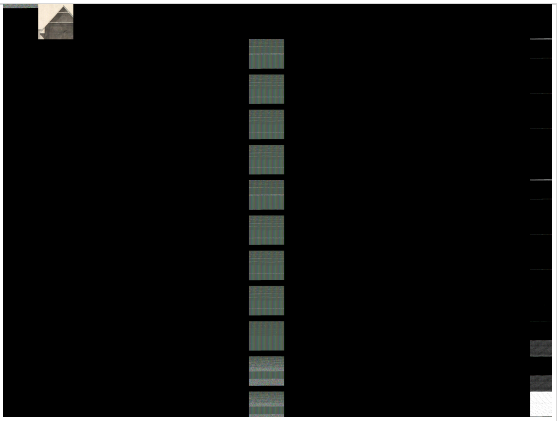
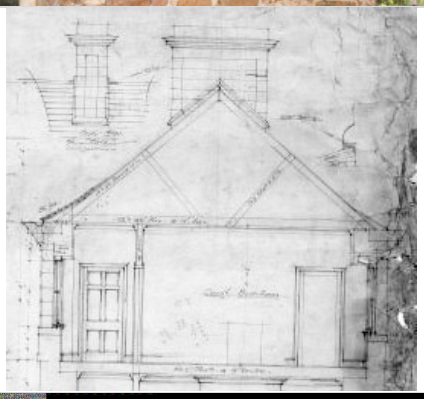
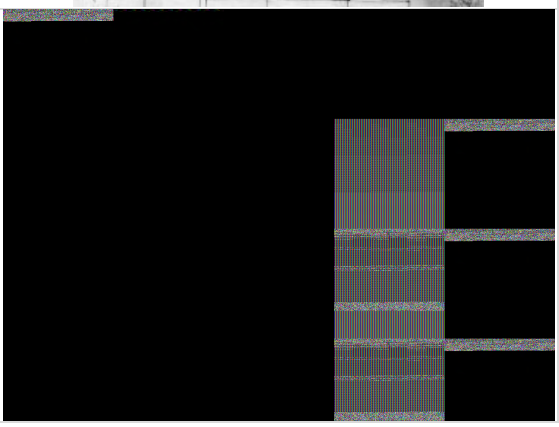
			baulks	
Binns House	1621-30	no (replaced in 1990s)		Owner Hanke (2006)
Provost Skene's House	1622 (1952 picture)			RCAHMS SC 1327351
Baberton House	1622-23	yes	 common rafter roof	Hanke (2006)
Black Castle South Queensferry	1623	yes	 common rafter roof	Hanke (2006)
Cupar Preston Lodge	1623	no	roof raised and replaced	RCAHMS
Pilrig House	1623	no	roofless in 1975	RCAHMS

Saughton Mills	1623			Macgibbon and Ross (1887-92)
Stewart Castle	1625 (1948 drawing)			RCAHMS DP 171707
Neidpath Castle	1625-50	probably not	roofless in 19C drawing	RCHAMS
Culross Tolbooth	1626	yes	span 7.3m, common rafter roof	Hanke (2006)
Hamilton House	1628	yes	common rafter roof	Hanke (2006)
Edinburgh Parliament Hall	1631-40	yes	 oak, span 13m, 15° pitch, open purlin roof supported by arch system, John Scott wright	picture by Author Gomme (2002) Hanke (2006) Hay (1976) Hannay and Watson (1924)
Acheson House	1633	no	reroofed in 1930s	Ben Tindall architect
Invermay Old House	1633	no		Owner

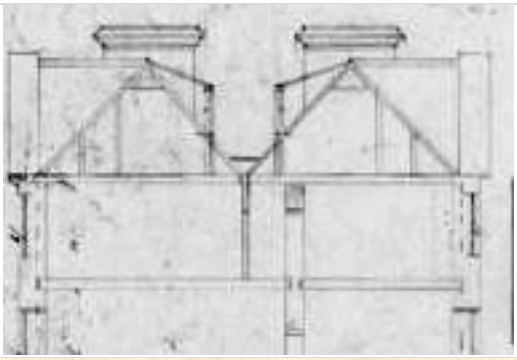
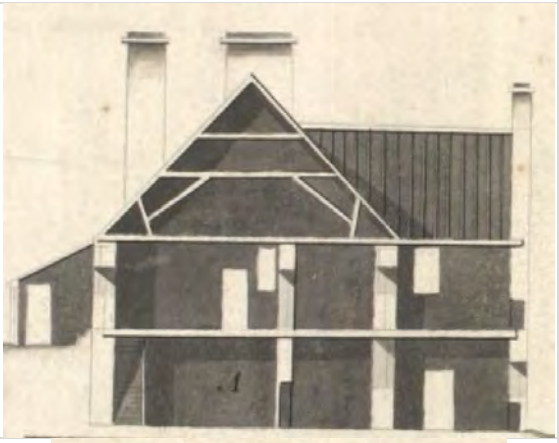
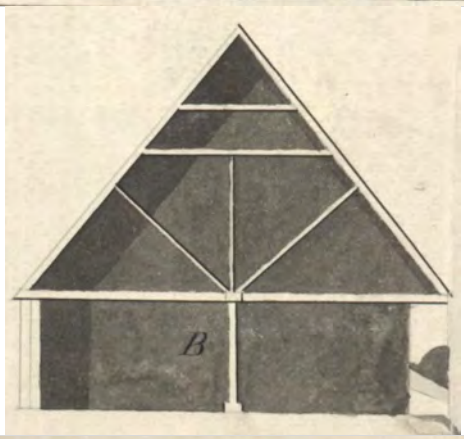
Skelmorlie Aisle	1636	yes		Ian Lambie HES
Edinburgh Tron church	1636-47	yes	 open purlin roof supported by arch system, John Scott wright	picture by Author Gomme (2002) Hanke (2006) Hay (1976)
Halkerston Lodge	1638-42	yes	 conifer, span 4.15 m, pitch 53°, common rafter roof with rafter feet and pyramidal roof, big roughly sawn roman numerals	Hanke (2004)
Moray House	1640	yes	 spans 5.8m and 7.2m, common rafter roofs with one collar and rafter feet, one has scissor braces	Hanke (2004)
Lyne Church	1640-5	yes		Ian Lambie HES

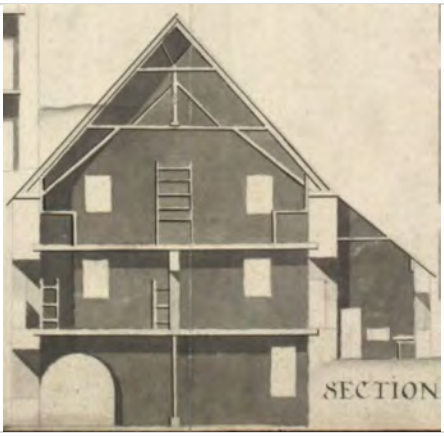
Auchterhouse	mid 17C (1923 drawing)			RCAHMS AND/8/8
Leith Hall	mid 17C	yes	pine	Shannon Fraser NTS
Provan Hall Glasgow	mid 17C	yes	 56° pitch, big roughly sawn roman numerals	Hanke (2009)
Arbuthnott House	1660 (1972 drawing)			RCAHMS KCD/72/6.P
Rowallan Castle	1661 (1993 picture)			RCAHMS SC 1133552
Dirleton Castle	1660s	no		Hanke (2006)
Craignethan Castle	1665	yes		Ian Lambie HES
Queensberry House	1667-70	no	reroofed in 21C	Cristina Gonzalez Longo

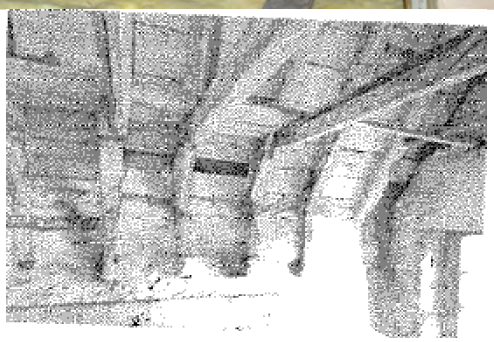
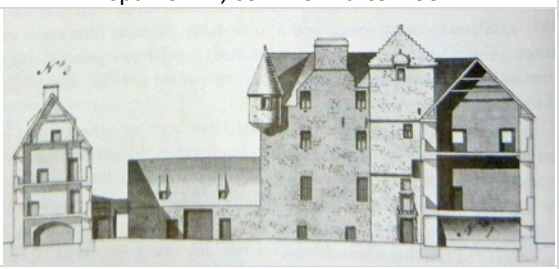
				architect
Lauder Parish Church	1673-4	yes	 common rafter roof with dovetail joints	Hanke (2008)
South Leith Parish Church	1674	no	entirely renovated in 1848	RCAHMS
Edinburgh Castle Powder Magazine (demolished)	1677-80 (1719 drawing)	no		NLS Military Maps MS.1645 Z.02/01c
Ferniehurst Castle Chapel	1680	no	picture without roof	RCAHMS
Ford House	1680	yes		Ben Tindall architect
Craigiehall House	1695-9	no	reroofed in 1951	RCAHMS
Edinburgh Old Surgeon's Hall	1697	no	extra floor added in 19C	HES
Newbattle Sun Inn	1697	no		Owner
Drummuir Mains	17C	no		Crone and Mills (2012)
Edinburgh Greyfriars Church	17C	no	reroofed in 1845	HES
Haddington House	17C		span 5.5m, common rafter roof	Hanke (2006)

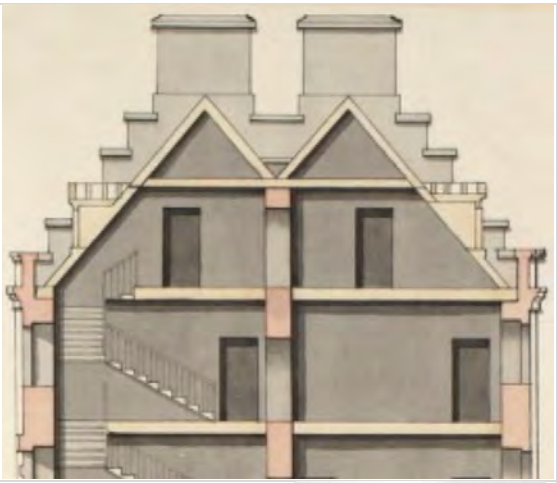
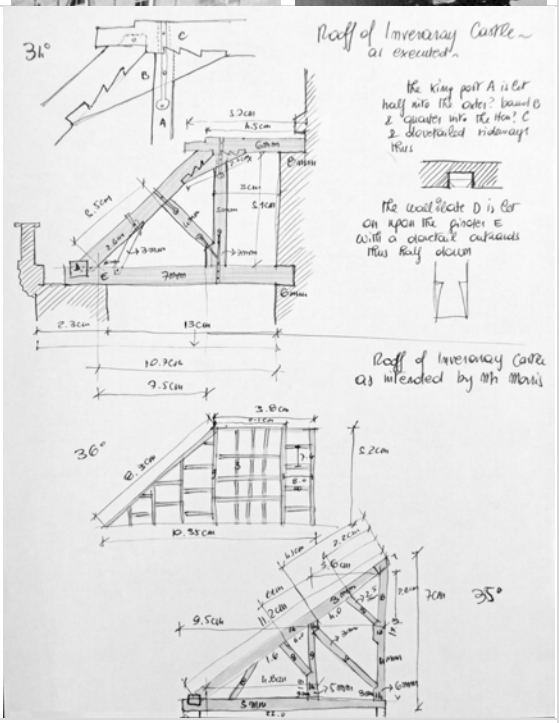
Hunting Tower Castle	17C	yes	 purlin roof with common rafters and sarking supported by frames composed of rafter couples, a tie-beam, a collar and two vertical struts between tie-beam and collars	picture by Author
Sornhill Farm	17C (2006 picture)			RCAHMS DP 010524
Lennoxlove House	17C or early 19C			RCAHMS DP 002754
Bannockburn House	end 17C	yes		picture by David Mitchell HES

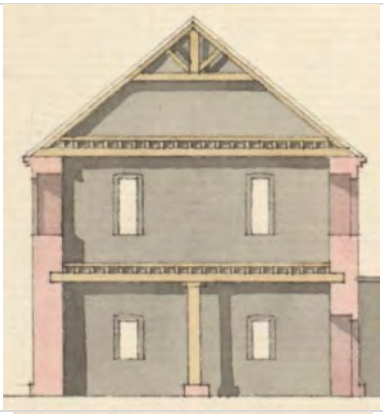
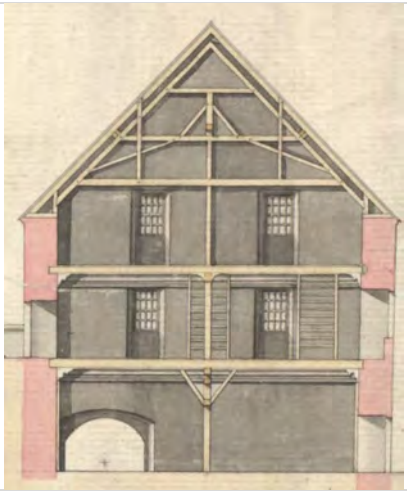
Moy Hall (demolished)	1700 (1872 drawing)	no		RCAHMS DP 006446
Dalkeith Palace	1702-11	yes	  platform roof with common rafters	pictures by Author
Polwarth Church	1703			RCAHMS
Mertoun House	1703-7	no	reroofed in 1915	Owner
Bowhill House	1708	probably not	raised one storey in 1831-33	Cruft (2005)
Edinburgh Castle Old Barracks	1708 (1754 drawing)			NLS Military Maps MS.1645 Z.02/14a
Gifford Parish church	1710	yes	common rafter roof	Hanke (2004)
Lethen House Granary	early 18C	no		Crone and Mills (2011)
Skellater House	early 18C	yes	common rafter roof with dovetail lapped collars secured by nails	Hay (1976)

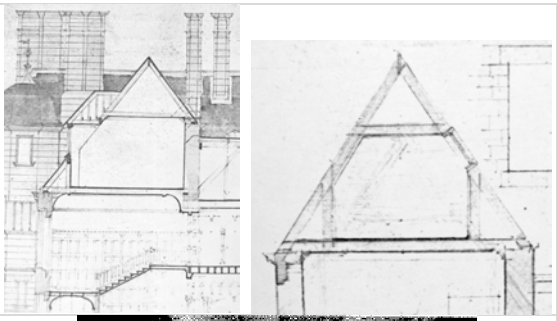
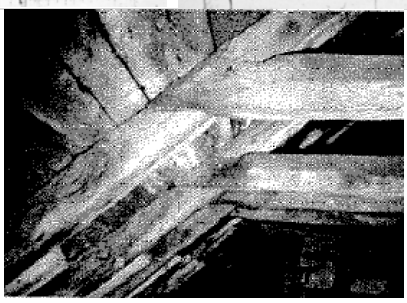
Bute Mount Stuart	1718	probably not (rebuilt 19C)		RCAHMS BMS/7/4
Edinburgh Castle Late Major Apartments (not sure which building it refers to)	1719 drawing			NLS Military Maps MS.1645 Z.02/01c
Edinburgh Castle Carriage Sheds (not sure which building it refers to)	1719 drawing			NLS Military Maps MS.1645 Z.02/01c
Edinburgh Castle Grand Storehouse (not sure which building it refers to)	1719 drawing			NLS Military Maps MS.1645 Z.02/10

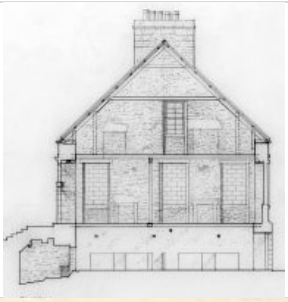
Edinburgh Castle Storehouse (not sure which building it refers to)	1719 drawing			NLS Military Maps MS.1645 Z.02/01b
Durisdeer Parish Church	1716-29	no	reroofed in 1957	HES
Hopetoun House South Pavilion	1721-48	yes		pictures by Author
Hopetoun House North Pavilion (Stables)	1721-48			(RCAHMS SC 767049, 1995)
Drum House	1723	yes		Owner
Harehope House	1723	no	raised one storey in early 19C	HES
Newbattle Parish church	1725	yes	common rafter roof, 9.16m span, struts linking rafters and collars	Hanke (2006)

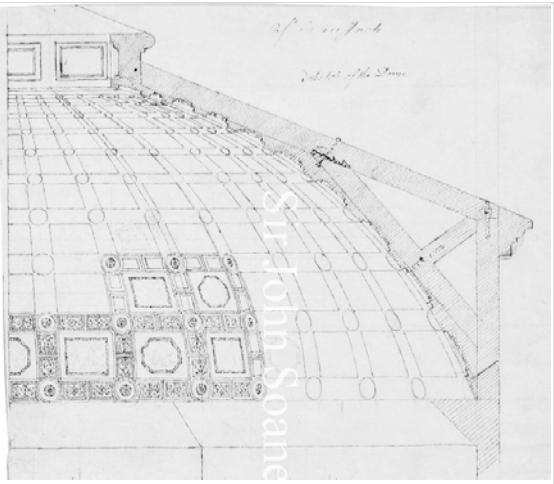
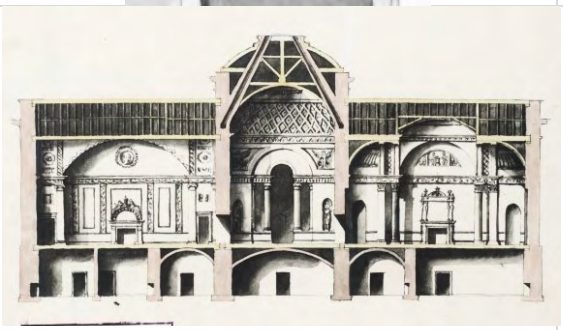
Chatelherault Hunting Lodge	1731-43	no	roofs fallen before restoration in 1978-87	Building manager
Hermits and Termites	1734	yes		Ben Tindall architect
Dumbarton Castle Governor's House	1735	yes		picture by Ian Lambie HES
Edinburgh St Ninian's Manse	1735	yes	 span 6.4m, common rafter roof	Hanke (2006)
Gowrie Lodging	1740 drawing			NLS in McKean (2001)
Skye Lyndale House	1740	no	reroofed in 1900	RCAHMS
Gartmore House	1740-5	no	mansard roof added in 1901/2	Adam (1812)
Glenkindie House	1741	no		Crone and Mills (2011)

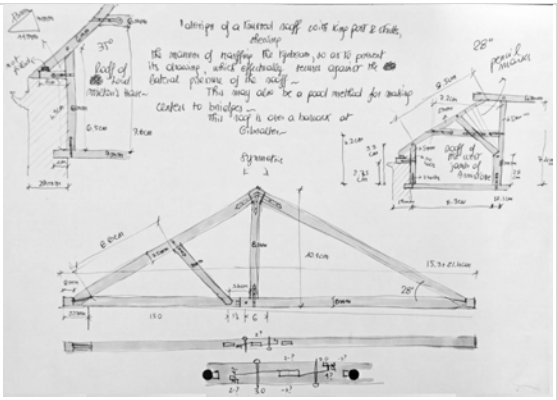
Edinburgh Castle Governor's House	1742 (1742 drawing)			NLS Military Maps MS.1645 Z.02/05c
Inveraray Castle	1744-61	no (reroofed after fire in 1975)	  	Pictures from building manager Author copy of a drawing in John Adam's diary held at Blair Adam
Edinburgh Castle Mills Mount Shed	1746 (1746 drawing)	yes		NLS Military Maps MS.1645 Z.02/06a

Edinburgh Castle Storehouse	1748-54 (1753-4 drawing)			NLS Military Maps MS.1645 Z.02/13b
Edinburgh Castle Powder Magazine (demolished)	1748-54 (1747 drawing)	no		NLS Military Maps MS.1645 Z.02/07b
Burntisland Parish Church	1748-1822	yes	dovetail joints	Hanke (2008)
Bellabeg Mill	mid 18C	no		Crone and Mills (2011)
Dumfries House	1754-9	no	concrete attic built in 1923	Charlotte Rostek NTS
Edinburgh Castle Barracks (demolished)	1755 (1754 drawing)	no		NLS Military Maps MS.1645 Z.02/14a

Ballochmyle House	1760			RCAHMS DC2067
Musselburgh Tolbooth	1762	yes	 span 5.6m, common rafter roof, dovetail lapped collars	Hanke (2006)
Applegarth Parish Church	1762-3	no	reroofed in 1884	Gifford (1996)
Edinburgh St Cecilia's Hall	1763	no	reroofed in 20C	RCAHMS
Gayfield House	1763-5	yes	 platform roof with common rafters	picture by Author
Edinburgh Royal Botanic Gardens Cottage	1764-5	yes but dismantl ede and reassem bled	 common rafter roof with one collar, joints between rafters and collars are dovetail lapped	Picture by Author
Ardgour	1765	probabl	roof remodeled in 1826-30 after a fire	Gifford

House		y not		(1992)
Clestrain Hall	1769 (1998 drawing)			RCAHMS DP 112429
Edinburgh New Barracks	1769-99 (1755 drawing)			NLS Military Maps MS.1646 Z.02/15
Penicuick Parish church	1771		common rafter roof	Hanke (2006)
Kinglassie Parish Church	1773-4	no	reroofed in 1887-88	HES
Pitlour House	1774	yes		HES, RCAHMS and John Addison engineer
Alness Old Parish Church	1775	no	unroofed in 1970	Gifford (1992)
Baillie Craig's House	1775	no	reroofed in 1890	McKean et al. (1989)
Abernethy Old Parish Church	1775-9	no		Crone and Mills (2011)
Canna the Bothy	1781-7	probably not	reduced to single storey in 19C	RCAHMS
Dalquharran Castle	1782-90	no		HES and RCAHMS

Edinburgh Assembly Rooms	1784-7		 drawing by James Adam	Adam (1755)
New Tarbat House	1787	no	roofless after fire in 1988	BARR
Dumbarton Castle Barracks (not built)	1788 drawing	no		NLS Military Maps MS.1649 Z.03/49
Gosford House	1790-1800		 Robert Adam	Adam (1812)
Glenbuchat Old Parish Church	1792	no		Crone and Mills (2011)
Inverness Greyfriars Free Church	1792-4	probably not	heighteneed in 1822	Gifford (1992)
Applecross Old Manse	1796	probably not	top floor heightened in 19C	Gifford (1992)

Edinburgh Lord Milton's House	18C		 drawing of roof of Lord Milton's House (possibly the one in Edinburgh), of Arniston House's roof and a roof in Gibraltar	Author copy of drawing in John Adam's diary held at Blair Adam
Bush House Adam Office Wing	18C	no	reroofed in 19C	HES
Newe Mill	18C	no		Crone and Mills (2011)
Strathleven House	18C	no	roof burnt	Cristina Gonzalez Longo architect

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APPENDIX B

ONLINE QUESTIONNAIRES TO BUILDING OWNERS, USERS, MANAGERS, PROFESSIONALS IN CHARGE OF THE BUILDING MAINTENANCE

ARNISTON HOUSE.....361

BALCASKIE HOUSE.....364

BLAIR ADAM.....367

BLAIR CASTLE.....370

BRODIE CASTLE.....373

COWANE'S HOSPITAL.....376

CULROSS PALACE.....379

CULZEAN CASTLE.....382

DUFF HOUSE.....385

FOUNTAINHALL HOUSE.....388

GARDYNE'S LAND.....391

GAYFIELD HOUSE.....394

GEILSTON HOUSE.....397

FORT GEORGE.....400

GLAMIS CASTLE.....403

HADDO HOUSE.....406

HOPETOUN HOUSE.....409

INNES HOUSE.....412

KELBURN CASTLE.....415

MAGDALEN CHAPEL.....418

MALLENY HOUSE.....421

MAYBOLE CASTLE.....424

MELVILLE HOUSE.....427

METHVEN CASTLE.....430

PRESRTONFIELD HOUSE.....433

ROBERT GORDON'S COLLEGE.....436

ROYSTON HOUSE.....439

SAILOR'S WALK.....442

STIRLING TOLBOOTH.....445

GLASGOW TRADES HALL.....448

GLASGOW TRON THEATRE.....451

WINTON HOUSE.....454

YESTER HOUSE.....457

Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Arniston House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

1970

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  May Dundas Arniston Trustees
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  Please see our online list at Register House for older documents. We are in the process of listing more recent documents such as plans etc for our archive room.
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- (•) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [x] Roof covering (slates, lead, etc)
  Chimneys require repair.
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☑
Inspection of roof structure (timbers and sarking)	☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☑
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑

***Q13.* Please specify what the programmed works involve:**

Structural report followed by prioritised works where resources allow

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- (•) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)	1980	Roof material not fit for purpose	Roofing specialist	Complete relead of main roof
Repairs to flashings				
Repairs to attic ceiling				

Q17. **Please give any further comments:**

Location Data

Location: (51.496398925781, -0.12240600585938)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Balcaskie, Fife

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Owned since around 1680. In charge of it since 2000. Lived in since 2008

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  yes. Owner: William Bruce (architect) Occupant: Sir Ralph Anstruther (d. 2000) Manager: various
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  Yes - archive at Nat Archives of Scotland and St Andrews University. Various theses written previously (all on public record)
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ( ) Yes
- (•) Partly (please specify what is missing)
  Partly. Some restricted access. Some care needed in many attic/roof spaces
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  Mainly.
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☐ Structure (timbers and sarking)
- ☑ Roof covering (slates, lead, etc)
  Odd slates missing (due to be repaired) but only as usual
- ☐ Flashings
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☑	☐

***Q13.* Please specify what the programmed works involve:**

Regular inspection. Repair as needed. Regular programmed repainting of exposed metal (rones and skylights) and wood (windows).

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	None needed			
Repairs to roof covering (slates, lead, etc)	Annually	Missing slates	Roofer	Replaced slates
Repairs to flashings	As req'd			

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Sorry for the delay in completing this survey! Kind regards, Toby

Location Data

Location: (43.774200439453, 7.4990997314453)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Blair Adam House.

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Stephen Newsom, info@stephennewsom.co.uk

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Since inheriting in 1988.

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  Father. Deceased.
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  Many.
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ( ) Yes
- (•) Partly (please specify what is missing)
  Some parts are less easy than other parts. i.e. one may need to squeeze tthrough some narrow spaces. Some parts not accessible to move across as too fragile.
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  Mostly. The library roof is not visible owing to the curving barrel shaped ceiling being close to the roof timbers.
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  Yes. North side of the South Section has some poor sarking/timbers.
- ☑ Roof covering (slates, lead, etc)
  Which will be repaired before complete reslating work.
- ☑ Flashings
  A lead valley on the Central Section will need remedial work, probably complete renewal, although this had previously been done aprox 1960.
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☑	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

A very gradual programme of phased renovation works as funds allow. After a long period of minor repairs we are now embarking on a further stage of work. This will be Phase 4, with the formal first phase beginning about 1970 although other repair works had been done prior to then.

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ○ Yes
- ○ No
- ◉ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	From 1970	Deterioration	Tradesmen	
Repairs to roof covering (slates, lead, etc)	From 1970	Deterioration	tradesmen	

Repairs to flashings	From 1970	Deterioration	tradesmen	
Repairs to attic ceiling	From 1970	Deterioration	tradesmen	

***Q17.* Please give any further comments:**

Most receipts for the three previous phases have been retained.

Location Data

Location: (51.573394775391, -0.42340087890625)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Blair Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☑ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: User , building manager

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Estate Property manager

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Involved in maintenance since 2012

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Yes
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Yes
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  Yes
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  Sarking - damp being replaced
- ☑ Roof covering (slates, lead, etc)
  Yes - slates old being replaced
- ☑ Flashings
  Damaged, being replaced
- ☑ Attic ceiling
  Damp -work above should solve

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
Inspection of roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

Replacement of slates, use of membrane, replacement of sarking and timbers if required. Two sections of roof complete, 1 underway this year 1 part to monitor

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	Previously present programme since 2012	Damp and woodworm	Various. Bruar Construction	New sarking
Repairs to roof covering (slates, lead, etc)	Previously and present programme since 2012	Leaks	Bruar Construction	new slates

Repairs to flashings	Over many years	Leaks	Various trademen	lead work
Repairs to attic ceiling	None	None	none	none

***Q17.* Please give any further comments:**

Location Data

Location: (55.952102661133, -3.1965026855469)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Brodie Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☑ Building manager
- ☐ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

1997

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Yes, John Dymock NTS Surveyor (deceased)
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Some considerable archive files
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  In places there are safe walk boards. Some hatches are constrictive. Some roof spaces have known bat roosts. Our team have survey equipment to allow access and operate a risk assessment and method statement for surveying roof spaces.
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  Due to coombed ceiling there are areas that are no on show. Also insulation obscures timbers in limited places
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  One live issue with a sunk valley rafter picked up in recnet quinquennial survey.
- ☐ Roof covering (slates, lead, etc)
- ☐ Flashings
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☐	☑	☑	☑	☐	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☑	☑	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

We have a measured term contract for roof maintenance and repair that is undertaken in May and November of each year. This examines all lead, slate, cast iron and drainage, or any other potential fabric deficiencies that could lead to water ingress. There is a defined performance specification for the works

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (56.117401123047, -3.5345001220703)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Cowane's Hospital

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Charity Administrator

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

The Cowane's Hospital Maintenance Trust, Registered Scottish Charity SCO42873, 49 St John Street, Stirling, FK8 1ED 01786 472247

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2011

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Patrons of Cowane's Hospital Trust Registered Scottish Charity SCO19364 49 St John Street Stirling FK8 1ED 01786 472247
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes Plans Drawings Optional Appraisals
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  No access
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  Other parts of the building not accessible
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☐ Structure (timbers and sarking)
- ☑ Roof covering (slates, lead, etc)
  Need replaced in parts
- ☑ Flashings
  loose
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☑	☑	☑	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☑	☑	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

Ad hoc until the proposed restoration programme in 2017

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)	2015	loose slates	roofer	replace slates
Repairs to flashings				

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

The Charity has been successful in securing funding from the Heritage Lottery Fund stage 1, stage 2 application is due in 2017 and if successful will undergo restoration

Location Data

Location: (53.479202270508, -2.2859039306641)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

culross palace

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☑ Architect in charge
- ☑ Other: Building Surveyor

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Surveyors - East area of NTS

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

1996

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  HES
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  yes - many
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  risk assessment required before entry
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [x] Roof covering (slates, lead, etc)
  limited life and appropriate replacement material to be decided
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☐	☑	☐	☑	☐	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☐	☑	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

general roof maintenance

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- (•) Yes
- ( ) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

records would need to be checked for details to support previous question - many works are undertaken to the Palace

Location Data

Location: (55.932601928711, -3.2530975341797)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Culzean Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Building Surveyor in charge of maintenance

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

N/A

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

The organization (NTS) has owned the building since 1945. I have been in charge of its maintenance since 2000

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Yes. Kennedy family (pre-1945)
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes. some original drawings exist. We have maintenance records from the period 1945-1980 and detailed records of work done between 1980 to date.
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Some parts of the roof are flat lead covered decks with no accessible void below
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○

- ○ No (please specify why)

Q12. **Are the roof timbers visible?**

- ◉ Yes
- ○ Partly (please specify where they are not visible and why)
- ○ No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  Structure appears to be in satisfactory condition
- ☑ Roof covering (slates, lead, etc)
  Coverings are in fair condition. Frequent maintenance is undertaken along with a programme of ongoing repairs
- ☑ Flashings
  There are a large number of cover flashings throughout the roof. Due to ongoing stone decay, many of the cover flashings have been renewed when raggles recut/ reformed.
- ☑ Attic ceiling
  appears satisfactory

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☑	☐	☐	☐	☑	☑	☐	☑
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☑
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☑	☐	☑
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☑

Q13. **Please specify what the programmed works involve:**

1. Cleaning gutters, valleys, roof penetrations/ rooflights etc. Sweeping down pitches, replacing slipped slates. inspecting leadwork & general features and undertaking small repairs as necessary. 2. Planned repairs including flashing replacement, re-slating sections, masonry repair & repointing

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	2012	Decay discovered	Roofing contractor	Replacing decayed sarking

Repairs to roof covering (slates, lead, etc)	2015	Replacing slipped slates	Roofing contractor	renewing slipped slates
Repairs to flashings	2015	Flashing found to be damaged	Roofing contractor	Removing rooflight. Replacing flashings & refitting rooflight
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

The roof is large and complex. The key to maintaining the roof in satisfactory condition is to carry out regular inspections during regular cleaning/ maintenance regimes and follow up any necessary work required by undertaking the necessary repairs. If regular cleaning/ inspection work was to stop, the roof condition would deteriorate rapidly.

Location Data

Location: (56.460998535156, -2.9765930175781)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Duff House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☑ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

HS/HES Duff House 1992

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Yes various
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes building files
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Parts -
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Areas between double piles and areas without access hatches
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [ ] Roof covering (slates, lead, etc)
- [x] Flashings
  Some failure
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☑	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☑	☐	☑	☐	☑	☐	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

Depends what is identified during inspection

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- (•) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	1993	Dry rot and general needs	HS/contractor	repairs and replacement
Repairs to roof covering (slates, lead, etc)	as above	as above	as above	as above
Repairs to flashings	as above	as above	as above	as above
Repairs to attic ceiling	as above	as above	as above	as above

Q17. **Please give any further comments:**

Location Data

Location: (41.11149597168, 16.855392456055)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Fountainhall

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Na

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2014

Q8. **Do you know who the previous owners, tenants or managers were?**

- ○ Yes (please specify name and contact details if known)
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ○ Yes (please specify what documents you have)
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○ No (please specify why)

Q12. **Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q13. **Please specify what the programmed works involve:**

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- ( ) Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				
Repairs to attic ceiling				

Q17. **Please give any further comments:**

Location Data

Location: (53.533294677734, -1.1499938964844)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Gardyne's land

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [ ] Owner
- [ ] Tenant
- [ ] User
- [x] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Dundee City Council

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

I've been living in the building since September 2013

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  Building was unoccupied until renovation in 2008.
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  Yes, hostel has all the renovation plans and photos of the building's condition before.
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- (•) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- (•) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (56.460998535156, -2.9765930175781)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Gayfield House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Owned since 2012, resident since early 2013

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  Yes. Previous owner is Trevor Harding, a former roofer. I can pass a message to him if required.
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  We have copies of some 19th century drawings that are in public collection and second hand published and private accounts of construction.
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ( ) Yes
- (•) Partly (please specify what is missing)
  Access is through a small hatch and space is very limited. I can get in but not very easily and moving around inside is quite tricky.
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  I am not aware of any major problems with the roof, but there are associated issues with cracking urn finials, a leaking rooflight and gutters
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

No programmed works underway but we will need to address urn finial cracking

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- (•) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

I don't have detailed records of past roof work but I believe substantial repair was carried out by the previous owner

Location Data

Location: (55.952102661133, -3.1965026855469)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Geilston House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Building Surveyor

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2001

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  John Young NTS Building Surveyor
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Archaeological Reports and Surveys
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Access not available in all areas. No ladders, etc provided other than those on site.
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  Minor areas of decay and deflection
- [x] Roof covering (slates, lead, etc)
  Slates/Tiles
- [x] Flashings
  Lead/Mortar
- [x] Attic ceiling
  Plaster/Timber

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

maintenance, repairs and Inspection

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- (•) Yes
- ( ) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	c2005	Decay	NTS	Local repairs
Repairs to roof covering (slates, lead, etc)	Annual	Maintenance	NTS	Local repairs
Repairs to flashings	Annual	Maintenance	NTS	Local repairs

Repairs to attic ceiling	na	na	na	na

***Q17.* Please give any further comments:**

Location Data

Location: (55.63330078125, -3.1833038330078)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Fort George

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☑ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Fort george HES/HS 1962

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Yes various
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes building files and original work book and board of ordnance drwgs for Fort George
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Parts -
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Areas between double piles and areas without access hatches
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  Mostly OK but local water ingress.
- [x] Roof covering (slates, lead, etc)
  slates are maintained regulalry but there is oftern storm damage etc. Modern roof coverings have failed.
- [x] Flashings
  Some failure
- [x] Attic ceiling
  Some water ingress

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☑	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☑	☐	☑	☐	☑	☐	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

Depends what is identified during inspection

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- (•) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Bit difficult to answer as FG is a large site.

Location Data

Location: (41.11149597168, 16.855392456055)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Glamis Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Archivist

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Mark Wedderburn, Glamis Castle

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

N/A

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  The Castle has been owned by the Strathmore family since the 15th century
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes. See National Register of Archives Scotland -NRA(S) Survey list 885.
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Yes
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Yes
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ○ Partly (please specify where they are not visible and why)
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  General Roof repairs were recetly carried out at the end of February/beginning of March 2016
- ☐ Roof covering (slates, lead, etc)
- ☐ Flashings
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ○ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Roof repairs were carried out at the end of February/beginning of March 2016. The roof is checked every year and there is a 4 year rotation maintenance schedule.

Location Data

Location: (56.649993896484, -2.88330078125)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Haddo House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Building owned by National Trust for Scotland

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Surveying team NE

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

National Trust for Scotland took ownership in 1979

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  The Gordon Family of Aberdeenshire
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  There is an archive which includes original architects drawings, some are on display at Haddo, others are held by Haddo Estate (the Gordon family)
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Some areas of flat roof
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  In some areas only

○ No (please specify why)

***Q12.* Are the roof timbers visible?**

○ Yes

◉ Partly (please specify where they are not visible and why)
In accessible areas only

○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

☑ Structure (timbers and sarking)
No current issues - historic insect attack in some areas

☑ Roof covering (slates, lead, etc)
On-going maintenance requirements due to age of roof for slipped slates etc.. extensive leadwork done in 2015

☑ Flashings
Extensive leadwork done in 2015 to parapet walls

☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

Routine clearance of rainwater goods, high level inspections and minor repairs

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

◉ Yes

○ No

○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	2014	Water ingress	Roofing contractor	Repalcement sarking in areas and lintols to window below at Chapel cupola

Repairs to roof covering (slates, lead, etc)	every year	good maintenance practice	roofing contractor	slipped slates, gutter clearance etc..
Repairs to flashings	2014-15	Defective detailing at raggle	roofing contractor	repalcement leadwork to parapet walls
Repairs to attic ceiling	none			

***Q17.* Please give any further comments:**

Location Data

Location: (57.276092529297, -2.4488983154297)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Hopetoun House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [ ] Owner
- [ ] Tenant
- [ ] User
- [x] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2007

Q8. **Do you know who the previous owners, tenants or managers were?**

- ○ Yes (please specify name and contact details if known)
- ◉ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes - please visit our archive
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Varied access arrangements in varied roof spaces. V.few are fully safe and secure without preparation
- ○ No (please specify why)

Q12. **Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  Signs of previous woodworm, which is being monitored
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐

Q13. **Please specify what the programmed works involve:**

None at present

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- (•) Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)	Annual	General check	roofer	Slate replacement
Repairs to flashings	Annual	General Check	roofer	mionor repair and sealing
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (55.949996948242, -3.1999969482422)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Innes House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [ ] Owner
- [ ] Tenant
- [x] User
- [x] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

May 2010

Q8. **Do you know who the previous owners, tenants or managers were?**

- ○ Yes (please specify name and contact details if known)
- ◉ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Specification and accounts for the 1996 renovation work.
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Don't know - many areas of the roof have not been accessed during my time here.
- ○ No (please specify why)

Q12. **Are the roof timbers visible?**

- (●) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [x] Roof covering (slates, lead, etc)
  Lead sheeting from the 1910 renovation has in places been worn to 'foil' thickness by dripping water, weather etc
- [x] Flashings
  Occasional repointing required
- [ ] Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☑	☑	☑	☐	☐	☐	☑	☑	☑
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☑	☑
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐

Q13. **Please specify what the programmed works involve:**

Repairs

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- (●) No
- ( ) Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings	2014	Storm damage	Roofer	Repointing the flashings
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (57.13330078125, -2.1000061035156)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Kelburn Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☑ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

David Boyle and Lord Glasgow are the owners of the castle; contact via the Estate Office on 01475 568 685

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

We have worked at Kelburn Castle for around 20 years and have been in charge of various fabric repair projects over that period

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  The castle has always been in the ownership of the Boyle family
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  The castle archive is managed by a part-time archivist. We as architects have contract drawings relating to fabric repair projects
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Most of the roofspace areas are accessible or at least visible via ceiling access hatches
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Access varies from one part of the castle to another. The main tower roofspaces are partly accessible via stairs. Part of the tower roofspace may be viewable by access hatch but access into this space is not recommended due to age of timbers and no walkboards or lighting are provided. No access into tower corner turret roof voids.
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  Where access is available otherwise timbers not visible
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  Currently under repair to tower
- ☑ Roof covering (slates, lead, etc)
  Currently under repair to tower
- ☑ Flashings
  Currently being renewed to tower
- ☑ Attic ceiling
  Dry rot in tower bedroom

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☑	☑	☑	☐	☐	☐	☑	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☑	☑	☐	☐	☐	☑	☐
Programmed works to roof covering and flashings	☐	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

Renewal of leadwork; overhaul of slates; renewal of cast iron rainwater goods; chimneystack new cope stones; repair of harling; redecoration of harling; reforming lead flat roofs to falls to improve rainwater discharge; window repairs; rooflight renewal

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	2013-2016	rotten timbers	Contractor	repair & renewal of timber

Repairs to roof covering (slates, lead, etc)	2013-2106	loose & missing slates	Contractor	repair & renewal of slates
Repairs to flashings	2013-2016	leadwork defective, worn & patched	Contractor	replacement of leadwork
Repairs to attic ceiling				

Q17. **Please give any further comments:**

Funding is a major problem in a building of this type as the owner has few financial resources so relies on grant aid from Historic Scotland which is in demand across the country and will only fund a % of the work, with the remainder needing to be found by the owner. As a result the repair projects are done in several phases and need to prioritise the most badly affected areas so that other areas have to be left until funds are available. This building is lived in by the owner but is used commercially as well and so repairs are often directed to areas which are required for commercial purposes ie attic level bedrooms

Location Data

Location: (55.966705322266, -3.61669921875)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Magdalen Chapel, Edinburgh

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

We are

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

We have owned the building since 1860.

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  The Edinburgh Hammermen
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  There is a good account in Book of Old Edinburgh Club (Vol. 8??); and Simpsons, the Edinburgh architects also have a lot of records.
- ( ) No

Q10. **Is the roof space of your building accessible?**

- ( ) Yes
- (•) Partly (please specify which parts are not accessible and why)
  The oldest part is accessible. Some of the nineteenth century parts may not be.
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- (•) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  Some of the timbers show signs of damp, but this not considered to be a current problem.
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐

***Q13.* Please specify what the programmed works involve:**

Resolving whatever problem has been identified

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- (•) Yes
- ( ) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	1990s	don't know	Simpsons	
Repairs to roof covering (slates, lead, etc)	1990s	don't know	Simpsons	
Repairs to flashings	1990s	don't know	Simpsons	
Repairs to attic ceiling	1990s	don't know	Simpsons	

***Q17.* Please give any further comments:**

Please consult Simpsons for furthe details.

Location Data

Location: (57.143707275391, -2.0980987548828)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Malleny House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Building Surveyor in charge

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Approximately 8 years

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Other NTS Building Surveyors were responsible for the building maintenance before me including William Napier and Bryan Dickson. The NTS has owned the building and garden since 1968.
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Yes, accounts and drawings of later repair works
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  The roof space is accessible but there are rooms built into the roof so a lot of the roof structure is concealed behind wall linings.
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  The voids above the ceilings are not very big and there are no walking boards so access into the roofspace although possible isn't easy.
- ○

No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  As previous - rooms are built into the attic so much of the roof timbers are obscured by wall linings
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  Yes, roof timbers have been affected by insect attack although this is understood to be historic. Some roof timbers displaced. A structural engineer has inspected and believes the roof structure is in reasonable condition for it's age and type with only relatively minor repairs needed
- ☐ Roof covering (slates, lead, etc)
- ☐ Flashings
- ☑ Attic ceiling
  Damaged plaster nibs to lath & plaster ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☑	☐	☐	☐	☑	☐	☑
Inspection of roof structure (timbers and sarking)	☐	☐	☑	☐	☑	☑	☑	☐	☐	☐	☑
Programmed works to roof covering and flashings	☑	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☑	☐	☐	☐	☑

***Q13.* Please specify what the programmed works involve:**

At the NTS we arrange annual inspections and minor maintenance of our roofs by a roofing contractor. We also have a programme of quinquennial surveys by a conservation accredited architect / surveyor / engineer to identify any repair needs and would programme the works thereafter. NTS surveyors also make regular visits to the properties and are in regular contact with the Property Managers to monitor repair need

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				

Repairs to roof covering (slates, lead, etc)	2011 and minor repairs annual	Repairs recommended in quinquennial survey and minor repairs identified during annual inspections	roofing contractor	Reslating localised areas
Repairs to flashings	2011	Repairs recommended in quinquennial survey	Roofing contractor	External fabric repairs including replacement of some lead flashing
Repairs to attic ceiling				

Q17. **Please give any further comments:**

Location Data

Location: (55.932601928711, -3.2530975341797)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Maybole Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [ ] Owner
- [ ] Tenant
- [ ] User
- [x] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2003

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  David Gray Estate Office
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  Various old drawings and extensive accounts
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ( ) Yes
- (•) Partly (please specify what is missing)
  Requires a ladder and caution walking on the floored areas
- ( ) No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  Previous fire in 1917 damp water ingress lack of heating in the building(now sorted)
- [x] Roof covering (slates, lead, etc)
  Slate nail sick
- [x] Flashings
  lead pointing
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☑	☐	☑	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☑	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

routine inspection cleaning gutters of pigeon muck replacing slates checking valley gutters and clean

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- (•) Yes
- ( ) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	2007	identified need	builder	cherry picker access
Repairs to roof covering (slates, lead, etc)	every 2 months	routine	builder	fix and repair
Repairs to flashings	every 2 months	routine	builder	check, fix and repair

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (55.75, -4.9499969482422)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Melville House monimail

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

December 2013

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  Jennifer Harvey
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ( ) Yes (please specify what documents you have)
- ( ) No

Q10. **Is the roof space of your building accessible?**

- ( ) Yes
- (•) Partly (please specify which parts are not accessible and why)
  All of roof space accessible
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ( ) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

Q12. **Are the roof timbers visible?**

- ○ Yes
- ○ Partly (please specify where they are not visible and why)
- ○ No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☐ Structure (timbers and sarking)
- ☐ Roof covering (slates, lead, etc)
- ☐ Flashings
- ☐ Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q13. **Please specify what the programmed works involve:**

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ○ Yes
- ○ No
- ○ Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				
Repairs to attic ceiling				

Q17. **Please give any further comments:**

This question was not displayed to the respondent.

Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Methven Castle

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2005

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  My parents from 1984
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- (•) Yes (please specify what documents you have)
  Some but these are not listed or available for your use.
- ( ) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- (•) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

Q12. **Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q13. **Please specify what the programmed works involve:**

Works are carried out on an as and when required basis. As an architect with knowledge of the building for in excess of 30 years an inspection, specification is produced by me.

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- (•) No
- ( ) Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	1984	defective timber	Contractor	Replacement and repair
Repairs to roof covering (slates, lead, etc)	1984	Defective sarking, demolition of adjacent building and slates thatdid not match	Contratcor	Slaterwork
Repairs to flashings	1984	as above	Contractor	Lead flashings
Repairs to attic ceiling				

Q17. **Please give any further comments:**

Location Data

Location: (56.399993896484, -3.4333038330078)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Prestonfield House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Project Manager

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2003

Q8. **Do you know who the previous owners, tenants or managers were?**

- ○ Yes (please specify name and contact details if known)
- ◉ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Some account books from 1680s, technical drawings from RCAHMS in 1943
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  Most covered by lath and plaster
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  floored but little visible structure
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  lath and plaster covers most
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☐ Structure (timbers and sarking)
- ☐ Roof covering (slates, lead, etc)
- ☑ Flashings
  Inevitable weak spots and need repairs
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐
Programmed works to roof covering and flashings	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

Most recent has been some lead replacement

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (55.905197143555, -3.2005004882812)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Auld Hoose

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☑ Building manager
- ☐ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

1993

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  James Hamlton
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Documents may be held by the Archive Department
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Hatch access but no walkway or lighting
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☑	☐	☑	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- (•) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	1993 to date	water ingress	various	not known
Repairs to roof covering (slates, lead, etc)	1993 to date	water ingress	various	not known
Repairs to flashings	1993 to date	water ingress	various	not known
Repairs to attic ceiling	1993 to date	water ingress	various	not known

***Q17.* Please give any further comments:**

Location Data

Location: (57.143707275391, -2.0980987548828)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Caroline Park House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

25 dec 1987

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  Buccleuch Estates Limited
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ( ) Yes (please specify what documents you have)
- (•) No

Q10. **Is the roof space of your building accessible?**

- ( ) Yes
- (•) Partly (please specify which parts are not accessible and why)
  Yes partly excluding State appartments
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ( ) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

Q12. **Are the roof timbers visible?**

- ○ Yes
- ○ Partly (please specify where they are not visible and why)
- ○ No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☐ Structure (timbers and sarking)
- ☐ Roof covering (slates, lead, etc)
- ☐ Flashings
- ☐ Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☑
Inspection of roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☑
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☑
Programmed works to roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☑

Q13. **Please specify what the programmed works involve:**

regular maintenace

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ○ Yes
- ○ No
- ○ Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)	2015	storm damage	Mike Courtney	slates
Repairs to flashings				
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (55.949996948242, -3.1999969482422)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Sailor's Walk

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Building Surveyor

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

2001

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  John Young NTS Building Surveyor
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  Archaeological Reports and Surveys
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ○ Yes
- ◉ Partly (please specify what is missing)
  Access not available in all areas. No ladders, etc provided other than those on site.
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  Minor areas of decay and deflection
- [x] Roof covering (slates, lead, etc)
  Slates/Tiles
- [x] Flashings
  Lead/Mortar
- [x] Attic ceiling
  Plaster/Timber

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

maintenance, repairs and Inspection

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- (•) Yes
- ( ) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	c2005	Decay	NTS	Local repairs
Repairs to roof covering (slates, lead, etc)	Annual	Maintenance	NTS	Local repairs
Repairs to flashings	Annual	Maintenance	NTS	Local repairs

Repairs to attic ceiling	na	na	na	na

***Q17.* Please give any further comments:**

Location Data

Location: (55.63330078125, -3.1833038330078)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Tolbooth

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Admin

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Christabel Wandless, T: 01786 274003, E: wandlessc@stirling.gov.uk

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Have been part of the building staff sine 2003.

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  It has always been owned by the town council and thus maintained by their representatives or those that they let the building to.
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  The plans for the refurbishment in 2001, other documents are held in archives.
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  They may be all available to see, but as I'm not 100% sure will pick this answer.
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☐ Structure (timbers and sarking)
- ☐ Roof covering (slates, lead, etc)
- ☐ Flashings
- ☑ Attic ceiling
  We have had an ongoing issue with water coming in through the attic which is currently being dealt with.

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐

***Q13.* Please specify what the programmed works involve:**

It would depend on the nature of the problem and probably a question best directed to Christabel.

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ◉ Yes
- ○ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				

Repairs to attic ceiling	This year	Water damage	Outside contractor	Ongoing

***Q17.* Please give any further comments:**

The exact nature of what is going on in the building should be best addressed to either Christabel Wandless or Alan Petrie, T: 01786 233240, E: petriea@stirling.gov.uk

Location Data

Location: (56.11669921875, -3.9499969482422)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Trades Hall, Glasgow

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☐ Architect in charge
- ☑ Other: Chief Executive

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

I am in charge along with the Hall Committee of Trades House

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

The Building has been owned by Trades House since it was built in 1794.

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  See last response
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  There are copies of various plans which show alterations made about ten years ago. These can be provided to you.
- ○ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [x] Structure (timbers and sarking)
  No problems
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

No programmed works - repairs carried out when required

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- (•) No
- ( ) Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)	2 years ago	Ingress of water	Not Known	Repairs to lead
Repairs to flashings	2 years ago ago	Ingress of water	Not Known	Repairs to lead
Repairs to attic ceiling				

Q17. **Please give any further comments:**

Location Data

Location: (52.476806640625, -1.9340972900391)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Tron Theatre & Tron Steeple

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☑ Building manager
- ☐ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Billy Humes

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

Aprox.14 years December 2002

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Glasgow City Council
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ○ Yes (please specify what documents you have)
- ◉ No

Q10. **Is the roof space of your building accessible?**

- ◉ Yes
- ○ Partly (please specify which parts are not accessible and why)
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○ No (please specify why)

Q12. **Are the roof timbers visible?**

- (•) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [x] Roof covering (slates, lead, etc)
  odd loose slate causing leaks but it is maintained
- [ ] Flashings
- [ ] Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
Inspection of roof structure (timbers and sarking)	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐

Q13. **Please specify what the programmed works involve:**

Replacing slates etc.

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- ( ) Yes
- ( ) No
- (•) Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)				
Repairs to roof covering (slates, lead, etc)				
Repairs to flashings				
Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (55.870803833008, -4.3056945800781)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Winton House

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- [x] Owner
- [ ] Tenant
- [ ] User
- [ ] Building manager
- [ ] Architect in charge
- [ ] Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

1996

Q8. **Do you know who the previous owners, tenants or managers were?**

- (•) Yes (please specify name and contact details if known)
  Parents
- ( ) No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ( ) Yes (please specify what documents you have)
- (•) No

Q10. **Is the roof space of your building accessible?**

- (•) Yes
- ( ) Partly (please specify which parts are not accessible and why)
- ( ) No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- (•) Yes
- ( ) Partly (please specify what is missing)
- ( ) No (please specify why)

Q12. **Are the roof timbers visible?**

- (●) Yes
- ( ) Partly (please specify where they are not visible and why)
- ( ) No (please specify why they are not visible)

Q13. **Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- [ ] Structure (timbers and sarking)
- [ ] Roof covering (slates, lead, etc)
- [ ] Flashings
- [ ] Attic ceiling

Q15. **Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☑	☐	☐	☐	☐	☐	☐	☑	☑	☐	☑
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☐	☑	☑	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☑	☐	☑	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☐	☑	☐	☐	☐

Q13. **Please specify what the programmed works involve:**

none at present other than routine maintenance. Replacement of lead roofs have been a rotational programme to completion 5+ years ago.

Q14. **Are reports given to you after the inspections/programmed works have been carried out?**

- (●) Yes
- ( ) No
- ( ) Sometimes

Q15. **Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	Ongoing	Resolution to a problem	Joiners and roofers	splicing timbers with timber or occasionally with steel
Repairs to roof covering (slates, lead, etc)	Annually	Slate replacement or lead works	roofer	replacement - like for like
Repairs to flashings	Ongoing	Where inadequate covering	Roofer or specialist lead worker	additional lead or replacement with shorter sheets
Repairs to attic ceiling	As and when needed	Ingress of water	Joiner, plasterer	replacement like for like

***Q17.* Please give any further comments:**

Property generally believed to be in good order. Whole house is used so problems tend to be spotted. Full-time caretaker with duties for property inspections and maintenance. I am a surveyor by profession and live at the property.

Location Data

Location: (55.962203979492, -3.2606048583984)

Source: GeoIP Estimation



Q1. **Thank you for taking part in this survey.**

It will take you less than 5 minutes!

Q4. **Please specify the name of the building:**

Yester house

Q5. **Please specify if you are the building owner, tenant, manager or architect in charge of the building's maintenance (please select all that apply):**

- ☐ Owner
- ☐ Tenant
- ☐ User
- ☐ Building manager
- ☑ Architect in charge
- ☐ Other:

Q6. **If you are not in charge of the maintenance of the building, please specify the name and contact details of who is in charge of the building maintenance:**

Sandy Stewart (eml sandystewart@yesterestate.com)

Q7. **Since when have you owned the building, lived in it or been in charge of the maintenance?**

We have been appointed as architects for the property since approx. Nov 2014

Q8. **Do you know who the previous owners, tenants or managers were?**

- ◉ Yes (please specify name and contact details if known)
  Gian Carlo Menotti (composer, now deceased)
- ○ No

Q9. **Do you have or know of any documents related to the building's original construction and later alterations (such as accounts, letters, drawings, etc), including recent repair works?**

- ◉ Yes (please specify what documents you have)
  We have many documents here. A full list of these can be provided on request
- ○ No

Q10. **Is the roof space of your building accessible?**

- ○ Yes
- ◉ Partly (please specify which parts are not accessible and why)
  The building has been heavily altered in the past, including the addition of an attic floor which is largely flat-roofed. Only certain sections of the original pitched roofs now remain and are accessible.
- ○ No (please specify why it is not accessible)

Q11. **Is the access easy (opening big enough for anyone to pass, well lit, walking boards provided, etc) and do you have the necessary equipment (ladders, torches, etc)?**

- ◉ Yes
- ○ Partly (please specify what is missing)
- ○ No (please specify why)

***Q12.* Are the roof timbers visible?**

- ○ Yes
- ◉ Partly (please specify where they are not visible and why)
  See previous.
- ○ No (please specify why they are not visible)

***Q13.* Are you aware of any current problems in your roof? Which parts are affected? Please select all the apply and specify what the problem is:**

- ☑ Structure (timbers and sarking)
  Several roof leaks occur during periods of heavy rain
- ☐ Roof covering (slates, lead, etc)
- ☑ Flashings
  The leaks appear mainly to relate to lead gutters and flashings. These are to be repaired during forthcoming refurbishment works.
- ☐ Attic ceiling

***Q15.* Do you have a regular maintenance regime for your roof? What parts of the roof are inspected, how often and by whom? What are your programmed works?**

	How often? Please select all that apply:					Who does the inspection/works? Please select all that apply:					
	every year	every 2 years	every 5 years	after a storm	when there seems to be a problem	an architect	an engineer	a surveyor	a roofing specialist	a general builder	myself
Inspection of roof covering and flashings	☐	☐	☐	☐	☑	☑	☑	☐	☐	☐	☐
Inspection of roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☑	☐	☐	☐	☐
Programmed works to roof covering and flashings	☐	☐	☐	☐	☑	☑	☑	☐	☐	☐	☐
Programmed works to roof structure (timbers and sarking)	☐	☐	☐	☐	☑	☑	☑	☐	☐	☐	☐

***Q13.* Please specify what the programmed works involve:**

The property is soon to undergo a comprehensive programme of repair and refurbishment works.

***Q14.* Are reports given to you after the inspections/programmed works have been carried out?**

- ○ Yes
- ◉ No
- ○ Sometimes

***Q15.* Have repair works been carried out in the past? What parts of the roof have been repaired, when and by whom?**

	When?	Why?	By whom?	What did the repairs involve?
Repairs to roof structure (timbers and sarking)	1980s	Rot repairs	Not known	Not known
Repairs to roof covering (slates, lead, etc)	1980s	Failure	Not known	Complete renewal
Repairs to flashings	1980s	Failure	Not known	Complete renewal

Repairs to attic ceiling				

***Q17.* Please give any further comments:**

Location Data

Location: (51.514404296875, -0.094100952148438)

Source: GeoIP Estimation



APPENDIX C

INTERVIEWS TO THREE SCOTTISH CONSERVATION ENGINEERS

ENGINEER 1.....460
ENGINEER 2.....463
ENGINEER 3.....466

ENGINEER 1

1. Where and what did you do your studies in?
I did a bachelor (4 years) in Civil Engineering in Dundee, then I got a PhD (3 years) studying new additives for concrete: it was an experimental research carried out on models in the laboratory.

2. Have you ever attended a course specific for conservation?
The University didn't offer any course on conservation. We did very little on masonry and on timber. I learnt what I know about conservation only when I started working for Historic Environment Scotland.

3. What are your previous professional experiences?
I worked for Jacobs Engineering, looking at marine structures and dealing mainly with concrete repairs (like grouting) for the first 8 months, then looking at existing bridges and calculating their capacity based on the surveys made by specialists (for about a year). I later passed to ARUP where I worked for 2 and a half years, designing new built mainly.

4. What is your current professional experience and how long have you been doing it for?
I now work for Historic Environment Scotland (HES) where I've been for the past 7 years.

5. What kind of projects do you normally work on?
We look at planning applications and take care of HES's 345 monuments. We deal with all sorts of structures and materials, even car parks and roads.

6. What is your role in these projects?
We deal with all the structural aspects.

7. If there is a team, what do the other members do?
We are three engineers in HES: one senior (John), myself, and an assistant (Franceska). Me and John deal mainly with the planning applications, Franceska does the surveys when necessary. Franceska's is a new post because before her we had a technician doing the surveying/drawing work. He had a lot of experience though, he was even better than a chartered engineer, so when he retired we could only replace him with an engineer.

8. Are you ever asked to inspect roof spaces and assess historic timber roof structures?
Yes, when the architects or the people from the Monuments Conservation Unit think there might be something wrong in the roof of a building they have surveyed they ask us to go and have a look. HES architects do a condition survey of our monuments every 2 or 3 years. The Monuments Conservation Unit people are instead based regionally so they go around the monuments all the time. If either of them sees something that they think might be a structural problem, they ask us to go and check it. This has happened for example in Tantallon Castle where a crack has been monitored with LVDT for 5 years now. We might be asked to inspect a roof even because an alteration is needed, for a change of use or something else. I haven't been dealing with historic timber structures so far though – they seem to be all in good condition.

9. Do you usually carry out any kind of preliminary investigation (such as historical research) prior to the inspection?
Yes, we do a desk survey prior to any visit, looking at the available data/documents related to the building.

10. What do you normally look out for during these inspections?
We look out for water ingress, which can come from the roof or the walls. It usually damages the end of the rafters. **What about the sarking?**
We always look at the sarking as well.
And open joints, deflections, deformations?
They are very rare.

11. Do you normally need to go back more than once?
After the desk survey we go on site, either me or John with Franceska, to see if any urgent intervention is needed. Then Franceska goes to carry out a more detailed survey, sometimes with the help of an architectural assistant.

12. Do you use any testing devices or do you simply carry out a visual inspection?
We sometimes use laser scanning but we use mainly traditional surveying techniques. Laser scanning is more useful for coastal protection, it is not reliable for detailed surveys. We tried to use it to monitor an intervention at the Great Hall at Stirling Castle, where we inserted steel ties because the lateral walls were opening. We found it to be not useful for engineering because it's not accurate enough to study deformations. So we use strain gauges instead at Stirling Castle. Laser scanning is good for big things, like changes in coasts, so we use it for that.
Do you usually monitor interventions you do?
Normally no, anything wrong with them is picked up by the architect's condition surveys. But for big things, like the Stirling Castle Great Hall, we monitor it ourselves.

13. Are you able to identify the different timber species and do you think it's an important part of the assessment?
It's important to know the timber species only if the element is of historical value. In that case we would call a wood specialist to identify the species and look at the condition of the timber. If not, we would just make assumptions.

14. In your experience, what problems are roof timbers normally affected by?
Water is always the main problem for timber. It usually damages the end of the rafters. Rot is the main issue, not deflections/deformations.
What about past interventions?
Also past interventions curing the symptoms rather than the causes can create more problems.

15. How do you take a decision on if and what kinds of repairs are needed?
We take a decision all together, me, John and Franceska. We call a timber specialist if we think there is active insect/fungi attack (if we see bore-dust or other similar symptoms). They do an inspection

and they propose the necessary treatment. In case of rot we cut out the rotten part and either replace it with a prosthesis connected with steel plates on the sides, or with an additional timber next to the original one bolted together. If the timber has no historical value we might even replace the whole element completely. If the timber is in contact with masonry we wrap the end of the timber to avoid humidity.

16. Do you do any calculations? By hand or with a computer modeling software?
We carry out hand calculations for simple elements and use modelling only in case of 3D structures. It is either me or John carrying out calculations.

17. How do you consider the timber resisting sections and mechanical properties?
We make assumptions.

18. What are the principles you follow when designing a repair intervention?
We follow conservation principles:

- Minimum intervention;
- Like for like;
- Honesty/distinguishability.

What do you mean with like for like in case of timber structures?
Like for like is valid for masonry structures, not for timber. We did replace a timber handrail like for like once (it was oak) and it lasted only for 2 years. I think the timber we have today is not as durable as the one used in the past. The architect can specify the species if he/she thinks it's important, but we only specify the strength.

ENGINEER 2

1. Where and what did you do your studies in?
In 1970 I graduated in civil engineering (BSC with honors) in Aberdeen. The first two years of the course were the same for all engineering. I didn't do a Masters because I wanted to go into industry and know more about the practical side and become a designer.

2. Have you ever attended a course specific for conservation?
During the three years of BSC there was no course on conservation or any aspect of history. It was all very much focused on mathematics. We had a design course only in our third year. There was no appreciation of the architectural and aesthetical aspect in any course. I learnt that later, during my professional experience, and also thanks to the collaboration with architects (in 1976 I did my first work with an architect).

3. What are your previous professional experiences?
Between 1970 and 1973 I worked at Taylor Woodrow civil engineering company in North England. We followed a project on 2 nuclear power stations. We also did a lot of temporary structures. There were many people with high practical and intellectual knowledge.
In 1975 I moved to Edinburgh to work in a smaller consultancy doing smaller engineering design projects: buildings rather than dams and power stations. All of my career has been about balancing between big and small things. This is important as there is a lot of difference in workmanship between big and small projects.
In 1976 I moved to Cuthbertson civil engineering, again in Edinburgh, designing dams for 7 years on and off. In between I left a bit because they were pushing me into management, which I didn't like at the time (I wanted to focus on design). I worked one year with a multidisciplinary team of engineers and architects who grew out of ARUP.
At that time I got my MICE (part III for engineers).
In 1982 I put up a practice in partnership with Peter Stephen, an engineer who was previously working with ARUP. We worked together up to 2000. There were 10 people in the team. We were working with architects for new buildings, but also started doing some conservation projects. We were heavily dependent on architects at that time, but I started wanting to do things on my own: this is the time when I started appreciating the management side of projects. That's why I eventually separated from Peter and created a new practice with Cristina. She joined us for an internship in 2000 - she was doing her Masters in York at that time. She went back to York to finish her Masters and then came back to form a new practice with me.

4. What is your current professional experience and how long have you been doing it for?
Me and Cristina started working together in 2000. She studied engineering/architecture in Poland and then did an architecture Masters in York.

5. What kind of projects do you normally work on?
We work a lot on ruins, doing stabilisation, consolidation, conservation of these ancient monuments. Mainly repairs, only rarely we do reuse/integration, because architects tend to deal with this aspect of projects. We almost never lead the projects, it's almost always architects, mainly for economic reasons. We also do pure engineering stuff, like bridges, and especially temporary works like scaffolding and management. Now for example I am following a project that deals with the movement of Aberdeen's obelisk.

6. What is your role in these projects?
I deal with the structural aspects of the projects, but recently also with the management.

7. If there is a team, what do the other members do?
It's just me and Cristina. We do some works together, others separately, but we always ask for advice one to the other. I collaborate with architects sometimes.

8. Are you ever asked to inspect roof spaces and assess historic timber roof structures?
Yes, it can happen for different reasons. Sometimes we are called by a building owner who is worried about the ceiling/walls of the attic underneath: in that case we need to assess if there is a problem, and if there is one find a way to fix it. Other times there is an architect involved who wants to do something in the roof space or on the roof, and in that case we have to assess what kind of loads the roof structure can endure, if it can be altered and how it can be altered to obtain the desired intervention (for example to increase headroom). A roof inspection can also be necessary as part of a bigger project. The first thing in any case would be to discover if it's a listed building, so that we can advise the client what he is actually allowed to do. Even if the building is not listed, but the structure has a historic value, we would in any case advise to conserve it, and would fight against any action contrary to our advice.

9. Do you usually carry out any kind of preliminary investigation (such as historical research) prior to the inspection?
If we are in the lead role yes, but normally the architect is the "leader" and therefore he carries out the historical research. But often they don't actually look for things that are useful for the project itself, they focus more on historical facts, even unrelated to the actual fabric. So normally we have to integrate it.

10. What do you normally look out for during these inspections?
Firstly I try to get an overall impression of the roof. If the structure is in really bad conditions you can realize right away, because it will "feel" unsafe, shaky. I look for deflected rafters, failing struts, distortions, decay, rusting of nails. Elements that were meant to behave in a way, but are actually doing something completely different. I look at secondary elements like the sarking/boarding as well, because that's what makes it work in 3D, as a box. Even the nails between the sarking and the timbers are fundamental. I try to compare parts that are in good conditions with parts that are in bad conditions. I look at the section of the elements. I look at the ceiling underneath too.
How do you spot old decay and new decay?
There are always signs of recent decay/attack. Sticking a knife into the timber normally gives you an idea, but if the timber is heavily punctured I normally call the timber specialist to do some tests. In any case it's normally just about scraping all the bad timber off until you reach the good timber that is left. That is what we did in Verdant High Mill Museum: there were huge chunks of timber beams missing there because of decay – we just left them there because there is actually no load on the floor.

11. Do you normally need to go back more than once?
No if what is required is just an opinion on the value of the structure. Yes if there seems to be any problem. In this case the first inspection is only to organize access. You have to have some plaster removed most of the times to see parts of the structure that are not visible. If you can't, you have to adjust your report accordingly, and suggest in how much time the building should be inspected again, or if something should be monitored.

12. Do you use any testing devices or do you simply carry out a visual inspection?
I use moisture meters, and a spirit level and tape if I think that deflection is worth measuring.

13. Are you able to identify the different timber species and do you think it's an important part of the assessment?
Sometimes we take samples for the species identification. We call in a timber specialist. It's important to know the species for grounding of the project, but also because the deflections and the durability are proportional to the species. It's necessary to know the species also when a prosthesisation is needed, because you need to find a compatible piece of timber.
How would you connect a prosthesis?
I would glue it, or peg it, or screw it. It depends on the position of the prosthesis and the stresses. Many times it all depends on practicalities, like accessibility and safety. In the end it's down to

finding a way to do what you need to do without wrecking everything else. A big part of the work is making sure that you have enough resources to do what you need to do. In a recent project in Edinburgh and in another one in Fife we pushed a sagged ceiling and roof structure above back into position, and the client was enthusiastic about it. You can do it if you know what you're doing and if the client agrees. It's very quick and efficient but the hardest part is to convince people (contractors and clients) that it can actually be done.

14. In your experience, what problems are roof timbers normally affected by?
One of the biggest problems in roofs is normally decay and/or deflection in valley rafters caused by water ingress. Where there are valley rafters the structure is 3D, so it's very difficult to push the valley rafter back up as this would affect all the other members. Deflections are not always a problem: they are dangerous only if their shape shows that they are close to rupture, so if they are not "curved". Pushing the deflections back in place doesn't always work. They can also become a problem if they are not dealt with and other structures and parts of the building are built on top of them, increasing the charges.
Another common problem that roof structures have is notching made for cables, services, etc. A building in Marchmont (Edinburgh) where I worked had a 200mm notch into a 250mm beam! However, roofs are often saved by their redundancy: even though the situation looks bad it might be that the parts in good condition are enough to keep it safe. You need experience to be able to tell this.
15. How do you take a decision on if and what kinds of repairs are needed?
It depends very much on practicalities, such as access, etc.

16. Do you do any calculations? By hand or with a computer modeling software?
I do some basic hand calculations for some types of joints sometimes, and always in case of alteration because we have to prove that we comply with regulations and standards.

17. How do you consider the timber resisting sections and mechanical properties?
I assume average sections and average properties for the first calculations, then I adjust them based on the results I get. Timber in old buildings can sometimes be worse than you might think, especially if the timber used was homegrown in Scotland. In a Castle up near Forfar all floor joists were broken because the loads on them where high but mainly because the timbers were bad quality homegrown. Their sections were actually huge, so they shouldn't have deflected and broke as they did, but they did because they were made of very weak Scottish timber.
What if part of the section is missing inside, and you don't see it? How can you tell?
That will happen only if there is dry rot, which will be clearly visible. Even if the dry rot damage is old, you will have some kind of legacy of it. I saw that in many church roofs, as in the Church of the Sacred Heart in Lauriston Place in Edinburgh. There had been dry rot in the past but they thought they got rid of it – I closed the church and put scaffolds up and found that all the beams had been eaten up by dry rot. We then had moisture monitoring in for 15 years.

18. What are the principles you follow when designing a repair intervention?
If I had to choose 5 principles, I would say:
- minimum intervention (also because of costs);
- do no harm: you don't want to ruin what's around just because you think of stability only!
- easily reversible, but only for temporary works. There is no reason for permanent works to be reversible, unless you have a good reason for wanting it to be reversible;
- appropriate materials;
- distinguishability.
But I think the principles can be different based on the situation.

ENGINEER 3

1. Where and what did you do your studies in?
I studied Civil Engineering in Nottingham University, where I finished the Masters in 1997.

2. Have you ever attended a course specific for conservation?
The University didn't offer any courses in conservation. I could only take two modules out of the Civil Engineering department, so I took one in Architecture and one in Archaeology. Then I got a SPAB scholarship in 2005 and that's how I learnt about conservation. The scholarship is for building professionals, it lasts 9 months and is full-time. It's always on-site, visiting all sorts of conservation sites across the country, guided by professionals that are working there or have done the works there in the past. The first 6 months you follow practitioners, the last 3 months are spent in country houses. At the end you have to submit a report with sketches that you made on-site.
I'm the only conservation accredited engineer in Scotland, even though there are other engineers in Scotland who are experienced enough to be accredited.

3. What are your previous professional experiences?
I worked as a structural engineer in London for Alan Baxter & Associates for 10 years. They were doing some conservation work and that's why I got interested in conservation and decided to take a sabbatical year to do the SPAB scholarship.

4. What is your current professional experience and how long have you been doing it for?
I'm a Director in the Edinburgh practice of David Narro Associates since 2007.

5. What kind of projects do you normally work on?
We are not developers, we do mainly architect–led projects. 80% of the time we collaborate with architects, even because often the funders require an architect. In the case of Glasgow School of Art or St Cecilia's Hall, for example, we are working with Page & Park. The practice deals mainly with new built, but I work mostly on the existing: extensions, adaptations, refurbishment, consolidation. This includes modern concrete structures as well.

6. What is your role in these projects?
7. If there is a team, what do the other members do?
We are a total of 20 engineers here in the Edinburgh practice. Me and two others are directors. Everyone does a little bit of everything, we are all structural engineers. Many projects are never big enough to require more than one engineer to work on it.

8. Are you ever asked to inspect roof spaces and assess historic timber roof structures?
Yes.

9. Do you usually carry out any kind of preliminary investigation (such as historical research) prior to the inspection?
Usually the client provides that, or the architect. It's nice to know the history of the building before going on-site, but it's not always necessary.
But what about past repairs/loading history? Do you normally try to find out something related to that?
If others carry out a historical research, it is normally more factual, related to aesthetical/artistic aspects – so yes, I need to find out about past repairs myself.

10. What do you normally look out for during these inspections?
I look at the roof from outside first, to see if there are any holes, vegetation, water stains or other obvious things. I try to understand the complexity of the structure: if there are many valleys, many gutters, hidden gutters, etc. Weak areas to check are: joints between roofs, behind parapets, or in general where the geometry changes. Then I look at the condition inside: is there any water? How

does the timber look? Is there any infestation? Finally, I try to understand the performance of the roof structure, so I look if there are any distortions or deflections.

11. Do you normally need to go back more than once?

Yes, even though sometimes it's sufficient to take thousands of pictures.

12. Do you use any testing devices or do you simply carry out a visual inspection?

I use traditional techniques and sometimes coring (it leaves 5/8mm diameter holes) to check if the timber is sound inside. I call a timber specialist if there are large section timbers or signs of active infestation, like bore-dust - even though most infestations affect only the sapwood. It also depends on how big the building/contract is, because this influences the available funds.

13. Are you able to identify the different timber species and do you think it's an important part of the assessment?

I can distinguish between hardwoods and softwoods. I did a course at Weald & Downland open air Museum in Sussex to learn how to do Visual Strength Grading of hardwood timbers. It's important to know the species if you need to do any calculations.

14. In your experience, what problems are roof timbers normally affected by?

Roof timbers are mostly affected by water problems and rot, rather than distortions/deflections. You might find something broken or other failures, but generally speaking I find that rot is normally what triggers the other problems. Past interventions/alterations are often a problem as well.

Do you think poor initial design is often a problem?

Yes, it can happen. People think that since a roof has been there for a while it is been designed in an acceptable way, but sometimes it's not true. For example in the case of a project in Dunoon, there was a purlin roof with lots of purlins carried by sort of hammer-beam trusses that were not able to tie the walls together, which therefore started spreading quickly. Or in the case of another Victorian roof with scissor frames where the part of the rafters closer to the wall is highly stressed because the ties have been put at a higher level. In that case many later alterations/repairs contributed to the current problems as well.

Do you normally monitor interventions that you make?

Not formally, we just go back to check if we think it's necessary.

15. How do you take a decision on if and what kinds of repairs are needed?

It depends on many factors: what the client wants, if the building is listed or not, how much money is available, if you have a skilled carpenter available. You need a very skilled carpenter to do a good prosthesis, for example. Sometimes it's more about telling the carpenter what you want in terms of the structure, and let him decide how to solve the problem practically.

In the case of the Victorian roof I was talking about, the client wanted to get rid of the ties. We proposed to replace the whole roof, but it was too expensive. So we had to compromise: we are keeping the original timbers but putting new trusses so that the original structure is not loaded at all, it becomes redundant. Sometimes roofs are completely rotten, and look like they shouldn't be standing, but they actually do. In that case you close the building and prop the roof and then you have to do something even if you're not sure it's necessary. You have to stay on the safe side. That's valid also in the case of a roof which has been repaired many times in the past, like this Victorian roof, but still has problems.

16. Do you do any calculations? By hand or with a computer modeling software?

No, if it's clear what the problem is. Yes in case of a sensitive situation, such as a listed A building. But normally no, because it's too expensive to do too much analysis. The types of calculations depend on what you're dealing with. Loads in a roof can be indeterminate: you don't actually know what is happening. Sometimes you might conclude that a purlin is undersized if you apply all the loads: but maybe it's just providing extra resistance to wind pressure, in which case it wouldn't be undersized.

17. How do you consider the timber resisting sections and mechanical properties?

If I need to do calculations it is necessary to know the species. The problem is knowing the actual properties. A lot of testing will only give you a strength class, but nothing specific. So normally we look up reference tables for properties of different timber species. Often older timbers tend to be better. In the case of the Glasgow School of Art we had TRADA to identify the timber species and do Visual Strength Grading.

18. What are the principles you follow when designing a repair intervention?

- Simplicity
- Reversibility: because someone might think of a better way to do it in the future
- Traditional and tested materials/methods: I don't use innovative materials/techniques because I'm not sure they will work
- Distinguishability: for fool-proofing, so that someone who comes after you can see and understand what you did, and not destroy it creating structural problems

APPENDIX D

LIST OF POSSIBLE SOURCES OF INFORMATION ON SCOTTISH TIMBER ROOF STRUCTURES WHICH HAVE NOT BEEN CONSULTED

Surveys and reports by Addyman Archeology held at their office in The Old Printworks, 77a Brunswick Street, Edinburgh EH7 5HS

Ted Ruddock's slides held in Edinburgh University

John Adam's diary held at Blair Adam House

Extensive archives held at Blair Castle

Extensive archives held at Glamis Castle

Extensive archives held at Hopetoun House

Earl of Mar's drawings held at RIAS archives

APPENDIX E

STRUCTURED FORMS OF THE REFERENCE BUILDINGS

ABBEYSTRAND.....472
ARNISTON HOUSE.....476
AUCHINDINNY HOUSE.....482
AUCHINLECK HOUSE.....486
BALCASKIE HOUSE.....490
BLAIR CASTLE.....497
BRODIE CASTLE STABLES.....504
BRUSNTANE HOUSE.....508
COWANE'S HOSPITAL.....515
CRAIGSTON CASTLE.....519
CULROSS PALACE.....525
CULZEAN CASTLE.....529
DUFF HOUSE.....537
EDINBURGH PANMURE HOUSE.....542
FOUNTAINHALL HOUSE.....548
GARDYNE'S LAND.....555
GEILSTON HOUSE.....561
GEORGE FORT.....565
GEORGE HERIOT'S HOSPITAL.....583
GLASGOW TRADES HALL.....599
GLASGOW TRON THEATRE.....606
HADDO HOUSE.....610
HOPETOUN HOUSE.....615
KELBURN CASTLE.....623
KINROSS HOUSE.....630
MALLENY HOUSE.....635
MAYBOLE CASTLE.....639
MELVILLE HOUSE.....643
METHVEN CASTLE.....652
OAKSHAW TRINITY CHURCH.....659
PILMUIR HOUSE.....663
ROBERT GORDON'S COLLEGE.....667
ROYSTON HOUSE.....671
SAILOR'S WALK.....681
STIRLING TOLBOOTH.....688

TWEEDDALE HOUSE.....694
YESTER HOUSE.....705

ABBEY STRAND

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)

X coordinate: 326796 Y coordinate: 673926

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC

Protection status: NATIONAL

HS Listing: A Rcahms ID: 124288

Original Use: Residential

Current Use: School

Freestanding ☐ N. of floors above ground level: 2 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1475	1525	3 STOREYS TENEMENT TO WEST	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1545	1555	WEST BUILDING RECONSTRUCTED AND EXTENDED TO NORTH	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1600	1625	L-SHAPED 2 STOREYS ADDITION ON SOUTH-EAST OF THE WEST BUILDING	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1647		ROOF OF SOUTH EAST ATTIC	PICTURES GIVEN BY HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1800	1825	ADDITIONAL STOREY AND ATTIC TO WEST	HS

People involved:

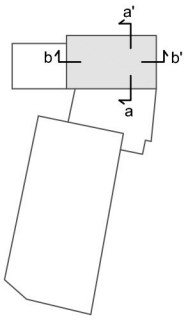
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1915	1916	WEST BUILDING	HS

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	
HANKE T.		☑	STRUCTURAL CARPENTRY AT ABBEYSTRAND, EDINBURGH	

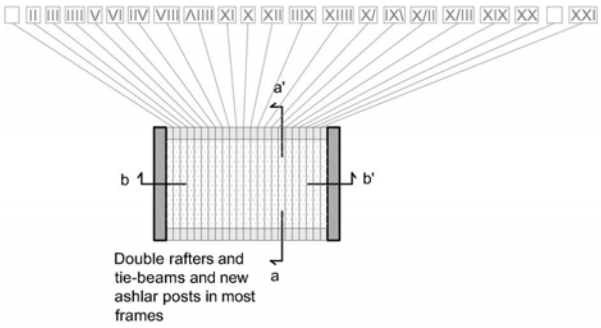
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

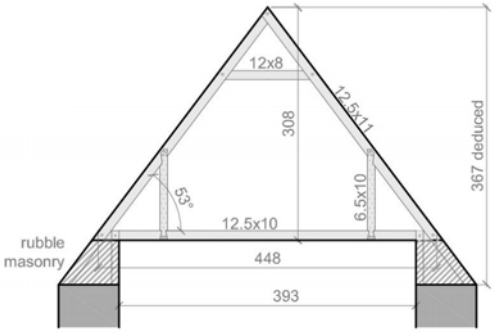
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

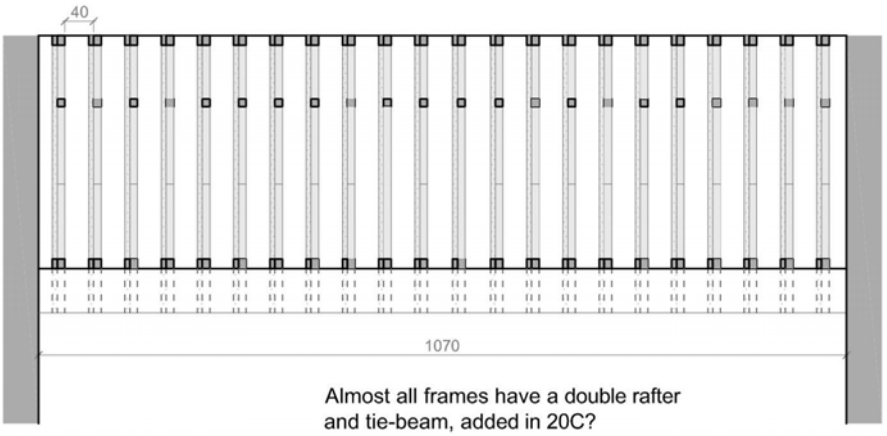
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** ABBEY STRAND | **Roof location** SE attic

Survey date(s) 08/09/2014 12/02/2016 | See drawing: AS-SE-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 3.9 | Roof Height [m]: 3.7

Roof Pitch/es [°]: 53 | Roof Length [m]: 10.7

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Masonry infill

Connection with gables:

Roof Construction Period: From 1630 To | Identified by: Estimated

Roof General Description:

Two-pitch gabled roof composed of closely spaced rafter couples connected transversally by two collars and longitudinally by sarking boards only. The collars are linked to the rafters also by a pair of vertical struts, probably added later since they are machine sawn and have notched dovetail joints. The rafters and collars are all whole logs roughly hand axed and joined with mortice and tenon joints secured by timber pegs. The connection with the wall is not well visible but there seems to be an ashlar post and rubble masonry infill in between the rafters. The frames are numbered with roughly sawn roman numerals

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 12.5 B: 11 | Or Purlin - H: | B:

Timber elements' Dressing: civil (machine-sawn), rustic (hand-axed), rustic | Bark ☑

Joint Types: dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

All mortice and tenon with timber pegs not flush. The ashlar posts have notched dovetail half lapped joints with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

They go from I to XXI. The trusses are 22, the first one has no visible marks and the last one has XXI on the collar, while frame XX has a new collar. The rest are in sequence.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:

Carried out by Anne Crone on the ceiling panels and beams and dated to 16th century



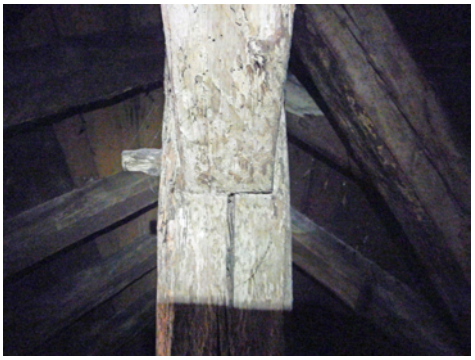
Roof structure | link I:\Arch\A



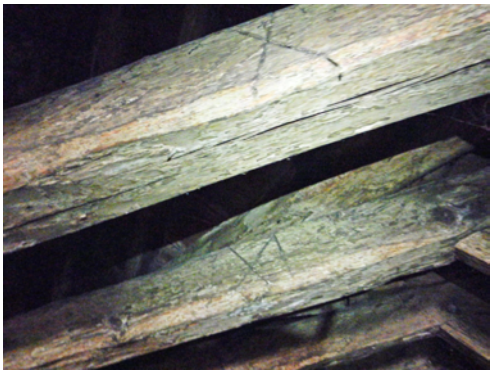
Roof structure | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation

Accessibility limitations

Past interventions: Most of the rafters and tie-beams doubled and ashlar posts added, probably all in the victorian period because it's machine sawn timber. Some sarking replaced.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

ARNISTON HOUSE

Location: MIDLOTHIAN | BORTHWICK
X coordinate: 332589 Y coordinate: 659467
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 53271

Original Use: Residential
Current Use: Museum, Residential

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1620			

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION, LANDSCAPE	1726	1733	ON FOUNDATIONS OF EARLIER HOUSE	HS

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐
ENZER	JOSEPH	PLASTERER	☐
DUNDAS	ROBERT LORD ARNIS	COMMISSIONERPATRON	☐
CALDERWOOD	SAMUEL	PLASTERER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1753	1755	WEST THIRD OF THE HOUSE, INTERIORS AND ORANGERIE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	JOHN	ARCHITECT	☑
DUNDAS	ROBERT LORD ARNIS	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1764		GARDEN HOUSE	

People involved:

Intervention type:	From:	To:	Description:	Reference:
LANDSCAPE	1791		GARDENS REDESIGNED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1800		CENTRAL PROJECTION ON GROUND STOREY AND DOUBLE STAIR TO GARDEN LEVEL	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1868		NEW LIBRARY ON GROUND FLOOR	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1872		PORCH	HS

People involved:

Last Name	First Name	Role	Attributed
WARDROP & REID		ARCHITECT	☐
WARDROP & REID		ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1875	1900	NORTH PEDIMENT REBUILT	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1950	1959	STEEL BEAMS AND WALLS IN WEST ATTIC	ROBIN KENT

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1980		RESLATED	OWNER

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1997			

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	210
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 39-44
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	39-44

ARCHIVAL REFERENCES

Archive	Doc.Num.	Folios
Royal Commission on the Ancient and Historical Monuments of Scotland	DPM 1940/110/4	7, 8, 12

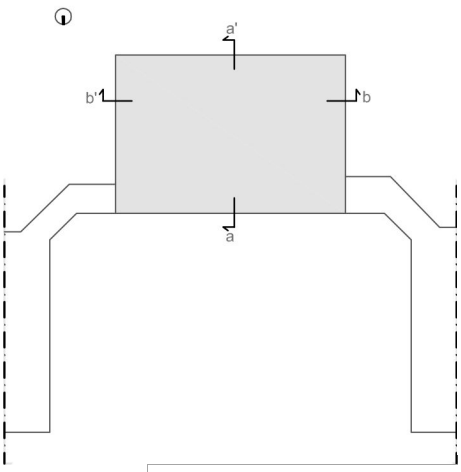
Title: Heating plans. Plans and details of West wing affected by dry rot. Plans, sections and details of roof.

Suggestions for further research: NRS: Dunda of Arniston papers (RH4/15) and plans (RHP5246 and RHP5248)

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive	Royal Commission on the Ancient a	Doc. Num.	DPM 1940/110/4	Folios	7, 8, 12
Title	Heating plans. Plans and details of West wing affected by dry rot. Plans, sections and details of roof.	Date: from	1948	to	1952
Contents					
Summary and comments					

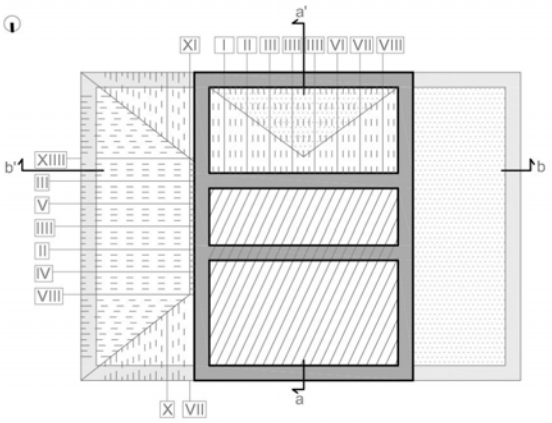


Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

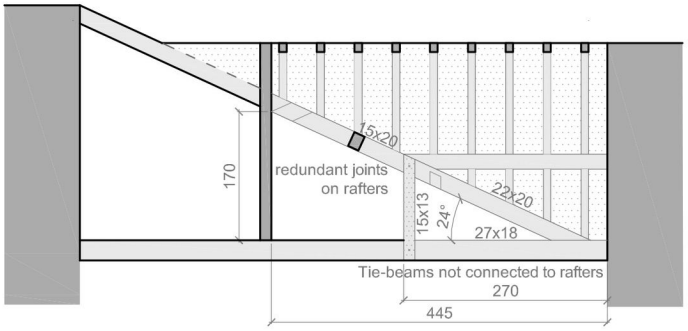


Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

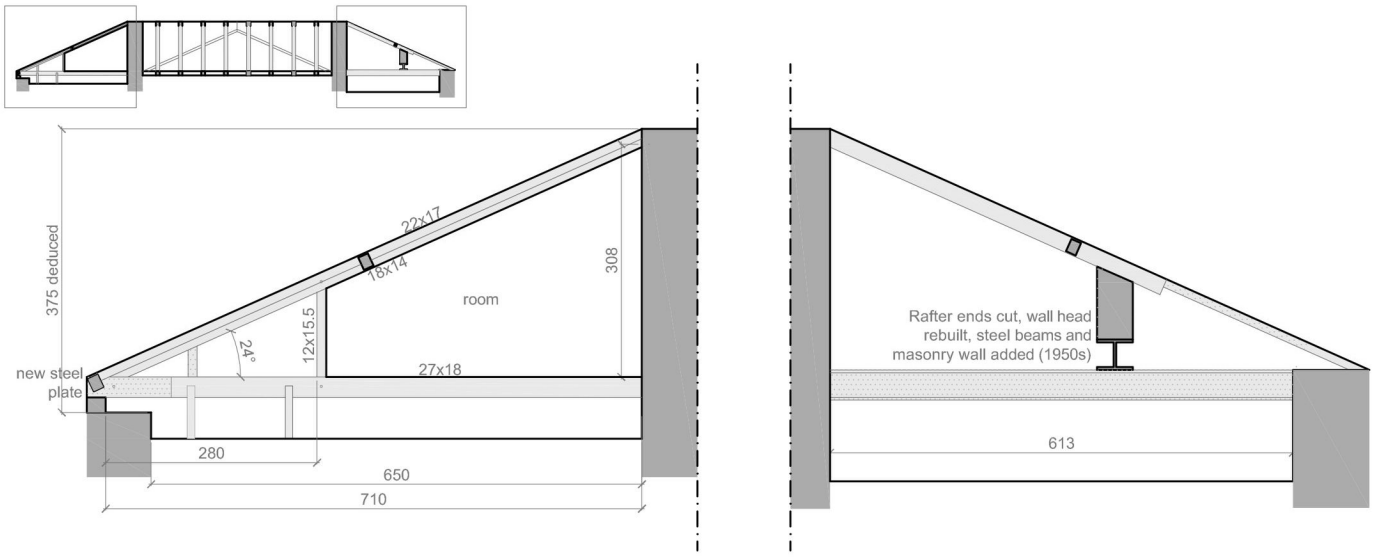
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section aa'



Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** ARNISTON HOUSE | **Roof location** Main block

Survey date(s) 08/10/2014 | See drawing: ANH-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 6.5 | Roof Height [m]: 3.75

Roof Pitch/es [°]: 24 | Roof Length [m]: 29.1

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Other

Average Distance in between Primary Structure [m]: 1.5

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1726 To 1755 | Identified by: Estimated

Roof General Description:

A hipped platform roof with two transversal walls supporting the roof in both directions. Frames with tie-beam, rafter and vertical strut in-between. Upper part of structure not visible. 3 common rafters in-between the frames. Hand sawn timbers with big scantlings, joined by mortice and tenon joints. Big roughly sawn roman numerals marks some timbers; there are also some unusual carpentry marks. West side has been gutted in the 50s, almost nothing original remains. South side has pediment roof added in 19C.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 22 | B: 17 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber dowel, Timber wedge

Joints description:

All mortice and tenon with timber dowels flush. Vertical struts have timber wedges too.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description:

Roman numerals in sequence in central South part, not in sequence in East part.

Signs of reused timbers:

Redundant joints in rafters in South side, probably due to removed elements

Timber Treated ☐

Other Materials:

Steel beams and plates added in 1950s

Dendrochronology:



Roof structure: east | link I:\Arch\A



Roof Structure: center south | link I:\Arch\A



Connection with wall: east | link I:\Arch\A



Connection with wall: south | link I:\Arch\A



Carpentry marks and dressing | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation, presence of pigeons/wasps/bats

Accessibility limitations: Upper part of structure not visible.

Past interventions: Sarking replaced recently. Steel plates to reinforce tie-beams ends' in east side. West side almost completely gutted: rafter ends cut, wall head rebuilt, steel beams and masonry wall added (1950s).



Past interventions: east side | link I:\Arch\A



Past interventions: west side | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☐

Humdity stains on sarking

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

AUCHINDINNY HOUSE

Location MIDLOTHIAN | LASSWADE

X coordinate 325168 Y coordinate 661338

Geogr. Referencing System BRITISH NATIONAL GRID





Property status PRIVATE

Protection status NATIONAL

HS Listing A Rcahms ID 51853

Original Use Residential

Current Use Residential

Freestanding ☑ N. of floors above ground level 3 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1702	1707	FENWICK 1970 SAYS MAYBE THERE WAS AN EARLIER HOUSE FROM 16C	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT	☐
INGLIS OF LANGBYRES	JOHN	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1914	1920		

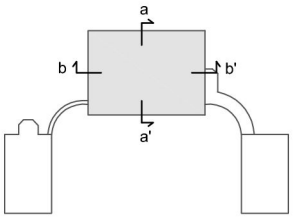
People involved:

Last Name	First Name	Role	Attributed
LEADBETTER & FAIRLEY & R		ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	85
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	120
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	12
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	16-17

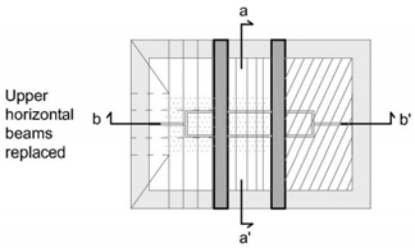
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

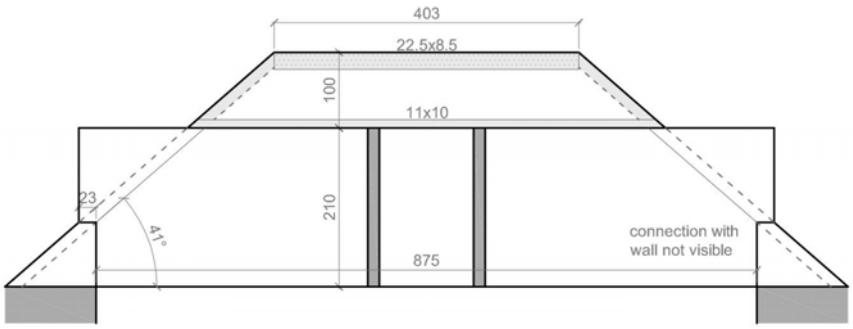
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

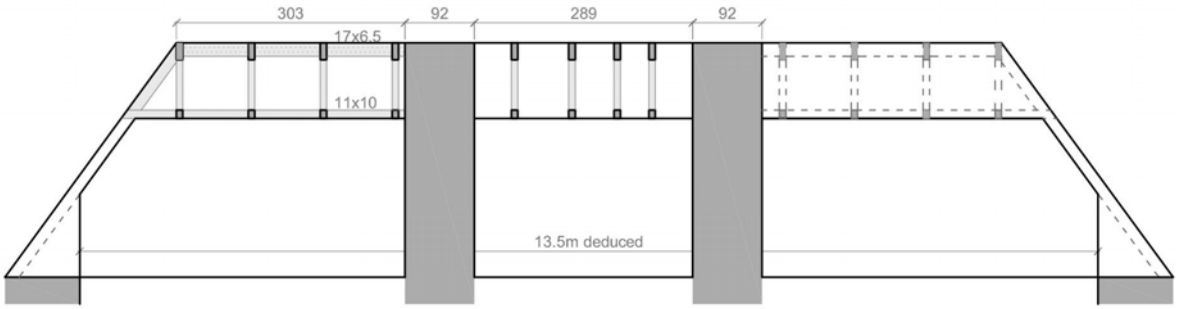
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** AUCHINDINNY HOUSE | **Roof location** Main block

Survey date(s) 07/07/2015 | See drawing: AYH-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 8.7 | Roof Height [m]: 3.1

Roof Pitch/es [°]: 41 | Roof Length [m]: 13.5

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Other

Average Distance in between Primary Structure [m]: 0.6

Type of Secondary Structure: purlins, sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 3

Connection with lateral walls: Unknown

Connection with gables: no gables

Roof Construction Period: From 1702 To 1707 Identified by: Estimated

Roof General Description:

Hipped platform roof divided in 3 sections by two transversal walls. Roof space between wallhead and collar beam plastered and occupied by bedrooms. Central section has 4 parallel frames composed of rafter couples connected transversally by an upper horizontal beam and a collar and longitudinally by sarking boards. East section has 4 frames running in the same direction as the ones in the central section, and 2 running perpendicular to these. West section not accessible. Connection with wall not visible.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: | B

Timber elements' Dressing: civil (machine-sawn), rustic (hand-axed), rustic | Bark ☐

Joint Types: lapped

Fasteners Types:

Joints description: All lapped - fasteners not visible

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof space used as bedrooms link I:\Arch\A



Roof structure from hatch link I:\Arch\A



Roof structure from hatch link I:\Arch\A



Joints: rafter and upper beam link I:\Arch\A



Joints: rafter and upper beam link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation

Accessibility limitations: Connection with the walls not visible. West section not accessible (there is no hatch). Other parts visible from hatch only, therefore not possible to closely inspect/measure

Past interventions: Upper horizontal beams seem to be more recent (they're machine sawn) - they might be contemporary to the early 20C rear addition



Past interventions: upper beam | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:		
Roof Damage				link	
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

AUCHINLECK HOUSE

Location: EAST AYRSHIRE | AUCHINLECK
X coordinate: 250726 Y coordinate: 623016
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 43613

Original Use: Residential
Current Use: Hotel, Museum

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1755	1762	PRESENT MANSION ATTRIBUTED TO ROBERT ADAM	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	ROBERT	ARCHITECT	☑
LORD AUCHINLECK	ALEXANDER BOSWEL	COMMISSIONERPATRON, DESIGNER	☐
JOHNSTON	JOHN	WRIGHT	☐
BOWIE	JAMES	SLATER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1774		4 WINGS	LANDMARK TRUST

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1986	2001		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
SIMPSON & BROWN		ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
SURVEY	2000			CANMORE

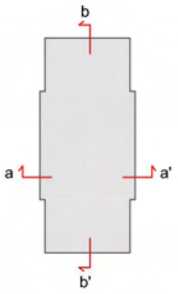
People involved:

Last Name	First Name	Role	Attributed
ADDYMAN ARCHAEOLOGY		ARCHAEOLOGIST	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CLOSE R.	2012	☐	THE BUILDINGS OF SCOTLAND COLLECTION: AYRSHIRE AND ARRAN	
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME III. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	496-497
STANFORD C.	2001	☑	AUCHINLECK HOUSE - HISTORY ALBUM	

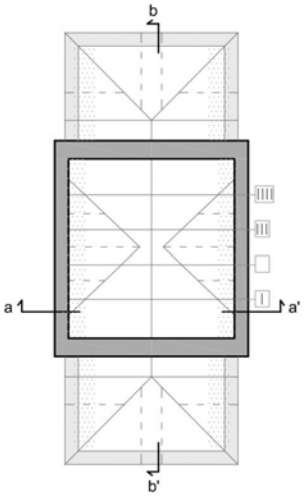
Suggestions for further research: NRS: drawings of late 18th century and 1978 (RHP23133 and RHP38293)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

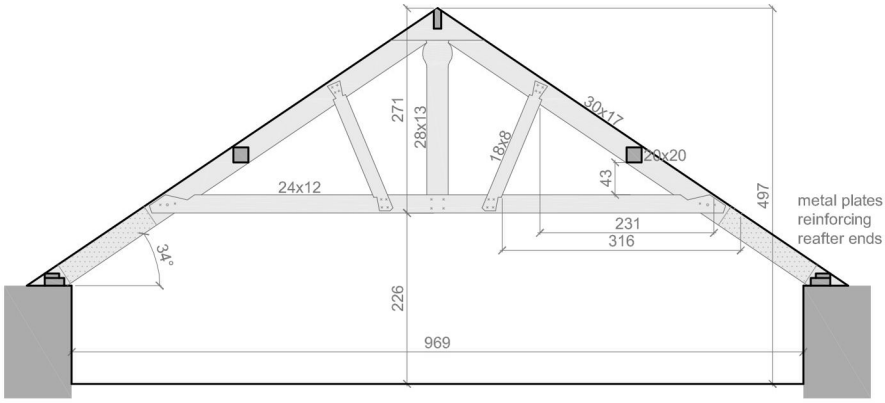
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

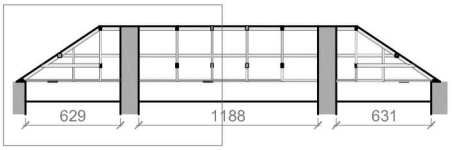
Section aa'

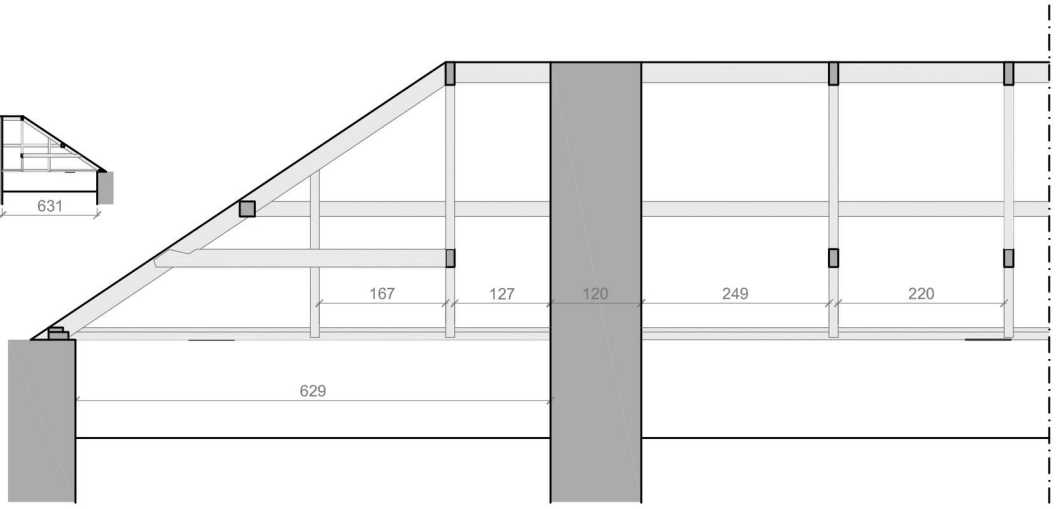


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** AUCHINLECK HOUSE | **Roof location** Main block

Survey date(s) 29/09/2014 | See drawing: AKH-MB-1

Roof Geometry: hipped

Roof Max Span [m]: 9.7 | Roof Height [m]: 5

Roof Pitch/es [°]: 34 | Roof Length [m]: 26.8

Type of Primary Structure: 2D framing

Truss ☑ KING-POST

Frame ☐

Average Distance in between Primary Structure [m]: 2.25

Type of Secondary Structure: common rafters, purlins, sa | Plane: horizontal, roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1755 To 1762 | Identified by: Estimated

Roof General Description:

A hipped roof with two transversal walls: central block with four trusses and cross roofs from the two pediments; side blocks with one truss and hip rafters. Trusses have a raised tie-beam and a king-post in tension with diagonal struts. They are connected by butt-purlins, one on each side. The cross roofs from the pediments are supported by 3 purlins and common rafters. The pitch is quite low. The attic spaces were used as rooms: remains of panels and nails can be seen under all rafters and tie-beams, and there are fireplaces.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 30 | B: 17 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: bulb shaped joggle, cleat, dovetail, joggle, lapped, mortice and teno

Fasteners Types: Metal nail, Timber peg flush

Joints description:

Rafters apex: mortice and tenon with rounded joggle; between raised tie-beam and post: half lapped with iron nails; All others are dovetail notched lapped with iron nails. The joints between raised tie-beam and rafters also have timber pegs.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description:

Numbered from I to IIII from south to north (number II isn't visible).

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology



Roof Structure | link I:\Arch\A



Roof Structure | link I:\Arch\A



Joints: rafter and raised tie-beam | link I:\Arch\A



Joints: post and raised tie-beam | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Wall heads rebuilt and some timbers replaced, mainly common rafters, purlins and sarking. Steel plates added to the strengthen the rafters ends. Insulation and partition added.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

BALCASKIE HOUSE

Location	FIFE		CARNBEE
X coordinate	352465	Y coordinate	703582
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PRIVATE		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	34206
Original Use	Residential		
Current Use	Residential		

Freestanding ☑ N. of floors above ground level 3 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1629		3 STOREY L-PLAN HOUSE. MAIN BLOCK STILL VISIBLE ON THE SOUTH, WHERE IT OCCUPIES THE WEST THIRD OF THE FRONT	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1668	1674	INCORPORATED ORIGINAL L PLAN HOUSE (HEIGHTENED IT TO 4 STOREYS) TRANSFORMING IT INTO A U PLAN	CANMORE

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT, COMMISSIONERPATRON	☐
HAMILTON	JOHN	MASON	☐
SCOTT	ALEXANDER		☐
WALLACE	ARCHIBALD		☐
DUNSTERFIELD	GEORGE	PLASTERER	☐
DE WET	JACOB	PAINTER	☐
PATERSON	ALEXANDER	WRIGHT	☐
WADDELL	ANDREW	WRIGHT	☐
BAINE	JAMES	MATERIAL SUPPLIER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1745	1755	REMOVED OFFICE BUILDINGS AND REPLACED THEM WITH PAVILIONS JOINED TO THE HOUSE; CENTRE BLOCK LARGELY REBUILT AND RAISED TO 3 STOREYS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1830	1832	JACOBEAN PORCH ADDED, LOWERED SILLS ON SOUTH FRONT AND INTRODUCED AN IRON BALCONY ACROSS THE MAIN BLOCK TO THE REAR; TWIN GABLED EAST ADDITIONS AND WEST STABLE BLOCK	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BURN	WILLIAM	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1856	1858	ORIEL TO SOUTHWEST TOWER AND BARONIAL ADDITIONS TO WEST ELEVATION	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BRYCE	DAVID	ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	77
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	119

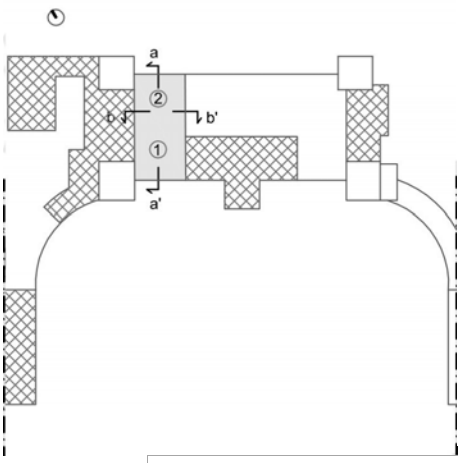
Author	Year	Unpubl.	Title	Pages
GIFFORD J.	1988	☐	THE BUILDINGS OF SCOTLAND COLLECTION: FIFE	

Author	Year	Unpubl.	Title	Pages
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	78

Author	Year	Unpubl.	Title	Pages
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	12

Author	Year	Unpubl.	Title	Pages
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	10

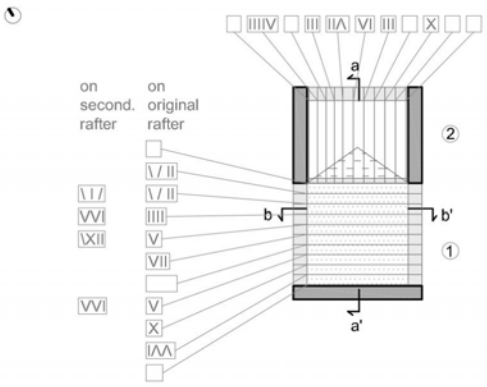
Suggestions for further research	Owner has 3D laser scan of house St Andrews University Library Department of Special Collections: Papers of the Anstruther family of Balcaskie (GB227/msdep121)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



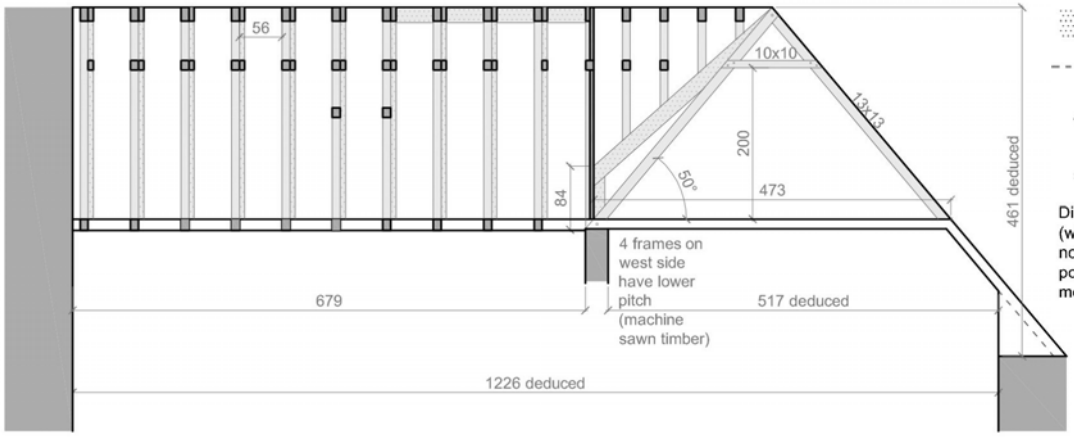
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

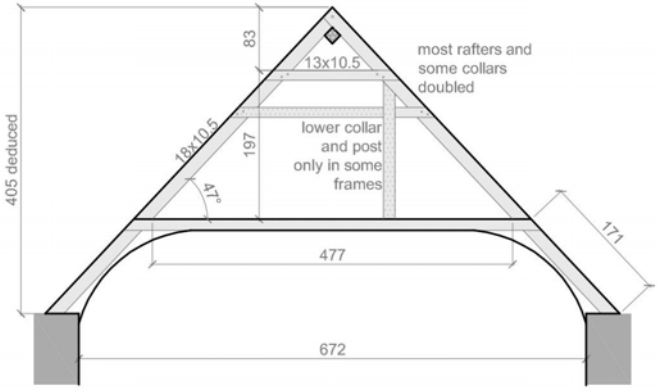
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section aa': Roof 2



Section bb': Roof 1



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** BALCASKIE HOUSE | **Roof location** 1: NE corner of main block

Survey date(s) 12/09/2014 | See drawing: BCH-W-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 6.7 | Roof Height [m]: 4

Roof Pitch/es [°]: 47 | Roof Length [m]: 6.8

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.55

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables:

Roof Construction Period: From 1668 To 1674 | Identified by: Estimated

Roof General Description:

Two gabled roofs intersecting one another. Roof 1 is composed of closely spaced rafter couples connected trasversally by two or three collars (some collars have been added later) and longitudinally by sarking boards only. The timbers are all full logs roughly hand axed. The rafters simply sit on the wall-head. The frames have been doubled, maybe in the 18th century. The sarking is not visible because insulation panels have been placed between the rafters. To the West is a 19C roof.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 18 | B: 10.5 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters' apex: mortice and tenon with timber pegs. Between collars and rafter: lapped with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description:

Roman numerals not in sequence and not every frame has one.

Signs of reused timbers: three rafters have redundant joints

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure: south side | link I:\Arch\A



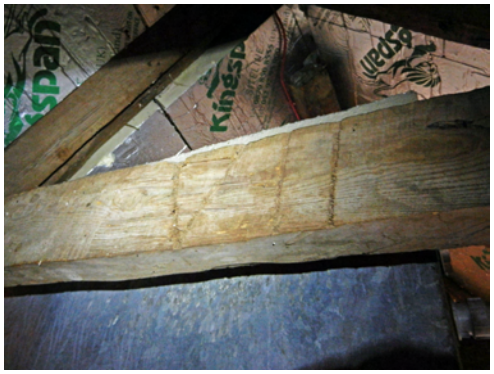
Connection with wall | link I:\Arch\A



Dressing & carpentry marks | link I:\Arch\A



Signs of reused timber | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☑

Decorative features

Unfavourable conditions: poor ventilation, presence of pigeons/wasps/bats, presence of water tank

Accessibility limitations: Connection with the wall and raised tie-beam only partly visible. Side of rafters and sarking not visible due to insulation panels.

Past interventions: Double rafters and collars added (maybe in 18C). Ridge beam and some lower collars added, as well as insulation panels (20C?). Water tank placed above the new collars.



Past interventions link I:\Arch\A



Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack link I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link I:\Arch\A

Description of visible damage

link I:\Arch\A

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link I:\Arch\A

INITIAL SURVEY | **Building name** BALCASKIE HOUSE | **Roof location** 2: NE corner of main block

Survey date(s) 12/09/2014 | See drawing: BCH-W-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.2 | Roof Height [m]: 4.6

Roof Pitch/es [°]: 50 | Roof Length [m]: 6.7

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.6

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables

Roof Construction Period: From 1668 To 1674 | Identified by: Estimated

Roof General Description: Two gabled roofs intersecting one another. Roof 2 is composed of closely spaced rafter couples connected trasversally by two collars and longitudinally by sarking boards only. The timbers are all full logs roughly hand axed. The connection with the wall is not visible. The sarking is not visible because insulation panels have been placed between the rafters. There are some unusual carpentry marks.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 13 | B: 13 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: mortice and tenon with timber pegs. Between collars and rafter: lapped with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description: Roman numerals not in sequence and not every frame has one.

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology



Roof structure: north side | link I:\Arch\A


Connection with wall in intersection | link I:\Arch\A


Timber elements' dressing | link I:\Arch\A


Joints: rafter and collar | link I:\Arch\A


Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☑

Decorative features

Unfavourable conditions: poor ventilation, presence of pigeons/wasps/bats

Accessibility limitations: Connection with the wall not visible on north side. Tie-beam not visible. Side of rafters and sarking not visible due to insulation panels.

Past interventions: Double rafters and collars added (maybe in 18C). Lower pitch added (18C?). Insulation panels added (20C?).



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:	
Roof Damage				link
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link I:\Arch\A

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link I:\Arch\A

Other Notes

Attachments I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link I:\Arch\A

BLAIR CASTLE

Location: PERTH AND KINROSS | BLAIR ATHOLL
X coordinate: 286577 Y coordinate: 766186
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 25802

Original Use: Residential
Current Use: Hotel/Inn, Museum

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1296			HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1500		ORIGINALLY A 16TH CENTURY TOWER HOUSE, ALTERED AT DIFFERENT PERIODS.	HES LISTING

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1500	1525	CENTRAL PART	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1617		DATED STONES 1617	HES LISTING

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1629	1650	SOUTH, BUT NEVER COMPLETED DUE TO CIVIL WARS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
MURRAY	JOHN 2ND EARL & 1S	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1668		DATED STONES 1668	HES LISTING

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1700		18TH CENTURY EAST WING	HES LISTING

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1736		SOUTH END RAISED	HS

People involved:

Last Name	First Name	Role	Attributed
DOUGLAS	JOHN	ARCHITECT	☐
MURRAY	JAMES 2ND DUKE OF	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1743	1745	2 STOREY SOUTH EAST WING	HS

People involved:

Last Name	First Name	Role	Attributed
WINTER	JAMES	ARCHITECT	☐
MURRAY	JAMES 2ND DUKE OF	COMMISSIONERPATRON	☐
ADAM	WILLIAM	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1745		BESIEGED AND CANNONATED: ALL REROOFED	

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1747	1758	TOWERS LEVELLED TO COMMON WALL HEAD, ANGLE	HS

TURRETS REMOVED, S. END REBUILT AND COMPLETED

People involved:

Last Name	First Name	Role	Attributed
CLAYTON	THOMAS	PLASTERER	☐
SWAN	ABRAHAM	JOINER	☐
DOUGLAS	JOHN	ARCHITECT	☐
WINTER	JAMES	CONTRACTOR	☐
CHESSELS	ARCHIBALD	JOINER, WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1814		FIRE IN SOUTHEAST WING	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1869	1871	REBARONIALISED: ESIGN OF WEST FRONT APPROXIMATELY BASED ON ORIGINAL WITH CUMMING'S TOWER WIDENED BY CORBELLING, ENTRANCE HALL ADDED ON EAST SIDE, THAT SIDE BEING LARGELY REDESIGNED ANEW	HS

People involved:

Last Name	First Name	Role	Attributed
BRYCE	DAVID	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1876	1877	BALLROOM	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1886			HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1893		1893 NORTH WING AND RE-FRONTING OF EAST RANGE BY THOMAS LEADBETTER	HES LISTING

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1920	1921		HS

People involved:

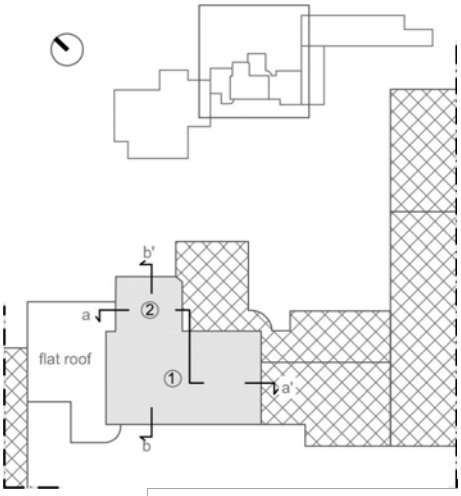
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1990	1999	SARKING AND SLATES REPLACED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	240-244
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	20, 51, 103, 104
GIFFORD J.	2007	☐	THE BUILDINGS OF SCOTLAND COLLECTION: PERTH AND KINROSS	

Suggestions for further research: Extensive archive material at the castle

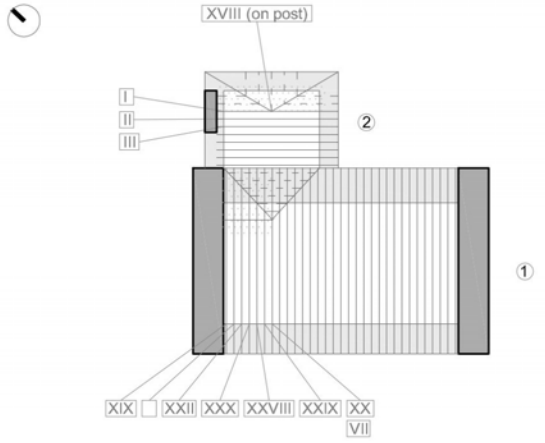


Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

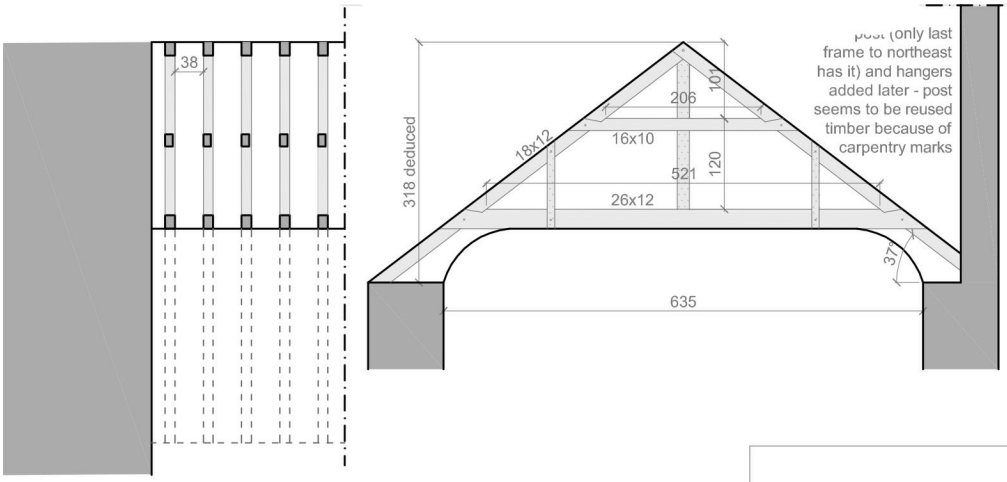
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

Plan 1:1000 I:\Arch\ADCRU\1718cent scott



Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

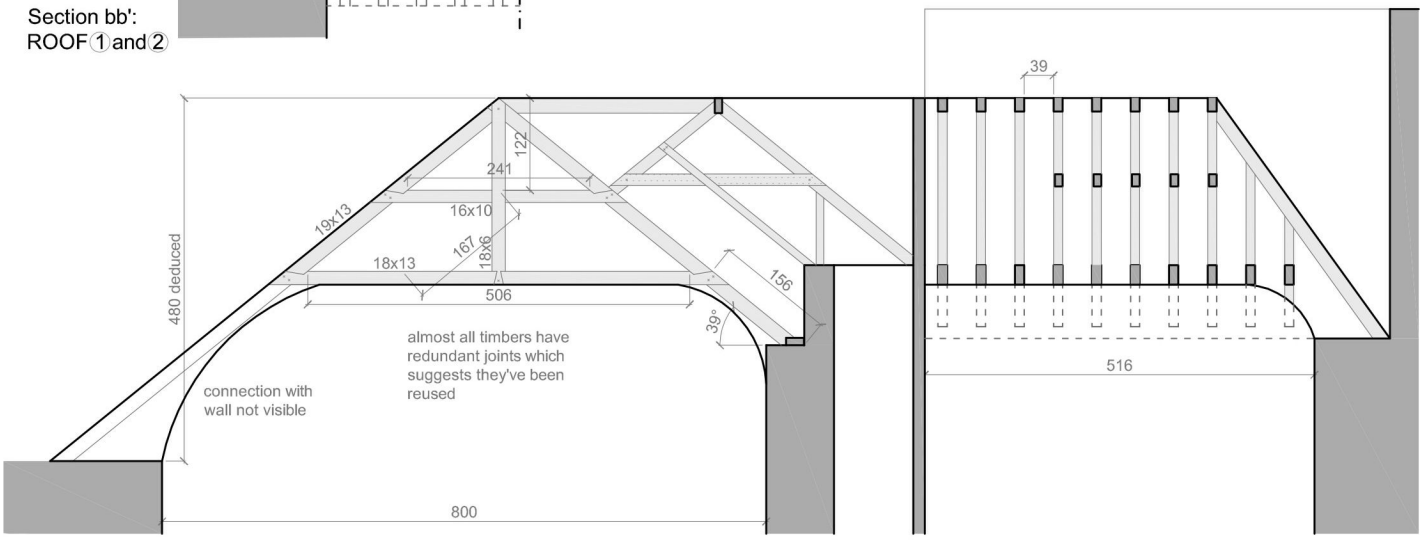
Section aa':
ROOF ① and ②



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb':
ROOF ① and ②



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Roof 1 from outside I:\Arch\A



Roof 2 from outside I:\Arch\A

INITIAL SURVEY | **Building name** BLAIR CASTLE | **Roof location** 2: E part of central block

Survey date(s) 04/08/2015 | See drawing: BLC-W&E-1

Roof Geometry: Hipped, Two-pitch gabled with intersections

Roof Max Span [m]: 6.35 | Roof Height [m]: 3.18

Roof Pitch/es [°]: 37 | Roof Length [m]: 5.16

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, King-strut

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1745 To | Identified by: Estimated

Roof General Description:

Hipped roof intersecting roof 1 to South-East. Composed of closely spaced rafter couples connected trasverally by two collars (except for 3 frames on South-West side which have only one lower collar) and longitudinally by sarking boards only. Some frames have vertical struts too. The rafters simply sit on the wall-head. The timbers are numbered with two sets of roman numerals, some big and sawn, other small and chiselled.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 18 B: 12 | Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters' apex: lapped with timber peg not flush. Between collars and rafters dovetail lapped with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, small chiseled roman numerals

Carpentry Marks Description:

Signs of reused timbers: More than one carpentry mark on post - probably reused

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not well visible.

Past interventions: Sarking replaced. Some rafters reinforced with timber.



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:	
Roof Damage				link
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes

Attachments I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link

INITIAL SURVEY | **Building name** BLAIR CASTLE | **Roof location** 1: W part of central block

Survey date(s) 04/08/2015 | See drawing: BLC-W&E-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 8 | Roof Height [m]: 4.8

Roof Pitch/es [°]: 39 | Roof Length [m]: 15.6

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, King-strut

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown, Wall-plate

Connection with gables:

Roof Construction Period: From 1745 To | Identified by: Estimated

Roof General Description: Gabled roof intersecting roof 2 to North-West. Composed of closely spaced rafter couples connected trasverally by two collars and longitudinally by sarking boards only. All frames have vertical struts too. The connection with the wall is visible only on the North-West side: the rafters simply sit on the wall-head. The timbers are numbered with two sets of roman numerals, some big and sawn, other small and chiselled.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 19 B: 13 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: lapped with timber peg not flush. Between rafters and collars: dovetail lapped with two metal nails. Hanger is nailed only at the top, but dovetail lapped with metal nail at the bottom.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, small chiseled roman numerals

Carpentry Marks Description:

Signs of reused timbers: A lot of redundant joints on almost all timbers: mortice and tenon, lapped, and very strange lapped ones with curved shape.

Timber Treated ☐

Other Materials: Steel

Dendrochronology: Coralie Mills carried out dendrochronolgical analysis on some roof timbers - need to ask her



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: lower collar and strut | link I:\Arch\A



Redundant joints | link I:\Arch\A



Joints, carpentry marks, reused | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: Original plaster ceiling underneath

Unfavourable conditions: poor ventilation

Accessibility limitations: Connection with wall not visible on southwest side

Past interventions: Sarking replaced. Stell brackets and timber reinforcing some rafters. Some new collars.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

Insect attack in some timbers, not sure if active

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes: Many redundant joints that suggest the timbers have been reused. The 1745 date is only estimated: the castle was besieged and cannonated at this date and it seems it had to be completely reroofed (this is what the archivist says). They might have reused the timbers from the previous 16C roof. Need to have a look at archives at the castle.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

BRODIE CASTLE STABLES

Location MORAY | DYKE AND MOY

X coordinate 297871 Y coordinate 857803

Geogr. Referencing System BRITISH NATIONAL GRID





Property status PUBLIC

Protection status NATIONAL

HS Listing B Rcahms ID 171454

Original Use Stables

Current Use Meeting Hall

Freestanding ☑ N. of floors above ground level 2 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1775	1800	NOT ON ESTATE PLAN OF 1770. BUILT AROUND GABLE WALL OF AN EARLIER STRUCTURE (REMAINS VISIBLE IN THE NW GABLE).	ADDYMAN REPORT 2000

People involved:

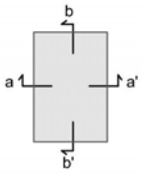
Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1845	1855	THE EARLY NW RANGE WAS TO BE REPLACED BY A SCOTS BARONIAL TOWER AND THE STABLES REMODELLED. THE EARLY NW RANGE WAS DEMOLISHED AND THE CENTRAL POSTS OF THE STABLES ROOF WERE REMOVED. ARCHES WERE INFILLED AND BUTTRESSES WERE ADDED.	ADDYMAN REPORT 2000

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
ADDYMAN & KAY LTD	1999	☑	THE OLD STABLES, BRODIE CASTLE - MORAYSHIRE - AN ARCHITECTUI RECORD AND ANALYSIS FOR THE NATIONAL TRUST FOR SCOTLAND	
CRONE A. & MILLS C.	2011	☐	THE NATIVE OAK AND PINE DENDROCHRONOLOGY PROJECT – AND S OBSERVATIONS ON TIMBER AND WOODWORKING IN SCOTTISH BUIL C.1450–1800	
WALKER D. & WOODWORTH M.	2015	☐	THE BUILDINGS OF SCOTLAND COLLECTION: ABERDEENSHIRE: NORT MORAY	

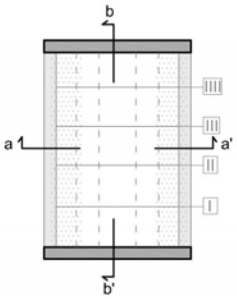
Suggestions for further research: Collection of papers at Brodie Castle in Nairn: online catalogue can be found at NRS website (search NRAS770)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

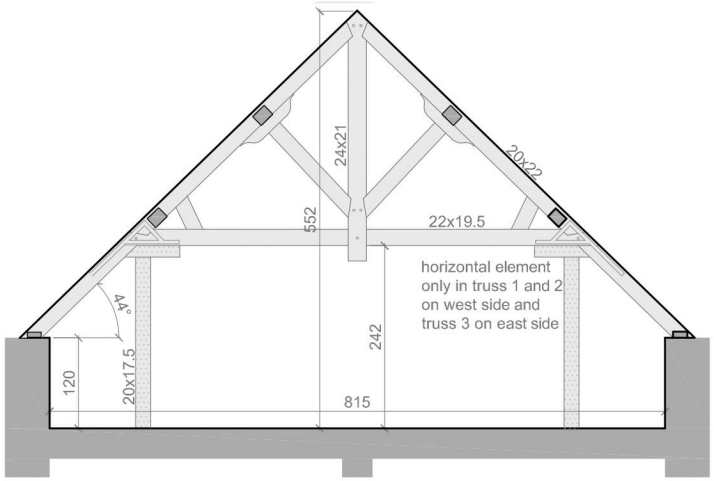
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

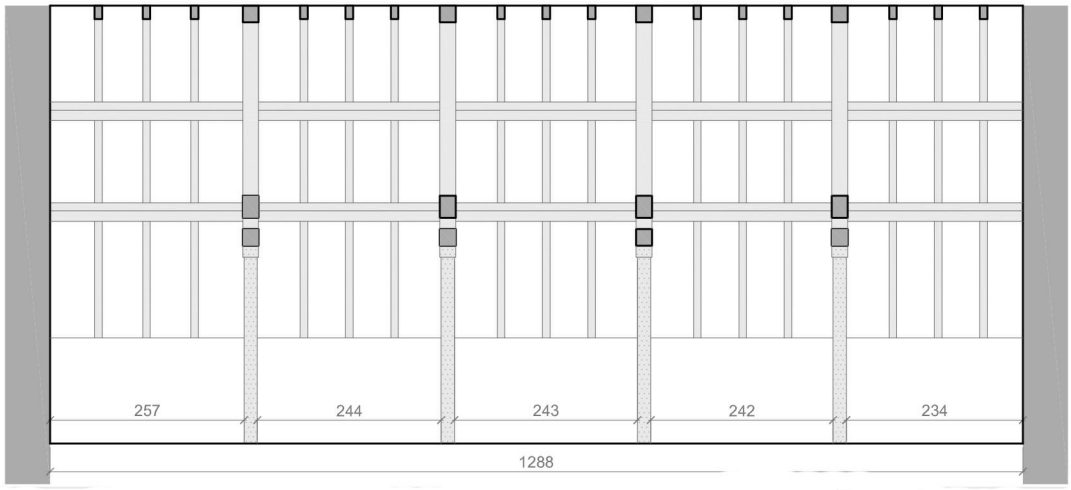
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** BRODIE CASTLE_STABLES | **Roof location** Stables

Survey date(s) 05/09/2014 | See drawing: BRC-S-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 8.1 | Roof Height [m]: 5.5

Roof Pitch/es [°]: 44 | Roof Length [m]: 12.9

Type of Primary Structure: 2D framing

Truss ☑ KING-POST

Frame ☐

Average Distance in between Primary Structure [m]: 2.4

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: purlins

Roof Construction Period: From 1775 To 1800 Identified by: Estimated

Roof General Description: Gabled roof with 4 king-post trusses supporting butt-purlins, common rafters and sarking boards. The trusses have a collar, two pairs of slanted struts (with cleats) and two purlins on each side. Two lateral posts and metal straps have been added later. The collar ends have also been partly replaced with prostheses. The rafters simply sit on the wall-head. The king-post curiously overlaps the collar and continues beneath it with a short stump. The frames are numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square

Rafter Scantling [cm] H: 20 B: 22 Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: cleat, dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal nail, Metal strap, Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush except for the joint between collar and rafters which is dovetail lapped with timber pegs and metal stripes that have been added later. The post has notches at the top and bottom for the rafters and the struts.

Wood Species: pine (Crone & Mills 2011) | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Numbered from I to IIII from south to north. There is a big X on the rafter end of truss 1 and 2

Signs of reused timbers:

Timber Treated ☐

Other Materials: Metal straps in joint between rafter and raised tie-beam

Dendrochronology: dendrochronology not doable.



Roof Structure link I:\Arch\A



Connection with wall link I:\Arch\A



Joints: king-post link I:\Arch\A



Joints: rafter and raised tie-beam link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☐ Insulation on sarking ☑

Decorative features

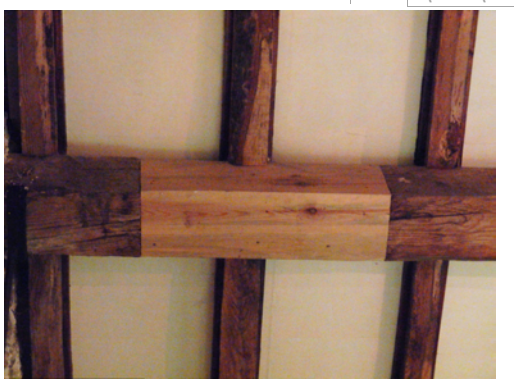
Unfavourable conditions

Accessibility limitations

Past interventions: Lateral posts and metal straps in the joints between raised tie-beams and rafters seem to be later than the rest (19C?). In 1999 tierods inserted in the floor to hold together the walls in both directions, metal supports added on the gables to help keep in position the purlins, sarking replaced and rotten elements partially replaced (mainly rafter ends).



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes: The hypothesis is that originally the central king-post went down to the floor, and stood on the spine wall underneath. That's why the raised tie-beam is interrupted and not the post itself. But the joint at the apex doesn't go well with this idea, because the post is supported by the rafters and not viceversa (but maybe they just copied that joint from another roof or from a manual and they didn't understand its structural role...). In any case, when they cut the central post, they

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

BRUNSTANE HOUSE

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)
X coordinate: 331773 Y coordinate: 672432
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 53920

Original Use: Residential
Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
DEMOLITION	1547		TOWERHOUSE DEMOLISHED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1565		L PLAN HOUSE BUILT	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1639		NORTH JAMB EXTENDED TO WEST AND TOWER ADDED IN NORTHEAST CORNER	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
MAITLAND	JOHN 1ST DUKE OF L	ARCHITECT, COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1672	1674	SUPPOSED TO DOUBLE IN SIZE BUT EAST RANGE SHORTER THAN ENVISAGED AND SOUTH RANGE ONLY OFFICE WING	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT	☐
YOUNG	JOHN	WRIGHT	☐
STARK	JAMES	OVERSEER	☐
WOTHERSPOON	PATRICK	MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1735	1744	S RANGE REBUILT AND NEW OFFICE COURT BUILT	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
FLETCHER	ANDREW LORD MILT	COMMISSIONERPATRON	☐
ADAM	WILLIAM	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1775	1800	SOUTH WING HEIGHTENED? NORTH WING REROOFED?	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1800	1899	MODERN CORRUGATED ASBESTOS ROOF ON SOUTH WING	HS

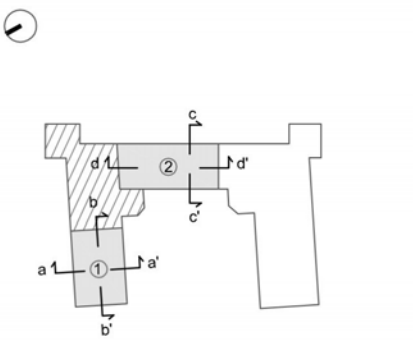
People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	79
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	

Author	Year	Unpubl.	Title	Pages
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	12
RCAHMS WEBSITE	2015	☐	HTTP://WWW.RCAHMS.GOV.UK/	
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	13

Suggestions for further research



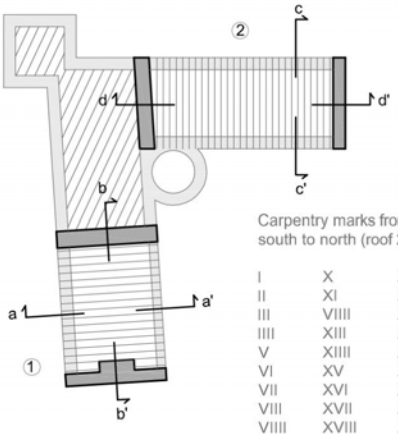
Legend (plans):

Plan 1:1000

- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500

- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Carpentry marks from east to west (roof 1):

VIII	XI
XII	XIII
V	III
I	IIΛX
X	VIIII
IΛX	ΛX
II	ΛIX
IIII	not visible

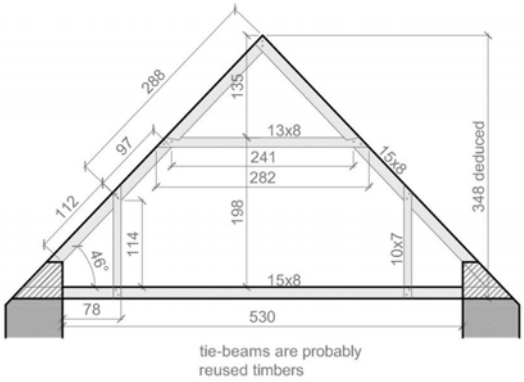
Carpentry marks from south to north (roof 2):

I	X	XIX
II	XI	XX
III	VIIII	XXI
IIII	XIII	XXII
V	XIIII	XXIII
VI	XV	XXIV
VII	XVI	XXV
VIII	XVII	XXVI
VIIII	XVIII	XXVII

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

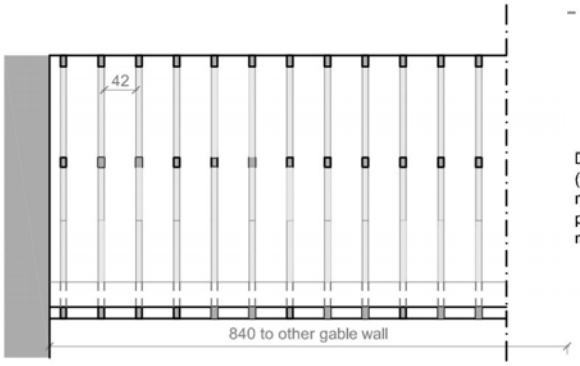
Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa': ROOF 1



tie-beams are probably reused timbers

Section bb': ROOF 1

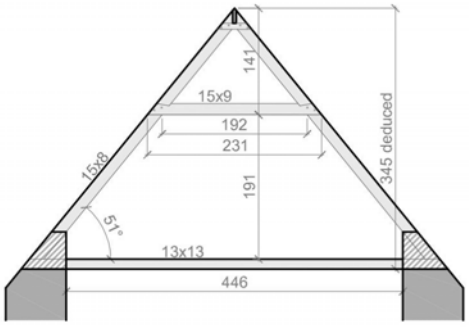


Legend (section):

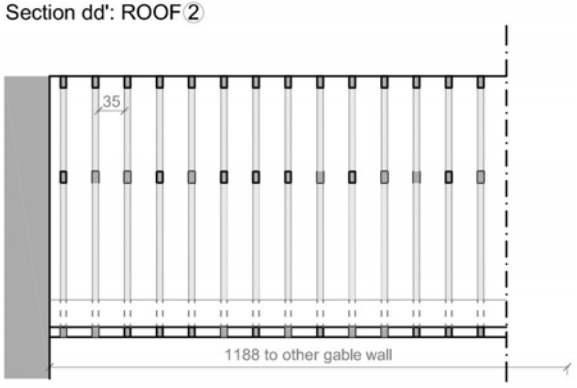
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section cc': ROOF 2



Section dd': ROOF 2



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** BRUNSTANE HOUSE | **Roof location** 2: central E range

Survey date(s) 11/08/2015 | See drawing: BRH-NW&C-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4.46 | Roof Height [m]: 3.45

Roof Pitch/es [°]: 51 | Roof Length [m]: 11.88

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.35

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Masonry infill, Tie-beam

Connection with gables:

Roof Construction Period: From 1775 To 1800 Identified by: Estimated

Roof General Description: Gabled roof composed of closely spaced rafter couples connected transversally by one collar and a tie-beam and longitudinally by sarking boards only. Rafters and tie-beams are embedded in the masonry wall-heads. The tie-beams are reused timbers (the are more roughly dressed and have redundant joints), probably from the 1632 roof. Big hip rafters on the north side, connecting with the roof the North-East roof structure that is only partly visible.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular, Square with wanes

Rafter Scantling [cm] H: 15 B: 8 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description: Rafters' apex ridge beam with short horizontal strut underneath (fixed with metal nails). Between rafters and collars lapped dovetail with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Mostly in sequence numbered from 1 to 27 from south to north

Signs of reused timbers: The tie-beams look older, all hand axed and with square scantlings - they could be reused timbers from the 1632 roof

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: A couple of rafters on east side replaced. Sarking recently replaced.

link

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	link
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link

INITIAL SURVEY | **Building name** BRUNSTANE HOUSE | **Roof location** 1: NW range

Survey date(s) 11/08/2015 | See drawing: BRH-NW&C-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 5.3 | Roof Height [m]: 3.48

Roof Pitch/es [°]: 46 | Roof Length [m]: 8.4

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.42

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Masonry infill, Tie-beam

Connection with gables:

Roof Construction Period: From 1775 To 1800 | Identified by: Estimated

Roof General Description:

Gabled roof composed of closely spaced rafter couples connected transversally by one collar and a tie-beam and longitudinally by sarking boards only. Each frame also has a vertical strut on each side connecting tie-beams and rafters. Rafters and tie-beams are embedded in the masonry wall-heads. Hand sawn timbers with rectangular scantlings joined with lapped joints secured by metal nails. The frames are numbered with small chiselled roman numerals, not in sequence.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 15 | B: 8 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description: All lapped with metal nails - collars are sometimes dovetail too

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description: Not in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not visible

Past interventions: Sarking recently replaced

link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	link I:\Arch\A
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link I:\Arch\A

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link I:\Arch\A

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link I:\Arch\A

COWANE'S HOSPITAL

Location: STIRLING | STIRLING
X coordinate: 279172 Y coordinate: 693674
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 46196

Original Use: Hospital
Current Use: Museum, Offices

Freestanding: ☑ N. of floors above ground level: 2 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1637	1648	AN OLDER HOUSE ON THE SITE WAS DEMOLISHED TO MAKE WAY FOR IT	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
MYLNE	JOHN JUNIOR (3)	DESIGNER, ROYAL MASTER MASON	☐
RYND	JAMES	MASTER MASON	☐
BIZATT	JAMES	MERCHANT	☐
CUNNINGHAM	ALEXANDER	WRIGHT	☐
CUNNINGHAM	ARCHIBALD	WRIGHT	☐
ROBERTSON	JAMES	MERCHANT, OVERSEER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1700	1725	MAIN BLOCK DIVIDED IN TWO HALLS NAMED "GILDHALL". INTERIORS REMODELLED	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1852		OTHER ALTERATIONS MADE IN 1852	RCAHMS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1852		INTERIORS REMODELLED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
SURVEY	2010			PAUL HARDING

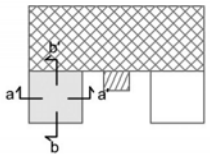
People involved:

Last Name	First Name	Role	Attributed
NARRO	DAVID	ENGINEER	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	77
GIFFORD J.	2002	☐	THE BUILDINGS OF SCOTLAND COLLECTION: STIRLING AND CENTRAL	
HARRISON J.		☑	CONSTRUCTION OF COWANE HOSPITAL	
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	15

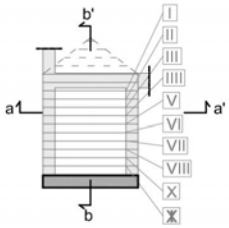
Suggestions for further research: Cowane Trust Archives



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

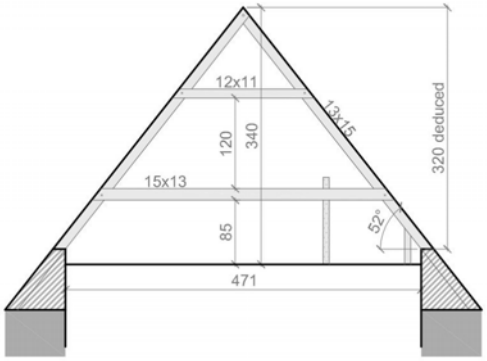
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

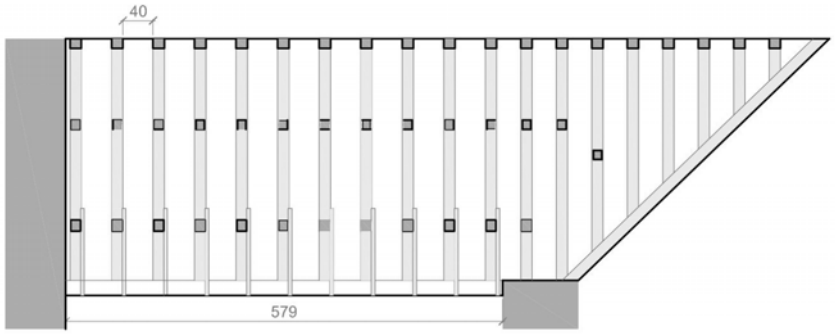
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** COWANE'S HOSPITAL | **Roof location** E wing

Survey date(s) 30/09/2014 | See drawing: CWH-E-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4.7 | Roof Height [m]: 3.4

Roof Pitch/es [°]: 52 | Roof Length [m]: 5.5

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Masonry infill

Connection with gables:

Roof Construction Period: From 1637 To 1648 Identified by: Estimated

Roof General Description:

Gabled roof intersecting the roof over the great hall (which has been replaced in 19C) on the South-East side. It is composed of closely spaced rafter couples connected transversally by two collars and longitudinally by sarking boards only. Rafters embedded in the masonry wall-heads. Timbers are all full logs roughly hadn axed. The timber pegs fixing the slates to the sarking boards partly survive. The frames are numbered with buig sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails, Timber Pegs

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 13 B: 15 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed) Bark ☐

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters apex: mortice and tenon with timber pegs; between collars and rafters: chamfered half lapped with iron nails

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Numbered from south to north from I to VIII, then there is X and then an X with I in the middle.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure link I:\Arch\A



Roof structure link I:\Arch\A



Timber elements' dressing link I:\Arch\A



Joints: rafters and collars link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance, poor ventilation, presence of water tank

Accessibility limitations: No lighting in roof space

Past interventions: Ceiling redone, maybe in mid 19C when the great hall roof was redone as well (original ceiling was probably attached under the raised tiebeam: there are some remains of laths and iron nails under the timbers). Insulation added on ceiling and water tank inserted on raised tie-beams. Some hangers added between raised tiebeams and ceiling.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☑

Insect attack on collars, not sure if active



Fungi attack | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Humidity stains | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes: In 1637 'two short trees and 39 long trees were bought in Burntisland, 20 great trees and 30 short trees at Leith'. In 1640 James Bizzat, timber merchant in Perth, was commissioned to bring timbers from Norway: '60 great trees (beams) 36 feet long and 12 inches square (11m - 30cm), 32 trees of 24 feet long (7.3m) and 380 'schorne deals' of redwood (probably pine) each 14 feet long and 12 inches wide (4.3m - 30cm)'. There were also 190 deals of 12 ells long and 60 single trees. The

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

CRAIGSTON CASTLE

Location: ABERDEENSHIRE | KING EDWARD
X coordinate: 376221 Y coordinate: 855021
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 19228

Original Use: Residential
Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 5 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1604	1607	DATE ON INSCRIPTION PANEL	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BEL	JOHN	DESIGNER, MASON	☑
URQUHART	JOHN	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
DESIGN	1733		FOR A PALLADIAN HOUSE, NOT EXECUTED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1745	1755	WINGS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1770		WINGS REMODELLED AND CHAPEL ADDED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

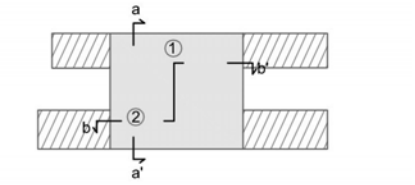
Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1834	1836	PORCH AND INTERIORS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME II. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL/ THE TWELFTH TO THE EIGHTEENTH CENTURY	483-484
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	15
WALKER D. & WOODWORTH M.	2015	☐	THE BUILDINGS OF SCOTLAND COLLECTION: ABERDEENSHIRE: NORT MORAY	

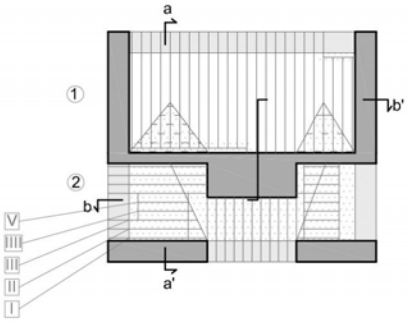
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

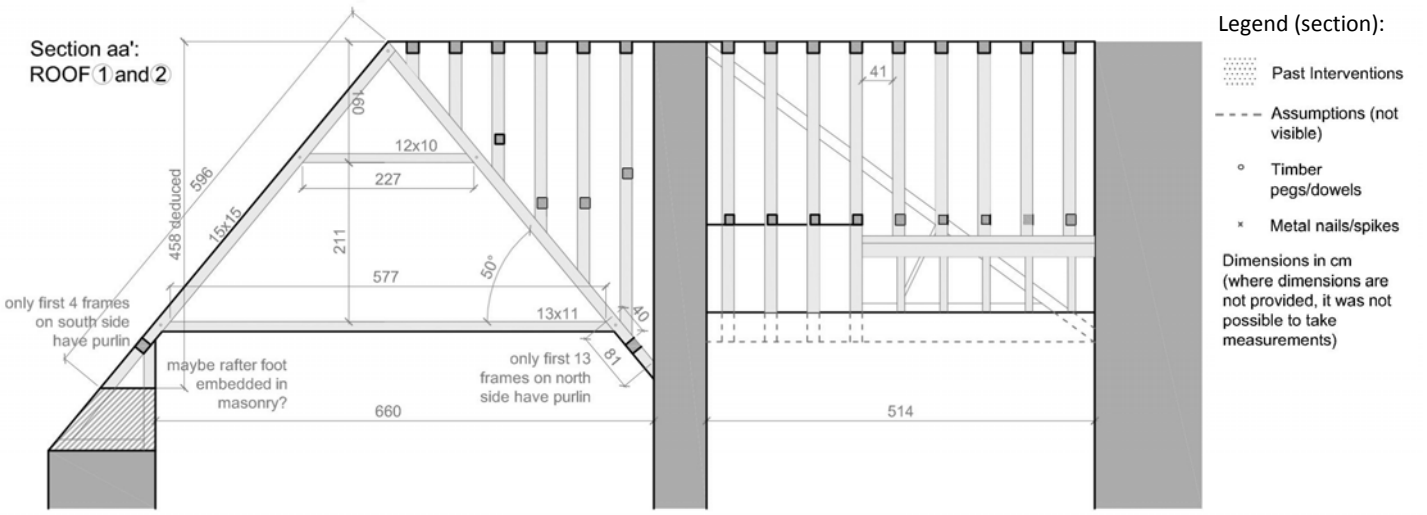


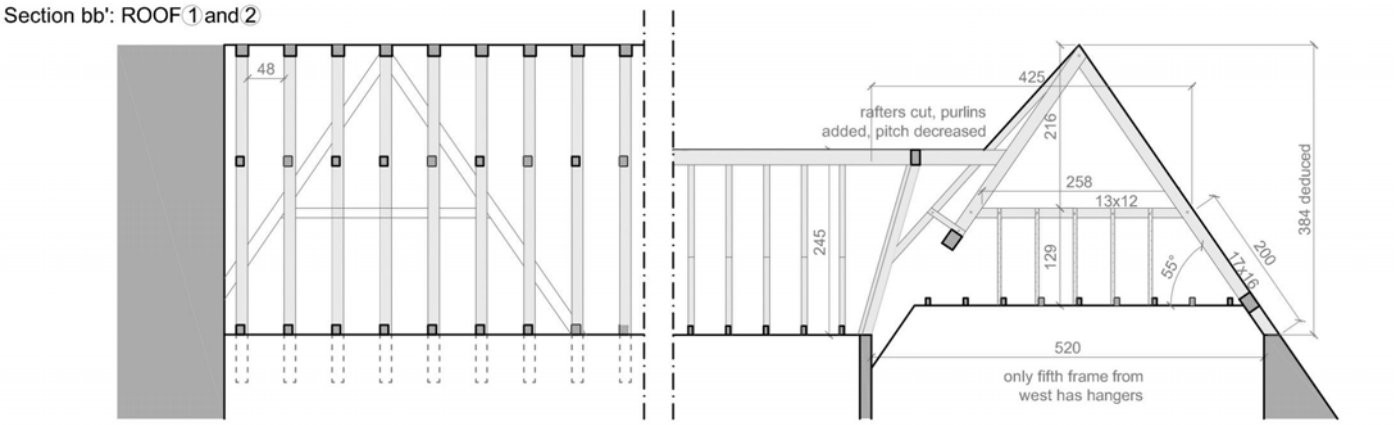
Carpentry marks from north to south (roof 1):

I	XIII
II	XIIII
III	X/
IIII	X/I
V	X/II
VI	X/III
VII	X/IIII
VIII	XX
VIIII	XXI
X	XXII
X	XXIII
XII	XXIIII

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Roof 1 from outside I:\Arch\A



Roof 2 from outside I:\Arch\A

INITIAL SURVEY | **Building name** CRAIGSTON CASTLE | **Roof location** 2: N range

Survey date(s) 05/08/2015 | See drawing: CRC-E&N-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.2 | Roof Height [m]: 3.84

Roof Pitch/es [°]: 55 | Roof Length [m]: 5.14

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: purlins, sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1604 To 1607 Identified by: Estimated

Roof General Description: Two gabled roofs intersecting a mono-pitch roof in the central part. Each roof has 9 frames with one collar each. The roofs have been heavily altered during the 18C: some rafters have been cut and are now supported by purlins. Ceiling was probably higher originally.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 17 B: 16 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, small chiseled roman numerals

Carpentry Marks Description: Big roughly cut roman numerals on collars and rafters - numbered in sequence from 1 to 5 from west to east. Purlins have small chiseled roman numerals, so they were probably added in 18C.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure link I:\Arch\A



Roof structure link I:\Arch\A



Joints: rafter and purlin link I:\Arch\A



Joints: rafter and collar link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: 4 rafters on southwest side cut, purlins added to support remaining stumps, pitch decreased - probably in mid 18C when wings were added. Plaster ceiling lowered.



Past interventions | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes

Attachments I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** CRAIGSTON CASTLE | **Roof location** 1: E range

Survey date(s) 05/08/2015 | See drawing: CRC-E&N-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 6.6 | Roof Height [m]: 4.58

Roof Pitch/es [°]: 50 | Roof Length [m]: 15

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.55

Type of Secondary Structure: purlins, sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables

Roof Construction Period: From 1604 To 1607 | Identified by: Estimated

Roof General Description:

Gabled roof with two intersections to the North-East, interrupted by gable walls. It's composed of closely spaced rafter couples connected transversally by two collars and longitudinally by sarking boards only. The connection with the wall is not well visible, there might be a rafter foot. The timbers are all full logs roughly hand axed and joined with mortice and tenon joints secured by timber pegs. The frames are numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 15 | B: 15 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: In sequence

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology



Roof Structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not well visible

Past interventions: Pitch decrased in intersections. Sarking replaced in 18/19C.



Past interventions | link | I:\Arch\A



Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

Insect attack on some collars, not sure if active

Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	stacking up		
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage: | link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

CULROSS PALACE

Location FIFE | CULROSS

X coordinate 298515 Y coordinate 685950

Geogr. Referencing System BRITISH NATIONAL GRID





Property status PUBLIC

Protection status NATIONAL

HS Listing SCHED Rcahms ID 48021

Original Use Residential

Current Use Museum

Freestanding ☑ N. of floors above ground level 2 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1597	1611	PALACE (2 BUILDINGS) AND BESSIE BAR HALL - THE GROUND FLOOR OF THE WEST RANGE IS OLDER	HS

People involved:

Last Name	First Name	Role	Attributed
BRUCE	GEORGE		☐
BRUCE	GEORGE SIR OF CULR	COMMISSIONERPATRON	☐

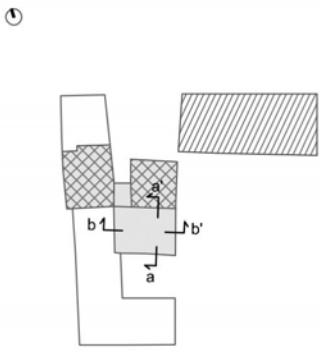
Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1700	1725	GEORGIAN PANELLING IN THE LAIRD'S ROOM. BESSIE BAR HALL WAS BUILT EITHER IN THE LATE 16TH CENTURY OR POSSIBLY AS LATE AS 1776	HS

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME II. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL/ THE TWELFTH TO THE EIGHTEENTH CENTURY	432-435
GIFFORD J.	1988	☐	THE BUILDINGS OF SCOTLAND COLLECTION: FIFE	
HANKE T.	2006	☑	THE DEVELOPMENT OF ROOF CARPENTRY IN SOUTHEAST SCOTLAND	

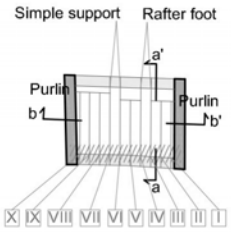
Suggestions for further research: NRS: DD27 conservation works in 1960/83, DD27 conservation works in 1992/99



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

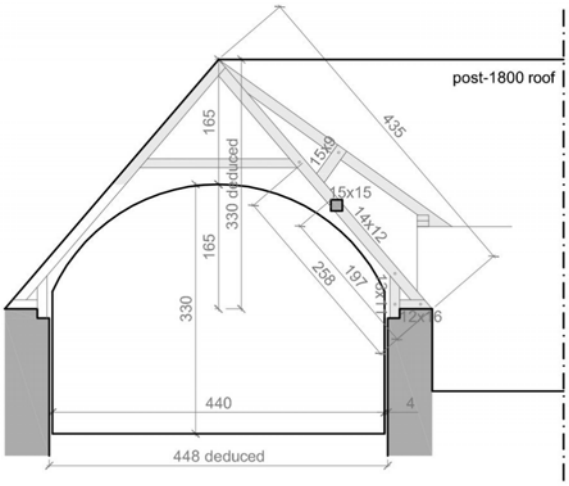
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

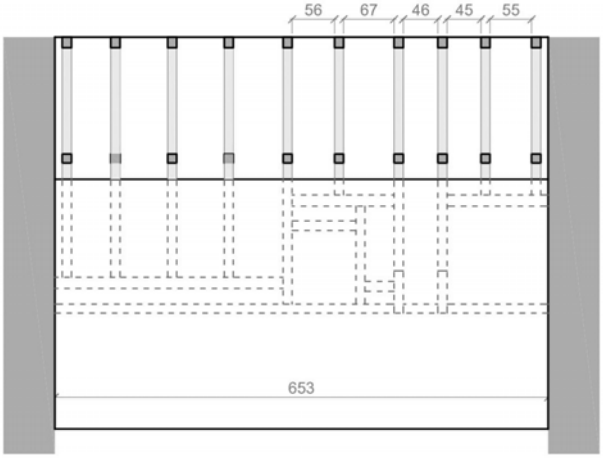
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Roof from outside I:\Arch\A



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** CULROSS PALACE | **Roof location** Central W block

Survey date(s) 17/02/2015 | See drawing: CP-W-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4.5 | Roof Height [m]: 3.3

Roof Pitch/es [°]: 49 | Roof Length [m]: 6.4

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.55

Type of Secondary Structure: purlins, sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1597 To 1611 Identified by: Estimated

Roof General Description: Gabled roof composed of closely spaced rafter couples connected transversally by one collar and longitudinally by sarking boards only. The connection with the South wall is not visible, but on the North side frames 3 and 4 have rafter feet, whilst the others rest on purlins (which could be a later alteration). Additional rafters with a reduced pitch have been added on the North side and connected to the original ones with struts. There is a secondary structure composed of curved timbers that support the timber barrel vaulted ceiling. The timbers are all full logs hand axed and joined with mortice and tenon joints secured with timber

Roofing Material: clay tiles

Roofing Material Fixing: Unknown

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 14 B: 12 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed) Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: All mortice and tenon with timber pegs - rafters' apex not visible

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Numbered 1 to 10 from east to west

Signs of reused timbers:

Timber Treated ☐

Other Materials: metal spikes used to secure purlin and part of a rafter that were added later to bypass one of the little lateral vaults of the ceiling

Dendrochronology:



Roof structure link I:\Arch\A



Connection with wall link I:\Arch\A



Connection with wall link I:\Arch\A



Joints: collar and rafter link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: original painted timber barrel vault underneath

Unfavourable conditions:

Accessibility limitations: Connection with wall on south side not visible. Rest of roof structure only visible from north side, therefore some parts were not closely inspected/measured.

Past interventions: Sarking replaced. Additional rafters with a reduced pitch added on the north side. Purlins could be a later alteration.



Past interventions: reduced pitch | link | I:\Arch\A



Past interventions: new sarking | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☐

Some insect attack, not sure if active.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

CULZEAN CASTLE

Location: SOUTH AYRSHIRE | KYRKOSWALD
X coordinate: 223265 Y coordinate: 610285
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC
Protection status: NATIONAL
HS Listing: A Rcahms ID: 40959

Original Use: Residential
Current Use: Hotel/Inn, Meeting Hall, Museum

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1100	1199	BUILDINGS OF SCOTLAND SAYS IT WAS CALLED COIF OR COVE CASTLE	

People involved:

Intervention type:	From:	To:	Description:	Reference:
RECONSTRUCTION	1590			BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1645	1655	THE DEFENSIVE BARMKIN WALL WAS BREACHED AND 3 TERRACES WERE CONSTRUCTED AS HANGING GARDENS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1740	1770	IMPROVEMENTS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
DESIGN	1755		FOR A VILLA, NOT EXECUTED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	ROBERT	ARCHITECT	☐
KENNEDY	THOMAS 9TH EARL O	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
DESIGN	1759		FOR A BANQUETING HOUSE, NOT EXECUTED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
CHAMBERS	SIR WILLIAM	ARCHITECT	☐
KENNEDY	THOMAS 9TH EARL O	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1766	1768	A DETACHED, PLAIN, BARRACK-LIKE OFFICE HOUSE WAS BUILT ALONG THE CLIFF EDGE NORTH OF THE L-SHAPED TOWER HOUSE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1776	1782	RECASTING AND ENLARGEMENT OF THE TOWER HOUSE INTO A REGULAR RECTANGULAR PLAN, A SEPARATE KITCHEN BLOCK WAS BUILT, AND A CIRCULAR BREWHOUSE AND OFFICES IN A BUTTERFLY-LIKE PLAN	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	ROBERT	ARCHITECT	☐
KENNEDY	DAVID 10TH EARL OF	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1784	1792	SECOND PHASE OF WORKS INTENDED TO REMEDY TO THE LACK OF SEA VIEW: ALL THE PRE-1776 WORKS WERE SWEPT AWAY AND THE NORTH FRONT OF THE CASTLE TAKEN DOWN; IN ITS PLACE A 3-STOREY ADDITION; INTERIORS WERE ALTERED; MUCH WAS LEFT UNFINISHED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	ROBERT	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1877		WEST WING AND SOME INTERIOR REMODELLING	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
WARDROP & REID		ARCHITECT	☐

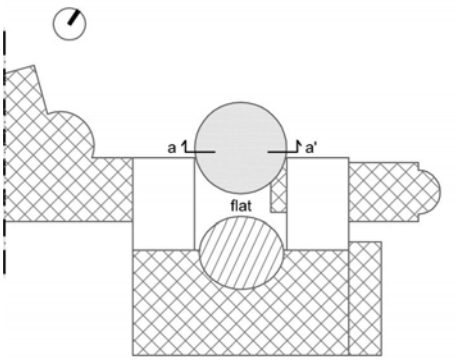
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1945		BY NTS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CLOSE R.	2012	☐	THE BUILDINGS OF SCOTLAND COLLECTION: AYRSHIRE AND ARRAN	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	113
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	205

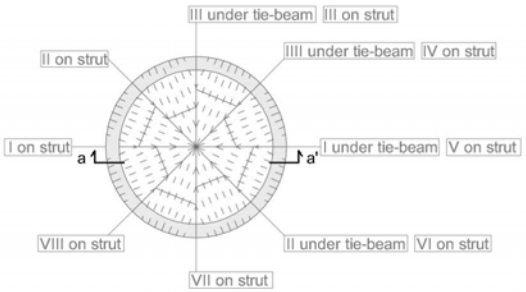
Suggestions for further research: Ayrshire Archives: building drawings by Robert Adam of Culzean Castle, 1785, 1787 (GB244/ATD34)
NRS: 1947 drawings (RHP6692) and GD25/



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

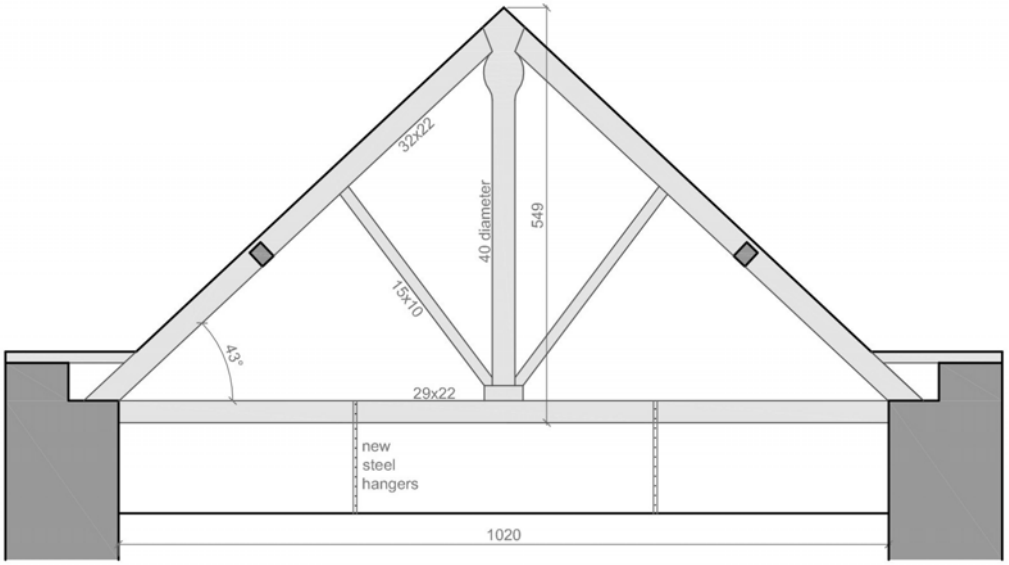
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** CULZEAN CASTLE | **Roof location** 1: Drum tower

Survey date(s) 14/08/2014 | See drawing: CUC-dt-1

Roof Geometry: Conical

Roof Max Span [m]: 10.2 | Roof Height [m]: 5.49

Roof Pitch/es [°]: 43 | Roof Length [m]: 10.2

Type of Primary Structure: 3D framing

Truss ☑ KING-POST

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm]: | thickness [cm]:

Connection with lateral walls: None

Connection with gables: no gables

Roof Construction Period: From 1791 To | Identified by: Estimated

Roof General Description: The roof was built after 1791 (there is a drawing of that date showing the drum tower unroofed). 4 radial trusses with a central post in tension supported by the rafters and holding up the tie-beams, and slanted struts. 1 tie-beam is continuous, the others are interrupted in the middle. 1 butt-purlin between each couple of pricipal rafters. The flat ceiling underneath hangs from the tie-beams. Hand sawn timbers of big scantlings joined with mortice and tenon joints secured by metal straps.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular, Round

Rafter Scantling [cm] H: 32 B: 22 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: bulb shaped joggle, joggle, mortice and tenon

Fasteners Types: Metal strap

Joints description: All mortice and tenon. Central post made of 2 half-rounded timber pieces kept together by 2 metal straps. A metal strap at the bottom end of the central post ties all the tie-beams together and with the post. The upper end of the post has a bulb shaped joggle.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description: Mostly in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials: Metal straps

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: post | link I:\Arch\A



Joint: under post and tie-beams | link I:\Arch\A



Joints and carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐



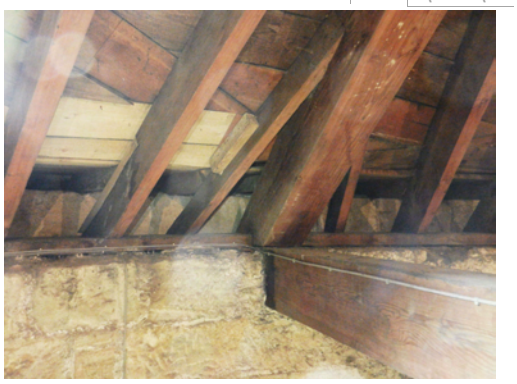
Decorative features: Original plaster ceiling underneath

Unfavourable conditions:

Accessibility limitations:

Past interventions: Some sarking replaced. Some new steel hangers connecting the ceiling to the tie-beams.

Past interventions | link | I:\Arch\A



Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

Past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

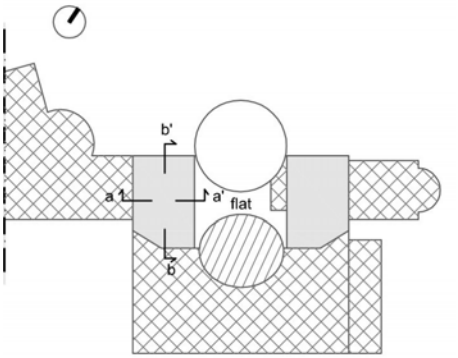
Estimated cause(s) of the primary damage: | link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes

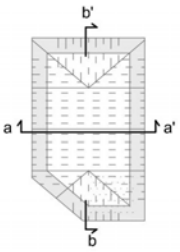
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

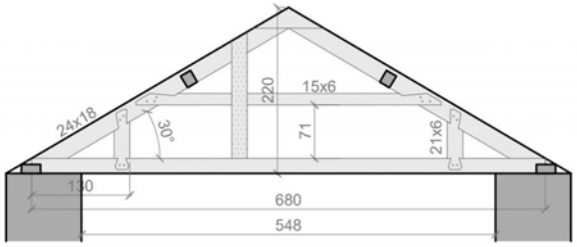
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

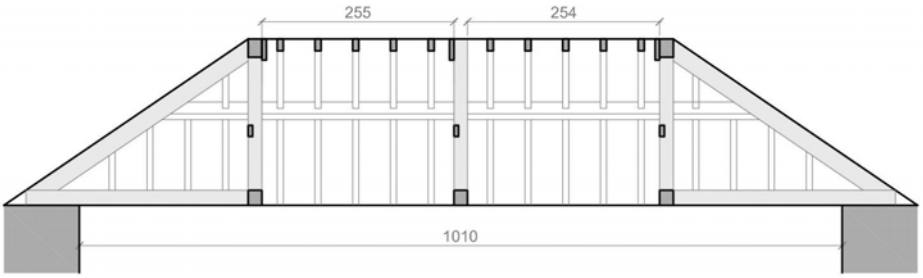
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** CULZEAN CASTLE | **Roof location** 2&3: SE & SW of drum tower

Survey date(s) 14/08/2014 | See drawing: CUC-SE&SW-1

Roof Geometry: hipped

Roof Max Span [m]: 5.48 | Roof Height [m]: 2.2

Roof Pitch/es [°]: 30 | Roof Length [m]: 10.1

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 2.5

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Tie-beam, Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1784 To 1792 Identified by: Estimated

Roof General Description:

Roof probably built during the second phase of works of R. Adam (1784-1792), when the Drum tower and these two lateral rooms were added. Hipped roof supported by 4 frames with one collar each, tie-beam and vertical struts on the sides. Frames have onebutt- purlin on each side. The timbers are hand sawn and joined with notched dovetail lapped joints. Only a few small chiselled roman numerals are visible.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 24 B: 18 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal nail

Joints description:

Dovetail notched lapped between collar and rafter and between ashlar post and rafter, with metal nails. Rafter's apex not visible. It has a rounded joggle.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Joints: rafters' apex and hip | link I:\Arch\A



Joints: rafter and collar/strut | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourablec onditions

Accessibility limitations

Past interventions: Some sarking replaced, especially in the lower part. South corner completely rebuilt, all timbers replaced.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☐

Humidity stains on common rafters in the hip area especially

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Humidity stains | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

DUFF HOUSE

Location ABERDEENSHIRE | BANFF

X coordinate 369062 Y coordinate 863316

Geogr. Referencing System BRITISH NATIONAL GRID





Property status PUBLIC

Protection status NATIONAL

HS Listing SCHED Rcahms ID 18493

Original Use Residential

Current Use Museum

Freestanding ☑ N. of floors above ground level 4 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1735	1740	INCOMPLETE	HS

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐
DUFF	WILLIAM	COMMISSIONERPATRON	☐
JAMIESON	GEORGE	MASON	☐
BURN	JOHN	CARVER	☐
JOHNSTON	JOHN	WRIGHT	☐
BURT	JOHN	OVERSEER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1754		FITTING OUT OF INTERIORS AT FIRST FLOOR	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
DOTT	THOMAS	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1790		INTERIORS COMPLETED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
LYON	JAMES	PLASTERER	☐
ROBERTSON	JAMES	PLASTERER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1870		WINGS, DAMAGED IN 1941 BY A BOMB AND LATER DEMOLISHED	ADAM/SIMPSON 2011

People involved:

Last Name	First Name	Role	Attributed
BRYCE	DAVID		☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1956	1995		BUILDINGS OF SCOTLAND COLLECTION

People involved:

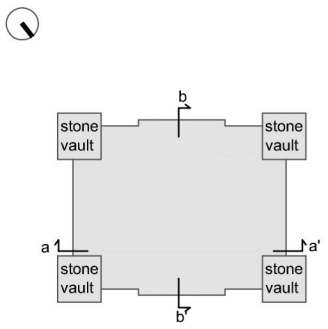
LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CRONE A.	2008	☑	THE NATIVE OAK AND PINE PROJECT: DENDROCHRONOLOGICAL ANA DUFF HOUSE, BANFF	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	104
WALKER D. & WOODWORTH M.	2015	☐	THE BUILDINGS OF SCOTLAND COLLECTION: ABERDEENSHIRE: NORT MORAY	

Author	Year	Unpubl.	Title	Pages
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 146-148

Author	Year	Unpubl.	Title	Pages
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	146-148

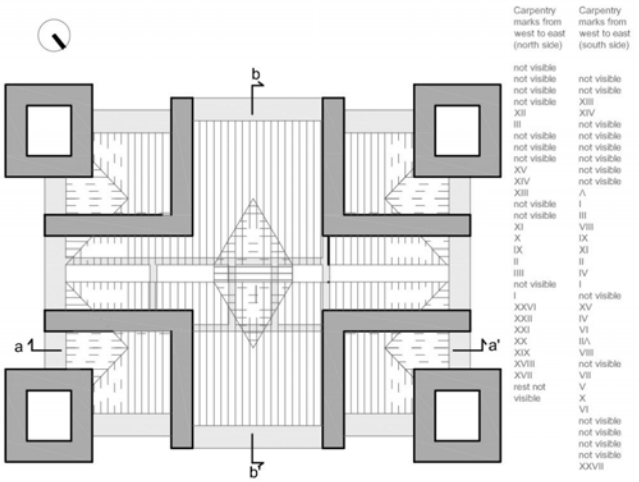
Suggestions for further research	University of Aberdeen Special Libraries and Archives: Duff family papers (GB231/MS 997 - GB231/MS 2727 - GB231/MS 3175) NRS: plan of ground floor 1740 (RHP31470) and correspondance



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



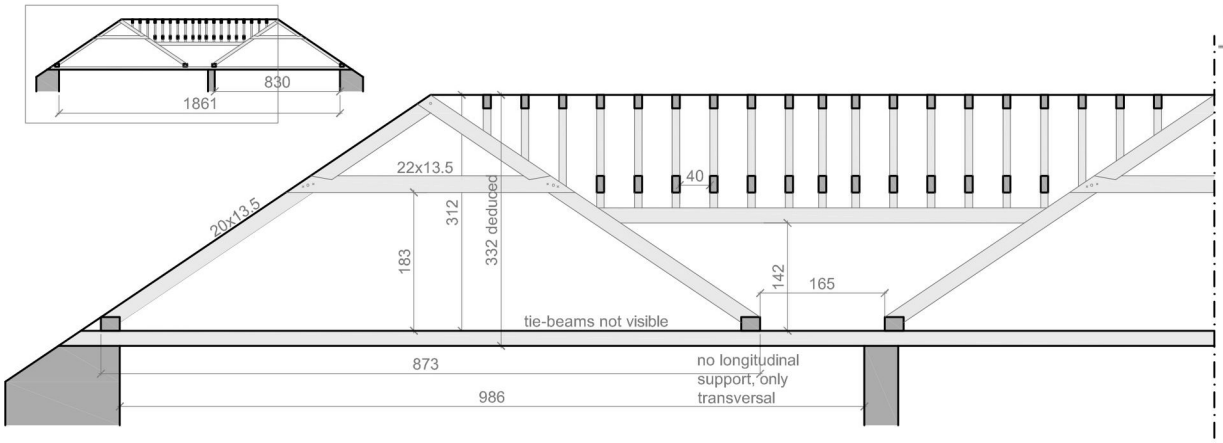
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

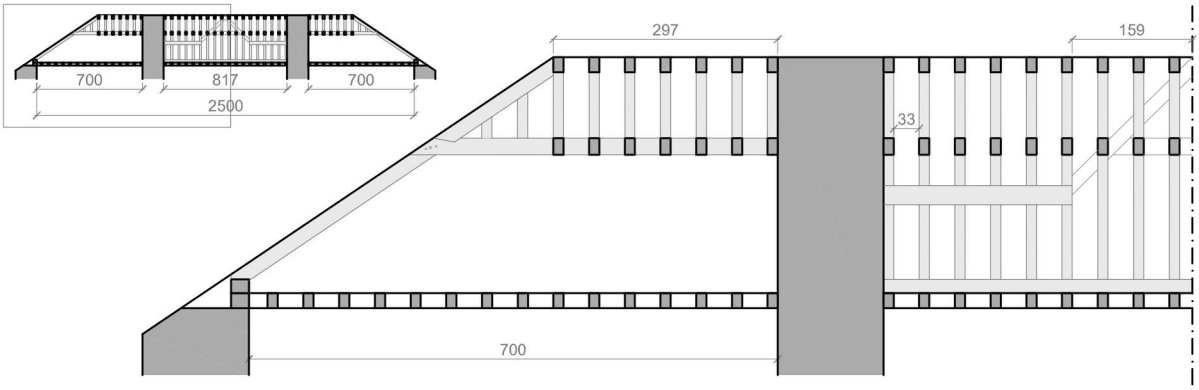
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section aa'



Section bb'



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0 1 5



Maquette of house I:\Arch\A

INITIAL SURVEY | **Building name** DUFF HOUSE | **Roof location** Main block

Survey date(s) 02/09/2014 | See drawing: DH-MB-1

Roof Geometry: Hipped, M shape

Roof Max Span [m]: 9.86 | Roof Height [m]: 3.32

Roof Pitch/es [°]: 34 | Roof Length [m]: 25

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.35

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Tie-beam, Wall-plate

Connection with gables:

Roof Construction Period: From 1737 To | Identified by: Dendrochronol

Roof General Description: The house is a double pile with 4 small turrets in each corner. The turrets are covered by stone vaults. The rest of the roof is a hipped M roof with an intersecting roof in the middle. Supported by corner walls and frames with a tie-beam and a collar. South-East corner room is still plastered (as was everything once, probably). Connection with the wall is not well visible.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 20 | B: 13.5 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon, scarf

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters apex: mortice and tenon with timber pegs; between rafters and collars: dovetail lapped with metal nails (some have a timber peg as well); between rafters and tie-beam not visible; 2 different scarf joints in wall plates

Wood Species: scandinavian pine (Crone 2008) | Way of identification: dendrochronology

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description: Not in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology: Dendrochronology carried out by Crone on the roof structure and dated to 1565-1737 (scots pine from braemar or norway)



Roof structure | link I:\Arch\A


Roof structure | link I:\Arch\A


Dressing and carpentry marks | link I:\Arch\A


Joints: scarf joint in wall-plate | link I:\Arch\A


Joints: rafter and collar | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation, presence of water tank

Accessibility limitations

Past interventions: Re-sarked and re-leaded in 1958. Works done in 1990s (not sure what). Few timbers partly replaced.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link | I:\Arch\A

Description of visible damage

link

Other Notes: Some frames have bigger scantlings: rafter: 27x20cm; collar 22x18cm

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

EDINBURGH PANMURE HOUSE

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)

X coordinate: 326511 Y coordinate: 673873

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 132518

Original Use: Residential

Current Use: Museum, School

Freestanding: ☑ N. of floors above ground level: 2 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1690		T PLAN HOUSE	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1840	1849	HOUSE TRUNCATED TO THE NORTH, REDUCING IT TO AN L PLAN	

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1956	1957	COMPLETELY GUTTED, ONLY OUTSIDE MASONRY AND ROOF STRUCTURES LEFT, EXCEPT FOR TIE-BEAMS THAT WERE REMOVED TO MAKE NEW CEILINGS.	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
SURVEY	2011		ARCHAEOLOGICAL	HS STEVEN ROBB

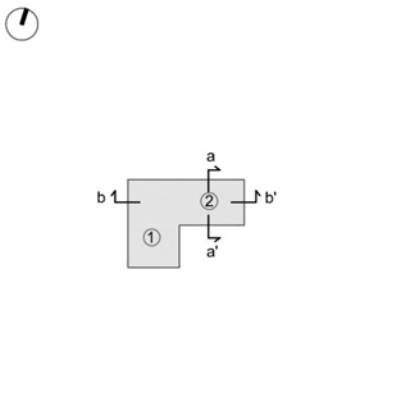
People involved:

Last Name	First Name	Role	Attributed
ADDYMAN ARCHAEOLOGY		ARCHAEOLOGIST	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
ADDYMAN ARCHAEOLOGY	2011	☑	PANMURE HOUSE - PANMURE CLOSE, CANONGATE, EDINBURGH - A AND HISTORICAL APPRAISAL OF THE HOUSE AND ITS URBAN CONTE EDINBURGH BUSINESS SCHOOL	
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	

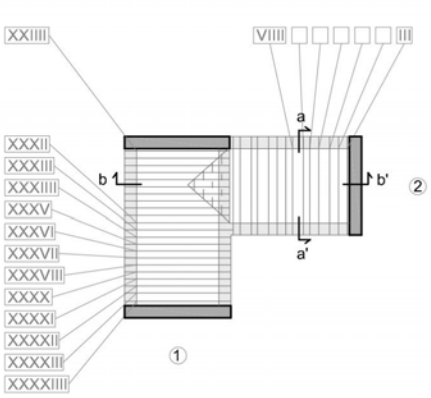
Suggestions for further research:



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

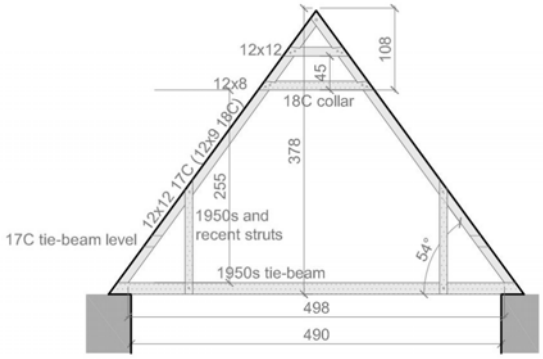
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

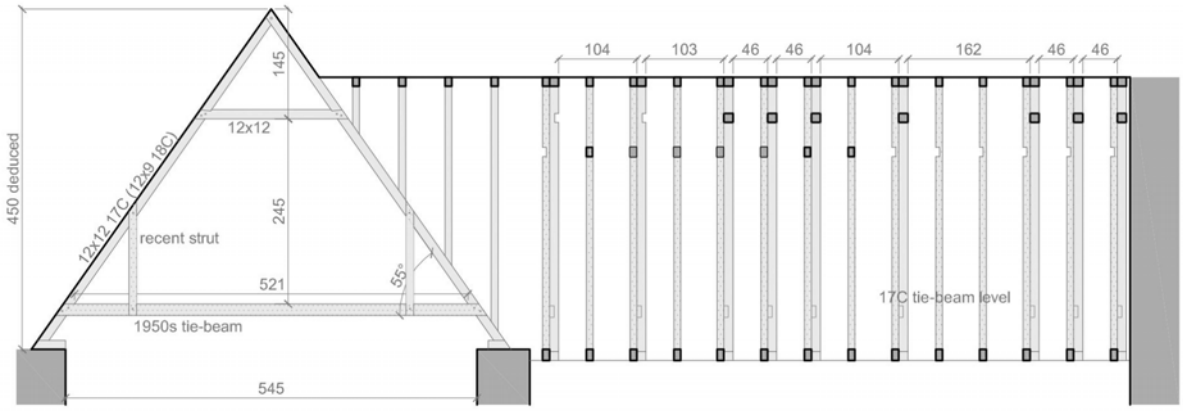
Section aa': ROOF 2



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb': ROOF 1 and 2



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INITIAL SURVEY | **Building name** EDINBURGH PANMURE HOUSE | **Roof location** 1: S range

Survey date(s) 16/09/2014 | See drawing: EPH-ALL-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.45 | Roof Height [m]: 4.5

Roof Pitch/es [°]: 55 | Roof Length [m]: 10.4

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.48

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1690 To | Identified by: Estimated

Roof General Description: Gabled roof intersecting roof 2 on West side. Original frames placed side by side with later frames (probably 18C) and very recent ones. Original frames are fragmentary: they had a tie-beam, which has been removed, one collar and rafter feet, which have been cut and partly removed. Some original collars have been removed. 18C frames have one collar. Sarking is probably from 18C too.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 12 B: 12 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: half lapped with timber pegs; between rafters and collars: dovetail lapped with metal nails; between rafters and tie-beams: lapped; between rafter and sole piece: mortice and tenon with timber peg

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

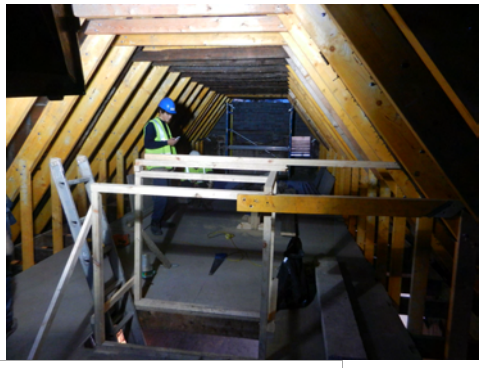
Carpentry Marks Description: Visible numbers are in sequence. Nembered from 24 to 34 from north to south. Frames from 1 to 23 were in the northern jamb that has been removed in 19C.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



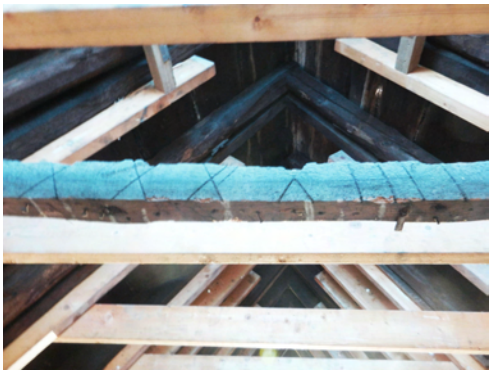
Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourablec onditions

Accessibility limitations

Past interventions: Frames doubled in 18C, and sarking replaced. Works in 1950s include: removed tie-beams and placed new ones at a lower level (attached to the 18C structure), replaced some masonry with bricks. Ongoing works to transform the house into an educational centre: frames doubled again, 1950s tie-beams raised to original 17C height, reslating.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

Insect attack on original timbers, not sure if active

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

INITIAL SURVEY | **Building name** EDINBURGH PANMURE HOUSE | **Roof location** 2: E range

Survey date(s) 16/09/2014 | See drawing: EPH-ALL-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4.9 | Roof Height [m]: 3.78

Roof Pitch/es [°]: 54 | Roof Length [m]: 7.95

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.46

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1690 To | Identified by: Estimated

Roof General Description: Gabled roof intersecting roof 1 on East side. Original frames placed side by side with later frames (probably 18C) and very recent ones. Original frames are fragmentary: they had a tie-beam, which has been removed, one collar and rafter feet, which have been removed too. Some original collars have been removed. 18C frames have lower collars and vertical struts. Sarking is probably from 18C too.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 12 B: 12 | Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: half lapped with timber pegs; between rafters and collars: dovetail lapped with metal nails; between rafters and tie-beams: lapped; between rafter and sole piece: mortice and tenon with timber peg

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Only few visible

Signs of reused timbers:

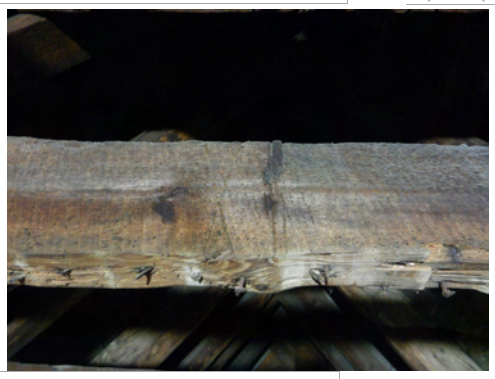
Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Redundant joints | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations



Past interventions link I:\Arch\A

Past interventions: Frames doubled in 18C, and sarking replaced. Works in 1950s include: removed tie-beams and placed new ones at a lower level (attached to the 18C structure), replaced some masonry with bricks. Ongoing works to transform the house into an educational centre: frames doubled again, 1950s tie-beams raised to original 17C height, reslating.

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:	link I:\Arch\A
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link I:\Arch\A

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes

Attachments I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui link

FOUNTAINHALL HOUSE

Location: EAST LOTHIAN | PENCAITLAND
X coordinate: 342657 Y coordinate: 667715
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 54713

Original Use: Residential
Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

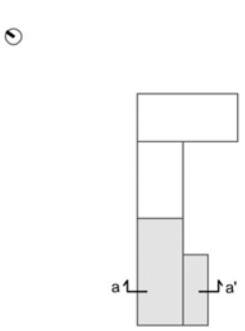
INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1575	1600	WEST PART	CANMORE
People involved:				
ADDITION	1600	1625	EXTENDED TO EAST	CANMORE
People involved:				
ADDITION	1638		EAST JAMB	BUILDINGS OF SCOTLAND COLLECTION
People involved:				
ALTERATION	1920		ALTERATIONS TO ROOF SPACE TO MAKE LIBRARY - NEVER COMPLETED	OWNER
People involved:				

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME II. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL/ THE TWELFTH TO THE EIGHTEENTH CENTURY	550-554
HANKE T.	2006	☑	THE DEVELOPMENT OF ROOF CARPENTRY IN SOUTHEAST SCOTLAND	
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	

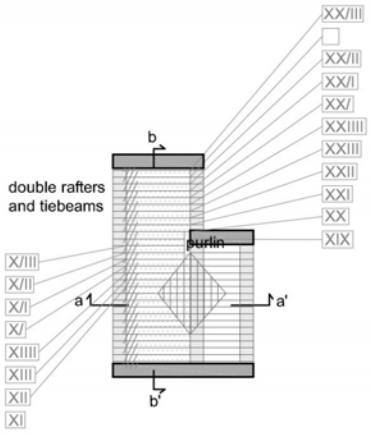
Suggestions for further research: NRS: plan of 1782 (RHP22306); papers relating to alterations in 1782/6 (GD1/1252/1/22); repairs in 1837 (GD41/523)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

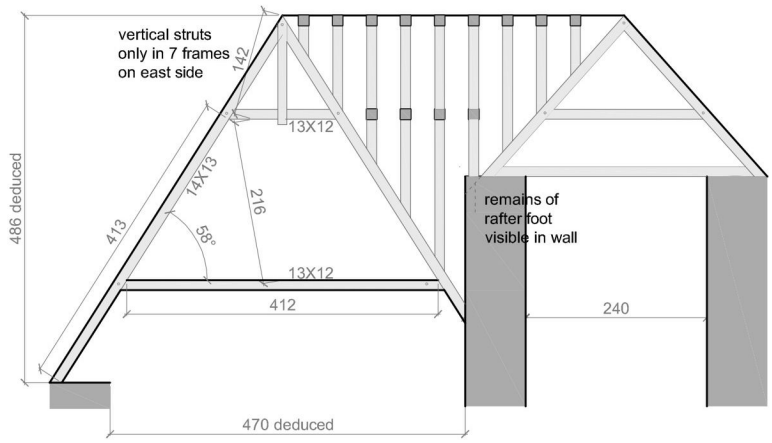
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

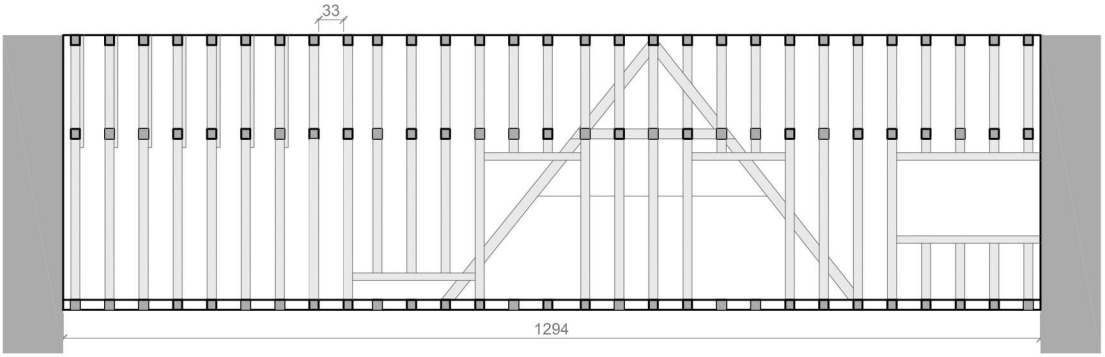
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** FOUNTAINHALL HOUSE | **Roof location** 1: SW range

Survey date(s) 08/07/2015 | See drawing: FH-SW-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4.7 | Roof Height [m]: 4.8

Roof Pitch/es [°]: 58 | Roof Length [m]: 12.9

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.33

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 3.5

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1600 To 1625 | Identified by: Estimated

Roof General Description:

2 two-pitch gabled roofs, joined in the central part by an intersecting roof (which is of later date). Both roofs composed of closely spaced rafter couples connected transversally by two collars and longitudinally by sarking boards only. The connection with the wall of the North side roof is not visible, but the South side roof has remains of rafter feet. The timbers are all full logs hand axed and joined with mortice and tenon joints secured by timber pegs. They are all covered with a black paint (tar probably). They are numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails, Timber Pegs

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 14 | B: 13 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Mostly in sequence.

Signs of reused timbers:

Timber Treated ☑ bitumen

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



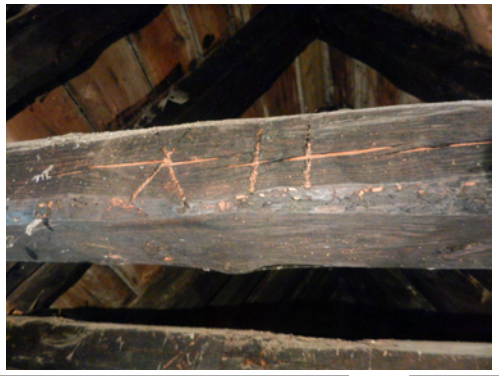
Roof structure | link I:\Arch\A



Timber elements' dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: The connection with the wall on the west side is not visible

Past interventions: Double rafters have been added, and tie-beams as well. Some rafters have been cut to leave space for new dormers. Some sarking has been replaced.



Past interventions | link | I:\Arch\A



Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains on sarking.

Stacking up | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	stacking up	Unknown	Primary
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient overall arrangement
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

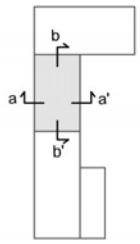
link

Description of visible damage: The frames seem to be leaning to west.

link

Other Notes

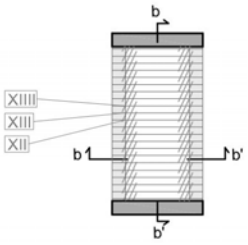
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

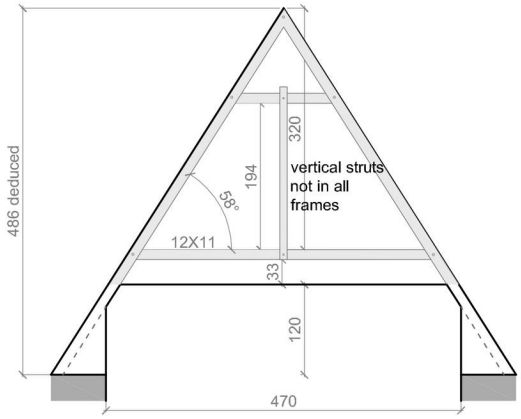
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

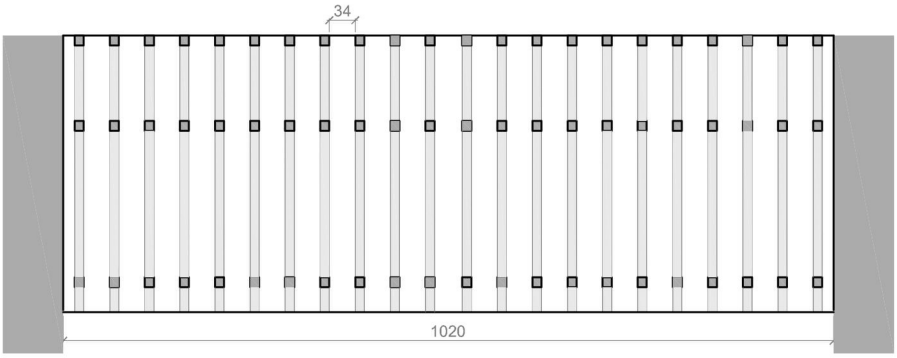
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** FOUNTAINHALL HOUSE | **Roof location** 2: central block

Survey date(s) 08/07/2015 | See drawing: FH-CB-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 4.7 | Roof Height [m]: 4.8

Roof Pitch/es [°]: 58 | Roof Length [m]: 10.2

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ King-strut

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1600 To 1625 | Identified by: Estimated

Roof General Description:

Two-pitch gabled roof, composed of closely spaced rafter couples connected transversally by two collars and longitudinally by sarking boards only. The connection with the wall is not visible. The timbers are all full logs hand axed and joined with mortice and tenon joints secured by timber pegs. They are all covered with a black paint (tar probably). They are numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: | B: | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description:

All mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☑ bitumen

Other Materials:

Dendrochronology:



Roof Structure | link I:\Arch\A



Roof Structure | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: collar and rafter | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Roof visible from hatch only, therefore most of it was not closely inspected/measured

Past interventions



Material degradation | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

insect attack on collar, not sure if active

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes

Attachments link

GARDYNE'S LAND

Location: DUNDEE, CITY OF | DUNDEE (DUNDEE, CITY OF)

X coordinate: 340334 Y coordinate: 730292

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 186050

Original Use: Residential

Current Use: Hotel/Inn

Freestanding ☐ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1560		TOWER HOUSE TO NORTH EAST	HS
People involved:				
ADDITION	1630	1680	MERCHANT HOUSE ON CENTRE SOUTH	SIMPSON AND BROWN
People involved:				
ALTERATION	1700	1725	FRONTAGE ON HIGH STREET	HS
People involved:				
ADDITION	1790		MERCHANT HOUSE ON SOUTHWEST	SIMPSON AND BROWN
People involved:				
ALTERATION	1800	1899		SIMPSON AND BROWN
People involved:				
ADDITION	1820		BUILDING TO REAR (NORTH)	SIMPSON AND BROWN
People involved:				
ADDITION	1870		BUILDING TO EAST	SIMPSON AND BROWN
People involved:				
CONSERVRESTOR	2004	2007	BY TAYSIDE BUILDINGS PRESERVATION TRUST	CANMORE

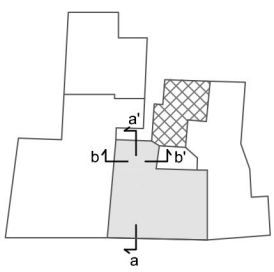
People involved:

Last Name	First Name	Role	Attributed
SIMPSON & BROWN		ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CRONE A.	2001	☑	GARDYNE'S LAND, DUNDEE; DENDROCHRONOLOGICAL ANALYSIS OF STRUCTURAL TIMBERS FOR TAYSIDE BUILDING PRESERVATION TRUS	
GIFFORD J.	2012	☐	THE BUILDINGS OF SCOTLAND COLLECTION: DUNDEE AND ANGUS	
NEWLAND K.	2010	☑	THE ACQUISITION AND USE OF NORWEGIAN TIMBER IN SEVENTEEN CENTURY SCOTLAND, WITH REFERENCE TO THE PRINCIPAL BUILDING JAMES BAINE, HIS MAJESTY'S MASTER WRIGHT	
TAYSIDE BUILDING PRESERVATION TRUST	2004	☑	GARDYNE'S LAND CONSERVATION PLAN	

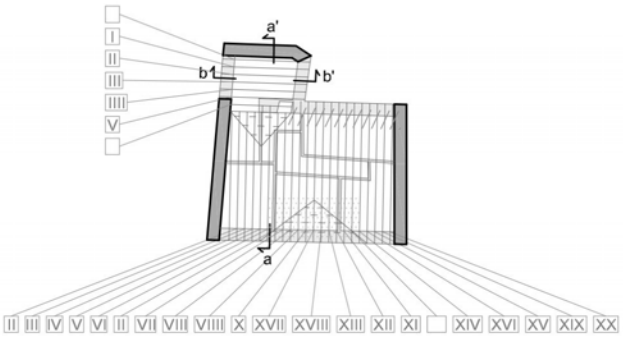
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

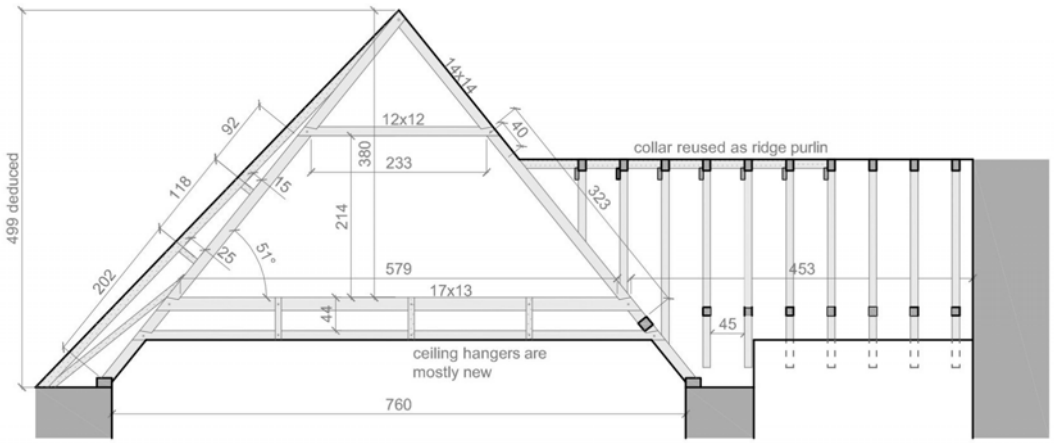
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

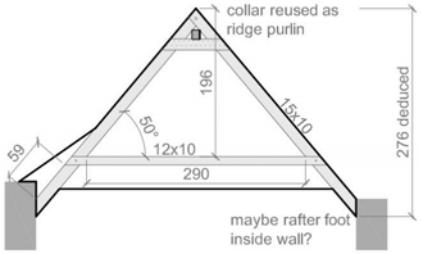
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** GARDYNE'S LAND | **Roof location** 1: centre S, roof spanning NS

Survey date(s) 28/07/2015 | See drawing: GL-CS-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 7.6 | Roof Height [m]: 5

Roof Pitch/es [°]: 51 | Roof Length [m]: 10.9

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 3

Connection with lateral walls: None

Connection with gables:

Roof Construction Period: From 1675 To 1690 | Identified by: Dendrochronol

Roof General Description: Two gabled roofs intersecting perpendicularly. Composed of closely spaced rafter couples connected trasversally by two collars and longitudinally by sarking boards only. The connection with the wall is only partly visible: there seems to be a wall-plate. In the intersection with the other roof there is a purlin suppoorting the rafter lower ends. The timbers are all full logs hand axed and numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 14 | B: 14 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafter's apex: mortice and tenon with timber pegs not flush. Between rafters and collars: lapped chamfered with metal nails.

Wood Species: pinus sylvestris and one oak element (Crone 2001) | Way of identification: dendrochronology

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description: Roman numerals partly in sequence.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology: Carried out by Anne Crone in 2001. Only 5 samples analysed: one is oak, the others pine. No dates fpr pine - only estimation for oak sample



Roof Structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

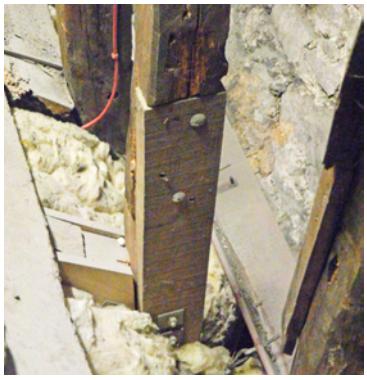
Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall only partly visible

Past interventions: Pitch lowered on south side and sarking replaced, probably in early 18C when the south frontage was remade and small pediment added. Steel cables and beam inserted in 2004/7 to counteract lower collars deflection in correspondence of 18C south gable. Double collars added, and rafters partly replaced (same period).



Past interventions | link | I:\Arch\A

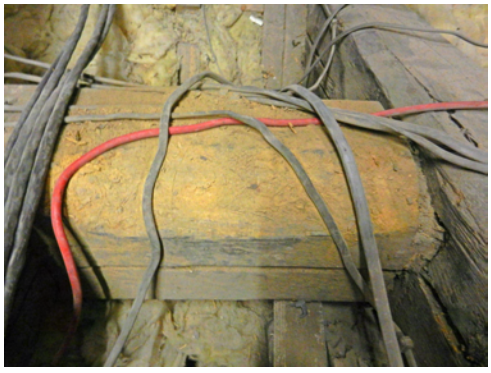
Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Some timbers, not sure if active



Deflection & past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage	Permanent Deformation	Intervened on	Primary
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☑ increase of dead loads
- Extreme actions ☐
- Other ☐

Description of visible damage: Lower collars of frames in correspondance with the 18C south gable are deflected. Steel cables and beam inserted in 2004/7 to counteract deflection - not sure if effective.

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** GARDYNE'S LAND | **Roof location** 2: centre S, roof spanning EW

Survey date(s) 28/07/2015 | See drawing: GL-CS-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4 | Roof Height [m]: 2.76

Roof Pitch/es [°]: 50 | Roof Length [m]: 3.7

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 3

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1675 To 1690 Identified by: Dendrochronol

Roof General Description: Two gabled roofs intersecting perpendicularly. Composed of closely spaced rafter couples connected trasversally by two collars and longitudinally by sarking boards only. The connection with the wall is embedded in the wall: there could be a rafter foot. The timbers are all full logs hand axed and numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 15 B: 10 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☑

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafter's apex: mortice and tenon with timber pegs not flush. Between rafters and collars: lapped chamfered with metal nails.

Wood Species: pinus sylvestris (Crone 2001) | Way of identification: dendrochronology

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: In sequence.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology: Carried out by Anne Crone in 2001. Only 5 samples analysed: one is oak, the others pine. No dates fpr pine - only estimation for oak sample



Roof Structure link I:\Arch\A



Connection with wall link I:\Arch\A



Timber dressing link I:\Arch\A



Joints: rafters' apex link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: presence of water tank

Accessibility limitations: Connection with wall only partly visible

Past interventions: Sarking replaced. Ridge beam added. Prosthesis at rafters ends.



Past interventions | link | I:\Arch\A



Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Some timbers, not sure if active

Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage: | link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

GEILSTON HOUSE

Location: ARGYLL AND BUTE | CARDROSS (ARGYLL AND BUTE)

X coordinate: 234017 Y coordinate: 678278

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC

Protection status: NATIONAL

HS Listing: B Rcahms ID: 141629

Original Use: Residential

Current Use: Not in use

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1666		PROBABLY INCORPORATING EARLIER FABRIC (SQUARE TOWERHOUSE?)	HS
People involved:				
ADDITION, ALTERATION	1729		NORTHEAST KITCHEN WING AND OVERALL REMODELLING	
People involved:				
ADDITION	1787		STABLES BLOCK (MAYBE)	
People involved:				
ADDITION, ALTERATION	1800	1850		HS
People involved:				
ADDITION	1900	1999	NORTHWEST WING, PORCH, GEENHOUSE	
People involved:				
SURVEY	1998		HISTORICAL AND ARCHAEOLOGICAL	NTS DEREK ALEXANDER

People involved:

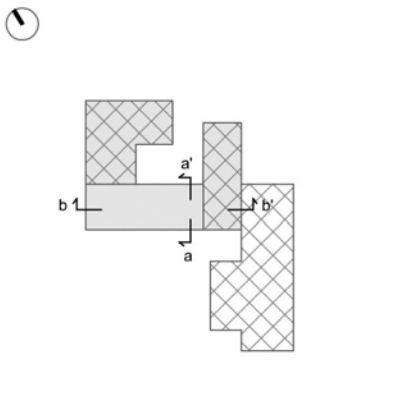
Last Name	First Name	Role	Attributed
ADDYMAN ARCHAEOLOGY		ARCHEOLOGIST	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2006		A STEEL FRAME WAS INSERTED TO HELP SUPPORT THE ROOF AS THE TIMBERS WERE AT QUITE AN ANGLE	NTS DEREK ALEXANDER
People involved:				

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
ARNEIL F.	2000	☐	THE BUILDINGS OF SCOTLAND COLLECTION: ARGYLL AND BUTE	
GLASGOW UNIVERSITY ARCHAEOLOGICAL RESEARCH DIVISION	1998	☑	GEILSTON HOUSE AND GARDEN, CARDROSS - AN HISTORIC BUILDINC LANDSCAPE SURVEY CARRIED OUT ON BEHALF ON THE NATIONAL TF SCOTLAND	

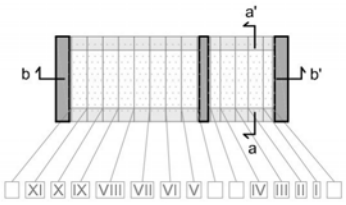
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

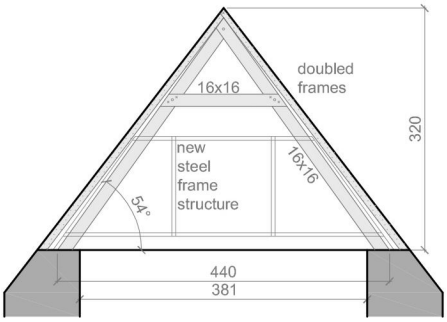
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

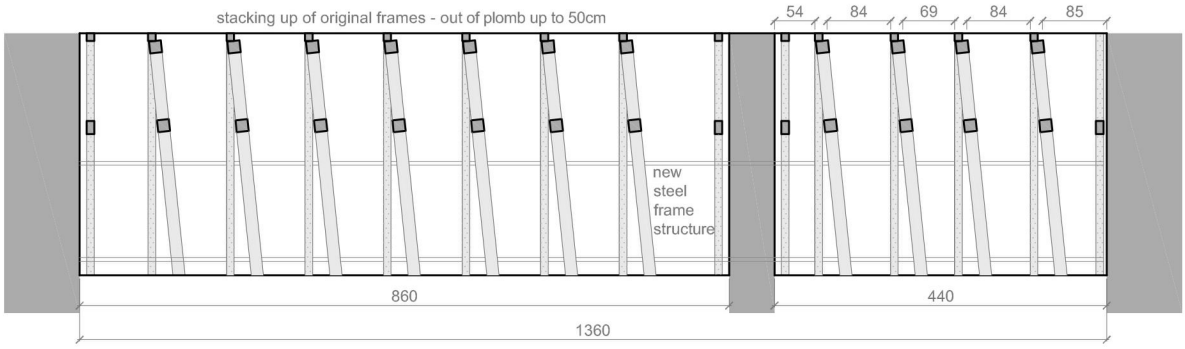
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** GEILSTON HOUSE | **Roof location** SW block

Survey date(s) 20/08/2014 | See drawing: GH-SW-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 3.95 | Roof Height [m]: 3.2

Roof Pitch/es [°]: 54 | Roof Length [m]: 13.6

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.9

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables:

Roof Construction Period: From 1666 To | Identified by: Estimated

Roof General Description:

Gabled roof supported by an intermidiate transversal wall and 14 frames with one collar each. The rafters simply sit on the walls. The frames have been doubled, and some new have been added, and there is a new steel frame structure. Some of the timbers of the original structure look older than the suggested construction date: 1666. They are probably reused timbers from the previous 16C construction. The building is not in use, which hinders its maintenance.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 16 B: 16 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☑

Joint Types: lapped

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters' apex: lapped with timber pegs not flush. Between rafters and collars: lapped with timber pegs not flush and metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: arabic numerals, big roughly cut roman numerals, lettering, runic marks

Carpentry Marks Description:

In sequence numbered I to XII from east to west

Signs of reused timbers:

Some redundant joints - also dressing of the timbers (very rough) suggests a date older than 1666

Timber Treated ☐

Other Materials:

Steel tubes frame

Dendrochronology:



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Redundant joints | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance

Accessibility limitations

Past interventions: Sarking partly replaced. Rafters and collars doubled, with lower pitch. New frames added close to walls. Steel frame structure added between floor and collars, standing on wall-head - supposed to be temporary, has been there for 10 years.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑



Past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	stacking up	Active	Primary
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient overall arrangement
- Poor Construction ☐
- Poor Maintenance ☑
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: stacking up | link | I:\Arch\A

Description of visible damage: Original frames are stacking up in west direction - out of plomb up to 50cm

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

GEORGE FORT

Location	HIGHLAND	ARDERSIER	
X coordinate	276076	Y coordinate	856678
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PUBLIC		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	14317
Original Use	Military		
Current Use	Military, Museum		

Freestanding ☑ N. of floors above ground level

Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
DESIGN	1746		NOT EXECUTED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
CAMPBELL	DUGAL	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1747	1769	FIRST DESIGN FOR THE SITE WHERE THE CROMWELLIAN CITADEL WAS (BEFORE BEING DEMOLISHED), THEN DESIGN MOVED TO PRESENT LOCATION. "ARTILLERY" AND "STAFF" BLOCKS (1762-66); BARRACKS (1757-64); CHAPEL 1763-67	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
SKINNER	COLONEL WILLIAM	DESIGNER	☐
ADAM	WILLIAM	CONTRACTOR, MASTER MASON	☐
ADAM	JOHN	CONTRACTOR, MASTER MASON, MATERIAL SUPPLIER	☐
ADAM	ROBERT	CONTRACTOR	☐
ADAM 1	JAMES 1	CONTRACTOR	☐
MONRO	ANDREW	MATERIAL SUPPLIER	☐
HUNTER	JAMES	MASTER WRIGHT, MATERIAL SUPPLIER	☐
NICHOLSON	ROBERT	WRIGHT	☐
FISHER	JOHN	WRIGHT	☐
GETZEN	ADOLPHUS	WRIGHT	☐
BOODLE	ROBERT	WRIGHT	☐
RUSSELL	JAMES	WRIGHT	☐
WIGTON	JOHN	WRIGHT	☐
LAWSON	WILLIAM	WRIGHT	☐
INNES	HENRY	WRIGHT	☐
MCLAY	WILLIAM	WRIGHT	☐
WIGTON	THOMAS	WRIGHT	☐
REID	DAVID	WRIGHT	☐
MONROE	DONALD	WRIGHT	☐
MCIWIN	JOHN	WRIGHT	☐
WILLSON	ROBERT	WRIGHT	☐
MONROE	ANGUS	WRIGHT	☐
SMITH	JOHN	WRIGHT	☐
GRANT	WILLIAM	WRIGHT	☐

HAY	JAMES	WRIGHT	☐
HOLMES	WILLIAM	WRIGHT	☐
THOMPSON	DUNCAN	WRIGHT	☐
BLACK	DONALD	WRIGHT	☐
FRAZIER	WILLIAM	WRIGHT	☐
ROY	DUNCAN	WRIGHT	☐
MCPHERSON	PETER	WRIGHT	☐
ATKIN	JAMES	WRIGHT	☐
GODDESS	AKEXANDER	WRIGHT	☐
SUTHERLAND	AKEXANDER	WRIGHT	☐
BLACK	JOHN	WRIGHT	☐
DONSKIN	HENRY	WRIGHT	☐
GRAHAM	DONALD	WRIGHT	☐
MURRAY	ROBERT	WRIGHT	☐
SIBBAL	WILLIAM	WRIGHT	☐
YOUNG	ALEXANDER	WRIGHT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CRONE A. & MILLS C.	2008	☑	DENDROCHRONOLOGICAL STUDIES AT FORT GEORGE, ARDERSIER, B INVERNESS	
GIFFORD J.	1992	☐	THE BUILDINGS OF SCOTLAND COLLECTION: HIGHLAND AND ISLAND	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	114
TABRAHAM C. & GROVE D.	1995	☐	FORTRESS SCOTLAND AND THE JACOBITES	92-100

ARCHIVAL REFERENCES

Archive	National Library of Scotland	Doc.Num.	MS 10694	Folios	
Title	Board of Ordnance account book for Fort George				
Archive	National Library of Scotland	Doc.Num.	MS.1646 Z.02	Folios	50a
Title	Plan and Elevations with Sections of the Barracks for 1600 Men and Officers Fort George. By William Skinner (engineer) and Charles Tarrant (draughtsman)				
Archive	National Library of Scotland	Doc.Num.	MS.1646 Z.02	Folios	50b
Title	Plan Elevations and Sections of the North Pile of Barracks Shewing how High they were rais'd in the Year 1754. By William Skinner (engineer)				
Archive	National Library of Scotland	Doc.Num.	MS.1646 Z.02	Folios	47a
Title	Plan Elevation and Section of the Guard House in the Ravelin at Fort George, 1752, No.3. By William Skinner (engineer) and Charles Tarrant (draughtsman)				
Archive	National Library of Scotland	Doc.Num.	MS.1647 Z.02	Folios	55a
Title	Plan Elevation and Sections of the Store-House for Provisions, and Barrack-Masters Stores 1762. By William Skinner (engineer)				

Suggestions for further research: NLS: Board of Ordnance drawings and accounts

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: National Library of Scotland | Doc. Num.: MS.1646 Z.02 | Folios: 47a
Title: Plan Elevation and Section of the Guard House in the Ravelin at Fort George, 1752, No.3. By William Skinner (engineer) and Charles Tarrant (draughtsman) | Date: from 1752 to
Contents:
Summary and comments:

Archive: National Library of Scotland | Doc. Num.: MS.1646 Z.02 | Folios: 50a
Title: Plan and Elevations with Sections of the Barracks for 1600 Men and Officers Fort George. By William Skinner (engineer) and Charles Tarrant (draughtsman) | Date: from 1753 to
Contents:
Summary and comments:

Archive: National Library of Scotland | Doc. Num.: MS.1646 Z.02 | Folios: 50b
Title: Plan Elevations and Sections of the North Pile of Barracks Shewing how High they were rais'd in the Year 1754. By William Skinner (engineer) | Date: from 1754 to
Contents:
Summary and comments:

Archive: National Library of Scotland | Doc. Num.: MS 10694 | Folios:
Title: Board of Ordnance account book for Fort George | Date: from 1757 to 1759
Contents:

Accounts 1757
Mr Adam master mason
Mr Andrew Monro timber merchant
Mr Hunter Master Carpenter
Mr Burton master glazier
Mr Robertson master smith
Mr Syme master slater
James Gray master smith

Account of materials provided by Mr John Adam for Fort George Preceeding the 1st November 1760 and remaining on the spott for for carrying on the works in 1761
door and window jambs
headers or inbands
window lintels
window stools
chimney jambs
…
steps for stairs
pieces of platform stones
…
unwrought free stone
…
bricks
unburnt lime stone
rubble stone
coal
TOT £ 2460.16
Humbly certified by James Branhom, Arch.d Robertson

Fort George 30th September 1757
A*ndrew Monroe merchant in Inverness* provided 20000 nails
James Hunter master carpenter to this office for North Britain humbly prays allowance of the undermentioned oak sashes and frames by him provided & delivered for the officers & soldiers barracks at this place from the 1st May to 30th September 1757 by order of Colonel William Skinner his majesty's chief engineer for Great Britain
2238 feet of oak sashes and frames with leads, lines & pully – £ 223.16

John Adam does foundations, retaining walls, stone and brick work for walls, chimneys

The slater already did £76 work in 1757

Account of sods cut and laid and carts employed in bringing them from the kirk-town to load the lunettes and covered way

Labourers employed […] pileing timber in the timber yard

smith makes spike nails, cramps -> are they for the timbers? they say *spike nails for scaffolding*

Mr George Fern is paymaster of his majesty's works for North Britain

Fort George 31st October 1757
We whose names are underwritten do hereby aknowledge to have received from Mr George Fern paymaster of his majesty's works for North Britain the particular sums against our names expressed for carpenter work by us performed at the above place in sawing timber, framing principle rafters for the soldiers barracks, fixing the ceiling joists of the centre pavilion, pileing timber, and deals, and enclosing the timber yard, and persons attending shops between the 1st Oc.t 31st instant
Rob.t Nicholson 26 days at 2.6 £ 3.5
John Fisher 31 days at 2 £ 3.2
Adolphus Getzen 26 days at 1.6 £1.19
Rob.t Boodle 26 days at 2 £ 2.12
James Russell 25 days at 1.4 £ 1.134
John Wigton 25 days at 1.4 £ 1.134
William Lawson 26 days at 1.4 £ 1.148
Hen. Innis? 26 days at 1.4 £ 1.148
William McLay 26 days at 1.4 £ 1.148
Thom. Wigton 26 days at 1 £ 1.6
Dav.d Reid 26 days at 1 £ 1.6
Don.d Monroe 26 days at 1 £ 1.6
£ 23.68 TOT

Fort George 30th November 1757
We whose names are underwritten do hereby aknowledge to have received from Mr George Fern paymaster of his majesty's works for North Britain the particular sums against our names expressed for carpenter work by us performed at the above place in sawing timber, and framing of rooffs for the north pile of barracks, and persons attending shops between the 1st November & 30th instant
Rob.t Boodle 30 days at 2 £ 3
Adolphus Getzen 26 days at 1.6 £1.19
Rob.t Nicholson 26 days at 1 £ 1.6
James Russell 25 days at 1 £ 1.5
John Wigton 26 days at 1 £ 1.6
William Lawson 26 days at 1 £ 1.6
Hen. Inniss? 25 days at 1 £ 1.5
William McLay 26 days at 1 £ 1.6
Thom. Wigton 26 days at 1 £ 1.6
Dav.d Reid 26 days at 1 £ 1.6
Don.d Monroe 26 days at 1 £ 1.6
John McIwin 26 days at 0.6 £0.13
£ 19.16 TOT

Carpenters accounts in December 1757 for laying floors of the centre pavilion of the north pile of barracks
same names
TOT £20.12

William Caldwell, James Mercer, Robert Bennett – overseers

Carpenters accounts in January 1758 for *laying floors and passages in the room of the centre pavilion of the north pile of barracks*
same names
TOT £ 20

Carpenters accounts in February 1758 for *repairing and mending wheel-barrows, sawing deals, for the same fixing skirting boards, to the rooms and passages of the center pavilion. Repairing the pump of the well and well-stouse*
same names
TOT £ 18.6

Carpenters accounts in March 1758 for *making doors, jambs, architraves, and sofits, for the rooms of the center pavilion. Sawing timber for joists for the soldiers barracks. Mending and repairing wheel-barrows*
same names
TOT £20.13

Carpenters accounts in April 1758 for *sawing timber for joists for the soldiers barracks. Making doors, jambs, architraves and sofits for the rooms of the center pavilion*
same names

TOT £ 23.168

Carpenters accounts in May 1758 for *sawing timber, framing the roofs of the west pavilion. Hanging doors and fisxing on lockson the doors of the center pavilion*
same names + John Wigton
+ labourers paid to assist carpenters in striking and removing centers at the west casemate and laying the floors of the west pavilion

besides carpenters there is only smith work and John Adam master mason

Carpenters accounts in June 1758 for *saw.g of joists, framing and raising the floors of the soldiers barracks and framing the roofs of the west pavilion*
same names + Rob.t Willson, Jam. Allan, Angus Monroe, John Smith, William Grant, James Hay, Will.m Holmes, Duncan Thompson, Don.d Black, Will.m Frazier, Duncan Roy, Peter McPherson
TOT £ 19.94

Carpenters accounts in July 1758 for *sawing timber for joists, and framing of floors for the soldiers barracks, Making ribs for centers for the magazine and door and window frames for the same. Making hand barrows. Raising scaffolding. Making gangways and repairing tools*
same names + James Atkin, Alex.r Goddess, Alex.r Sutherland, John Black, Hen. Donskin, Don. Graham, Rob.t Murray, William Sibbal, Alex.r Young
TOT £ 43.14

Adolphus Getzen also provides stone, leather, window nails, sprig nails, sheep skin…

Andrew Monro provides nails

John Chiselm provides deals: *1440 single deals 10 feet long at 5… £ 60* – August 1758

Task men and *country men* and *soldiers* employed for minor works and assisting carpenters

Carpenters accounts in august 1758 - £ 39.154
Carpenters accounts in September 1758 - £ 19.14 (they make a gate for the entrance)

Andrew Monro merchant in Inverness supplies *5348 feet solid of square firr timber for girders, tye beams principal rafters, purloins, and joisting for the building £ 312.17 – 50 feet cubical of barr iron £ 4.13*

Carpenters accounts October 1758 for *repairing timber for door jambs and soffits of the west pavilion and making rough shutters for the windows of the same. Making and setting centers for the great powder magazine and covering the same with sheeting boards. Making and hanging the rough gate of the north gateway*
TOT £ 26.12

Carpenters accounts November 1758 £ 22.12
they become less, retaining people from the "first" team
but they always have "task men" and "country men" assisting them

Carpenters accounts January 1759 £ 25.56

Carpenters accounts February 1759 £ 22.7

Carpenters accounts March 1759 £ 26

Carpenters accounts April 1759 £ 27.184

Carpenters accounts May 1759 £ 32.136 *in sawing timbers for rafters and wall-plates for the soldiers barracks*

Carpenters accounts June 1759 £ 31.108 *framing small rafters, roofing the west wing, making a temporary bridge […]*

Alexander Murray merchant provides large axes and hatchets?

Carpenters accounts July 1759 £ 44.17 *laying a temporary floor […] platforms for guns*

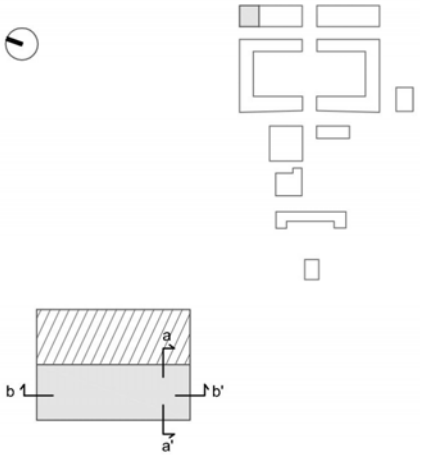
Provided gleu? and oile, sprig nails, ropes, window jacks?

Hugh Falconer merchant provides deals: 564+384+27 single deals 10 feet long 1 ¼ thick – TOT £ 52.13
David Frigge also provides deals: 376 single deals £ 18

Carpenters accounts August 1759 £ 21.19

Carpenters accounts September 1759 £ 16.17 + 24.11 + 21.4 (floor) + 10.10 (doors)

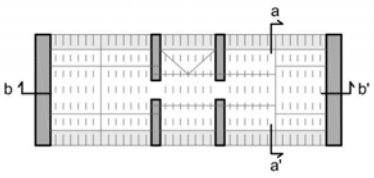
Summary and comments					
Archive	National Library of Scotland	Doc. Num.	MS.1647 Z.02	Folios	55a
Title	Plan Elevation and Sections of the Store-House for Provisions, and Barrack-Masters Stores 1762. By William Skinner (engineer)	Date: from	1762	to	
Contents					
Summary and comments					



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

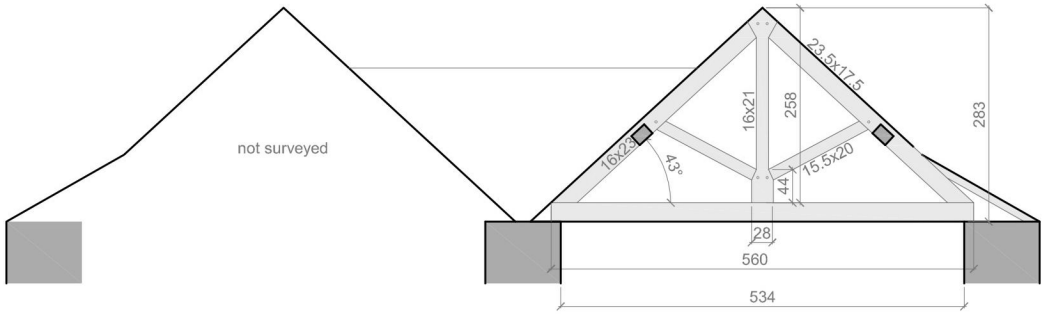
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

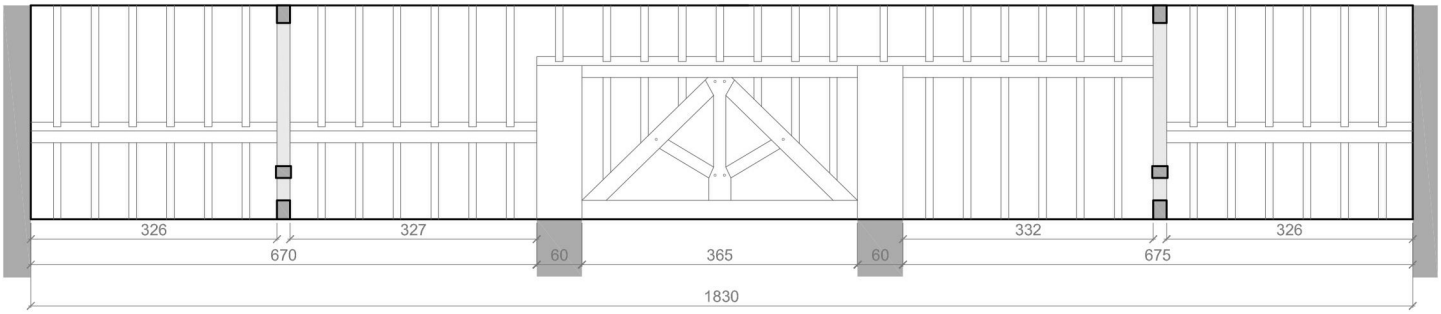
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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0 1 5



Roof from outside I:\Arch\A

INITIAL SURVEY | **Building name** GEORGE FORT | **Roof location** Museum

Survey date(s) 04/09/2014 | See drawing: GF-M-1

Roof Geometry: M roof, Two-pitch gabled with intersections

Roof Max Span [m]: 5.34 | Roof Height [m]: 2.83

Roof Pitch/es [°]: 43 | Roof Length [m]: 18.3

Type of Primary Structure: 2D framing, Purlins

Truss ☑ KING-POST

Frame ☐

Average Distance in between Primary Structure [m]: 3.25

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Tie-beam

Connection with gables:

Roof Construction Period: From 1764 To | Identified by: Estimated

Roof General Description:

Gabled M roof covering a double pile building. Only Western half could be surveyed. Supported by 2 transversal walls not reaching the ridge, 2 king post trusses on the sides and purlins (resting on the intermediate walls) in the middle. Trusses have a tie-beam, a kingpost and 2 slanted struts. There are sprocket rafters on the West side. Smaller king-post trusses support an intersecting roof on the West side. The timbers are well squared, hand axed, with big scantlings. No visible numbering.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 23.5 B: 17.5 | Or Purlin - H: 16 B 23

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: joggle, mortice and tenon

Fasteners Types: Timber dowel

Joints description: All mortice and tenon with timber dowels. The post has joggles.

Wood Species: pinus sylvestris (AOC 2008) | Way of identification: dendrochronology

Carpentry Marks Types:

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure: side sections | link I:\Arch\A



Roof structure: middle section | link I:\Arch\A



Roof structure: intersecting roof | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: post, tie-beam and struts | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions

link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	link I:\Arch\A
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

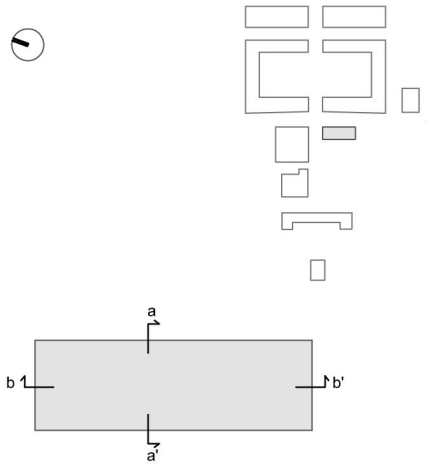
Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes

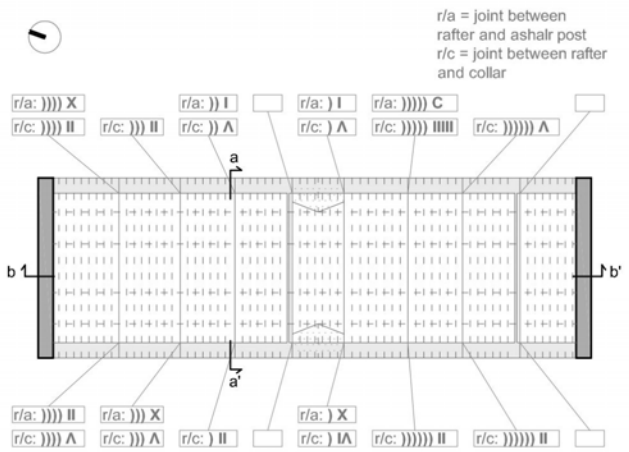
Attachments I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

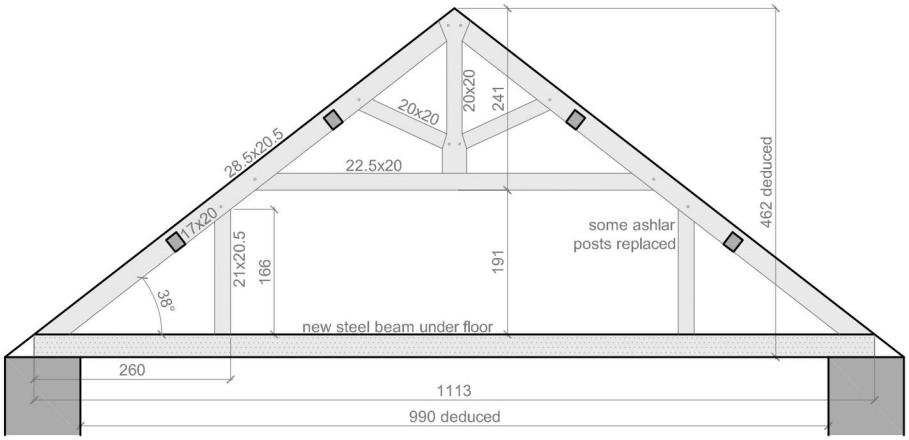
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

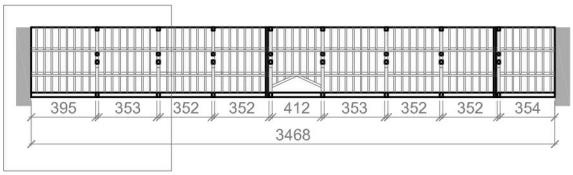
Section aa'

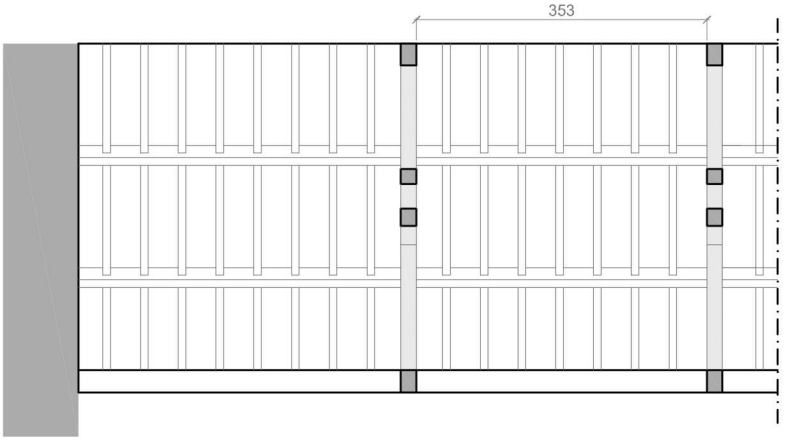


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** GEORGE FORT | **Roof location** South Ordnance Store

Survey date(s) 04/09/2014 | See drawing: GF-SOS-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 9.9 | Roof Height [m]: 4.62

Roof Pitch/es [°]: 38 | Roof Length [m]: 34.68

Type of Primary Structure: 2D framing

Truss ☑ PRINCESS-POST

Frame ☐

Average Distance in between Primary Structure [m]: 3.5

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1759 To 1761 | Identified by: Dendrochronol

Roof General Description: Gabled roof supported by 8 princess post trusses. Trusses have 2 butt-purlins on each side, probably a tie-beam (it is not visible), a collar, 2 slanted struts and 2 ashlar posts. The timbers are well squared, hand axed, with big scantlings. There are some unusual carpentry marks.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 28.5 | B: 20.5 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: joggle, mortice and tenon

Fasteners Types: Timber dowel, Timber peg not flush

Joints description: All mortice and tenon with timber dowels, except for purlins that have timber pegs not flush. The post has joggles.

Wood Species: pinus sylvestris (AOC 2008) | Way of identification: dendrochronology

Carpentry Marks Types: runic marks, small chiseled roman numerals

Carpentry Marks Description: Mix of small chiselled roman numerals and small half circles (from scandinavia?). Some of them are double, on each side of the joint, some of them are put across the members on the joint. There is C next to a joint.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology: dendrochronology carried out on the roof structure by Anne Crone and dated to 1757 (pine from southern Russia, possibly Belarus)



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Joints: post and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Carpentry marks | link I:\Arch\A

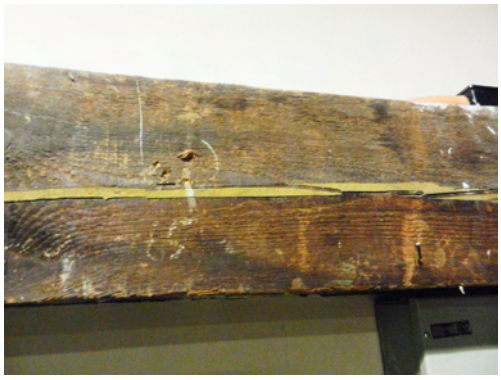
Roof space in use ☑ Insulation on ceiling ☐ Insulation on sarking ☑

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not visible

Past interventions: Some sarking replaced and the two intersecting roofs have all new timbers. Tie-beams replaced with steel beams, not sure if only one or all of them. Checks filled with resin. Some ashlar posts replaced



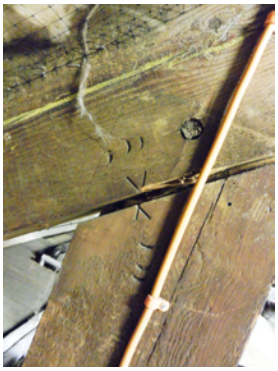
Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐



Damage: disconnection | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage	Disconnection	Unknown	Collateral



Damage: disconnection | link | I:\Arch\A

Estimated cause(s) of the primary damage:

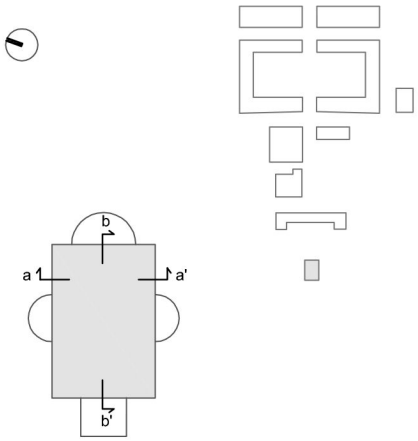
- Poor Design ☑ inefficient joints
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: Joints between ashlar post and rafter are opening. Probably connected with tie-beam deflection, which is probably why tie-beam has been substituted.

link

Other Notes

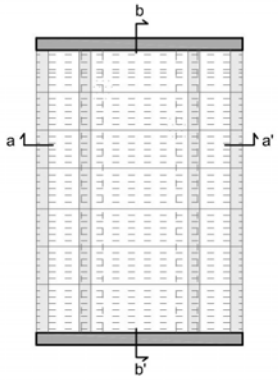
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

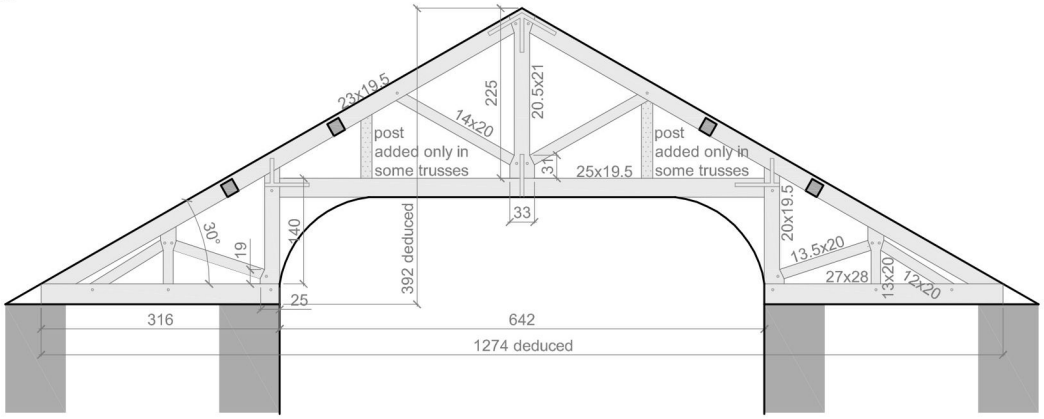
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

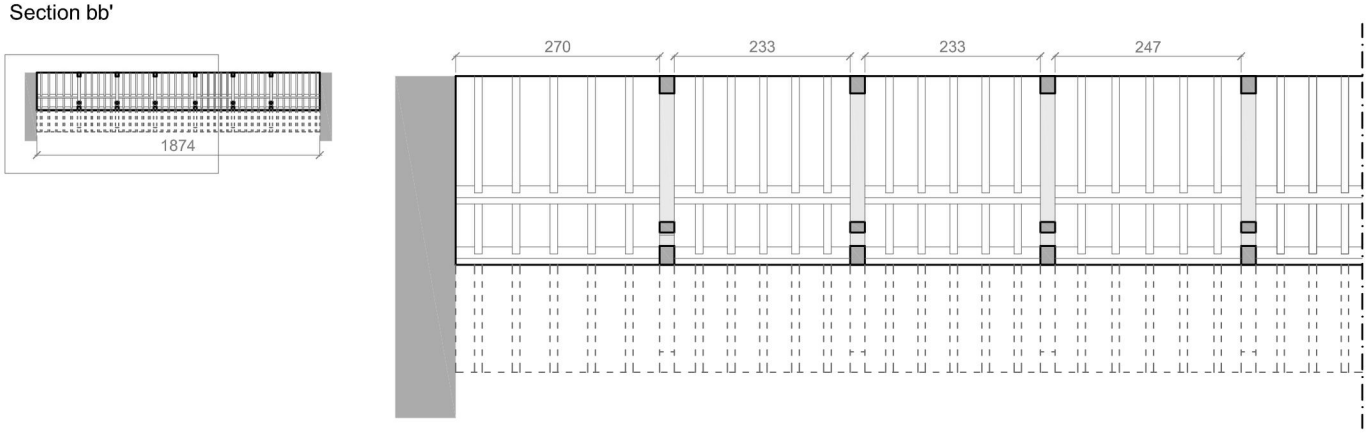
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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Roof from outside I:\Arch\A



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** GEORGE FORT | **Roof location** Chapel

Survey date(s) 05/09/2014 | See drawing: GF-C-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.42 | Roof Height [m]: 3.92

Roof Pitch/es [°]: 30 | Roof Length [m]: 18.74

Type of Primary Structure: 2D framing

Truss ☑ PRINCESS-POST

Frame ☐

Average Distance in between Primary Structure [m]: 2.5

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Tie-beam

Connection with gables:

Roof Construction Period: From 1763 To | Identified by: Dendrochronol

Roof General Description: Gabled roof supported by 6 princess post trusses that sit on the lateral walls and intermidiate columns. Trusses have 2 butt-purlins on each side, 5 posts and slanted struts supporting the tie-beam interrupted by the curved ceiling underneath. The timbers are well squared, hand axed, with big scantlings. No visible numbering.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 23 B: 19.5 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: joggle, mortice and tenon

Fasteners Types: Metal strap, Timber dowel

Joints description: All mortice and tenon with timber dowels. Metal stripes at rafters' apex, between the upper post and the collar and between the lower posts and the collar. Posts have joggles.

Wood Species: pinus sylvestris - 1 kingpost spruce (AOC 2008) | Way of identification: dendrochronology

Carpentry Marks Types:

Carpentry Marks Description: Not visible

Signs of reused timbers:

Timber Treated ☐

Other Materials: Metal straps in some joints

Dendrochronology: dendrochronology carried out on the roof structure by Anne Crone and dated to 1762/64 (pine from Karelia, a region spanning the modern finnish/russian border and close to St Petersburg)



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: post and tie-beam | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: Original plaster ceiling underneath

Unfavourable conditions: poor ventilation

Accessibility limitations:

Past interventions: Some common rafters and sarking replaced



Past interventions | link | I:\Arch\A



Material degradation | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☐

Humidity stains on sarking, common rafters and purlins. Insect attack on purlin, not sure if active

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

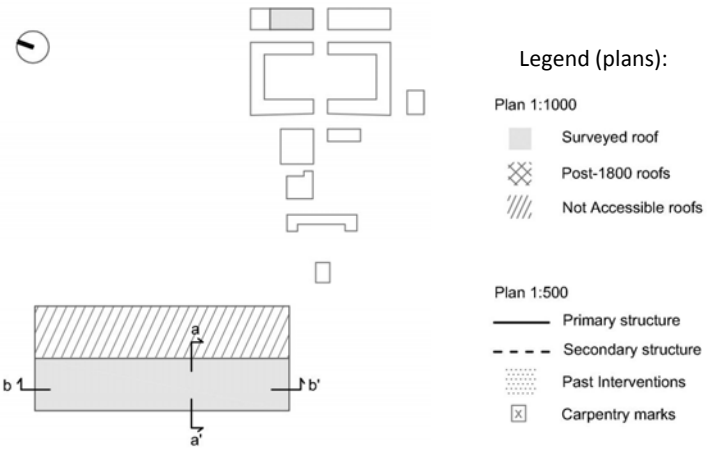
Estimated cause(s) of the primary damage: | link | I:\Arch\A

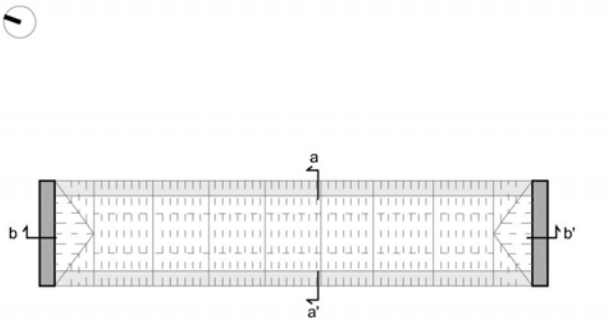
- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link





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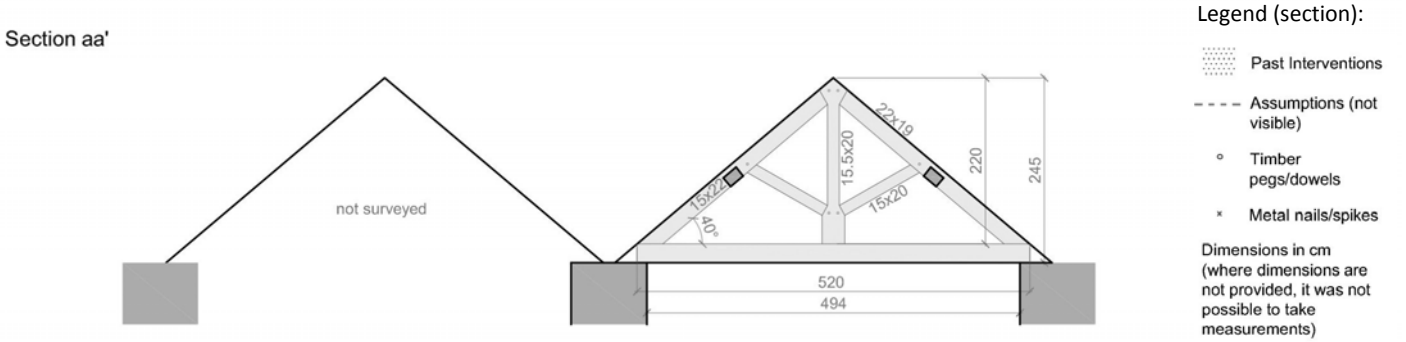
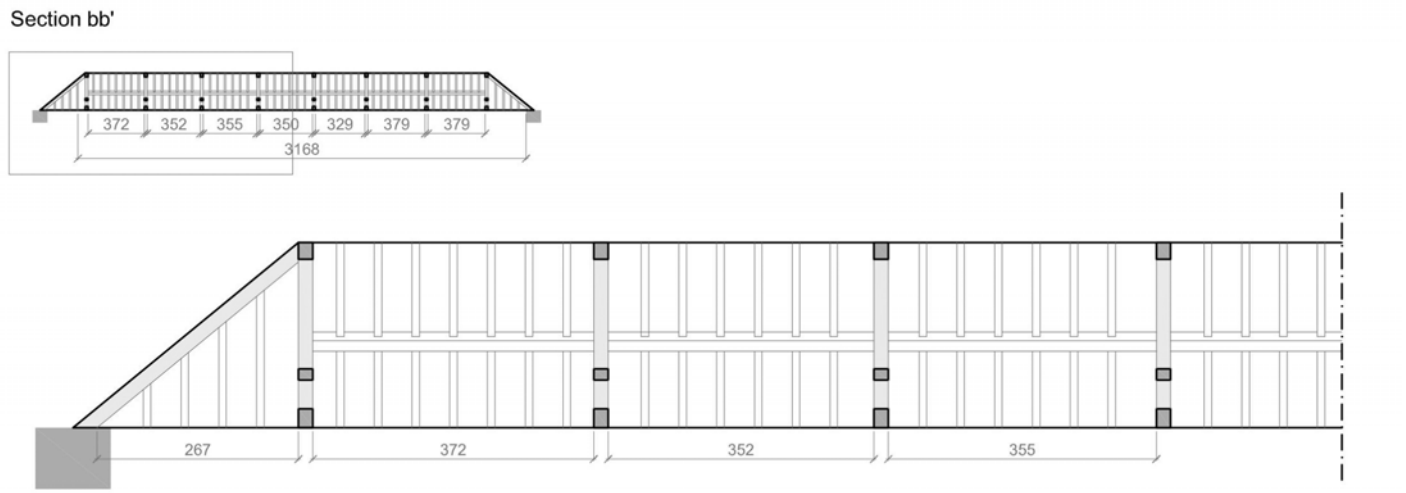
Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

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Roof from outside I:\Arch\A



Roof from outside I:\Arch\A

INITIAL SURVEY **Building name** GEORGE FORT **Roof location** Staff block

Survey date(s) 04/09/2014 See drawing: GF-SB-1

Roof Geometry: Hipped, M roof

Roof Max Span [m]: 4.94 Roof Height [m]: 2.45

Roof Pitch/es [°]: 40 Roof Length [m]: 31.68

Type of Primary Structure: 2D framing

Truss ☑ KING-POST

Frame ☐

Average Distance in between Primary Structure [m]: 3.5

Type of Secondary Structure: common rafters, purlins, sa Plane: roof plane

Sarking boards: width [cm] thickness [cm]

Connection with lateral walls: Tie-beam

Connection with gables:

Roof Construction Period: From 1762 To 1764 Identified by: Dendrochronol

Roof General Description: Hipped M roof covering a double pile building. Only East roof could be surveyed. It is supported by 8 king post trusses with a butt-purlin on each side (in some sections there is a second purlin). Trusses have a tie-beam, a kingpost and 2 slanted struts. The timbers are well squared, hand axed, with big scantlings. No visible numbering.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 22 B: 19 Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: joggle, mortice and tenon

Fasteners Types: Timber dowel, Timber peg not flush

Joints description: All mortice and tenon with timber dowels, except purlins that sometimes have timber pegs not flush. The post has joggles

Wood Species: pinus sylvestris (AOC 2008) Way of identification: dendrochronology

Carpentry Marks Types:

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology: dendrochronology carried out on the roof structure by Anne Crone and dated to 1762-1764 (pine from Karelia, a region spanning the modern finnish/russian border and close to St Petersburg)



Roof structure link I:\Arch\A



Roof structure: hip rafter link I:\Arch\A



Timber dressing link I:\Arch\A



Joints: rafter, strut, purlin link I:\Arch\A



Joints: rafters' apex link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation

Accessibility limitations

Past interventions

link

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	link
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui link

GEORGE HERIOT'S HOSPITAL SCHOOL

Location	EDINBURGH, CITY OF	EDINBURGH (EDINBURGH, CITY OF)	
X coordinate	325485	Y coordinate	673186
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PRIVATE		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	52134
Original Use	Hospital, School		
Current Use	School		

Freestanding ☑ N. of floors above ground level 4 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1628	1631	PLAN CHOSEN BY GEORGE HERIOT: PALACE IN SERLIO'S 7TH BOOK OF ARCHITECTURE (1550); WORKS STARTED AT THE NORTHWEST TOWER AND REACHED THE FIRST FLOOR WHEN WALLACE DIED IN 1631	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
MURRAY	SIR JAMES	ARCHITECT, ROYAL MASTER OF WORKS, WRIGHT	☑
HERIOT	GEORGE	COMMISSIONERPATRON	☐
WALLACE	WILLIAM	DESIGNER, ROYAL MASTER MASON	☐
AYTOUN	WILLIAM	ROYAL MASON	☐
DAVIDSON	ANDREW	OVERSEER	☐
ROBERTSON	DAVID	MATERIAL SUPPLIER	☐
BANNATYNE THE YOUNGE	JAMES	MATERIAL SUPPLIER	☐
GILBERT	JAMES	MASON	☐
SHORT	ROBERT	MASON	☐
MACMATH	JAMES	OVERSEER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION, CONSTRUCTION	1631	1647	CONSTRUCTION CONTINUED BY WALLACE'S ASSISTANTS. IN 1633 THE CHAPEL ROOF WAS COVERED IN LEAD. LEAD OGEE ROOFS ON THE TWO NORTH TOWERS WERE DISMANTLED AND REDONE FLAT, AND THE ATTIC BETWEEN THEM BUILT UP IN 1642. NORTH RANGE ROOF WAS REDONE FLAT BEFORE 1647	LOCKHART 2009

People involved:

Last Name	First Name	Role	Attributed
AYTOUN	WILLIAM	CONTRACTOR	☐
WATT	JOHN	CONTRACTOR, MASON	☐
CORNELISONE	PETER	MATERIAL SUPPLIER	☐
BLAND	JOHN	PLUMBER	☐
MYLNE	JOHN JUNIOR (3)	MASTER MASON	☐
HAMILTON	JOHN	MASON	☐
STIRLING	JAMES	MASON	☑
SCOTT	JOHN	WRIGHT	☐
BUCHGUHANNAN	JOHN	WRIGHT	☐
LAUDER	HENRY	WRIGHT	☐
HERIOT	JOHN	WRIGHT	☐
HERIOT	JAMES	WRIGHT	☐
HERIOT	GEORGE	WRIGHT	☐

CRYSHE	JAMES	WRIGHT	☐
WATSON	THOMAS	WRIGHT	☐
JOHNSTONE	JAMES	WRIGHT	☐
RIDDOCH	JAMES	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1648		TAKE DOWN THE SOUTHWEST TOWER ROOF AND REBUID IT FLAT AS THE NORTH ONES	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
SCOTT	JOHN	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1649		TAKE DOWN THE SOUTHEAST TOWER ROOF AND REBUID IT FLAT AS THE OTHER ONES	LOCKHART 2009

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1659		REPAIRS AFTER RAINSTORMS	LOCKHART 2009

People involved:

Last Name	First Name	Role	Attributed
MYLNE	JOHN JUNIOR (3)	MASTER MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1673	1683	CHAPEL REPAIRED BUT WALLS LEFT BARE AND ROOF LEFT WITH NO ORNAMENT. MATERIALS FROM DISMANTLED KIRK AT CROMWELL'S CITADEL IN LEITH WERE USED.	LOCKHART 2009

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION, DESIGN	1675		TOP OF THE ENTRANCE TOWER	LOCKHART 2009

People involved:

Last Name	First Name	Role	Attributed
MYLNE 1	ROBERT 1	CONTRACTOR, DESIGNER	☐
SMITH 1	JAMES 1	CONTRACTOR	☐
BRUCE 1	SIR WILLIAM 1	ARCHITECT, DESIGNER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1683	1684	WRIGHT WORK IN CHAPEL AND SUMMER HOUSE	NRS GD421/10/68

People involved:

Last Name	First Name	Role	Attributed
SANDILANDS	THOMAS	WRIGHT	☐
OGSTOUNE	JOHN	WRIGHT	☐
MILLAR	JOHN	WRIGHT	☐
WILSON	THOMAS	WRIGHT	☐
CHYRMSYD	THOMAS	WRIGHT	☐
MARSHALL	WILLIAM	WRIGHT	☐
STEWART	GEORGE	WRIGHT	☐
POTTAR	WILLIAM	WRIGHT	☐
SCOTT	JOHN	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1684		REPAIRS TO SOUTHEAST AND SOUTHWEST QUARTERS	LOCKHART 2009

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1727		REPAIRS TO EAST SIDE FOR £200	LOCKHART 2009

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1762	1765	ENTRANCE AVENUE AND STEPS	LOCKHART 2009

People involved:

Last Name	First Name	Role	Attributed
ADAM	JOHN	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1787		CHAPEL REFITTED WITH ADAMESQUE CEILING INSERTED	LOCKHART 2009

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1833		NORTH FRONT REDONE IN ASHLAR: SIX INCHES WERE REMOVED FROM THE WALLS AND REPLACED BY HEWN STONE - THEY EXPERIMENTED THE TECHNIQUE BEFORE ON THE RECEDING PART OF THE SOUTH FRONT	LOCKHART 2009

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1834	1836	INTERIORS OF CHAPEL REDONE, CEILING INCLUDED	LOCKHART 2009

People involved:

Last Name	First Name	Role	Attributed
GRAHAM	JAMES GILLESPIE	ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	138-155
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	74
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	67, 88
HANKE T.	2004	☐	THE STABLE OF HALKERSTON LODGE AND MORAY HOUSE - ROOF ARCHITECTURE OF THE 1630S AROUND EDINBURGH	
LOCKHART B. R. W	2003	☐	JINGLIN GEORDIE'S LEGACY: A HISTORY OF GEORGE HERIOT'S HOSPI SCHOOL	
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	9
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	4
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 105, 106

ARCHIVAL REFERENCES

Archive	National Records of Scotland	Doc.Num.	GD421/5/2	Folios	
Title	Heriot's Hospital Treasurer's Accounts				
Archive	National Records of Scotland	Doc.Num.	GD421/10/68	Folios	
Title	Account of wright work in George Heriot's Chapel and summer house by Thomas Sandilands				
Archive	Private: school archives	Doc.Num.	Uncatalogued drawing	Folios	
Title	George Heriot's School. Proposed additional class rooms. Plan and sections showing the roof of the East and West ranges.				
Archive	Royal Commission on the Ancient and Historical Monuments of Scotland	Doc.Num.	DP 055037	Folios	
Title	Sections through quadrangle including interior elevations of chapel, dining hall and classrooms. Title: 'GEORGE HERIOT'S HOSPITAL EDINBURGH'.				
Archive	National Records of Scotland	Doc.Num.	GD421/5/3	Folios	
Title	Heriot's Hospital Treasurer's Accounts 1642-1652				
Archive	National Records of Scotland	Doc.Num.	GD421/5/4	Folios	
Title	Heriot's Hospital Treasurer's Accounts 1652-69				
Archive	Royal Commission on the Ancient and Historical Monuments of	Doc.Num.	D.8.41.HER.P	Folios	

	Scotland				
Title	Heriot's Hospital - a short history by D. PRYDE. Extracts from minutes of George Heriot's Trustees. Special articles commemorating the 350th anniversary of the laying of the foundation stone, from the HERIOTER July 1978				
Archive	Private: school archives	Doc.Num.	Uncatalogued reports	Folios	
Title	Reports on repair works carried out on the roofs of George Heriot Hospital				

Suggestions for further research

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: National Records of Scotland | Doc. Num.: GD421/5/2 | Folios:

Title: Heriot's Hospital Treasurer's Accounts | Date: from 1633 to 1642

Contents

** Nov. 1633 - Nov. 1634 William Cochrane
??? William Cochrane his compt of his ??? ??? ??? ??? ??? ??? and ??? particularis belonging to ??? charge heriof his hospital? ??? the treheme? day of November 1633 ????????? day of November 1634 ???
Charge
The compter charged himself with the ?primll? ??? and ?????????????
Imprimis the compter charged himself with that ??? afterward ??? ??? ??? the said hospitall at the fitting of ??? said compt ??? ??? ??? the ??? day of aprrril 1634 ??? ??? be the said ?????????????
??? the 22 of November 1633 ??? from ??? lord ??? the address of ?????? if 5000 markis from ??? 1632 to ??? 1633 the ??? ???
[…]
??? the said day from Jon smyth of ???
[…]
Com? the said day from Johne Gorddonthe name of the lord ??? the amount? of 2000 tib ???????? 1633
???? 20 Januray 1634
James ???
Johnestone
Thomas???
??? Murray
[…]
Icom the compter charged himselff of the formis and feynil of the ??? of ??? ??? to the said hospital ??? ??? 1633 ??? they are fet and ????????? following
[…]
I com the compter charged himself of that after he has ressamto
Discharge
Followes the said William Cochrane his ??? of his intcoming soum With the ??? Srm.ll ??? and by Eis ??? and ??? ??? ??? be hime and payit and debursit be hime to ??? during the tyme forsaid ??? according to the particularis following
Imprimis ??? the fyift day of december 1633 lent to my lord ??? and his band bearis
*Item the sayt of december to **Johne hamiltoun of orbefton** and his ??? conforme to the band*
Item the same day and ??? ??? of Juny 1634 to Jonat ??? ??? to Charge ??? be yave mertunes ??? ??? 1633 and witsenday 1634 ??? be yave discharges
*Item ??? the feift day of februar **payit to Johne Jonsso in name of maister John Jonstone** of ??? ??? the ??? of ??? the said ??? ??? him from the ??? and ??? of mertimes 1632 to ??? 1633*
Item the ??? day of Juny lent to ??? ??? ??? his twa band bearis
Item the 18 of Juny lent to the lord ??? conforme to the band maid be him and his ??? yairanents
*Item payit to the laird of ??? and ??? oliphant ??? clerk **in name of Jon Scott** sumtyme of discharge for the ??? of ??? ??? arboris of laird ??? brighton ??? be ??? from the said Jon Scott ??? ??? the ??? and to his ??? at the ??? ??? ??? ??? consent ???????????*
Item ??? lent to the guard house of ??? at nortsonday 1634
The compter is ??? dischairgis of the particularis Debursit be him forgone the ??? and building of the hospitall and persone ??? materialls & ??? as followes
*Item forgone the 16 day of november the 1633 this compt of the ??? **maissones to Jon wat***
Item ??? may ??? fyve dayes and ane halfaday ???
*Item to **Albert sehortson** ??? and ??? gray all and haill ??? at ??? the peice ???*
*Item to **Goerge Stirling** ??? cunyinghame **James aytoun** ??? prestone ??? ???day menzes James ???sone Jon ??? ??? George honeymane Jon pillones ??? ??? all ??? and haill ??? at ??? the peice*
Item to ??? ??? ??? and to thomas ??? 5 days and ane half at
*Item to Michel ??? **jon thomsone James broun James Stirling Jon Hamiltoun Thomas gairdiner jon cunynghame** ??? ??? ??? barne **Simeone barrie thomas greay** and ??? all at all 12 ane haill ??? ???*
*Item to **Johne porteous** five dayes at ??? the day*
*Item to **James home** and **Jon hamiltoun** ane haill ???*
Item to wm wallace ane ???????
Item to patrick ??? and ??? patersone ane haill all
Item to James guhyte???
[...]
Item the 23 of no? 1633 to Jon ????????
*Item to ??? and **Jon bryce** ane haill all*
*Item to ??? 5 dayes and ane halfaday ??? cunynghame **Ja? aytoun** James ??? ??? ??? **Johne menzers** ??? maine James ??? ??? ??? ??? ??? **George homeyman** ??? ??? **wam aytoun** all and haill ???*
Item to wam aytoun ??? haill ???
*Item to Mitchaell ??? **Jon Thomsone** James ??? **Jon porteous Jon hamiltoun Thomas gardener Jon cunynghame** ??? ??? ??? **Symeone Barry Thomas Greay** and ??? ??? all ane haill ??? at 54s. the peice ???*

*Item to **James home** and **Jon hamiltone** and ???*
*Item to **wam wallace** ane day*
*Item to **Jon Pillones** ane haill ???*
*Item to **patrick cullane** and ??? patersone ??????*
*Item to **Jon Gairdner** James ??? **patrick witherspune** Jon ???rsone **James Stirling** ??? twa ogeris rabattis and Thomas ??? ??? and ???*
Item to Williame ??? for ??? of 20 ??? ??? ??? jon ??? 15 James ??? henrie ??? 16 and ??? ??? 6 ??? 93 ???
Item to Ja? ??? and Jon ??? ??? & ??? at 6 ???
Item to ??????????????
*Item to **James Walmate** and ??? Jamiesone*
*Item to **Jon Ronald** ?????????*
Item for 37 ????????
[...]
*Item to **Williame mure** and Johne ??????????*
[...]
*Item to **George Duncane** and **George ramsay** ????????*
Item the ??? of november ?????????
*Item to **Albert gray** ??? ??? and **Jon bryce** ???????????*
*Item to **wam aytoun** and ???*
*Item to ??? ??? ??? cunynghame **wm aytoun** thomas ??? ??? ??? ??? **James cuthbertsone** Jon ???ahie **James finart George honeyman Jon pillones** and **wam aytoun** all and hailll ane ??? ???*
Item to ??? ??? Jon thomson James broun Jon Porteous thomas gardner ??? ??? Symeone barry thomas greay and ??? abbott all haill ane haill ??? at 54 ???
Item to Jon hamilton and Jon cunynhame ??? ane 5 days at 9 s ??? day
Item to James home and Jon hamilton and haill ??? at 48 s the peice is
Item to wm wallace and ???????
*Item to patrick cullane and haill ??? 24 s and to **Albert patersone** ane day ???*
Item to ??? ??? James ????????? [...] Thomas ???????
*Item to **James Stirling** and ??? ??? patrik witherspune **Jon hamiersone** and Jon ???????????*
Item to Thomas abeel ??????
[...] Jon Ronnald [...] Jon maissone
Item the ??? 1633 to Jon ??? 5 days and ane half
Item to wam aytoun 5 days and ane half at 26 s a day
Item to Habert ??? ??? and Jon bryce anie ???
Item to (six) twelf maisones and ??? ???
*Item to ??? ??? James aytoun thomas ??? **Hobert preston** Jon ??? and James finart 5 days ane ??? and **Jon ritchie** ane day at ???*
Item to twelf maisons all ane haill oulb? at 54 s. the peice
Item to Jon hamilton and James home ane haill oulb? at 48 s. the peice is
Item to wam wallace ane haill oulb 40 s. and Jon pillones 30 s.
Item to patrick allane and Ho.t Patersone ane ??????
*Item to **James beng**? for hewing of 19 ornells wam meyie 21 **Ho.t algare** 21 Johne clarl??? and **henrie cubersone**? 23 ????????????? ornellis at 3 s. 4 d. the peice*
Item to James Stirling for hewing of 5 ogeris James pitte??? patrick witherspune 2 wam ??? 2 Jon handersone 2 Jon gardiner ??? and thomas abell 2 the of all ogeris at 30 s. the peice
Item to James broun Symeone barrie and thomas gray ??? twa rabettis a peice at 30 s.
Item to Jon ??? 3 rabettis thomas ??? twa and Holbert all of ane the os all for rabett at 26£ day
Item to Johne craufurd for hewing of ten ??? James ??? 8 ??? 8 and wan ??? in all 33 at 6s. 8 d.
Item to 5 ??? ??? for hewing of fyve orna??? at 3 s. 4 d. the peice
Item to 4 workmen ane haill oulb at 30 s. and ??????????????
[...] 60 laid walstones [...]
Item to Johne maissone and wam mure ??? 4 futis and 6/3 ??? at 3s. 4d.
[...]
Item the 14 of december to Jon ???????????
Item to Ho.t ??? ??? ??? and Jon bryce all ane haill ??? at 4 ???
*Item to ??? ??? ??? cunynghame James aytoun Thomas ??? Hobert preston **Johne menzers** ??? ??? Thomas gray ??? ??? ??? George honeyman ??? ??? Jon pillones ??? ??? aytoun all ane haill ??????*
*Item to Michaell ??????????????????????????? Jon cunynghame ???????? Thomas gray and **Ho.t abbot** all ane haill oulb? at 54 s. the peice is*
Item to James home and Jon hamilton ane haill oulb at ???
Item to william wallace ????????
Item to ??? ??? and Ho.t prestone ane haill oulb at 24 s. is
*Item to Johne ??? James stirling James ??? James witherspune **Jon hendersone** Jon gardiner and Thomas ???????? hewing ??????????*
Item to ?????????????? jon wat ??? ??? paid for hewing of ??? ornellis ?????
*Item to **Ho.t waterstone** James beng and Jon ??????????????*
Item to Thomas ??? ??? wam mure williame adame for hewing of 30 ??? at 6 s. 8 d. the peice is
*Item to **wam portens** and wam ????????*
Item to 4 workmen ane haill oulb at 30 s. and to ane ??? 36 s.
Item to James ?abmath and ?????????????
Item the ??? of ??? to Jon ??? and wam aytoun ???
Item to Ho.t ?hart Ho.t gray & jon bryce ane ???

Item to ??? ??? George stirling ??? cunynghame James aytoun ***Thomas amshe****? Hobert preston Johne menzers ??? meme James cuthberstone George honeymane Jon pillones Johne ?tthie and wam aytoun all ane haill oulb at ??? the peice is*
Item to ??? ??? ??? finairt jon thomsone James broun jon portens jon cunynghame ??? hayre ***peter hirne*** *Symeone barry and Thomas gray all ane haill oulb at ??? s.*
Item to thomas gairdner ?????????
Item to James home and jon hamiltone ane ???????
Item to wam wallace ane haill ??? and jon pillones
Item to patrick ?allane and Ho.t patersone ane haill ???????
Item to Ho.t ellot? ane haill oulb?
Item to James stirling jon hendersone thomas ??? ??? ?stone James beng? and ***jon clerk*** *for hewing of ??????????*
Item to jon gardner for hewing ?????????????
Item to Johne amishe wm adame ??? wam meme Ho.t ??? and ???????????
Item to ??? ??? for hewing 17 ornell jon ??? 17 henrie ??? 15 thomas ??? 16 ????????
Item to johne hamiltone ??? ??? for hewing 3 ??? at 48 s. is
Item to ***wam porteous*** *??? ??? James pitter??? and patrick witherspune ??????? at 48 s. the peice is*
Item to James pitte??? and patrick witherpune ????? scuncheones?
Item to jon clerk for 4 scumchenes? ????????
Item to 4 workmen ane haill oulb ??? 30 s. and ??? ??? 36 s. is
Item to ***james washmath****? and ??? ???*
Item to ***jon ronald*** *??? 4 teansomes? at 24 s. and 27 fute ??? at ??? s. is*
Item for 26? fute 19 ??? and 4/3 ??? the fut
[...]
Item to Jon maissone and wam mure ??? 4/3 ???
Item to ??? ??? for 63 fut & 34 fute at ???
Item to George duncane and ??? ??? for 53 futs and 2 ???????
Item the 28? of dec? to jon watt 3 days at 16 s. 8 d. the day
Item to wme aytoun twa dayes at 20 s. ???
Item to ??? ??? 5 days Ho.t gray? and ??????????
Item to George stirling? ??? cunynghame George honeyman Jon pillones ??? ??? 5 days at ???
Item to ????????? Ho.t preston ??????? and James cuthbertsone ??????
Item to James aytoun ??? ??? wm aytoun all a ???
Item to john thomsone ??? ??? and ***Ho.t ellot****? ?????????*
Item to Michell ??????? finairt James broun jon porteous jon cunynghame & thomas gray ??? 4 days at 9 s. the day is
Item to peter/patrick burne and symeone barry ??? ane 2 days at 9 s. the day is
Item to James home ??? jon hamiltone 5 days ???
Item to wam wallace 5 days at 6 s. 8 d. & jon pillones ??? days at ??? s.
Item to Patrick ?allane and Ho.t patersone 5 days at ??? s.
Item to Johne hamiltone for hewing of ????????? and ***James craufurd*** *??????*
[...]
Item to George duncane for 63 futs at 3 s. 4 d. ???
Item the 4 of january 1634 to Jon watt ane haill ???
Item to wam aytoun ane ??? 4 dayes
Item to Ho.t ??? Ho.t gray & jon bryce all ane haill ???
Item to ??? ???George stirling G??? cunynghame Thomas anishe
James Aytoun 5 days and a half at 10s.
John Thomson, John Cuningham, Symeone Barry, Thomas Gray *ane haill oulb at 54 s.*
David Finairt 5 days, Thomas Gardiner and John Porteous 4 days.
James Home and John Hamilton *ane oulb at ??? s*.
William Wallace *ane haill oulb at 40 s.* and John Pillones *??? s.*
Patrick Allane.
Patrick Witherspun.
John Gardiner, **William Adam** at 30 s.
William Adam at 26 s.
James Beng 48 s.
John Clerk.
John Hamilton.
William Porteons.
William Dyne, **Hobert Henrieson**.
John Ronald *for ane fute ne wall and ??? 6 fute lym wall.*
Item for 34 futes and 33 fute stones at ???
George Ramsay.
5 workmen.
James Mabmath sand?.
1634 Jon Watt 5 days.
Hobert Schort?, Hobert Gray, John Bryce 5 days at 5 s.
James Aytoun, Thomas Anishe, Hobert Prestoun, John Pillones, William Aytoun *all ane haill oulb at £3.*
George Stirling, **Gawne Cuningham**, George Honeyman all 5 days and a half.
William Aytoun.
Michael Drybrugh, David Finairt, John Thomson, James Brown, John Porteons, John Cuningham, Symeone Barry, Peter Burne, Thomas Gray *all ane haill oulb at 54 s*.
Hobert Abbot 5 days and a half a piece at 9 s.

John Hamilton *ane haill oulb at 48 s.*
William Wallace 40 s. and John Pillones 30s.
Patrick Allane.
William Porteous, **William Meme**, William Adam.
John Hamilton.
John Anishe.
John Henderson.
William Dyme, John Gardiner, **Step. Waterstone** *ane haill at 48 s.*
John Beng 2 scuncheones at 30s. the peice.
Henrie Cubersone 15 ornell at 3s. 4d.
James Mathmath.
John Ronald *ane 7 fute sconnes? 30 s. and ane garit? lyntell 24 s. and 33 fute 12 s.*
Item ??? and 7 fute newall and ane 7 fute ??? wt ane 6 fute transone at 18s.
John Morisone.
William Mure.
1634 to John Watt *ane haill oulb.*
William Aytoun.
Hobert Gray.
John Bryce 5 days.
Item to ten morisons all ane haill oulb at ??? the peice is.
Gowan Cuningham, James Aytoun, George Hennyman 5 days at 30 s.
maissones 54 s. the peice.
William Wallace 40 s. and John Pillones 30 s.
Patrick Allane, **Robert Paterson**.
[…**** Nov. 1634 – Nov. 1635 William Cochrane**
At the end:
1628 to 1635 – *£ 72000 for timber from Norway*
on the fabric £ 101308 : £ 11436 in 1628, £ 10500 in 1629, £ 12147 in 1630, £ 960 in 1631, £ 11001 in 1632, £ 19428 in 1633, £ 18398 in 1634, £ 24185 in 1635
**** Nov. 1635 – Nov. 1636 Robert Flemyng**
**** Nov. 1636 – Nov. 1637 Edward Edgar**
p. 79: *The compter discharged himselff with the moneyis susteyit and debursit be him forgone the buying of treis and dailles to the hospital the ??? of acoompt as follows*
Imprimis to peter? Cornelisone for? twa hundreth and seavin grait treis boagt be him in norroway for the rofe? of the hospitall
conforme to and aggreement maid betwyx him and Jon Edgar and me be the adbyse? of James rychard the ??? to the guid ???
Thomas meire? and James guthrie? conforme to his compt debyberis to me with ??? amounting to twa hundreth feifte
ancht ??????
Item payit to him also for 20 fathome burne wod and 5 dussone spares to fill ??? the ship ?????????
Item for fraucht? of the said ??? and hazard after? the ??? being his owne money supleyed forgone his awn? ??? & till his debybrie of the ??? at ??? twa hundreth fourtie twa ?????
Item for the charges of the said timber to the workemen that careit and laid the same ?????? and ane half ???
**** Nov. 1637 – Nov. 1638 Thomas Chairteris**
Followes the said Thomas Chairteris his discharge of his incomissone? w.t the ?rents ??? soumes and ?????????? with be him and apayit and debursit be him be him to sundrie persones during the tyme forsaid according to the particularis following
Imprimis payed to Cargo ??? ??? for his ??? ??? ??? 1637 and ??? anno 1639 conforme to his discherge
Icom to Cristiang heriot for his ??? ?? from November 1637 to November 1639 Conforme to his discharges
Icom to Jonac? macdull? the mercumes? ??? ??? 1637 and ??? 1639 of 5000 merkis
Icom to Cristane blaw? for the ??? ??? at 50 tib. in the ???
Icom to payit to Johne? bland? plumber conforme to the compell warrand
Icom to Johne Jonse? in name of ??? Albert Johnestonn ??? for the ?? of 6000 tib. ??? to him from ??? 1636 to ??? 1637
Icom lent? to the ??? of ??? Carrieson ??? to his band
Icom lent? to ??? ??? conforme to his band
Item to ??? ??? ??? ???????? conforme to his discharge
Item payit to patrick Cashelait? the ??? sundrie tymes conforme to his discharges ??? to me ??????????
The compter ??? to the dischargit of the particularis debursyt be him forgone the fabrick and building of the hospitall and provisone? and materiallis ??? as followes
Imprimis forgone the ??? day of november 1637 to jon watt 5 £ wam aytoun 6 £ and Hobert sohirt? 5 £
Item John menzers George Stirling ***patrick pringle*** *and Mathew witherspune ??? ??? ??? ane oulb at 3 £ the peice is*
Item to James ??? wam ??? james broun johne guthrle? Johne gairdner Ho.t ellot and Johne henriesone ??? ane of ??? and oulb at 54 ??? the peice is
Item to James cuthbertsone wam ellot George ran??? and wam ??? at 2 £ 10 s. the peice
Item david ??? 48 s. ??? ??? ***Johne edgar Ho.t banmebe and slep. baillie*** *??? ane of yame? at 40 £ the oulb is*
Item to ***Ho.t aytoun***
William Stirling.
seven workmen.
George Wade.
James Mabmath.
John Ronald.
John Watt, William Aytoun.
George Stirling, Patrick Pringle, Mathew Witherspun.
[...]

John Watt, William Aytoun,.
George Stirling, Patrick Pringle, Matthew Witherspun.
John Watt, William Aytoun, John Menzers, George Stirling, Patrick Pringle, Matthew Witherspun.
John Watt, William Aytoun, John Menzers, George Stirling, Patrick Pringle, Matthew Witherspun.
16 December John Watt, William Aytoun, John Menzers, George Stirling, Patrick Pringle, Matthew Witherspun.
23 December 1637 John Watt, William Aytoun, Ho.t Sehart?, John Menzers, George Stirling, Patrick Pringle, Matthew Witherspun 3£.
30 december 1637 John Watt, William Aytoun, Ho.t sihart, John Menzers, George Stirling, Matthew Witherspun.
[And so on... always same names, but Matthew Witherspune and Hobert something disappear in 1638]
p. 77: [...] paid to **John Andersone** ... for 3800 shirting/ftuirning nailles at 9 s. 69 d. the hundreth.
Thomas Broun smyth.
Hobert Scott *... guarrell to the warke*.
Item for three daill of caillis? to the maissones ...
p. 78 masons and barrowmen
*Item to **Hobert marstertoun** for 200 dailla at 44 £ the hundreth is*
Item to the said Ho.t marstertoun for 19 arbeir plankis at 4 £ 10 s. the peice is
Item for careage of the plankis fra leth to the wark
*Item to **jon scott** conforme to his accompt*
Item to Tho??? ??? and his twa men for ancht days work
Item for mending of ???????? and for ??? and timber to the workmen
Item to James H??? uffice? for arrasting? of the cornes of ??? and ??? the hennentis?
Item to James ??? for wreatting of ??? discharges and ?????????????
Last page: *On the fabrick 1638 £9898.16.6*
**** Nov. 1638 – Nov. 1639 Patrick Baxter**
p. 25: John Watt, William Aytoun, John Menzers, Geroge Stirling, Patirck Pringle
Wrichtis compt
*Item to **Johne Scott** ane oulb 6 £ **johne buchguhaman henrie lauder johne heriot James cryshe**? and **thomas watsone** all ane oulb at 54 s. the peice and **James heriot** 45 s. ??? in all*
p. 26 stones brought from quarry (*guarrell*)
p. 27 [...] *Wrichtis compt*
Item to Johne Scott ane oulb 6 £ Johne buchguhannan henrie lauder johne heriot james cryshe and thomas watsone all ane oulb at 54 s. the peice and johne heriottis fore 45 s. the oulb
p. 28 stones brought from quarry
p. 29 [...] *Wrichtis compt*
Item to Johne Scott 6 £ johne buchguhannan henrie lauder johne heriot james cryshe and thomas watsone all ane oulb at 54 s. the man and jon heriottis ??? at 45 s. the mall?
p. 30 stones brought from quarry
p. 31 John Watt 5 £, William Aytoun 6 £, John Menzers 5 £, Geroge Stirling 3 £, Patrick Pringle 3 £
mason work reduced a lot, from pages and pages to not even half a page
Taskwork? chimney pieces
Wrichtis compt
Item to Johne scott ane oulb 6 £ Johne buchguhannan henrie lauder jon heriot and james cryshe ??? ??? 54 s.
p. 32 stones brought from quarry
p. 33: [...] Taskwork? chimney pieces
Wrichtis compt
Item to Johne scott wrigt 6 £ Johne buchguhannan henrie lauder johne heriot and james cryshe ??? ??? 54 s.
p. 34 stones brought from quarry
p. 35: [...] Taskwork? chimney pieces
Wrichtis compt
Item to johne scott 6 £ jon buchguhannan henrie lauder and jon heriot at 54 s. the peice and james cryshe 5 dayes 45 s.
stones brought from quarry
p. 36: [...] Taskwork? chimney pieces
Wrichtis compt
Item to Johne Scott 5 dayes 5 £ Johne buchguhannan 4 dayes 36 s. jon heriot 5 dayes 45 s. and henrie lauder ane day ??? shillings
stones from the quarry
p. 37: John Watt, William Aytoun, John Menzers, George Stirling, **James guthrie?, James cuthbertsone, harie mudre?** - no other masons anymore
Taskwork? chimney pieces, chimney heads
Wrichtis compt
Item to Jon Scott 6 £ jon buchguhannan jon heriot and henrie lauder 5 £ 2 s. and james cryshe 2 dayes 18 s. ??? in all
stones from the quarry
p. 38 [...] *Wrichtis compt*
Item to Johne scott 6 £ johne buchguhannan johne heriot henrie lauder and james cryshe ??? 54 s.
p. 39 stones brought from quarry
p. 40 [...] *Wrichtis compt*
Item to jon scott 6 £ jon buchguhannan jon heriot henrie lauder and james crushe ??? ane 54 s. ??? mall?
p. 41 [...] *Wrichtis compt*
Item to Jon scott 6 £ Johne buchguhannan jon heriot henrie lauder and james cryshe at 54 s. the peice
p. 42-43-44-45-46-47-48-49-50 same
p. 51: *The compt of the wrichtis and ??? the ellevint day of May 1639 yeiris*
Item to Johne heriot for ancht dayes and ane half at 12 s. ????

*Item to **Geroge heriot** for 5 dayes and ane half at 10 s. ??? day 4 £ 5 s.*
Item for half ane hundreth plencher naills 4 s.
Item for thrie ???pis to the seat ??? Gairding 3 s.
*Item to **Ho.t ste?msone** 4 £*
Item to the saweris for four draucht treis at 3 s. the draucht ???
Account of the masons: John Watt, William Aytoun, John Menzers, Patrick Pringle
p. 52: Account of the masons
Wrichtis compt
Item to Jon heriot 5 dayes 3 £ and James cryshe 5 days 3 £
stone brought from quarry
account of the maisons
Wrichtis
Item to Jon heriot and james cryshe at thrie pund 12 s. the oulb
p. 53: stones brought from the quarry
Account of the masons
Wrichtis compt
*Item to Johne scott 6 £ jon heriot james cryshe **james jonstoun** and james ??? at 3 £ 6 s. the peice ??? 13 £ 4 s. ??? George Heriot 55 s. ???*
stones brought from the quarry
p. 54: [...] *Wrichtis compt*
*Item to Jon scott 6 £ jon heriot james cryshe james jonstoun and **james riddache**? at 3 £ 12 s. the peice ??? 14 £ 8 s. and George heriot 3 £*
p. 55: Date goes from week to week [...] *Wrichtis compt*
Item to Johne Scott 6 £ jon heriot james cryshe james jonstoun james riddach 14 £ 8 s. and George heriot 3 £
p. 56 same + *Item for 300 flooring naills 36 s. 100 plencher naills 8 s. 2 ?????????*
[...] Item to ??? ??? for 26 draucht wainscot at 3 s. the draucht 3 £ 18 s. and nyne draucht long treis at 4 s. the drau 36 £
p. 57 same + *Item for twa thousand and fyve hundreth fluring nailles at 18 s. the hundreth 15 £*
Item ane doubll heid? ???????
Item given to Jon Scott ??? he gaive ??? at leyt for transporting and careing the grait treis ??? the ??? 5 £ 5 s.
Again to the same guy for carving wainscot and *for sawing of five? doubll treis at 4 s. the draucht being 5 drauchts 20 s.*
p. 58 same + *Item for 700 floring naills at 13 s. 4 d. the hundreth is 4 £ 13 s. 4 d. and ancht hundreth floring naills at 14 s. the hundreth 5 £ 12 s. and thrie pund of butters?*
p. 59 same + *Item for 500 floring naills at 14 s. the hunfreth is 3 £ 18 s. ??? ??? ??? 600 floring naills at 16 s. the hundreth is 4 £ 16 s.*
p. 60 same + *Item 500 floring naills at 14 s. the hundreth is 3 £ 10 s.*
Item ane hundreth ??? plencher naills
Item 100 dure? naills 6 s.
p. 61 same + *Item for 4000 floring naills at 14 s. ????????*
Item for sawing 100 draucht of grait buappald? to ??? ??? 6 £ 13 s. 4 d.
Item for ane ??? of burnwood for melting the lead 6 £ and for careing the same to the wark 18 s.
p. 62 same + *Item ane stand of calk? 10 s. ??????????*
Item to same guy *for ??? draucht of great buappald? at 20 d. the draucht ??? and for sawing seavin daills 21 s.*
p. 63 same + *to the saweris for 10 draucht of doubll treis at 4 s. the draucht 40 s.*
p. 65 [...] *Item cost from johne wimald? ten grait plankis at 10 £ 6 s. the peice*
Item for careing of ??? out of leyt
Item boucht from wam steomson? ane hundreth buappold? at 20 s. the peice
[...] Item the 14 day of February 1639 to mr jon adamsone for 47 buappalt at 20 s. the peice
Item boucht from ane deusman 93 plankis at 4 £ 8 s. the peice
[...] Item to wam ??? for 400 small buapauld? at 20 £ the hundreth
[...] Item to Jon mudrie? and james wylie for 172 wainscot at 7 £ 3 s. 4 d. the peice
[...] Item the 17 day of august 1639 to ane deusman for ane thousand daills at 36 £ ???
people paid for carrying the material from leith
[...] Item the 25 of sept. 1639 bucht from lawrence cowrieson? ane deusman ane hundreth and 20 doubll treis at 24 s. the peice
Item that saime day bucht ??? 70 lang peastis? at 4 s. the peice
600 great buappald?

Summary and comments

Archive National Records of Scotland Doc. Num. GD421/5/3 Folios

Title Heriot's Hospital Treasurer's Accounts 1642-1652 Date: from 1642 to 1652

Contents

Summary and comments

Archive National Records of Scotland Doc. Num. GD421/5/4 Folios

Title Heriot's Hospital Treasurer's Accounts 1652-69 Date: from 1652 to 1669

Contents

Summary and comments

Archive National Records of Scotland Doc. Num. GD421/10/68 Folios

Title	Account of wright work in George Heriot's Chapel and summer house by Thomas Sandilands	Date: from	1683	to	1684

Contents

(outside) *Ane accompt of* ***worke wrought In heriots Wark Chappell and Ane summer house in the easter yeard ffor furnishing timber & nails ther tto***
To Thomas Sandilands
In Anno 1683 & 1684
£ 683
(inside) *Ane Accompt of Wright Work Wrought In Heriots Wark Chappell and att ane Loadge In The Easter Garding from 12 febry In Anno 1683*
Mond 12 febry to the 17 yrof
John Ogstone *5 days 1/2 £ 3.13.04*
John Millar *5 days 1/2 £ 3.13.04*
Thomas Wilsone *2 days 1/2 £ 1.13.04*
Mond 19 febry to the 24 yrof
John Ogstone 5 days 1/2 £ 3.13.04
John Millar 5 days 1/2 £ 3.13.04
Thomas Wilson 6 days £ 4
Mond 26 febry to the 3 of March
John Ogstone 6 days £ 4
John Millar 6 days £ 4
Thomas Wilson 6 days £ 4
Mond 5 March to the 10 yrof
John Ogstone 5 days 1/2 £ 3.13.04
John Millar 5 days 1/2 £ 3.13.04
Thomas Wilson 6 days £ 4
Mond 12 March to the 17 yrof
John Ogstone 4 days 1/2 £ 3
John Millar 6 days £ 4
Thomas Wilson 5 days £ 3.06.08
Mond 19 March to the 24 yrof
John Ogstone 4 days £ 2.13.04
John Millar 6 days £ 4
Thomas Wilson 4 days £ 2.13.04
Mond 26 March to the 31 yrof
John Ogstone 5 days 1/2 £ 3.13.04
John Millar 5 days 1/2 £ 3.13.04
Thomas Wilson 6 days £ 4
Suma is £ 74.13.04
[...]
7 May ***Thomas Chyrmsyd*** and ***William Craih*** **(or Craik?)** are added
14 May ***William Marshall*** is added
21 May ***George Stewartt*** is added (John Millar is lost)
16 July ***William Pottar*** is added
goes on until 6 August: they are always maximum 6, all working at least 4 days
Ittem furnisht 5 scores wenshcoatt planks att 1 lid 2 B yr pice is £ 121.10
Ittem 44 ??? of Nappell £ 15
Ittem 6 double tries £ 6
Ittem 4 greatt Dormants for yr Loft £ 25.12
Ittem 76 Sewdge daels with yr cairage £ 53
Ittem 4 fourtinells wt yr Cairage £ 8
Ittem payed to the sawers conforme to the Accompt for ***sawing of yor Timber wtin The Chappell*** *£ 6.16*
Ittem 7 pound 1/2 of glew at 8 Bre pound £ 3
Ittem 1990 florings £ 9.17
Ittem 290 Double florings £ 2
Ittem 24 single garrons £ 0.12
Ittem 360 polansher naiels £ 1.01
Ittem 1330 dovr naels £ 2.13
Ittem 700 window naiels £ 1.03.04
Suma is £ 288.11
Ane Accompt of Work Wrought at the ffoar ffare of The Laft within the Chappell Anno 1684
from 21 July to 11 August: John Ogstone, William Craih, ***John Scott***
Ittem furnisht of Long wenskcott ??? clifts ane Inch thick at 15 Bre pice is £ 4.1
Ittem 3 clifts inch 1/2 thick 3 the pice £ 9.1
Ittem 3 clifts a inch thick £ 7
Ittem 4 clifts 3/4 aff ane inch thick £ 6
Ittem 5 clifts of short nappell £ 1.16
Ittem 100 blind doors £ 0.03.04
Ittem 60 blind planshers £ 0.01.08
Ittem 60 florings £ 0.05
Ittem 30 florings £ 0.02.05
Ittem 60 planshers £ 0.03

Ittem 60 blind windows £ 0.01.06
tot £ 75.09.04
The 1 page £ 74.13.04
The 2 page £ 88.06.08
The 3 page £ 64
The 4 page £ 92
The 5 page £ 88.11
The 6 page £ 75.09.04
Suma totalis £ 683.00.04
I Thomas Sandilands wright burges of edr grants me to have received from James Kirk & ??? ??? george heriott hospitall the sowme of six hundreth ??? ??? & ane scotts money and that m full payment of the ??? accompt consisting of six ??? and that forr timber wright work and other furnishing furnished be me for the Chappell and ??? ??? ??? ??? discharged the ??? ??? of the accompt as witnes my hand the sixteen day of janry [...]
Thomas Sandilands
John Brown witnes
??? witness

Summary and comments

Archive: Royal Commission on the Ancient a | Doc. Num.: DP 055037 | Folios:

Title: Sections through quadrangle including interior elevations of chapel, dining hall and classrooms. Title: 'GEORGE HERIOT'S HOSPITAL EDINBURGH'. | Date: from 1891 to 1892

Contents

Summary and comments

Archive: Private: school archives | Doc. Num.: Uncatalogued drawing | Folios:

Title: George Heriot's School. Proposed additional class rooms. Plan and sections showing the roof of the East and West ranges. | Date: from 1908 to

Contents

Summary and comments

Archive: Private: school archives | Doc. Num.: Uncatalogued reports | Folios:

Title: Reports on repair works carried out on the roofs of George Heriot Hospital | Date: from 1997 to

Contents

Summary and comments

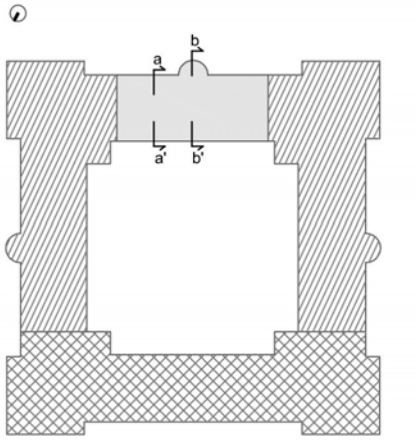
Archive: Royal Commission on the Ancient a | Doc. Num.: D.8.41.HER.P | Folios:

Title: Heriot's Hospital - a short history by D. PRYDE. Extracts from minutes of George Heriot's Trustees. Special articles commemorating the 350th anniversary of the laying of the foundation stone, from the HERIOTER July 1978 | Date: from Undated to

Contents

Heriot's Hospital - a short history by DAVID PRYDE (clerk of works to the governors of George Heriot Trust)
Often the Kingdom of Fife is mentioned as producing men of service to the Hospital: like W. Aytoune.
In July 1627 a ship was sent to Norway to bring over a cargo of timber for the work, and the Foundation Stone was laid on July 1st 1628.
All the roofs of the building are covered with lead. The council provided the material and employed John Bland, plumber, from Newcastle, to theak the hospital with lead, and paid 4/- Scots per stone for casting and working it.
In 1673 "the Kirk of the Citadel of Leith with all its pertinents, glass, timber, and steeple to be made use of in repairing the Hospital Chapel".
Extracts from minutes of George Heriot's Trustees
10 July 1676. Council etc cause Deacon Sandilands proceed to put on and with all possible diligence to putting a roof and Top to the Hospital Steeple according to the draught condesended upon be Sir William Bruce, his advice and finished of rest of the reparations as to the rounds and Roofs of the hospital formerly appointed to.
Special articles commemorating the 350th anniversary of the laying of the foundation stone,
from the HERIOTER July 1978
George Heriot's Hospital and School: a survey of the buildings 1628-1978 - by Brian Lockhart
Timber was brought from Dalkeith, but large timber was imported from Norway in a specially chartered vessel
George Heriot's Hospital, Edinburgh - by Alistair Rowan
Look at "George Heriot's Hospital" 1872 by Dr William Steven
By June 1627 the plan was settled and in July that year the Treasurer had been instructed to "fraucht a ship to bring home joisting and other commodious timber from Norway for their work".
John Watt mason working with Aytoun until 1642 when he dies.
Strange they altered the roofs just few years after doing them: north range, towers, all become flat before 1647.
The chapel ceiling installed in 1787 costed £ 96.16.
Memoirs of a modern monk 1906 - by C. B. Gunn
1627 July 13 - a ship to be sent to Norway to bring home joisting and other timber for the Hospital.
1673 April - The Kirk of the Citadel of Leith, with all its pertinents, glass, timber and steeple, to be made use of for repairing the Hospital Chapel.
George Heriot's Hospital described from an architectural standpoint by Hippolyte J. Blanc architect

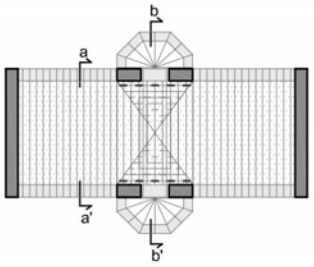
	Wherever the source, there is evidence of a local fashion in the application of features and details of what may be recognised as a special style. That points to the existence of a distinctively Scottish School of Architects, of whom William Wallace was doubtless one.
Summary and comments	



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



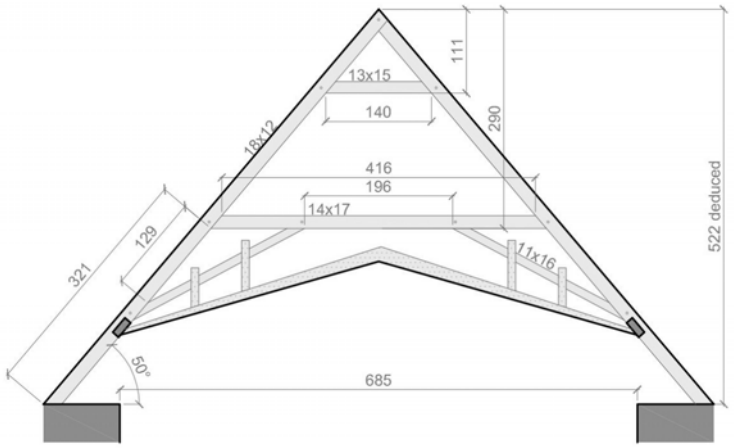
Carpentry marks from west to east:

XXX/II	X/II
XXX/I	X/I
XXX/	X/
XXXIIII	XIIII
XXXIII	XIII
XXXII	XII
XXXI	XI
XXX	X
XX/IIII	VIIII
XX/III	V
XX\II	VIII
XX/I	IIV
XX/	VI
XXIIII	V
XXIII	IIII
XXII	III
XXI	II
XX	I
X/IIII	XXX/III
X/III	

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

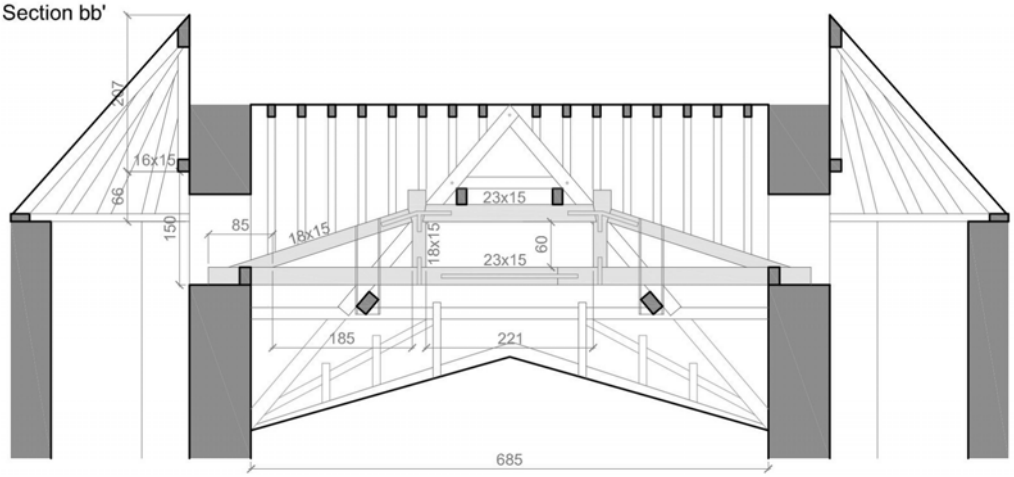
Section aa'



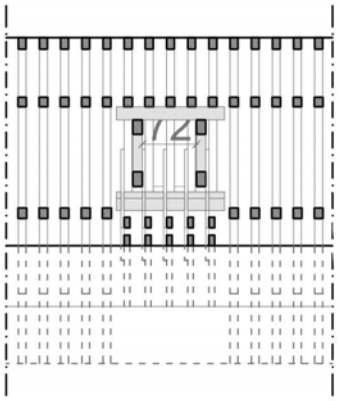
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section cc'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** GEORGE HERIOT'S HOSPITAL SCHOOL | **Roof location** Chapel

Survey date(s) 13/10/2014 | See drawing: GH-C-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.85 | Roof Height [m]: 5.2

Roof Pitch/es [°]: 50 | Roof Length [m]: 18.3

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.37

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1633 To 1637 | Identified by: Estimated

Roof General Description: Two pitch gabled roof with 38 frames, each with two collars and slanted struts under the lower collar. Connection with wall not visible. 2 19C queen trusses in the middle, to support new ceiling, and rafters cut in correspondance to these. Half conical roofs on the sides, joined to the main roof through intersected roofs (whose timbers look of later date).

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 18.5 | B: 12.5 | Or Purlin - H: | B:

Timber elements' Dressing: civil (machine-sawn), rustic (hand-axed) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description: Mostly in sequence, numbered from 1 to 38 from east to west

Signs of reused timbers:

Timber Treated ☐

Other Materials: Metal straps and bolts in 19C truss

Dendrochronology:



Roof Structure link I:\Arch\A



Connection with wall link I:\Arch\A



Timber dressing link I:\Arch\A



Joints: rafter and collar link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: early 19C timber ceiling underneath

Unfavourable conditions:

Accessibility limitations: Connection with wall not visible

Past interventions: Two trusses were inserted in the central part in 1835 to support new timber ceiling. Some sarking and some rafters were replaced recently.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

GLASGOW TRADES HALL

Location: GLASGOW, CITY OF | GLASGOW (GLASGOW, CITY OF)

X coordinate: 259329 Y coordinate: 665183

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 140766

Original Use: Meeting Hall

Current Use: Meeting Hall, Museum

Freestanding ☐ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1791	1794		RYKWERT 1985 & ML T-TH 1/1/7

People involved:

Last Name	First Name	Role	Attributed
ADAM	ROBERT	DESIGNER	☐
CRAIG	JOHN	DESIGNER	☐
BROWN	JOHN	CONTRACTOR, WRIGHT	☐
ADAM 1	JAMES 1	OVERSEER	☐
JAFFRAY	JAMES	DESIGNER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1812			

People involved:

Last Name	First Name	Role	Attributed
HAMILTON	DAVID	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1838			

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1856		"CONSIDERABLE" REPAIRS AND ALTERATIONS TO SECURE THE ROOF	ML T-TH 1/1/12 & TRADES HOUSE BASEMENT C. WILSON'S DRAWINGS

People involved:

Last Name	First Name	Role	Attributed
WILSON	CHARLES	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1887		INTERIORS	RYKWERT 1985

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1955		DOME TIMBER STRUCTURE SUBSTITUTED WITH A NEW STEEL STRUCTURE. GREAT HALL CEILING SUBSTITUTED WITH NEW TIMBER CEILING WITH A SMALLER DOME.	ML WYLIE SHANKS ARCHITECTS COLLECTION, BOX 152

People involved:

Last Name	First Name	Role	Attributed
WYLIE SHANKS ARCHITECT		ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1970	2000	ADDED STEEL BRACKETS TO SOME OF THE ROOF TIMBERS	SUTHERLAND 2000

People involved:

Last Name	First Name	Role	Attributed
ADDISON	JOHN	ENGINEER	☐
CAMPBELL DUFF	GEORGE	ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CRAWFORD G.	1858	☐	A SKETCH OF THE RISE AND PROGRESS OF THE TRADES HOUSE OF GL	

Author	Year	Unpubl.	Title	Pages
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	205
SUTHERLAND F.	2000	☑	"THE TRADES HALL OF GLASGOW." ARCHAEOLOGICAL DESK STUDY F CONSERVATION MANAGEMENT PLAN BY BMP ARCHITECTS	
WILLIAMSON E. & RICHES A.	1990	☐	THE BUILDINGS OF SCOTLAND COLLECTION: GLASGOW	

ARCHIVAL REFERENCES

Archive	Mitchell Library	Doc.Num.	T-TH 1/1/7	Folios	
Title	Trades House: docquetted minute book and Collectors' Accounts, Feb 1787 - 17 May 1798				
Archive	Mitchell Library	Doc.Num.	T-TH 1/34/4	Folios	
Title	New buildings proposed in 1883 & report of the building committee in 1878				
Archive	Mitchell Library	Doc.Num.	T-TH 1/34/1	Folios	
Title	Estimates for building and plasterwork				
Archive	Mitchell Library	Doc.Num.	T-TH 9/4/2	Folios	
Title	Incorporation of Wrights: membership roll, 1731 - 1811				
Archive	Mitchell Library	Doc.Num.	T-TH 9/4/3	Folios	
Title	Incorporation of Wrights: membership roll, 1811 - 1882				
Archive	Mitchell Library	Doc.Num.	T-TH 1/1/12	Folios	
Title	Trades House: docquetted minute book and Collectors' Accounts, 13 Oct 1853 – 8 Sep 1865				
Archive	Mitchell Library	Doc.Num.	T-TH 1/17/1	Folios	
Title	Copies of Trades House Accounts in MSS, 1711 – 1713, 1720 – 1817 and abstracts of same				
Archive	Mitchell Library	Doc.Num.	T-TH 5/19/15	Folios	
Title	James Jaffray designs for the Trades Hall 8th June 1791				
Archive	Mitchell Library	Doc.Num.	T-TH 5/19/16	Folios	
Title	Minutes of Building Committee 26th January 1792				
Archive	Mitchell Library	Doc.Num.	T-TH 5/19/17	Folios	
Title	Minutes of Building Committee 10th March 1792				
Archive	Mitchell Library	Doc.Num.	Wylie Shanks Architects Collection, Box 152, Drawings T6	Folios	5, 6, 7
Title	Survey of the Trades House of Glasgow and alterations by Wylie Shanks Architects				
Archive	Private: Trades Hall (basement)	Doc.Num.	1/899	Folios	2, 3, 4, 5
Title	Survey and Alterations to Glasgow Trades Hall roof structure by the Architect Charles Wilson in 1856: plan and sections				
Archive	Soane Museum London	Doc.Num.	Adam volume 48	Folios	2
Title	Glasgow Trades Hall section front to back by Robert Adam				
Archive	Mitchell Library	Doc.Num.	T-TH 1/34/3	Folios	
Title	The ceiling of the great hall in Glasgow Trades Hall				
Archive	Mitchell Library	Doc.Num.	T-TH 1/97/3	Folios	
Title	Plans and section of Glasgow Trades Hall by John Laird				
Archive	Mitchell Library	Doc.Num.	T-TH 1/97/2	Folios	
Title	New design for Glasgow Trades Hall proposed by architects James Salmon and Son				

Suggestions for further research

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: Mitchell Library | Doc. Num.: T-TH 1/17/1 | Folios:
Title: Copies of Trades House Accounts in MSS, 1711 – 1713, 1720 – 1817 and abstracts of same | Date: from 1711 to 1817
Contents:
Summary and comments:

Archive: Mitchell Library | Doc. Num.: T-TH 9/4/2 | Folios:
Title: Incorporation of Wrights: membership roll, 1731 - 1811 | Date: from 1731 to 1811
Contents:
Summary and comments:

Archive: Mitchell Library | Doc. Num.: T-TH 1/1/7 | Folios:
Title: Trades House: docquetted minute book and Collectors' Accounts, Feb 1787 - 17 May 1798 | Date: from 1787 to 1798
Contents:
26 January 1791
...it will be much better suited to the dignity of the house and incorporations to have a hall of their own...
21 March 1791: committee appointed to find land to build the hall
18 May 1791: many lands proposed, Glassford street is the preferred one – 80x87 feet. Architect James Jaffray was appointed to make the plans. The incorporations wants to put shops at ground floor to get some money from them.
8 June 1791: Jaffray does 2 plans
21 June 1791: masons suggest *to have a still greater choice and variety of plans*
22 June 1791: after consultation with Robert Smith, Daniel Wardrop and James Burns, architect Adam is proposed
28 June 1791: Adam returned to London so plans are asked to architect John Craig
18 July 1791: Adam came on the 15th, he did plans, and John Craig too
23 Januray: the estimates by Wardrop (mason), Morison & Burns (wrights), Lillie (plasterer), W Sangs (smith) are approved
24 January 1792: Adam proposes 6 shops instead of 4 (Jaffray). The total cost is 7000£ instead of 4000£ (Jaffray)
6 February 1792: they have problems with money so decide to ask for other estimates
16 February 1792: they ask Adam to modify the building design so that it costs less
20 March 1792: they want to write to William Adam *or any relative papers concerning the hall which may have been in his brothers possession at his death, and to know if it is agreeable to him to lodge an estimate for the work*
9 May 1792: estimate from William Purdie wright and John Brown wright. They prefer the latter, which becomes contractor for the hall, for a total of ca. 5000£.
11 May 1792: *the general committee resolve that the building shall immediately begin under the direction of the aforesaid James Adam, and his brother William Adam*
4 October 1793: the deafening of the floors of the hall and the sounding boards of the dome (they put a bell inside!) had been omitted in Brown's estimate
28 October 1793: so house has to pay for the extra works
20 March 1794: the hall is almost finished, so they want to make an insurance against fire
22 April 1794: furniture
24 June 1794: Adam suggests an external stair to go up to the hall from the street, but the magistrate doesn't allow it
21 August 1794: obtained an access to the grounds on the back of the hall
9 October 1794: delay in building the *retiring rooms*
18 November 1794: they want to let the hall for balls/dinners/exhibitions
22 December 1794: it's finished!
15 September 1795: Brown asked for money for extra work but his requests were only partially accepted
30 September 1795: the retiring rooms are finished
7 December 1795: coat of arms on façade is not well done
Summary and comments:

Archive: Mitchell Library | Doc. Num.: T-TH 1/34/1 | Folios:
Title: Estimates for building and plasterwork | Date: from 1791 to 1792
Contents:
Mason David Wardrop 1791
...all joisting to be laid by the wright as the work requires in its going forward and found by him likewise...
Wrights Morison & Burns 1792
...we have measured and calculated the whole of the wright, glazier and slate work for the trades hall […] *2820£*
Plaster estimates by William Meikle, Thomas Lillie, Robert Buchan
Summary and comments:

Archive: Mitchell Library | Doc. Num.: T-TH 5/19/15 | Folios:
Title: James Jaffray designs for the Trades Hall 8th June 1791 | Date: from 1791 to

Contents

Summary and comments

Archive: Soane Museum London | Doc. Num.: Adam volume 48 | Folios: 2

Title: Glasgow Trades Hall section front to back by Robert Adam | Date: from 1791 to

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 5/19/17 | Folios:

Title: Minutes of Building Committee 10th March 1792 | Date: from 1792 to

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 5/19/16 | Folios:

Title: Minutes of Building Committee 26th January 1792 | Date: from 1792 to

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 9/4/3 | Folios:

Title: Incorporation of Wrights: membership roll, 1811 - 1882 | Date: from 1811 to 1882

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 1/1/12 | Folios:

Title: Trades House: docquetted minute book and Collectors' Accounts, 13 Oct 1853 – 8 Sep 1865 | Date: from 1853 to 1865

Contents

Summary and comments

Archive: Private: Trades Hall (basement) | Doc. Num.: 1/899 | Folios: 2, 3, 4, 5

Title: Survey and Alterations to Glasgow Trades Hall roof structure by the Architect Charles Wilson in 1856: plan and sections | Date: from 1856 to

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 1/97/2 | Folios:

Title: New design for Glasgow Trades Hall proposed by architects James Salmon and Son | Date: from 1877 to

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 1/34/4 | Folios:

Title: New buildings proposed in 1883 & report of the building committee in 1878 | Date: from 1878 to 1883

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 1/97/3 | Folios:

Title: Plans and section of Glasgow Trades Hall by John Laird | Date: from 1931 to

Contents

Summary and comments

Archive: Mitchell Library | Doc. Num.: Wylie Shanks Architects Collection, | Folios: 5, 6, 7

Title: Survey of the Trades House of Glasgow and alterations by Wylie Shanks Architects | Date: from 1955 to

Contents

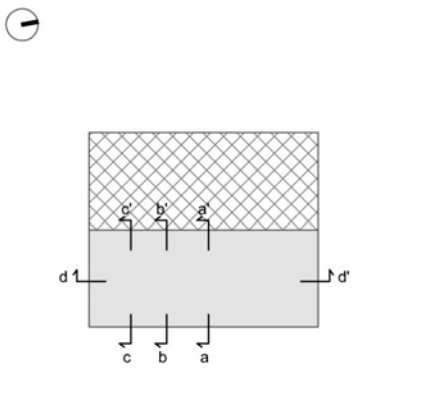
Summary and comments

Archive: Mitchell Library | Doc. Num.: T-TH 1/34/3 | Folios:

Title: The ceiling of the great hall in Glasgow Trades Hall | Date: from Undated to

Contents

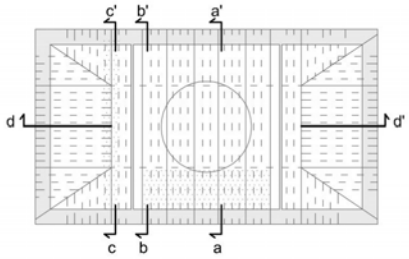
Summary and comments



Legend (plans):

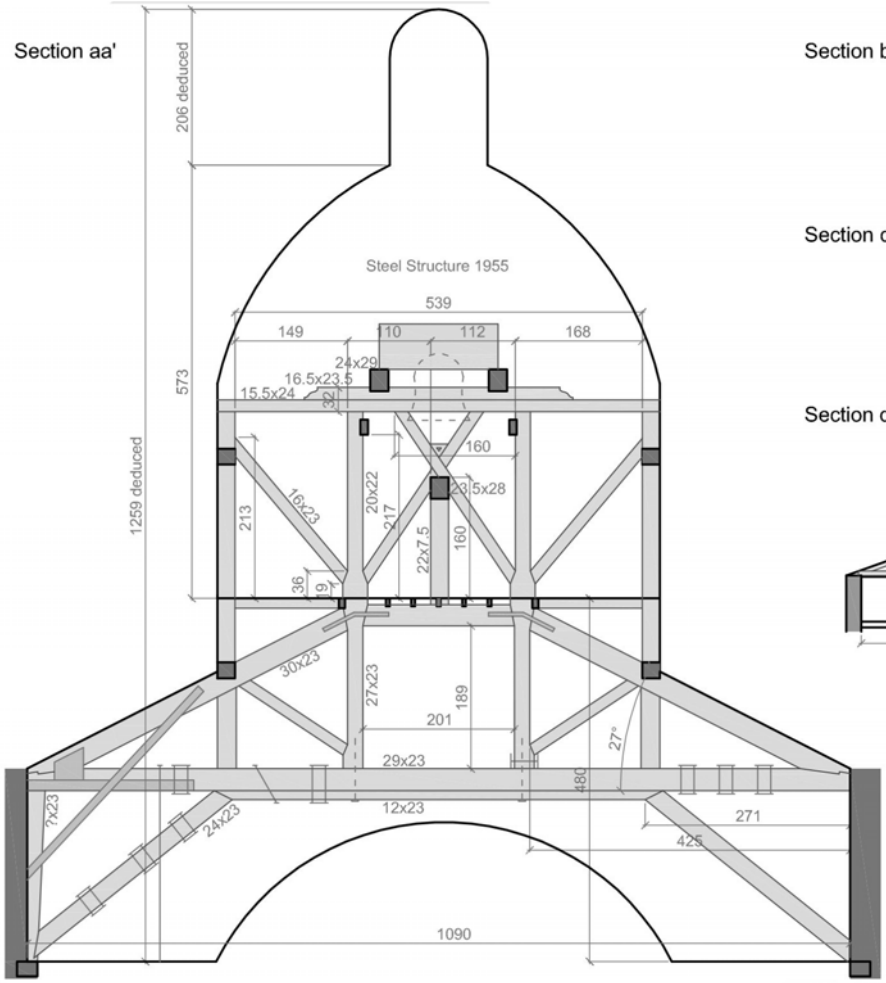
Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

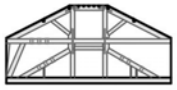


Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas



Section bb' (1:500)



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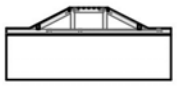

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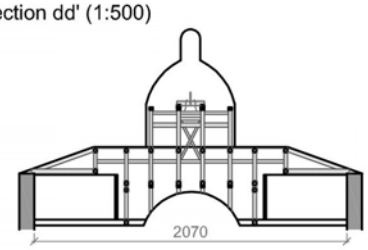


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** GLASGOW TRADES HALL | **Roof location** Great hall

Survey date(s) 13/06/2014 | 09/12/2014 | 25/08/2015 | See drawing: GTH-GH-1

Roof Geometry: Dome, Flat, Hipped

Roof Max Span [m]: 10.9 | Roof Height [m]: 12.59

Roof Pitch/es [°]: 27 | Roof Length [m]: 20.7

Type of Primary Structure: 2D framing

Truss ☑ QUEEN-POST

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, purlins, sa | Plane: horizontal, roof plane, vertical

Sarking boards: width [cm]: | thickness [cm]:

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1791 To 1794 | Identified by: Estimated

Roof General Description:

Hipped platform roof with 6 queen trusses supporting a small dome on top. 4 middle trusses are interrupted in the lower part by a small cupola. Trusses have tie-beam, 2 posts partly encased in the lateral walls, and an arch formed by 2 struts and a horizontal element; this arch supports an upper queen truss. Above this is the dome (now supported by a 1950s steel structure) and bell frame (original timbers). The timbers have big scantlings but some are roughly hand axed, others are more finely dressed with a hand saw. There are some unusual carpentry marks.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular, Square

Rafter Scantling [cm] H: 30 | B: 23 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: joggle, mortice and tenon

Fasteners Types: Metal bolt, Metal strap

Joints description:

All mortice and tenon. Fasteners not visible. Metal straps in the upper "arch" and along the posts. Posts have joggles at the top and bottom.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: arabic numerals, lettering, runic marks, small chiseled roman numerals

Carpentry Marks Description:

AM on a strut in the lower part. WC on a horizontal element in the dome. 8BS+other numbers engraved on many elements. Another engraving repeated: <c>. Also two small drawings, one in the lower part, one in the dome.

Signs of reused timbers:

Some redundant joints but probably connected with removed elements. Strange carpentry marks - maybe ship timbers?

Timber Treated ☑ white spray where lateral rooms are

Other Materials:

Dendrochronology:



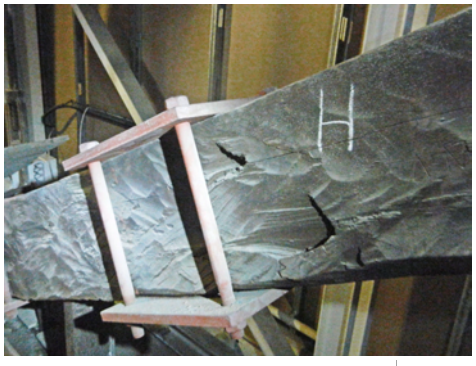
Roof structure: lower part | link I:\Arch\A



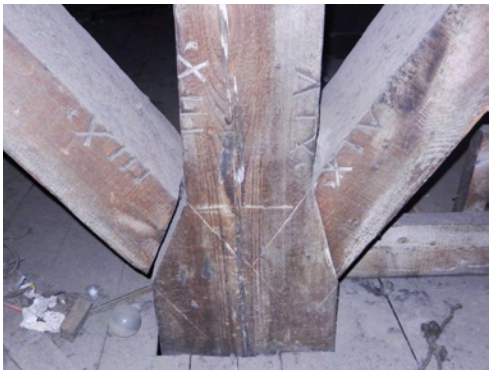
Roof structure: upper part | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Carpentry marks and joints | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor design

Accessibility limitations

Past interventions: Works in 1850s: metal straps and few timbers added. Works in 1950s: sarking and slating redone, façade on glassford st partly redone. Works in 1991: steel brackets installed on many upper tie-beams and struts, steel rods installed to link the rafters and the lower posts on glassford st side, checks filled with resin, opening connections filled with timber wedges.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☐

Humidity stains on sarking and common rafters



Past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	transversal opening	Intervened on	Primary
Unit Damage			
Element Damage	Cracks	Unknown	Collateral
Connection Damage	Disconnection	Unknown	Collateral



Past interventions | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient joints, inefficient overall arrangement
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: cracking | link | I:\Arch\A

Description of visible damage: Some timbers are cracked and many joints are opening: some have been "closed" with timber wedges, others not. The transversal opening of the trusses, that caused these problems and that the 80s and 90s works tried to counteract, could be still ongoing.



Damage: disconnection | link | I:\Arch\A

Other Notes: Robert Adam was the architect (even though J. Craig and J. Geoffrey made designs as well), but then he died and his design was changed and built probably not by his brother James, who also died before the works were finished, but by Paterson (this is F. Sutherland's opinion). He shrinked the whole building and the dome in particular. For sure John Brown, wright, was the contractor. He might have designed the roof structure, since it works better than the one drawn by

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui

GLASGOW TRON CHURCH

Location: GLASGOW, CITY OF | GLASGOW (GLASGOW, CITY OF)

X coordinate: 259526 Y coordinate: 664880

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 139510

Original Use: Religious

Current Use: Theatre

Freestanding ☐ N. of floors above ground level: 2 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1484			BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
RECONSTRUCTION	1592			BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1630	1636	STEEPLE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
DAMAGE, RECONSTRUCTION	1793	1794	CHURCH REBUILT AFTER FIRE (ONLY STEEPLE REMAINED), SET BACK AND INDEPENDENT OF THE STEEPLE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM 1	JAMES 1	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1855		ARCHES ON GROUND LEVEL OF TOWER INSERTED	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1899	1900	BAROQUE SCREEN WALL AND GATEWAY ADDED TO THE EAST WALL FORMING A COURTYARD	HS

People involved:

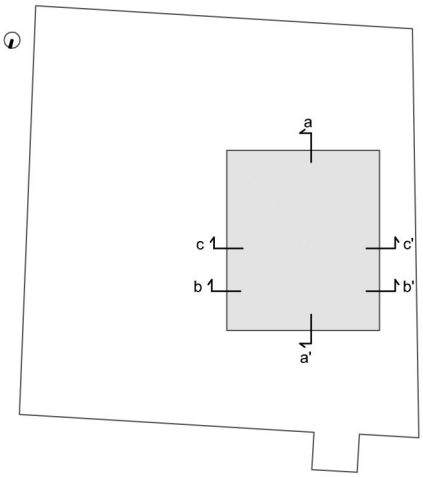
Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1979	1981	CONVERTED INTO A THEATRE - MOST OF THE INTERIOR WAS RECAST EXCEPT FOR THE PLASTER IN THE DOME (SAYS HS)	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	205
SUMMERSON S. J. N.	1963	☐	THE CLASSICAL LANGUAGE OF ARCHITECTURE	511
WILLIAMSON E. & RICHES A.	1990	☐	THE BUILDINGS OF SCOTLAND COLLECTION: GLASGOW	

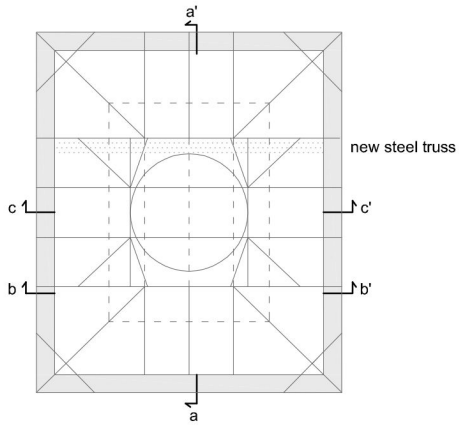
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

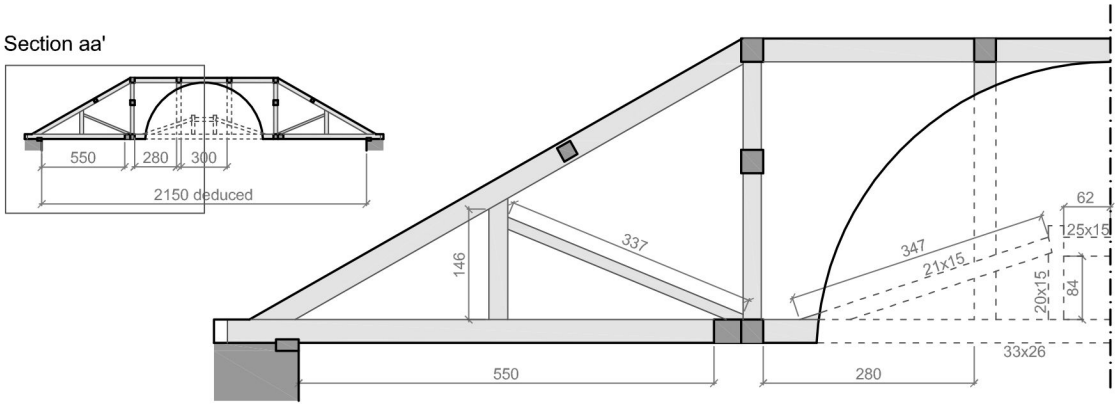
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

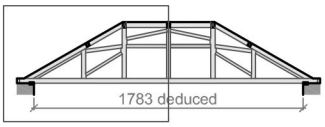
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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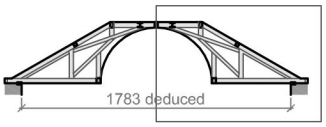
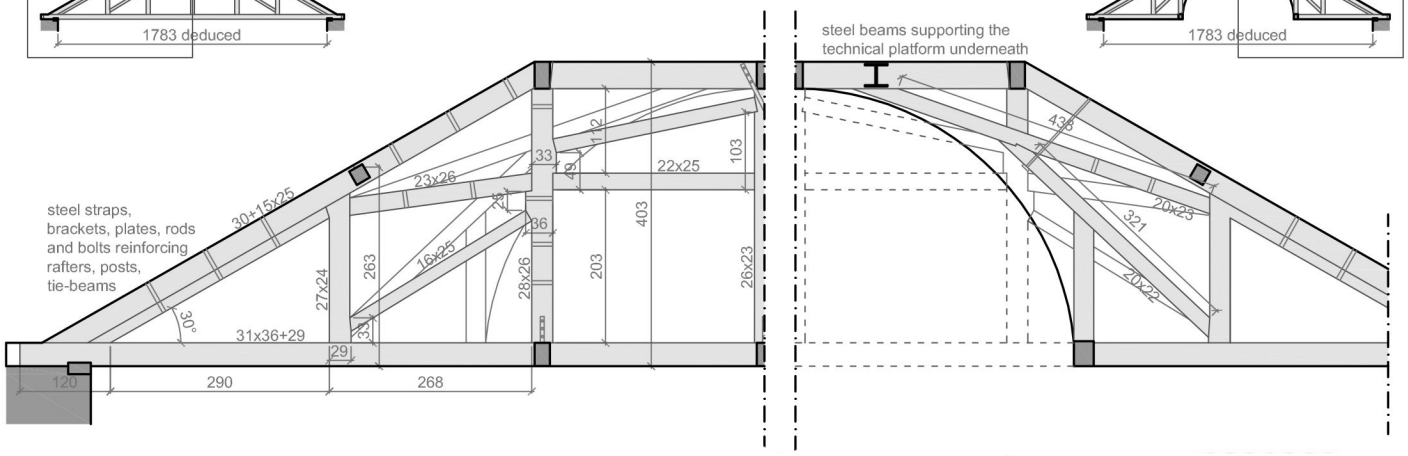




Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** GLASGOW TRON CHURCH | **Roof location** Main auditorium

Survey date(s) 14/08/2015 | See drawing: GTC-MA-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 17.8 | Roof Height [m]: 4

Roof Pitch/es [°]: 30 | Roof Length [m]: 21.5

Type of Primary Structure: 3D framing

Truss ☑ OTHER

Frame ☐

Average Distance in between Primary Structure [m]: 2.9

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Dragon tie, Tie-beam, Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1793 To 1794 Identified by: Estimated

Roof General Description:

Hipped platform roof with internal plaster dome. 4 trusses in the transversal direction, with five posts each. They have a truss inside another truss: short principals reach half the height and form an arch system with horizontal beams, inside the bigger truss. Two shorter trusses in the longitudinal direction, supporting the transversal trusses. Dragon beams and ties are used in the corners. The rest of the rafters rest on wall-plates. Timbers with big scantlings, partly hand axed and partly hand sawn. There are some unusual carpentry marks.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 30 B: 25 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: joggle, mortice and tenon, notch

Fasteners Types: Metal strap

Joints description:

All mortice and tenon with no fasteners, except for metal straps between posts and lower and upper beams and rafters. Posts have joggles or notches for the struts.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: runic marks, small chiseled roman numerals

Carpentry Marks Description:

Only a few visible.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



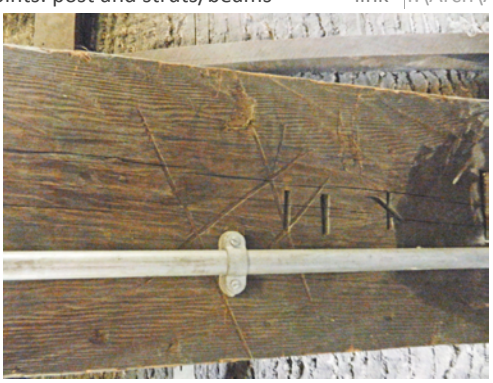
Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: post and struts/beams | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: Original dome plaster ceiling underneath.

Unfavourable conditions:

Accessibility limitations:

Past interventions: Steel straps, brackets, plates, rods and bolts reinforcing rafters, posts, tie-beams. Some sarking and common rafters replaced. New steel truss on south side of plaster dome. Timber wedges inserted in opened joints. Steel beams supporting technical theatre platform underneath. Timber replacements of some tie-beams' ends.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐



Past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks	Intervened on	
Connection Damage	Disconnection	Intervened on	



Damage: purlin cracking | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☑ increase of dead loads
- Extreme actions ☐
- Other ☐



Damage: post cracking | link | I:\Arch\A

Description of visible damage: Posts, rafters and purlins have cracks. Some joints have opened. All intervenend on, but not sure if effectively (some new cracks have opened in the plaster ceiling).



Damage: joint opening | link | I:\Arch\A

Other Notes:

Attachments:

HADDO HOUSE

Location: ABERDEENSHIRE | METHLICK
X coordinate: 386831 Y coordinate: 834750
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC
Protection status: NATIONAL
HS Listing: A Rcahms ID: 19842

Original Use: Residential
Current Use: Museum

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
DESIGN	1728			BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1732	1736		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BAXTER	JOHN THE ELDER	CONTRACTOR, MASON	☐
JOHNSTON	JOHN	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1822		STAIRCASE FROM FIRST TO SECOND FLOOR	CANMORE

People involved:

Last Name	First Name	Role	Attributed
SIMPSON	ARCHIBALD	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1843		KITCHEN COURT	CANMORE

People involved:

Last Name	First Name	Role	Attributed
SMITH	J & W	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1878	1880	CHAPEL	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1879	1881	INTERIORS - MAYBE ROOF STRUCTURE AS WELL (SAYS IAN DAVIDSON)	CANMORE

People involved:

Last Name	First Name	Role	Attributed
WARDROP & REID		ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1930	1940	FIRE IN SOUTH WING	IAN DAVIDSON

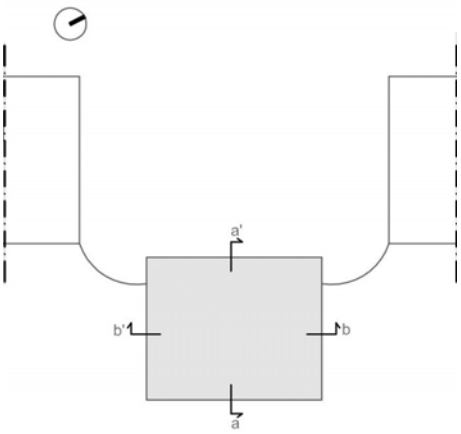
People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
WALKER D. & WOODWORTH M.	2015	☐	THE BUILDINGS OF SCOTLAND COLLECTION: ABERDEENSHIRE: NORT MORAY	
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 54-56

Author	Year	Unpubl.	Title	Pages
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	54-56

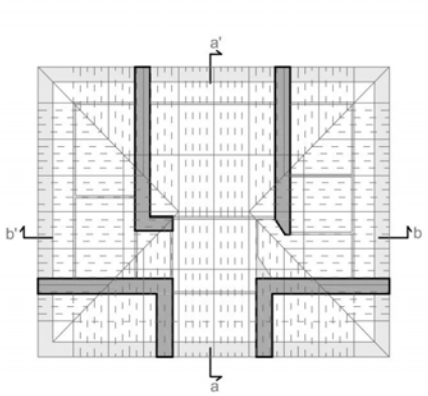
Suggestions for further research	NRS: accounts from 1739 to 1765 (GD33/65/112/4) and accounts from 1772 to 1811 (GD33/65/112/5) Papers held privately by the family



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

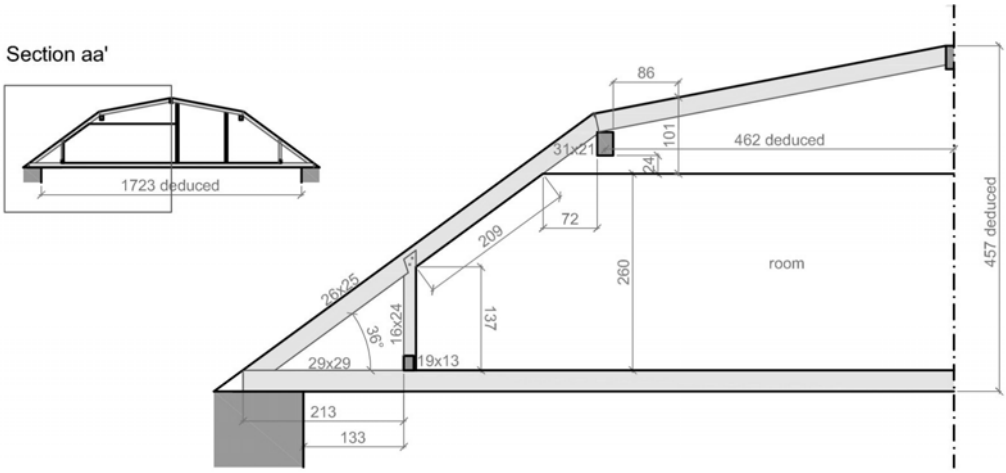
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

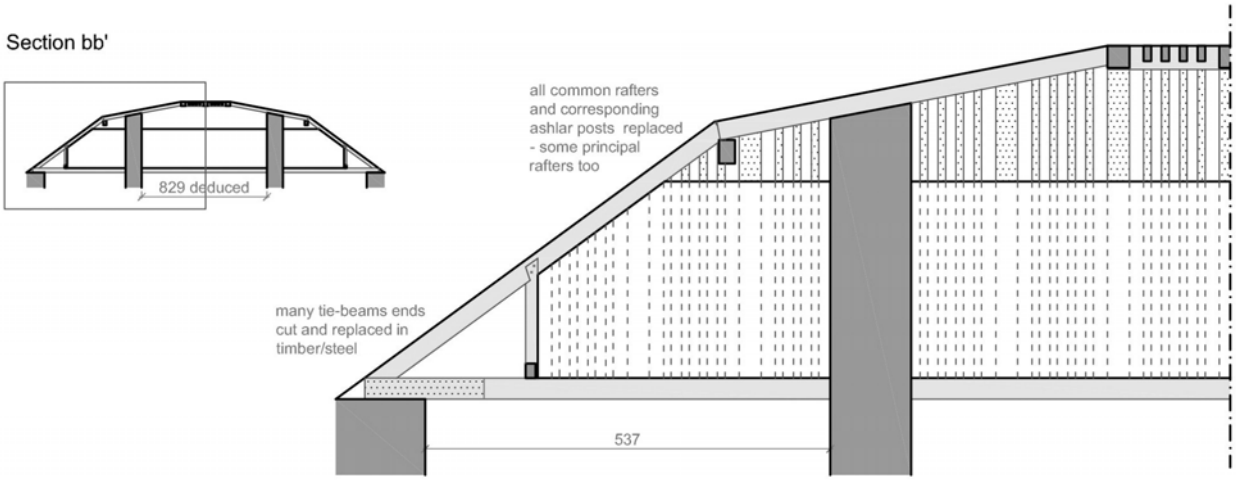
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY **Building name** HADDO HOUSE **Roof location** Main block

Survey date(s) 06/08/2015 See drawing: HDH-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 8.29 Roof Height [m]: 4.57

Roof Pitch/es [°]: 36 Roof Length [m]: 17.23

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]: 4.62

Type of Secondary Structure: common rafters, sarking Plane: roof plane

Sarking boards: width [cm] thickness [cm]

Connection with lateral walls: Dragon tie

Connection with gables: purlins

Roof Construction Period: From 1732 To 1736 Identified by: Estimated

Roof General Description: Hipped platform roof supported by transversal walls and purlins. Frames divided into primary and secondary ones (1 primary every 4 secondary), with different scantlings. Little remains of original timbers especially at wall-head level, where most of them have been replaced with prostheses. Rafters and tie-beams connected with tension ashlar posts. Dragon beams and ties in the corners.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular, Square

Rafter Scantling [cm] H: 26 B: 25 Or Purlin - H: 31 B 21

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail

Joints description:

Wood Species: softwood, probably pine Way of identification: estimated

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure link I:\Arch\A



Roof structure link I:\Arch\A



Connection with wall link I:\Arch\A



Joints: principal rafter and strut link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Most of the structure not visible because of plastering

Past interventions: Wallhead raised. All common rafters and their ashlar posts replaced. Sarking replaced. Some tie-beams replaced in timber and steel.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage: | link | I:\Arch\A

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link | I:\Arch\A

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link | I:\Arch\A

HOPETOUN HOUSE

Location	WEST LOTHIAN	ABERCORN (WEST LOTHIAN)	
X coordinate	308856	Y coordinate	679016
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PRIVATE		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	49127
Original Use	Residential		
Current Use	Meeting Hall, Museum, Residential		

Freestanding ☑ N. of floors above ground level 3 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1699	1701	ONY W FAÇADE AND SMALL ROOMS OF THE CENTRE BLOCK OF THE HOUSE SURVIVE	CANMORE

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT	☐
BACHOP	TOBIAS	STONE WORKER	☐
EIZAT	ALEXANDER	CARVER, WRIGHT	☐
EIZAT	WILLIAM	WRIGHT	☐
EDWARD	ALEXANDER	DESIGNER	☐
WARRANDER	THOMAS		☐
MORGAN	WILLIAM	CARVER	☐
TIDEMAN	PHILIP	PAINTER	☐
HOPE	LADY MARGARET	COMMISSIONERPATRON	☐
NORIE	JAMES	PAINTER	☑
FORSTER	JOHN	GLAZIER, PLUMBER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION, LANDSCAPE	1721	1748	CENTRE BLOCK WIDENED, COLONNADES AND PAVILLIONS ADDED	HS

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT, CONTRACTOR	☐
ADAM	ROBERT	ARCHITECT, CONTRACTOR	☐
ADAM	JOHN	ARCHITECT, CONTRACTOR	☐
HOPE	CHARLES 1ST EARL O	COMMISSIONERPATRON	☐
DAWSON	JOHN	PLASTERER	☐
CLAYTON	THOMAS	PLASTERER	☑

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1893		MAIN GATES AND LODGE	CANMORE

People involved:

Last Name	First Name	Role	Attributed
ROWAND ANDERSON	ROBERT	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2000		DATE NOT SURE	JOHN ADDISON

People involved:

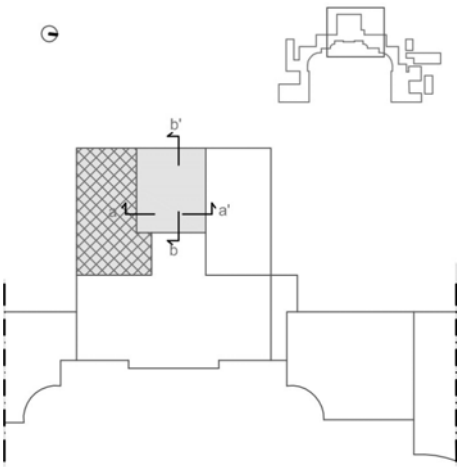
Last Name	First Name	Role	Attributed
ADDISON	JOHN	ENGINEER	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	80-81

Author	Year	Unpubl.	Title	Pages
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	120
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	86
LOWREY J.	2012	☐	A PROSPECT OF ANTIQUITY AND BRITANNIA ON EDGE: LANDSCAPE D THE WORK OF SIR WILLIAM BRUCE AND ALEXANDER EDWARD	ARCHITECTURAL HERITAGE, VOL. 23
MACAULAY J.	2009	☐	SIR WILLIAM BRUCE'S HOPETOUN HOUSE	ARCHITECTURAL HERITAGE, VOL. 20
MACKECHNIE A.	2012	☐	INTRODUCTION. SIR WILLIAM BRUCE AND ARCHITECTURE IN EARLY I SCOTLAND	ARCHITECTURAL HERITAGE, VOL. 23
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	12
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	210
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	17
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 14-21

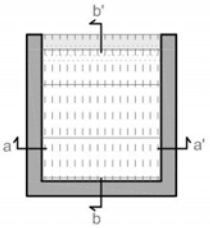
Suggestions for further research	Private archives at Hopetoun house (consultation fee) Wing roof is original even though it was not surveyed because of lack of time



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

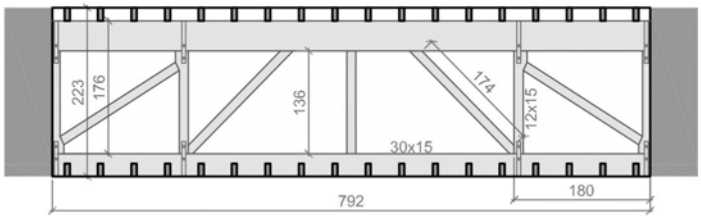
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

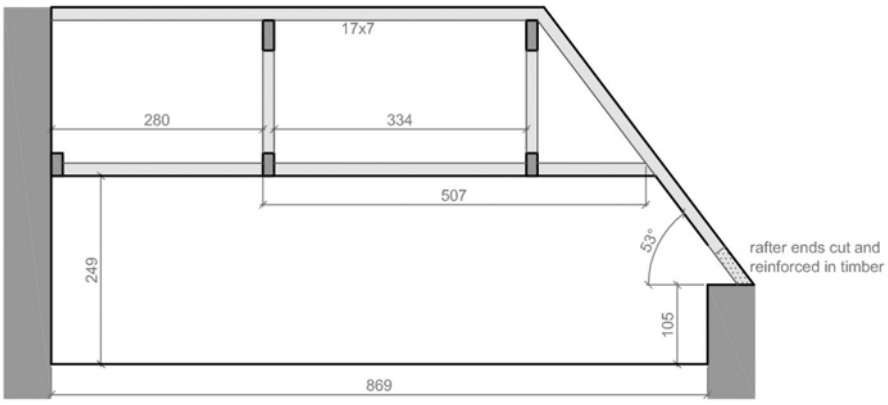
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

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Roof from outside I:\Arch\A

INITIAL SURVEY | **Building name** HOPETOUN HOUSE | **Roof location** 1: central block

Survey date(s) 21/08/2015 | See drawing: HPH-CB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 7.9 | Roof Height [m]: 2.2

Roof Pitch/es [°]: 53 | Roof Length [m]: 8.7

Type of Primary Structure: 2D framing

Truss ☑ | Frame ☐

Average Distance in between Primary Structure [m]: 3.34

Type of Secondary Structure: common rafters, sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables: purlins

Roof Construction Period: From 1721 To 1748 | Identified by: Estimated

Roof General Description: A hipped platform roof supported by transversal walls. Only central and South part fully visible. South part seems to have been almost fully replaced in 19C. Central part is supported by 2 trusses composed of an upper and a lower purlin and posts and slanted struts in between them, supporting common rafters and sarking. The two horizontal beams are full logs, with big scanltings. The posts and struts are smaller, porbably half logs or quarters of logs. They are all hand sawn. No numbering is visible.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: 30 | B 15

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: joggle, mortice and tenon

Fasteners Types: Metal strap

Joints description:

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description: Not visible

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: post and beam/strut | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Sarking and some horizontal common rafters replaced. Common rafter ends all cut and replaced in timber.



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	
Roof Damage				link
Unit Damage				
Element Damage				
Connection Damage				

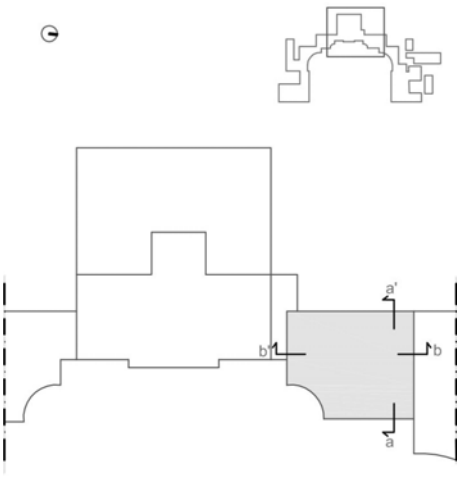
Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes

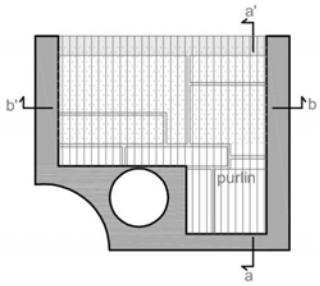
Attachments link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



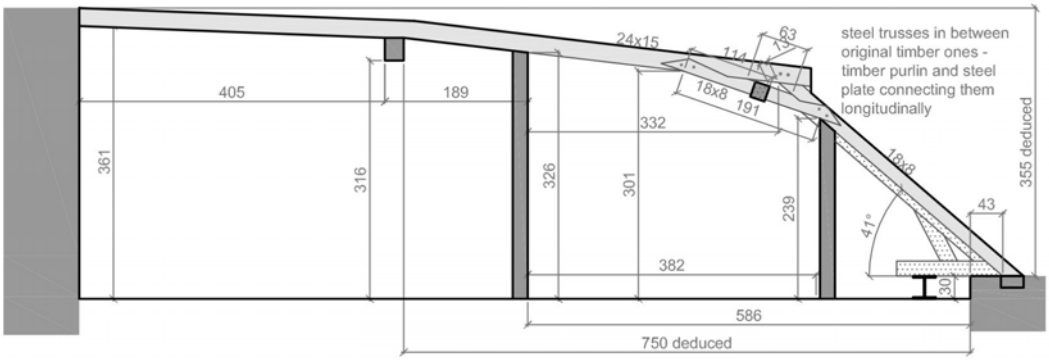
Carpentry marks from north to south:

not visible	XIX
IIII	XX
Λ	IIX
IIIIΛ	X
IX	ΛIX
I	II
IIΛ	IIIX
X	IIXX
III	IIIXX
IΛ	ΛXX
not visible	IIIΛ
XXI	IIΛX
IIIΛXX	IΛXX
IIIIXX	not visible

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

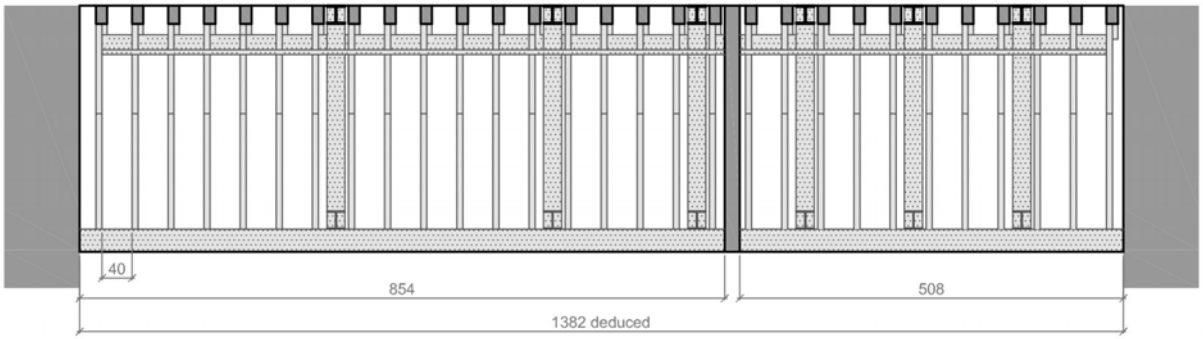
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Roof from outside I:\Arch\A

INITIAL SURVEY **Building name** HOPETOUN HOUSE **Roof location** 2: N range

Survey date(s) 21/08/2015 See drawing: HPH-N-1

Roof Geometry: Flat, Mansard, Shed

Roof Max Span [m]: 7.5 Roof Height [m]: 3.55

Roof Pitch/es [°]: 41 Roof Length [m]: 13.8

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]: 0.38

Type of Secondary Structure: sarking Plane: roof plane

Sarking boards: width [cm] thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: rafters

Roof Construction Period: From 1721 To 1748 Identified by: Estimated

Roof General Description: Monopitch roof supported by a spine wall and purlins, on which sit 29 rafters whose pitch decreases (from almost flat to 41 degrees). In the junction between the rafters with higher and lower pitch there is a short strut tying the two together. A steel frame has been recently added to support the rafters at wall-head level. The timbers are half logs, hand axed and then hadn sawn in two. They are numbered with big sawn roman numerals.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 24 B: 15 Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Mortice and tenon with two timber pegs not flush between rafter and rafter. Dovetail notched lapped with two metal nails between strut and rafters.

Wood Species: softwood, probably pine Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Not in sequence

Signs of reused timbers

Timber Treated ☐

Other Materials: Steel beams and rods

Dendrochronology



Roof structure link I:\Arch\A



Connection with wall link I:\Arch\A



Roof structure link I:\Arch\A



Joints: rafters and strut link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Flat part of roof structure not visible

Past interventions: Timber reinforcing rafter ends. Steel trusses in between the original timber ones, connecting all of them with a timber purlin and steel plates.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:		link	
Roof Damage						
Unit Damage						
Element Damage						
Connection Damage						

Estimated cause(s) of the primary damage: | link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes

Attachments | link

KELBURN CASTLE

Location: NORTH AYRSHIRE | LARGS
X coordinate: 221708 | Y coordinate: 656701
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A | Rcahms ID: 41169

Original Use: Residential
Current Use: Residential

Freestanding: ☑ | N. of floors above ground level: 4 | Location link: I:\Arch\AD | Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1175	1225		BENJAMIN TINDALL ARCHITECT

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1500	1550	EAST PART OF TOWER HOUSE - A CHARTER OF 1556 REFERES TO IT	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1581		EXTENSION TO FORM Z PLAN - DATE ON SOUTH WALL ABOVE CUSPED OF TOWER HOUSE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1692	1703	WEST END OF NORTH RANGE, REPLACING AN EARLIER BUILDING	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
CALDWELL	THOMAS	CONTRACTOR, MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1722		CENTRALO AND EAST PART OF NORTH RANGE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BOYLE	DAVID 1ST EARL OF	COMMISSIONERPATRON	☐

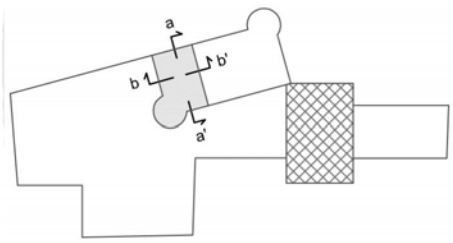
Intervention type:	From:	To:	Description:	Reference:
ADDITION	1879	1885	NORTH EAST WING	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CLOSE R.	2012	☐	THE BUILDINGS OF SCOTLAND COLLECTION: AYRSHIRE AND ARRAN	
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	24-31

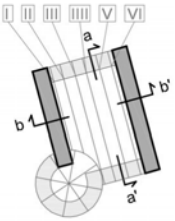
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

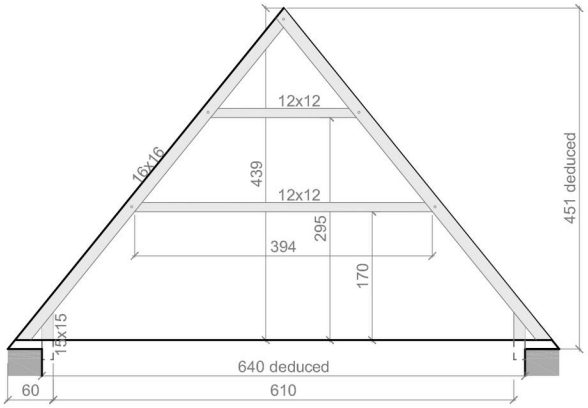
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

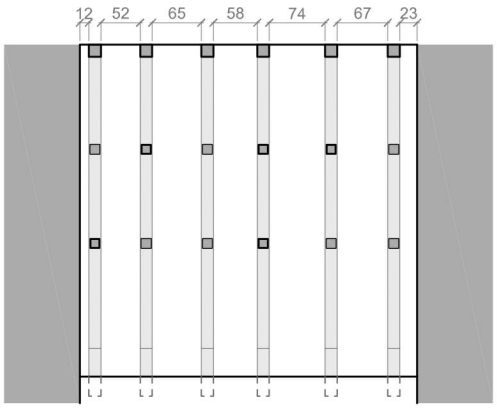
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** KELBURN CASTLE | **Roof location** 1: Old tower house to S

Survey date(s) 09/07/2015 | See drawing: KC-S-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.4 | Roof Height [m]: 4.5

Roof Pitch/es [°]: 51 | Roof Length [m]: 4.5

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.63

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 2.5

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1581 To | Identified by: Estimated

Roof General Description: Only part of the towerhouse gabled roof is accessible. It's composed of 6 frames with two collars and rafter feet. Timbers are very roughly squared, some are not even straight. There are saw marks as well, though. Some of the original timber pegs securing the slates to the sarking are still in place.

Roofing Material: slate

Roofing Material Fixing: Metal nails, Timber Pegs

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 16 B: 16 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush

Wood Species: the structure seems to be oak, the sarking pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Numbered from I to VI, in sequence (from east to west)

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Dressing and carpentry marks | link I:\Arch\A



Joints: rafter apex | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance

Accessibility limitations: Connection with wall not visible

Past interventions: Sarking on north side replaced (in 19C?).



Fungi attack in south-east corner | link I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☐

Serpula lacrimans attacking south-east corner (rafters and sarking) - active. There is water ingress in this area of the roof and an open water tank is in the roof space.

	Damage Type:	Damage Status:	Damage Role:	link
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

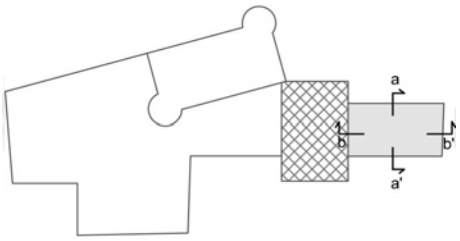
Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes: Repair works are undergoing (July 2015)

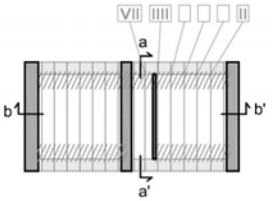
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

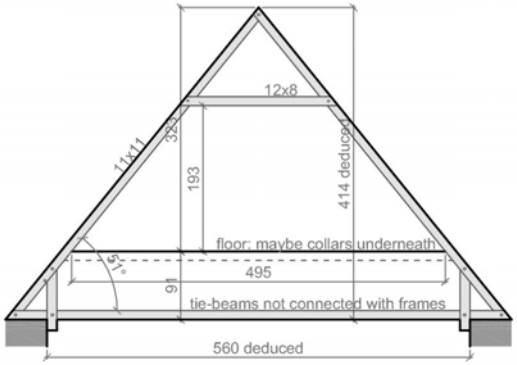
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

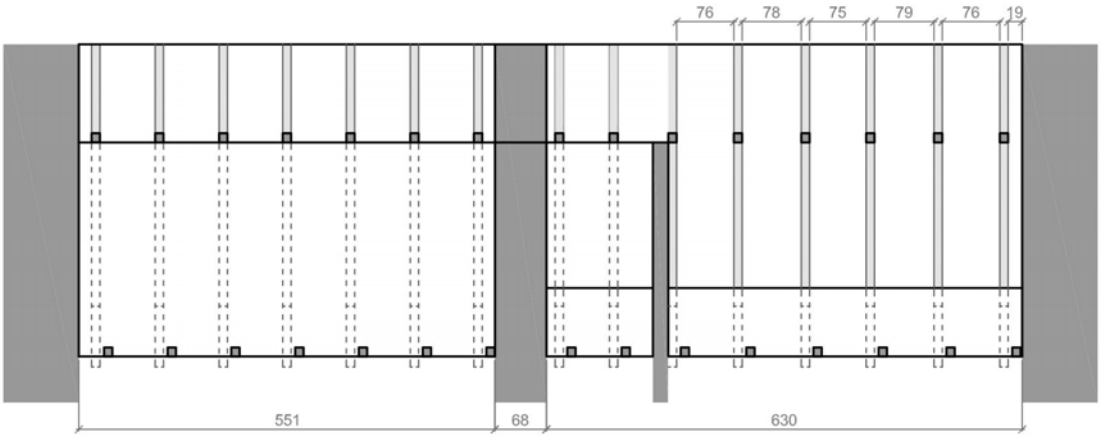
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** KELBURN CASTLE | **Roof location** 2: W wing

Survey date(s) 09/07/2015 | See drawing: KC-W-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 5.6 | Roof Height [m]: 4.14

Roof Pitch/es [°]: 51 | Roof Length [m]: 12.5

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.75

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 2

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1722 To | Identified by: Estimated

Roof General Description: Gabled roof composed of 16 frames with an intermidiate supporting wall. Frames have possibily two collars (one visible, one under the floor boards) and rafter feet. The timbers are all full logs hand axed and hand sawn. Some of the original timber pegs used to secure the slates to the sarking are still in place.

Roofing Material: slate

Roofing Material Fixing: Timber Pegs

Timber elements' Section Shape: Rectangular with wanes, Square with wanes

Rafter Scantling [cm] H: 11 B: 11 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: mortice and tenon with timber pegs not flush. Between rafter and collar: lapped with metal nail.

Wood Species: the structure seems to be oak, the sarking pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Few visible.

Signs of reused timbers: redundant joints in rafters, but probably because collars were moved

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber elements' dressing | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Redundant joints | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance, presence of water tank

Accessibility limitations: Connection with wall only visible in a small portion of the roof structure

Past interventions: Some double rafters and collars added, as well as tie-beams.



Fungi attack | link I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

Fungi attack on some timber elements - active, that's why they stripped off the plastering

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes: Repair works are undergoing (July 2015)

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

KINROSS HOUSE

Location	PERTH AND KINROSS	KINROSS	
X coordinate	312637	Y coordinate	702044
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PRIVATE		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	27882
Original Use	Residential		
Current Use	Hotel/Inn, Meeting Hall		

Freestanding ☑ N. of floors above ground level 3 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1550	1583	OLDER HOUSE ON ANOTHER SITE - NOTHING REMAINS	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1679	1693	ROOF DONE BY 1691 - INTERIORS STARTED IN 1692 - IT WAS LEFT UNFINISHED	GLENDINNING 2004

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT, COMMISSIONERPATRON	☐
EDWARD	ALEXANDER	DESIGNER	☐
BACHOP	TOBIAS	MASTER MASON	☐
MERCER	JAMES	CARVER	☐
OLIPHANT	THOMAS	WRIGHT	☐
BENNETT	ROBERT	WRIGHT	☐
FAIR	JOHN	WRIGHT	☐
VAN NERVEN	CORNELIUS	PLASTERER	☐
BOYS	PETER PAUL	PLASTERER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION, CONSERVRESTOR	1777	1790	REPLACEMENT OF WINDOWS, DEMOLITION OF ENTRANCE LODGES, INTERIOR ALTERATIONS, LOWERING OF THE GROUND ABUTTING THE BASEMENT FLOOR, CONSTRUCTION OF STABLE COURTYARD	SIMPSON AND BROWN REPORT

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR, DEMOLITION	1845	1855	REPAIRS TO THE ROOF, THE CEILING WAS LOWERED, AND THE MUSICIAN'S GALLERY BLOCKED - WINGS DEMOLISHED	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1863	1869	ROOF RENEWED - SOME 17C TIMBERS REMAIN OVER THE NORTH AND SOUTH PAVILION ENDS, PARTICULARLY OVER THE STATE STAIR AND THE CUPOLA	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION, LANDSCAPE	1899	1928	INTERIORS, STABLES, LODGES REBUILT, SOME LANDSCAPING AND PLANTING	SIMPSON AND BROWN REPORT

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1904	1906	INTERIORS - ALSO PLASTER CEILING	CANMORE

People involved:

Last Name	First Name	Role	Attributed
ROSS	THOMAS	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2011	2013	EXTENSIVE CRACKING BETWEEN INNER CROSS WALLS AND EXTERNAL SOLID WALLS AS A RESULT OF HISTORIC SETTLEMENT - STAINLESS STEEL HELIBARS AND GROUTED CEMTIES WERE USED TO STITCH CRACKS AND RESTORE THE INTEGRITY OF THE MASONRY	CANMORE

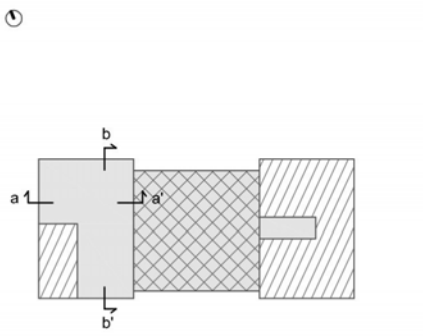
People involved:

Last Name	First Name	Role	Attributed
3DREID		ARCHITECT	☐
SIMPSON & BROWN		ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	79-80
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	119
GIFFORD J.	2007	☐	THE BUILDINGS OF SCOTLAND COLLECTION: PERTH AND KINROSS	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	72, 84
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	12
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	14
SIMPSON & BROWN ARCHITECTS	2010	☑	KINROSS HOUSE CONSERVATION PLAN	
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 61, 62

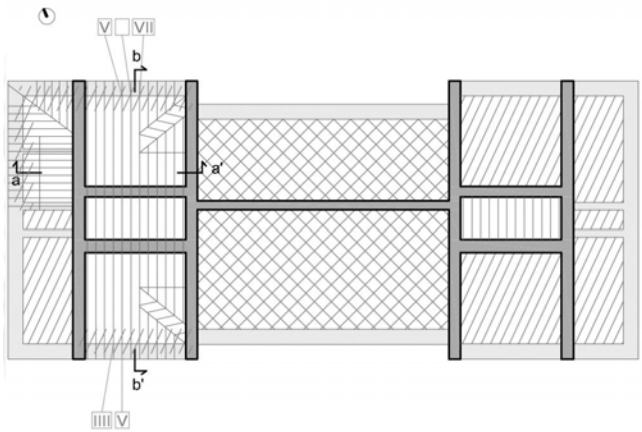
Suggestions for further research: NRS: GD29 Bruce papers and accounts - GD1/51/62 accounts 1688-90 - GD18/1859, 18C - RHP8787 Survey of Kinross 18C



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

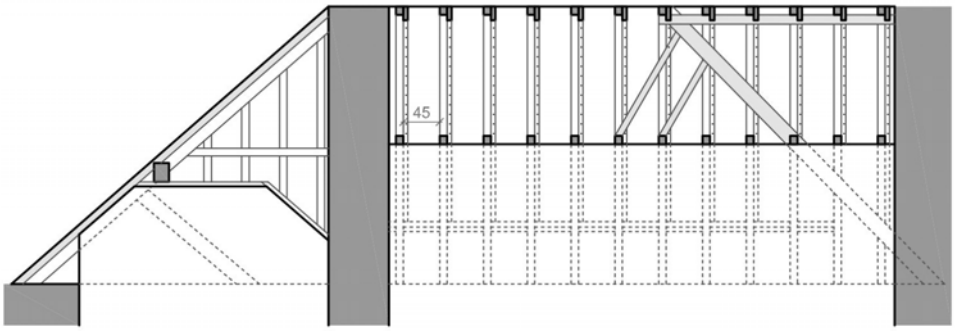
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

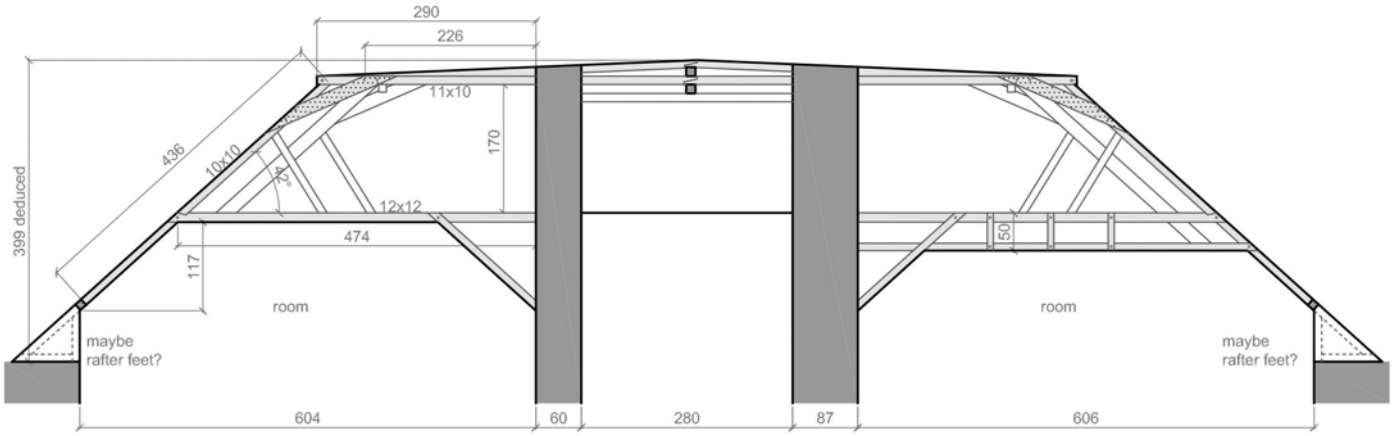
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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0 1 5



Roof from outside I:\Arch\A



Roof from inside I:\Arch\A

INITIAL SURVEY | **Building name** KINROSS HOUSE | **Roof location** Main block

Survey date(s) 10/11/2015 | See drawing: KH-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 6.04 | Roof Height [m]: 3.89

Roof Pitch/es [°]: 42 | Roof Length [m]: 39.8

Type of Primary Structure: 2D framing, Purlins

Truss ☐

Frame ☑ Other

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables: rafters

Roof Construction Period: From 1679 To 1693 Identified by: Estimated

Roof General Description:

Hipped platform roof with transversal walls as supports. Central section replaced in 19C. East section not accessible, esxcept for a small part. West section covered with a purlin roof on the East side, and with a 'platform frame' (like Melville, Holyrood, etc) in the West side. The purlin roof has been altered in the 19C. It is visible but not measurable. The West section has been strengthened but the original structure remains: it has upper horizontal beams supported by two transversal walls and joining the rafter upper ends on the sides (this joint has been reinforced later with short struts); collars join the rafters to the walls and slanted

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 12 B: 12 Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed) Bark ☑

Joint Types: dovetail, lapped, mortice and tenon, scarf

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Between upper beam and rafter: mortice and tenon with timber peg not flush. Between rafter and collar: dovetail lapped with metal nail.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Only two visible

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology



Roof structure: 2D framing link I:\Arch\A



Roof structure: purlin roof link I:\Arch\A



Timber dressing link I:\Arch\A



Joint: rafter and upper beam link I:\Arch\A



Joint: beams in central part link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with the wall not visible

Past interventions: Central part of the roof completely replaced in 19C. 19C and 21C timbers reinforcing the original timbers in the lateral parts. Sarking replaced.



Past interventions: lateral part | link | I:\Arch\A



Past interventions: central part | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☑

Water ingress close to walls. Insect and fungi attack on many timbers.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Water ingress | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Insect attack | link | I:\Arch\A

Description of visible damage



Fungi attack | link | I:\Arch\A

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber

MALLENY HOUSE

Location: EDINBURGH, CITY OF | CURRIE
X coordinate: 316485 Y coordinate: 666552
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC
Protection status: NATIONAL
HS Listing: A Rcahms ID: 50278

Original Use: Residential
Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1635		INCORPORATING EARLIER WORK - THERE IS A 1589 DATE ON THE KITCHEN CHIMNEY	RCAHMS

People involved:

Last Name	First Name	Role	Attributed
MURRAY	SIR JAMES	ARCHITECT, COMMISSIONERPATRON, WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1820		ONE STOREY, KNOWN AS THE GEORGIAN WING, WAS ADDED TO THE NORTH	RCAHMS

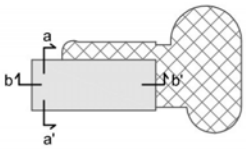
People involved:

Last Name	First Name	Role	Attributed
SCOTT	GENERAL THOMAS	COMMISSIONERPATRON, DESIGNER	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	

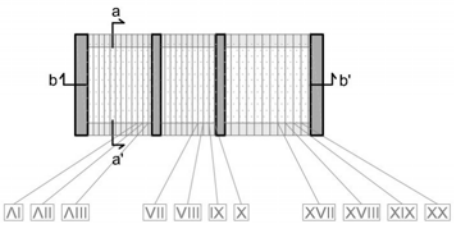
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

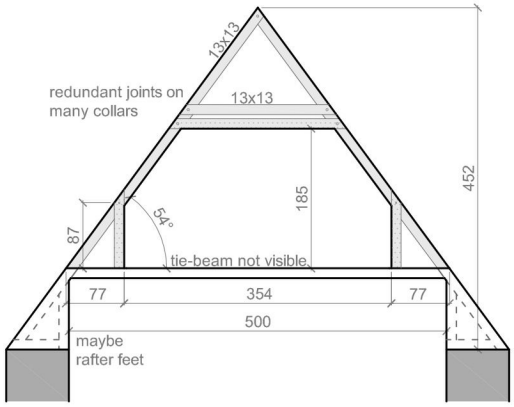
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

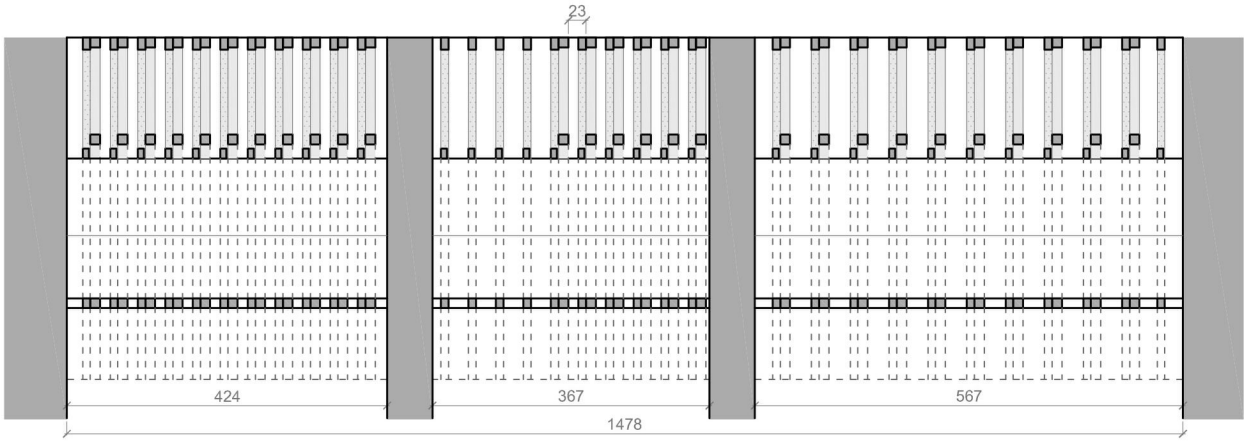
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** MALLENY HOUSE | **Roof location** Main block

Survey date(s) 22/08/2014 | See drawing: MNH-MB-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 5 | Roof Height [m]: 4.52

Roof Pitch/es [°]: 54 | Roof Length [m]: 14.78

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.23

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1635 To | Identified by: Estimated

Roof General Description:

Two-pitch gabled roof supported by frames with two collars (one visible and one under the floor boards) and ashlar posts (probably added later, when plastering was put up to make rooms). There might be rafter feet, but the connection with the wall is not visible. All timbers are full logs roughly squared with a hand axe. The frames have been doubled probably in 19C. The timbers are numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 13 | B: 13 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Between rafters and collars: lapped with timber pegs not flush.
Rafters' apex: mortice and tenon with timber pegs not flush.
Between ashlar posts and rafters: metal nails, no joint.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Few visible are in sequence

Signs of reused timbers: Some collars have redundant joints and look older than the rest

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Frames doubled and sarking replaced probably in 19C. Few frames replaced completely.



Past interventions | link | I:\Arch\A



Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack in collars and rafters' apex mainly, not sure if active

Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link | I:\Arch\A

Other Notes: The house was built in 1635, probably incorporating an older 16C core. It seems some 16C timbers were reused in the 17C roof.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

MAYBOLE CASTLE

Location: SOUTH AYRSHIRE | MAYBOLE
X coordinate: 230130 Y coordinate: 610031
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 41650

Original Use: Residential
Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1600	1625		HS

People involved:

Last Name	First Name	Role	Attributed
KENNEDY	JOHN 6TH EARL OF C	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1660		PROJECTING TWO STOREY SOUTH-WEST WING	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1800		17TH CENTURY, ENLARGED IN 19TH	RCAHMS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1849	1850	WINDOWS ON FIRST FLOOR AND TWO STOREY ADDITION TO NORTH	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1917		FIRE	CHRIS SAVAGE

People involved:

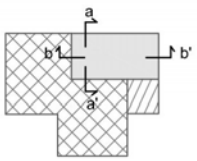
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2014		ONGOING	CHRIS SAVAGE

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CLOSE R.	2012	☐	THE BUILDINGS OF SCOTLAND COLLECTION: AYRSHIRE AND ARRAN	
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME III. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	498-502
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	15

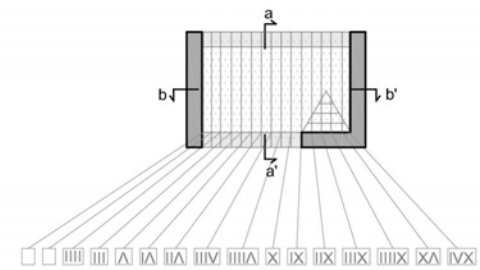
Suggestions for further research: NRS: miscellaneous papers (GD25/9/44)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

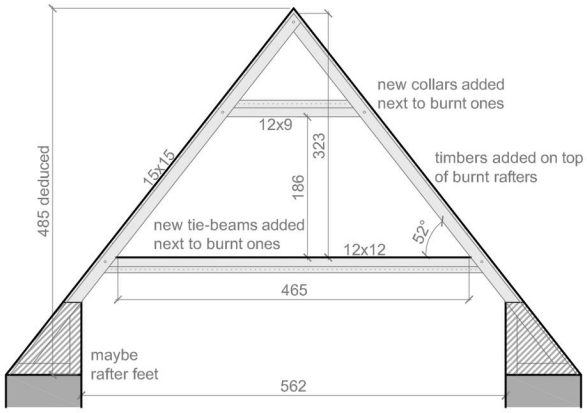
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

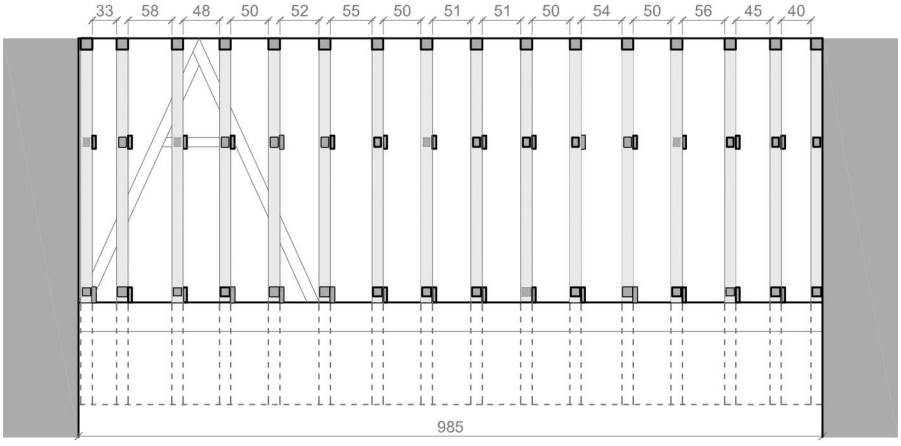
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** MAYBOLE CASTLE | **Roof location** N range of tower house

Survey date(s) 26/09/2014 | See drawing: MYC-N-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.62 | Roof Height [m]: 4.92

Roof Pitch/es [°]: 52 | Roof Length [m]: 9.85

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables

Roof Construction Period: From 1600 To 1625 Identified by: Estimated

Roof General Description:

Two-pitch gabled roof with intersection on the South, interrupted by gable wall. The roof is composed of closely spaced rafter couples connected trasversally by one collar and longitudinally by sarking boards only. The connection with the wall is embedded in masonry; there might be rafter feet. All the timbers are covered with a thick layer of char because the roof has burnt in 1917. The frames have been doubled to reinforce the original timbers. Big sawn roman numerals number the frames.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes, Square with wanes

Rafter Scantling [cm] H: 15 B: 15 Or Purlin - H: B:

Timber elements' Dressing | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description:

All mortice and tenon with timber pegs not flush

Wood Species: can't say because of char | Way of identification:

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Mostly in sequence from 5 to 16 from north to south. Number 3 and 4 are switched and the first two don't have any visible marks.

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology



Roof structure | link I:\Arch\A



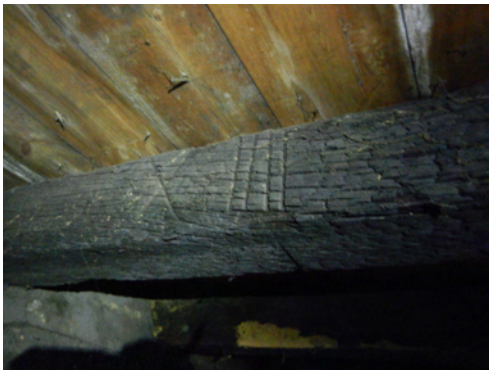
Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation, presence of pigeons/wasps/bats

Accessibility limitations: Connection with wall not visible

Past interventions: Frames doubled (collars and tie-beams, rafters only strengthened with boards a few centimeters thick) after 1917 fire. Most of the original timbers, although very damaged, left in situ. Probably at this time the sarking was replaced.



Past interventions | link | I:\Arch\A



Material degradation | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☐

problems of dry rot in all the house, and insect attack in some rafters, not sure if active

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	other	Intervened on	Primary
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☑ fire
- Other ☐

link

Description of visible damage: Many problems with humidity, dry rot and pigeons' droppings. The pigeons block the gutters, so the rain water overflows, damaging the outside walls. Dry rot affecting almost all the outside walls, and passing to the timbers. No ventilation. There is a crack running from basement to 4th floor and separating the south façade from the rest of the building.

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui

link

MELVILLE HOUSE

Location	FIFE		MONIMAIL
X coordinate	329893	Y coordinate	713801
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PRIVATE		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	30153
Original Use	Residential		
Current Use	Residential		

Freestanding ☑ N. of floors above ground level 4 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1697	1703		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	ARCHITECT	☐
BRUCE	SIR WILLIAM	DESIGNER	☐
MELVILLE	GEORGE 1ST EARL O	COMMISSIONERPATRON	☐
EDWARD	ALEXANDER	DESIGNER	☐
MCKENZIE	KENNETH	WRIGHT	☐
CARNABY	JOHN	PLUMBER	☐
HUTCHISON	JAMES	SLATER	☐
INNES	JAMES	SLATER	☐
BANNATYNE	ROBERT	GLAZIER	☐
ALBORN	THOMAS	PLASTERER	☐
MELVILLE	JOHN	PLASTERER	☐
CHRISTIE	JOHN	PLASTERER	☐
KYLE	THOMAS	JOINER, WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1800	1899	INTERIORS RECAST	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1800	1825	PORCH TO NORTH	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1939			HS

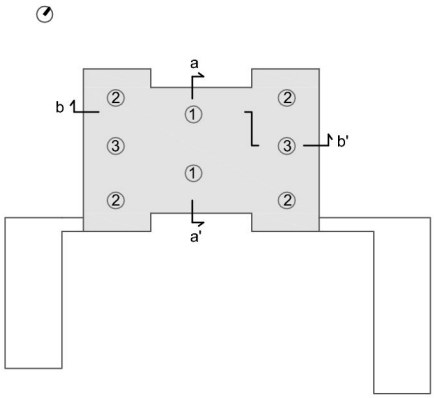
People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
ARC ARCHITECTS	2003	☑	HISTORIC AND ARCHITECTURAL INFORMATION RELATING TO MELVII	
GIFFORD J.	1988	☐	THE BUILDINGS OF SCOTLAND COLLECTION: FIFE	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	86

Suggestions for further research: NRS: GD 26/13/276 (Wage book for workmen and masons - 1747); GD 26/5/564 (Payment for building a new house at Melville

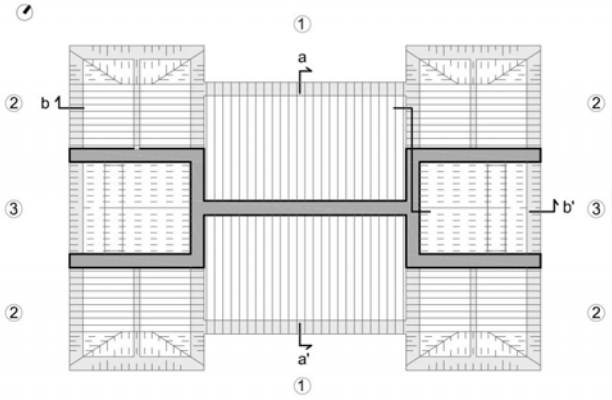
in 1697. Earl of Leven, James Smith and his partner - 1726); GD 26/6/164 (Providing a lead roof. Contract between George, Earl of Melville and John Carnaby, plumber - 1699); GD 26/6/158 (Description of house 1778); GD 126/Box 30 (late 19th century photograph); RHP4093 Smith drawings (RHP4093/6 roof plan)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



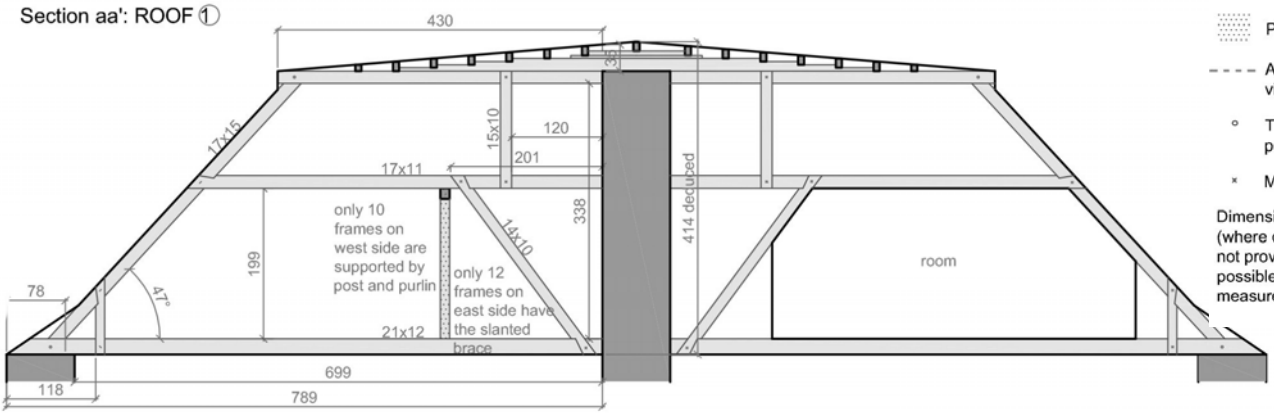
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

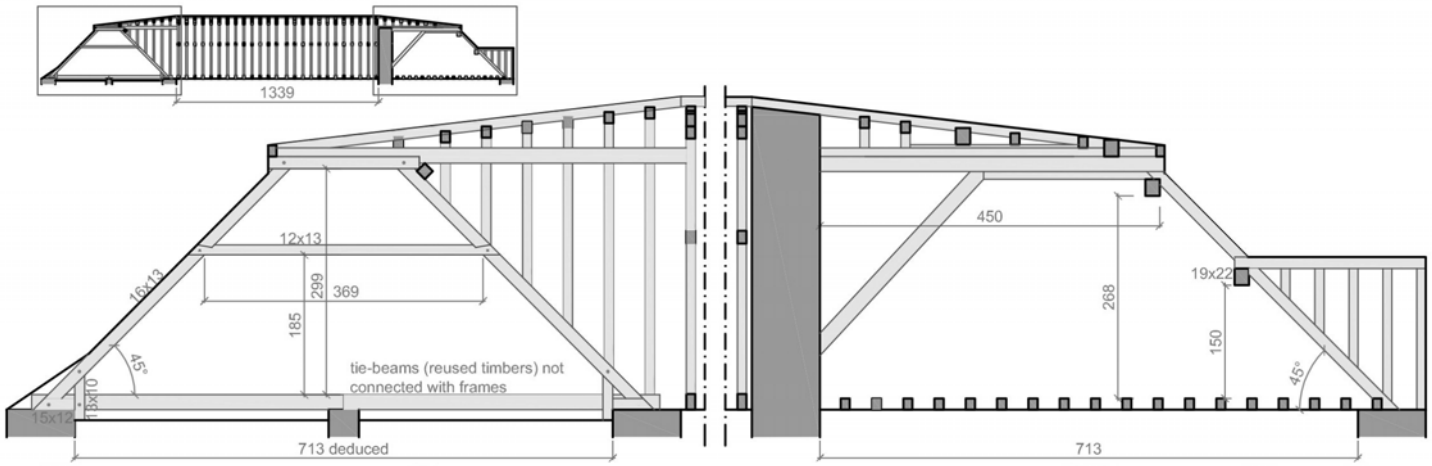
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section aa': ROOF ①



Section bb': ROOF ②and ③



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** MELVILLE HOUSE | **Roof location** 1: main block, central part

Survey date(s) 08/07/2015 | See drawing: MVH-all-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 7 | Roof Height [m]: 4.1

Roof Pitch/es [°]: 47 | Roof Length [m]: 13.4

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Other, Struts

Average Distance in between Primary Structure [m]: 0.42

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Tension ashlar post, Tie-beam

Connection with gables: rafters

Roof Construction Period: From 1697 To 1703 Identified by: Estimated

Roof General Description:

Hipped platform roof supported by intermediate trasversal walls and different typologies of roof timber structures. The central part is supported by complex frames composed of rafter couples joining a horizontal upper beam that rests on the intermediate wall. A collar and a tie-beam connect the rafter to the wall. A pair of vertical and slanted struts on each side connect the tie-beam to the collar and the upper beam. A tension absorbing ashlar post connects the tie-beam to the rafters. The timbers are all full logs hand axed and numbered with big sawn roman numerals and other unusual carpentry marks

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 17 B: 15 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed) Bark ☑

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Between rafters and upper and lower beams: mortice and tenon with timber pegs not flush. Between rafters and collars and between collars and struts: chamfered dovetail lapped with one or more metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: arabic numerals, big roughly cut roman numerals, runic marks, small chiseled roman numerals

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure: central part link I:\Arch\A



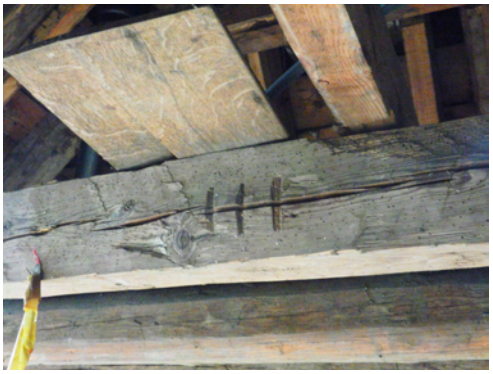
Connection with wall link I:\Arch\A



Joints: struts and collar link I:\Arch\A



Timber elements' dressing link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Sarking replaced.



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:	
Roof Damage				link
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes: The lateral roofs seem to belong to a construction phase prior to the central part, because they have sarking on the inner sides. Morevoer, the rafter foot indicates a late 15C/early 16C construction technique?

Attachments link

INITIAL SURVEY | **Building name** MELVILLE HOUSE | **Roof location** 2: main block, corners

Survey date(s) 08/07/2015 | See drawing: MVH-all-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 7.1 | Roof Height [m]: 4.1

Roof Pitch/es [°]: 45 | Roof Length [m]: 5.9

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Other

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables: rafters

Roof Construction Period: From 1697 To 1703 | Identified by: Estimated

Roof General Description: Hipped platform roof supported by intermediate trasversal walls and different typologies of roof timber structures. The corners are supported by complex frames composed of rafter couples joining a horizontal upper beam and connected by a collar. The connection with the walls is provided by rafter feet. The timbers are all full logs hand axed and numbered with big sawn roman numerals and other unusual carpentry marks.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 16 | B: 13 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Between rafters and upper beams, as well as in rafter foot: mortice and tenon with timber pegs not flush. Between rafters and collars: chamfered dovetail lapped with one or more metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Signs of reused timbers: Tie-beams not connected to frames and have redundant joints at their ends (they might have been collars or rafters)

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafters and upper beams | link I:\Arch\A



Timber elements' dressing | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Sarking replaced. Some rafters replaced. Insulation added.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

Some insect attack, not sure if active.



Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes: The lateral roofs seem to belong to a construction phase prior to the central part, because they have sarking on the inner sides. Morevoer, the rafter foot indicates a late 15C/early 16C construction technique?

Attachments | link

INITIAL SURVEY | **Building name** MELVILLE HOUSE | **Roof location** 3: main block, sides

Survey date(s) 08/07/2015 | See drawing: MVH-all-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 6.8 | Roof Height [m]: 4.1

Roof Pitch/es [°]: 45 | Roof Length [m]: 7.1

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, sarking | Plane: roof plane

Sarking boards: width [cm]: | thickness [cm]:

Connection with lateral walls: Wall-plate

Connection with gables: purlins

Roof Construction Period: From 1697 To 1703 | Identified by: Estimated

Roof General Description:

Hipped platform roof supported by intermediate trasversal walls and different typologies of roof timber structures. The sides are supported by purlin roofs, with two purlins each, supported by the intemrediate walls. The ridge purlin is also supported by a timber strut, which looks more recent (either replaced or added).The purlins support common rafters, secondary purlins and sarking boards.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: | B: | Or Purlin - H: 19 | B 22

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types:

Fasteners Types:

Joints description:

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A

link

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Sarking replaced. Some common rafters replaced. Insulation added. Strut replaced or added.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Permanent Deformation	Unknown	Primary
Connection Damage			



Damage: deflected purlin | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient overall arrangement, insufficient dimensions
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: Purlins are deflected

link

Other Notes: The lateral roofs seem to belong to a construction phase prior to the central part, because they have sarking on the inner sides. Morevoer, the rafter foot indicates a late 15C/early 16C construction technique?

Attachments | link

METHVEN CASTLE

Location: PERTH AND KINROSS | METHVEN

X coordinate: 304162 Y coordinate: 726043

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 26808

Original Use: Residential

Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION, CONSTRUCTION	1000	1500	A CASTLE HERE WAS IN THE HAND OF THE MOWBRAYS IN THE 11TH CENTURY, AND IS MENTIONED IN THE 14TH AND 16TH CENTURIES.	RCAHMS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1678	1681		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	ARCHITECT	☑
MYLNE	JOHN JUNIOR (3)	ARCHITECT, MASON	☑
SMYTH OF BRACO	PATRICK	MASON	☐

Intervention type:	From:	To:	Description:	Reference:
DESIGN	1813		FOR GOTHIC ADDITION NEVER CARRIED OUT	CANMORE

People involved:

Last Name	First Name	Role	Attributed
GRAHAM	JAMES GILLESPIE	DESIGNER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1960	1970	DEMOLISHED WEST WING, PORCH, CLOCKTOWER	CANMORE

People involved:

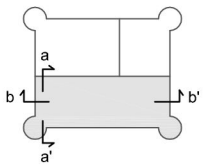
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1984	1985	REMADE FLOORS AND ROOF ON SOUTH SIDE AND ALL INTERIORS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	278
GIFFORD J.	2007	☐	THE BUILDINGS OF SCOTLAND COLLECTION: PERTH AND KINROSS	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	77
MURDOCH D.	2010	☐	MY LOVES BONNIE STRONG HOUSE	
NEWLAND K.	2010	☑	THE ACQUISITION AND USE OF NORWEGIAN TIMBER IN SEVENTEEN CENTURY SCOTLAND, WITH REFERENCE TO THE PRINCIPAL BUILDING JAMES BAINE, HIS MAJESTY'S MASTER WRIGHT	

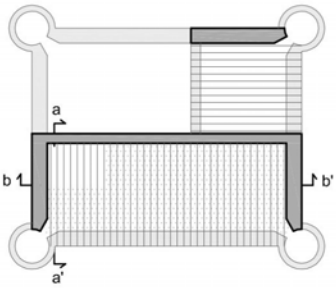
Suggestions for further research: Master dissertation by David Murdoch and book by his father
NRS: account sof works 1704/35 (GD190/3/255)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



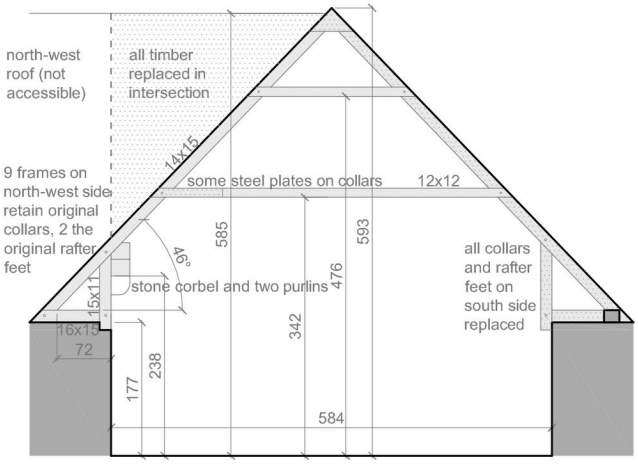
Carpentry marks from west to east:

III	IXX
II	XXII
IIII	IIIXX
V	IIIIXX
IIIII	ΛXX
IIV	IΛXX
IIIΛ	IIIIX
IIIIΛ	not visible
IIIIIΛ	IIIΛ
not visible	IIIIΛ
IIX	XXX
not visible	IXXX
not visible	IIXXX
IΛX	IIIXXX
IIΛX	IIIIXXX
XVIII	not visible
IIIIΛX	not visible
not visible	not visible

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

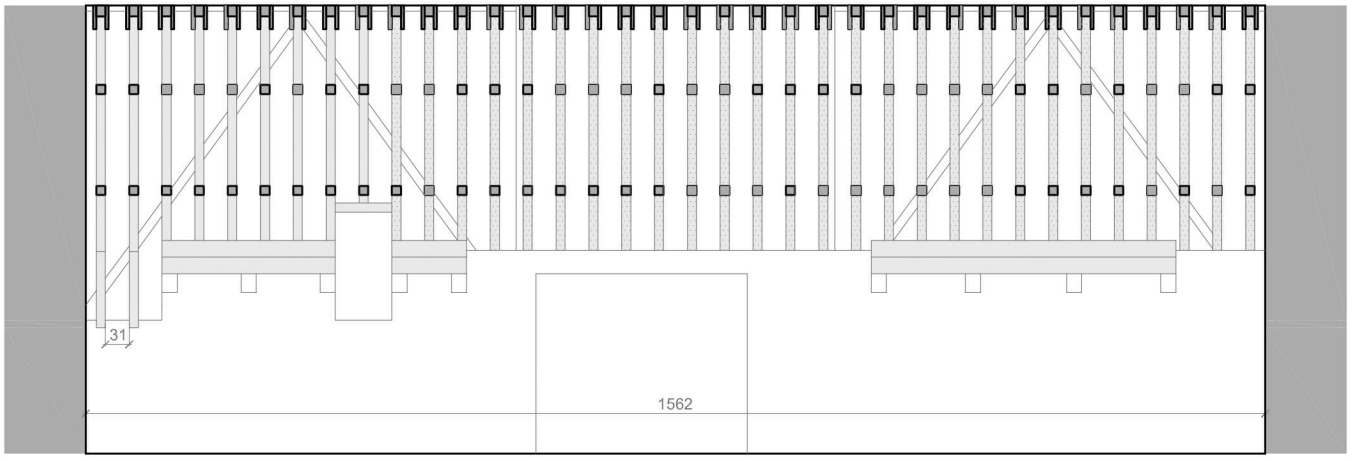
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** METHVEN CASTLE | **Roof location** 1: S part

Survey date(s) 29/07/2015 | See drawing: MTC-S-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.84 | Roof Height [m]: 5.92

Roof Pitch/es [°]: 46 | Roof Length [m]: 15.6

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.3

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 3

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1678 To | Identified by: Estimated

Roof General Description:

Two-pitched gabled roof with two intersections to the North interrupted by gable walls. Composed of closely spaced rafter couples connected trasversally by two collars and longitudinally by sarking boards only. The connection with the wall is provided by rafter feet (or purlins on stone corbels). Most of the timbers have been replaced, but a couple original rafter feet remain, as well as most collars. The timbers are all full logs roughly hand axed and numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular, Square with wanes

Rafter Scantling [cm] H: 14 | B: 15 | Or Purlin - H: | B:

Timber elements' Dressing: civil (machine-sawn), rustic (hand-axed) | Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Between rafter and collar: lapped chamfered with metal nail. Rafters' apex not visible. In rafter foot mortice and tenon with timber peg not flush.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Not in sequence.

Signs of reused timbers:

Timber Treated ☐

Other Materials: Steel plates

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks and dressing | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: All rafters and rafter feet on south side, and most of the ones on north side, replaced in 1980s because rotten (rafter feet were embedded in masonry). 9 Original rafters remain, and 2 original rafter feet (on west side). Original collars retained, some have steel plates to reinforce joint with rafter. All sarking replaced, as well as timbers in intersection roof.



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

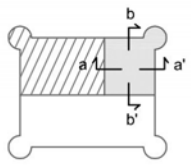
Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes: They kept pieces of original rafter feet, sarking, slates, metal nails and timber pegs. The timbers used for the rafters come from a 19C distillery.

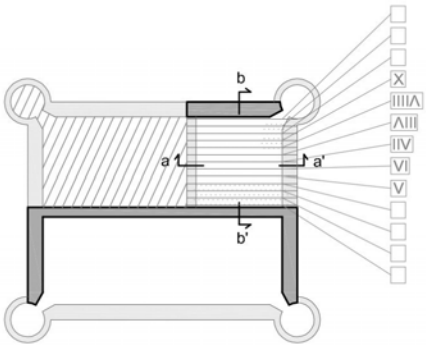
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

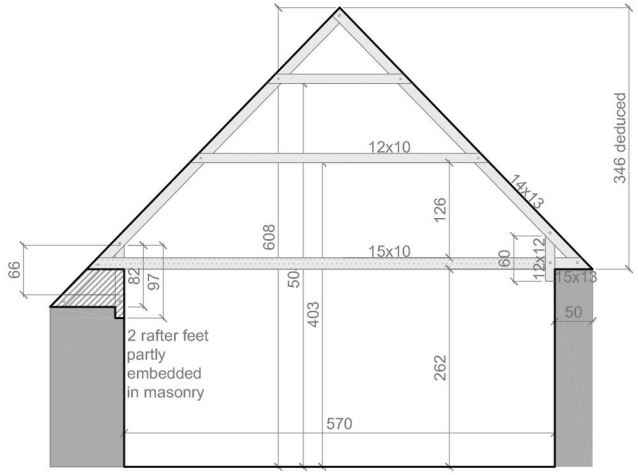
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

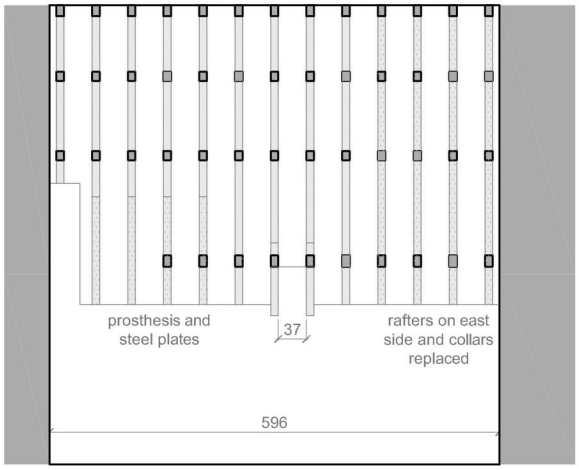
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** METHVEN CASTLE | **Roof location** 2: NE part

Survey date(s) 29/07/2015 | See drawing: MTC-NE-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 5.7 | Roof Height [m]: 3.46

Roof Pitch/es [°]: 46 | Roof Length [m]: 5.96

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.35

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1678 To | Identified by: Estimated

Roof General Description:

Two-pitched gabled roof composed of closely spaced rafter couples connected trasversally by three collars (the lowest one is embedded in masonry to the side of the rafter feet) and longitudinally by sarking boards only. The connection with the wall is provided by rafter feet: the ones on the East side are placed at a higher level and are smaller. The timbers are all full logs roughly hand axed and numbered with big sawn roman numerals.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 14 B: 13 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg flush, Timber peg not flush

Joints description:

Rafters' apex: mortice and tenon with timber peg not flush. Between rafter and collars: lapped chamfered with metal nail. In rafter foot all mortice and tenon with timber peg flush.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Not all visible, but visible ones are in sequence.

Signs of reused timbers:

Timber Treated ☐

Other Materials: Steel plates

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber element's dressing | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Tie-beam replaced in lower position. Some rafter ends cut and prosthesis applied with steel plates. Sarking replaced.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

OAKSHAW TRINITY CHURCH

Location: RENFREWSHIRE | PAISLEY (RENFREW)

X coordinate: 248073 Y coordinate: 664109

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 43169

Original Use: Church

Current Use: Church

Freestanding: ☑ N. of floors above ground level: 1 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1754	1756		CANMORE

People involved:

Last Name	First Name	Role	Attributed
WHITE	JOHN	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1770		STEEPLE	CANMORE

People involved:

Last Name	First Name	Role	Attributed
WHITE	JOHN	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1877		INTERIOR RECAST	CANMORE

People involved:

Last Name	First Name	Role	Attributed
RENNISON AND SCOTT	ARCHITECTS	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1994		REPAIR/STRENGTHENING OF THE TIMBER ROOF STRUCTURE	JOHN ADDISON

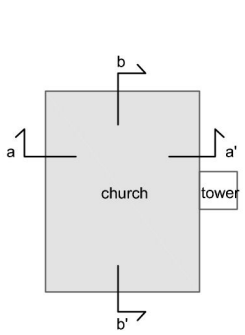
People involved:

Last Name	First Name	Role	Attributed
WALKER	GAVIN	ENGINEER	☐
RUTHBERTSON	JIM	ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
BROWN R.	1886	☐	HISTORY OF PAISLEY	
HAY G.	1957	☐	THE ARCHITECTURE OF SCOTTISH POST REFORMATION CHURCHES 1	
RIG L.	2014	☐	HTTP://WWW.GEOGRAPH.ORG.UK/PHOTO/3918504	
SINCLAIR SIR J. B.	1793	☐	OLD STATISTICAL ACCOUNT VOLUME SEVENTH	67

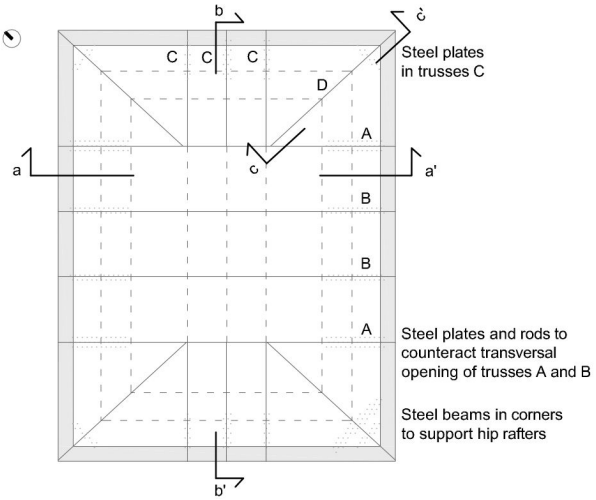
Suggestions for further research: Church convenor has documents on 1994 repairs



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

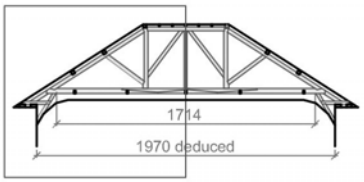
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

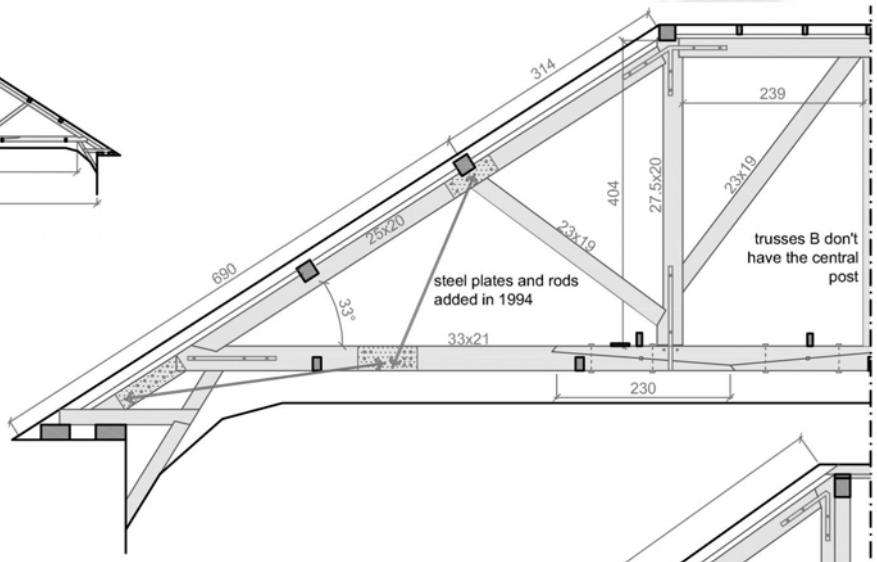


Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa': Truss A/B

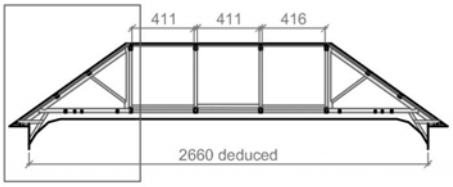


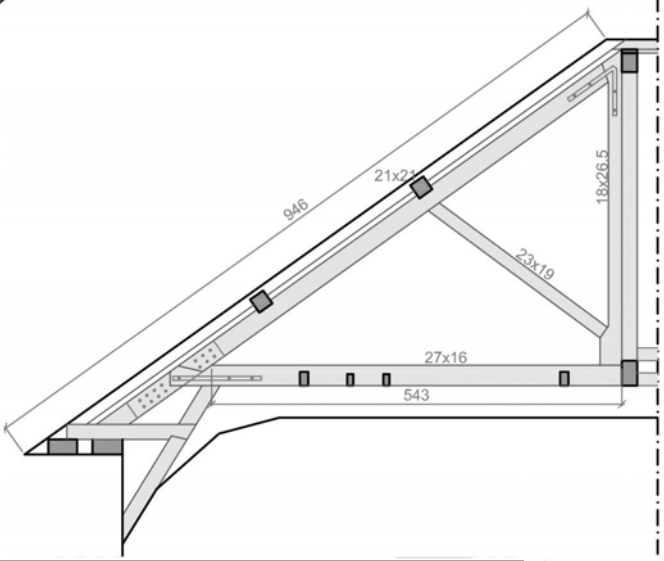


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

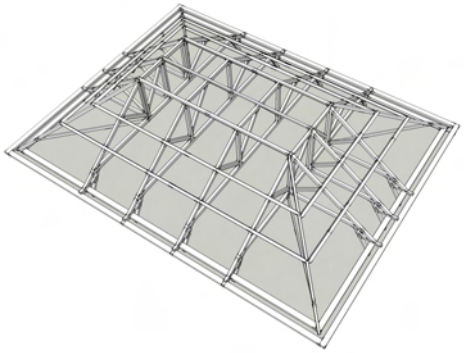
Section bb': Truss C



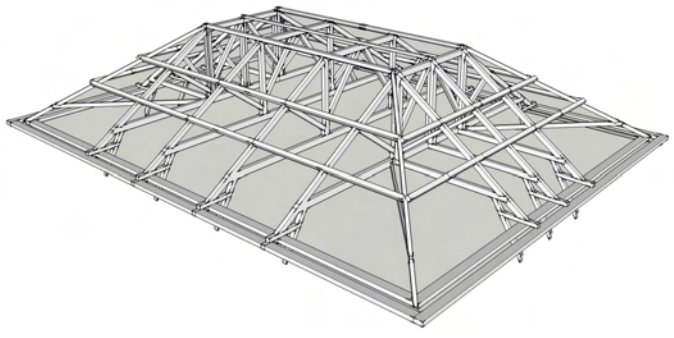


Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Perspective view I:\Arch\A



Perspective view I:\Arch\A

Building name: **OAKSHAW TRINITY CHURCH**

Roof location: Church main hall

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 20 | Roof Height [m]: 5.5

Roof Pitch/es [°]: 33 | Roof Length [m]: 26.6

Primary Structure Type: 2D framing

Truss ☑ QUEEN-POST

Frame ☐

Average Distance in between Primary Structure [m]: 4.13

Secondary Structure Type: common rafters, purlins, sarking

Sarking n. of layers | Sarking thickness [cm]

Connection with vertical load bearing system: Wall-plate

Roof Construction Period: From 1754 To 1756 Identified by:

Roof General Description: There are 4 main trusses spanning east-west. The tie-beams are composed of 5 elements. The 2 trusses in the middle have 2 posts, the trusses on the sides have 3 posts. The two side posts have two struts each, which are asymettrical. 5 purlins support the common rafters and sarking, 3 on top and 2 on each side. The tie-beam is raised so the rafters continue further down and form a triangle with a hammer-beam and an aShlar element.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 25 B: 20 Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: cleat, joggle, mortice and tenon, scarf

Fasteners Types: Metal strap, Timber dowel, Timber key

Joints description: All mortice and tenon with metal straps (except for struts which don't have metal straps); Tie-beams: scarf joints (very simple, with timber keys, low tension resistance). Posts have joggles at the top and bottom

Wood Species:

Carpentry Marks Types: big roughly cut roman numerals, lettering, small chiseled roman numerals, strange marks (from scandinavia?)

Carpentry Marks Description: C engraved close to some joints.

Signs of reused timbers: There are some redundant joints but they seem to be there because an element was removed rather than because the timbers have been reused

Timber Treated ☐

Other Materials: Metal straps and bolts (not sure if original or added later in the 18/beg19C). Steel beams, plates and rods added in 1994.

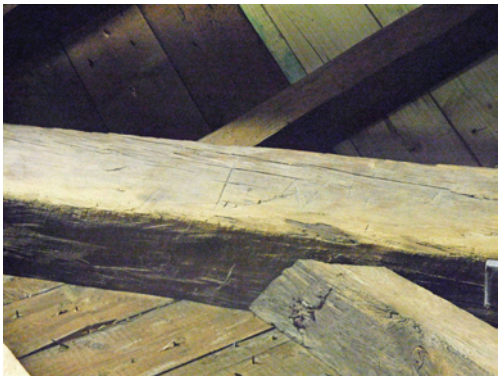
Dendrochronology:



Roof structure link I:\Arch\A



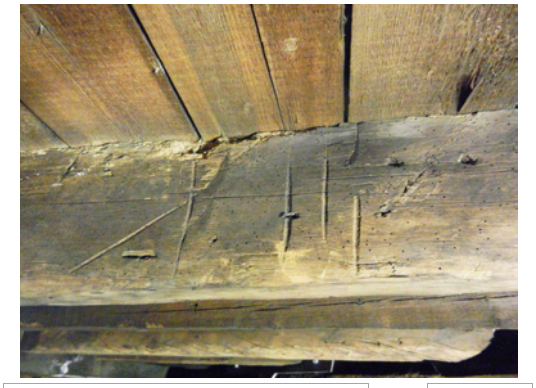
Connection with wall link I:\Arch\A



Timber elements' dressing link I:\Arch\A



Joints: lower part of lateral post link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Steel plates and cables installed in 1994 at the rafters ends to counteract the opening of the roof. Timber posts/braces and steel beams added to support the hip rafters in the same period.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐



Past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	transversal opening	Intervened on	Primary
Unit Damage	Disconnection	Unknown	Collateral
Element Damage	Cracks, Permanent Deformation	Unknown	Collateral
Connection Damage	Disconnection	Unknown	Collateral



Damage: opening of joints | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient joints, insufficient dimensions
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☑ increase of dead loads, repair/consolidation
- Extreme actions ☐
- Other ☐



Damage: opening of joints | link | I:\Arch\A

Description of visible damage: The building is affected by several craks in the masonry and in the plaster ceiling. The cause is probably the horizontal thrust deriving from the roof timber structure that is opening both transversally and longitudinally (many joints are open up to 4.5cm). The causes of this opening are probably more than one, starting from the partial inefficiency of the original design, to the weight of the plaster ceiling, to the 1994 repair works. Settlements could be contributing as a cause too.



Damage: secondary beams cut | link | I:\Arch\A

Other Notes: More thorough survey of damage carried out. The 1994 interventions probably increased the loads on the timber structure and on the masonry. Moreover the wall-plates and many secondary elements were cut, weakening the corners and leaving no support for the ceiling in many locations.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber

PILMUIR HOUSE

Location: EAST LOTHIAN | BOLTON

X coordinate: 348631 Y coordinate: 669357

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 54661

Original Use: Residential

Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1624		T PLAN	HS

People involved:

Last Name	First Name	Role	Attributed
CAIRNS	WILLIAM	COMMISSIONERPATRON	☐

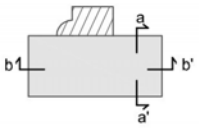
Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1700	1725		HS

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	4

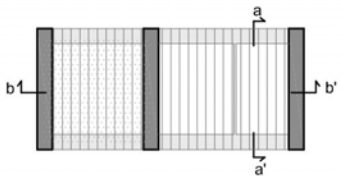
Suggestions for further research:



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



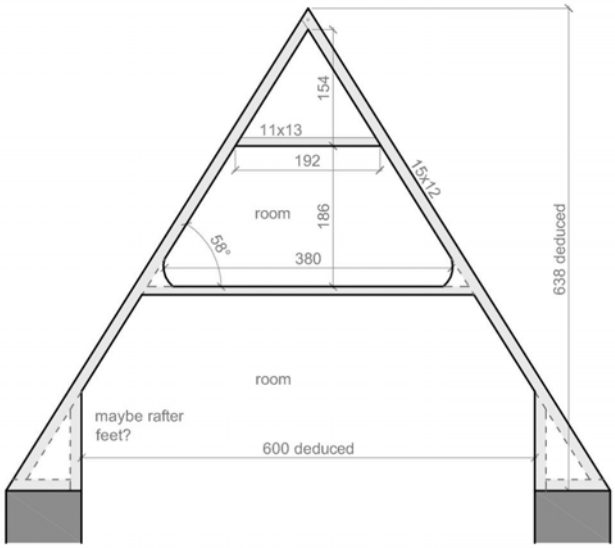
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

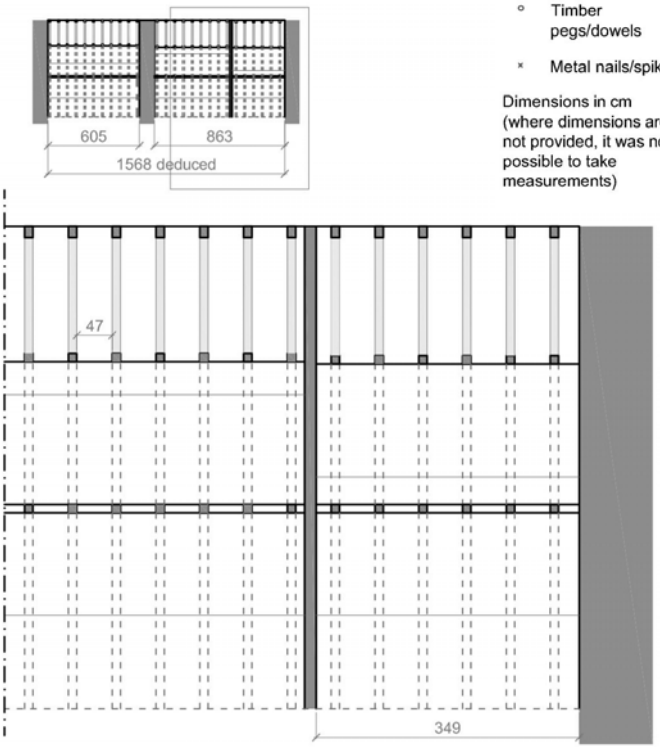
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section aa'



Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** PILMUIR HOUSE | **Roof location** Main block

Survey date(s) 08/10/2014 | See drawing: PLH-MB-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6 | Roof Height [m]: 6.38

Roof Pitch/es [°]: 58 | Roof Length [m]: 15.68

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1624 To | Identified by: Estimated

Roof General Description: Two-pitch gabled roof supported by one transversal wall. Composed of 26 frames with two collars each (only one visible). Connection with wall not visible but there could be a rafter foot. Very little of the structure is visible because it is mostly hidden behind plaster since the roof space is used as attic rooms. The timbers are full logs roughly hand axed.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 15 B: 13 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: Joint between rafters and collars not visible

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description: Not visible

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A

link

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: presence of pigeons/wasps/bats

Accessibility limitations: Most of the roof structure is not visible, especially the connection with the walls

Past interventions: Sarking replaced. Some new collars.



Past interventions | link | I:\Arch\A



Unfavourable conditions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack in some collars, not sure if active

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Material degradation | link | I:\Arch\A

Description of visible damage

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

ROBERT GORDON'S COLLEGE

Location	ABERDEEN, CITY OF	ABERDEEN	
X coordinate	393880	Y coordinate	806496
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PRIVATE		
Protection status	NATIONAL		
HS Listing	A	Rcahms ID	130652
Original Use	School		
Current Use	School		

Freestanding ☑ N. of floors above ground level 4 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1731	1732	DESIGN SIMILAR TO THE ONE PRESENTED IN VITRUVIUS SCOTICUS	HS

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐
SMITH	JOHN (700)	ARCHITECT	☐

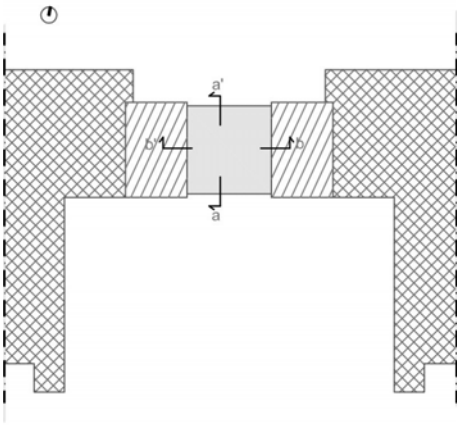
Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1830	1832		HS

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
WALKER D. & WOODWORTH M.	2015	☐	THE BUILDINGS OF SCOTLAND COLLECTION: ABERDEENSHIRE: SOUTI ABERDEEN	
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 107, 108

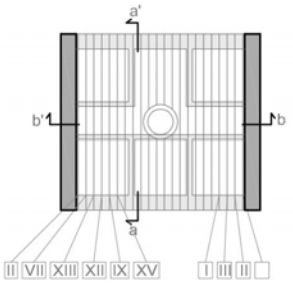
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

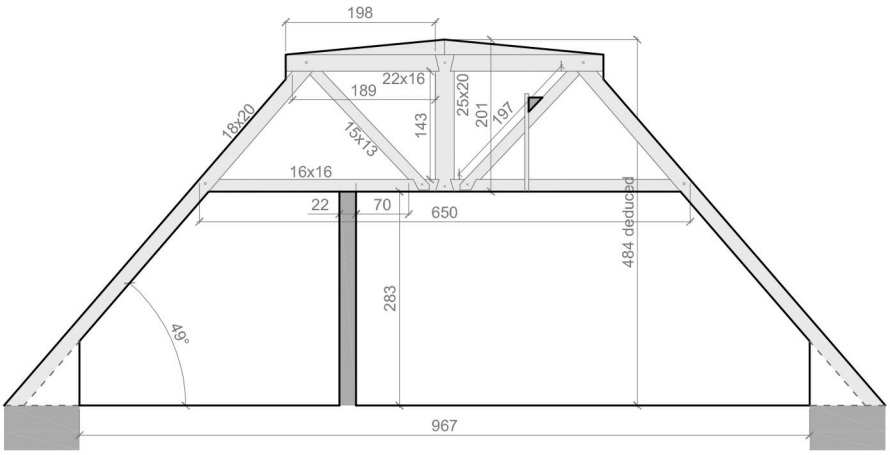
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

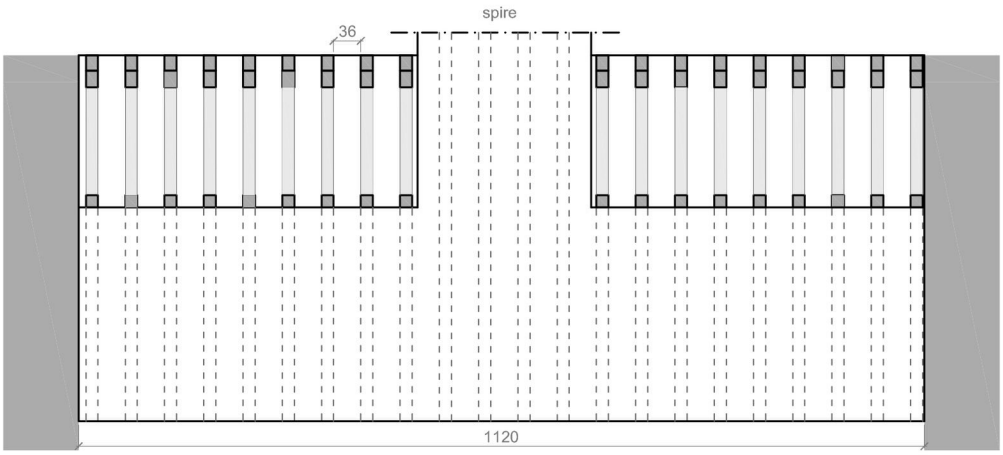
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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0 1 5



Roof structure from outside I:\Arch\A



Roof structure from outside I:\Arch\A

INITIAL SURVEY | **Building name** ROBERT GORDON'S COLLEGE | **Roof location** Main block

Survey date(s) 05/08/2015 | See drawing: RGC-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 9.67 | Roof Height [m]: 4.84

Roof Pitch/es [°]: 49 | Roof Length [m]: 11.2

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Other

Average Distance in between Primary Structure [m]: 0.36

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1731 To 1732 | Identified by: Estimated

Roof General Description: Hipped platform roof supported by two transversal walls and 22 closely spaced complex frames. Each frame has a collar and an upper horizontal beam, a central post and two slanted struts on the sides. The 4 central frames are interrupted by the spire - this part could not be closely inspected.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 20 | B: 18 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Mortice and tenon with timber peg not flush between rafters and horizontal beams. Dovetail lapped with metal nail between post/struts and horizontal beams.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Not all visible, but the few visible are not in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Joints: rafter and upper beam | link I:\Arch\A



Joints: post and lower beam | link I:\Arch\A



Carpentry marks and joints | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: The two sides of the main block are not accessible in safety

Past interventions: Few bits of sarking replaced



Past interventions | link | I:\Arch\A



link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Sarking on the slopes is extremely moist

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

ROYSTON HOUSE

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)

X coordinate: 322654 Y coordinate: 677220

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Protection status: NATIONAL

HS Listing: A Rcahms ID: 52056

Original Use: Residential

Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1585		L PLAN TOWERHOUSE	HS

People involved:

Last Name	First Name	Role	Attributed
LOGANS	ANDREW	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1683	1696	QUADRANGLE: E JAMB EXTENDED, N AND W RANGES ADDED, S FRONT REMODELLED - PAUL HARDING THINKS THE COURTYARD ALREADY EXISTED BEFORE THIS DATE	HS

People involved:

Last Name	First Name	Role	Attributed
EIZAT	ALEXANDER	WRIGHT	☐
MACKENZIE	SIR GEORGE 1ST EAR	COMMISSIONERPATRON	☐
BAINE	WILLIAM	PLASTERER	☐
GAIRDNER	ALEXANDER	SMITH	☐
HEUDE	NICOLAS	PAINTER	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1740	1741	WING AND INTERIORS	HS

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐
CAMPBELL	JOHN 2ND DUKE OF	COMMISSIONERPATRON	☐

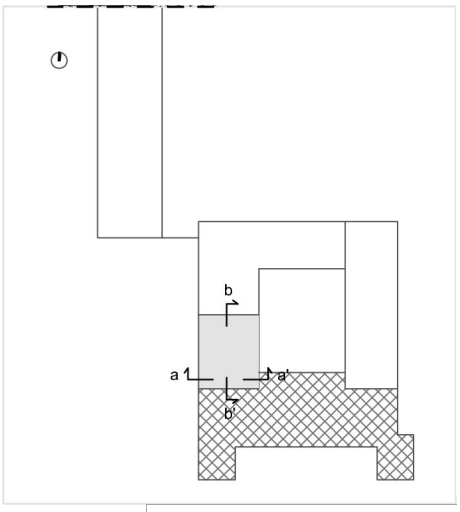
Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1930		FIRE DESTROYED SOUTH RANGE ROOF	OWNER

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME II. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL/ THE TWELFTH TO THE EIGHTEENTH CENTURY	453-463
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	

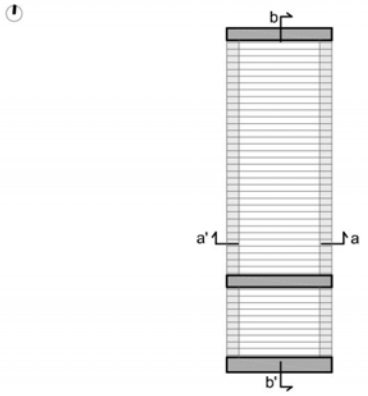
Suggestions for further research



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

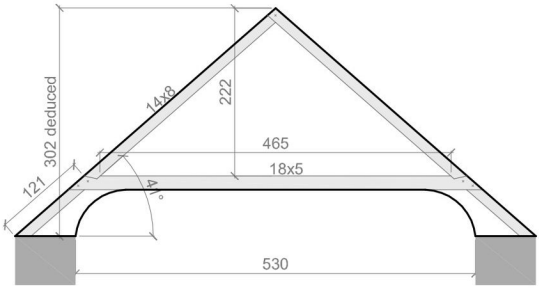
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

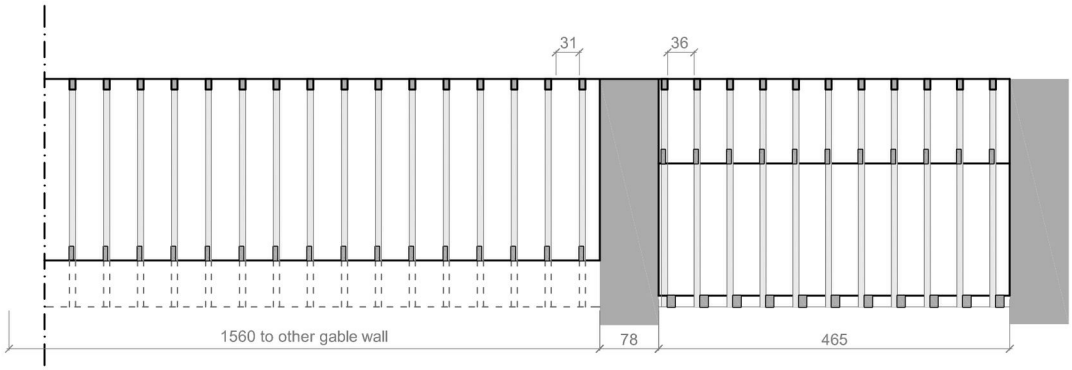
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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0 1 5



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** ROYSTON HOUSE | **Roof location** 3: E range

Survey date(s) 26/08/2015 | See drawing: RH-E-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 5.3 | Roof Height [m]: 3

Roof Pitch/es [°]: 41 | Roof Length [m]: 21

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.42

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables:

Roof Construction Period: From 1775 To 1800 | Identified by: Estimated

Roof General Description: Two-pitch gabled roof with a transversal wall and 47 frames, composed of one collar in the North section, where the plaster ceiling is, and tie-beams not connected to rafters in the South section, where the ceiling is lower. It doesn't look contemporary to the wing, it's probably end 18C, because the timbers have rectangular scantlings and are hand axed.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 14 | B: 8 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☑

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description: All lapped with metal nails - between collar and rafter dovetail chamfered

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks and dressing | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features: Original plaster ceiling underneath

Unfavourable conditions:

Accessibility limitations:

Past interventions:

link

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	link
Roof Damage				
Unit Damage				
Element Damage				
Connection Damage				

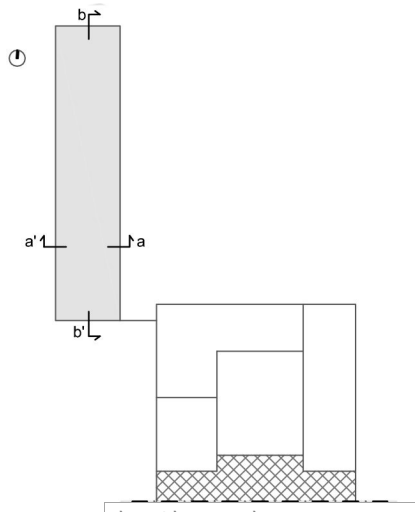
Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: link

Other Notes:

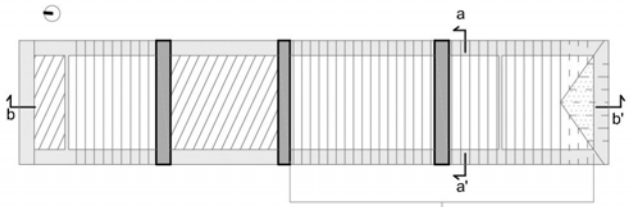
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



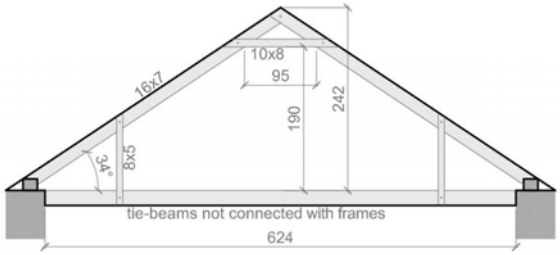
Carpentry marks from south to north:

XIII	XXXXXV	IIII
X	XXXXVIII	XXXXXVI
XII	XXXXXII	XXXXXIII
XV	not visible	XXXXXIIII
XIV	XXXXII	XXXXXII
XXXXIX	XXXXX	XXXXVII
VIII	VII	XX
not visible	V	IX
not visible	IA	XI
I	III	XXXX

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

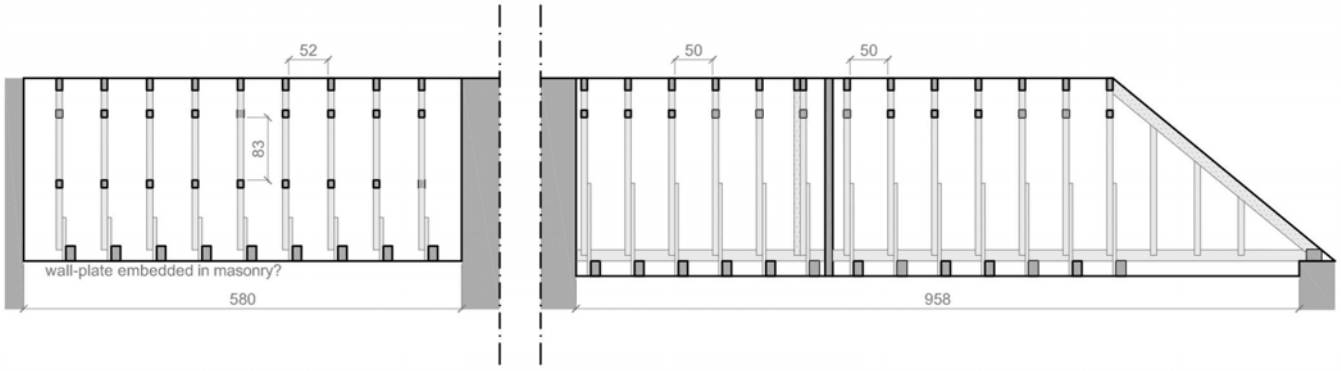
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** ROYSTON HOUSE | **Roof location** 2: wing

Survey date(s) 26/08/2015 | See drawing: RH-WI-1

Roof Geometry: Hipped

Roof Max Span [m]: 6.24 | Roof Height [m]: 2.42

Roof Pitch/es [°]: 34 | Roof Length [m]: 37.1

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables:

Roof Construction Period: From 1740 To 1741 | Identified by: Estimated

Roof General Description:

Two-pitch hipped roof supported by 3 transversal walls and closely spaced rafter couples connected trasversally by one short collar. The connection with the walls is provided by wall-plates. A tie-beam supports the ceiling and is connected to the rafters through slim vertical struts (no connection rafter/tie-beam at wall-head). In the North section the wall-plates are not visible. The timbers are numbered with big sawn roman numerals but there are also some unusual carpentry marks.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 16 | B: 7 | Or Purlin - H: | B:

Timber elements' Dressing: civil (machine-sawn), rustic (hand-axed), rustic | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafter's apex: mortice and tenon with timber peg not flush. Between rafter and collar: lapped, sometimes dovetail, chamfered with metal nail.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description:

Not in sequence.

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints - dressing - carpentry marks | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features: Original plaster ceiling underneath

Unfavourable conditions: poor ventilation

Accessibility limitations: In one central part of the wing, the roof structure is not visible

Past interventions: Sarking replaced. Timbers in hip replaced. Some frames have been doubled (recently?) - only rafters.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

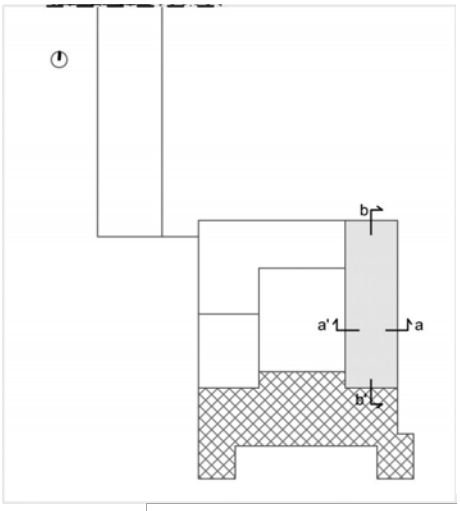
link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

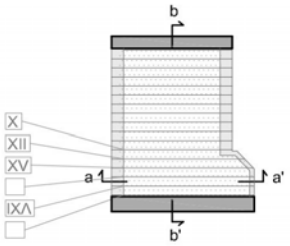


Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Legend (plans):

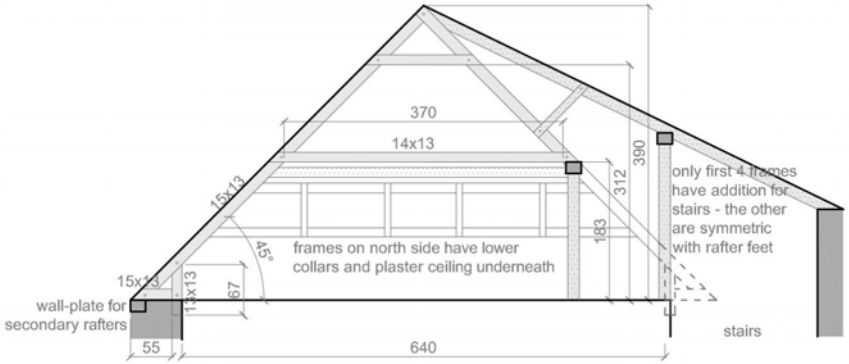
Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

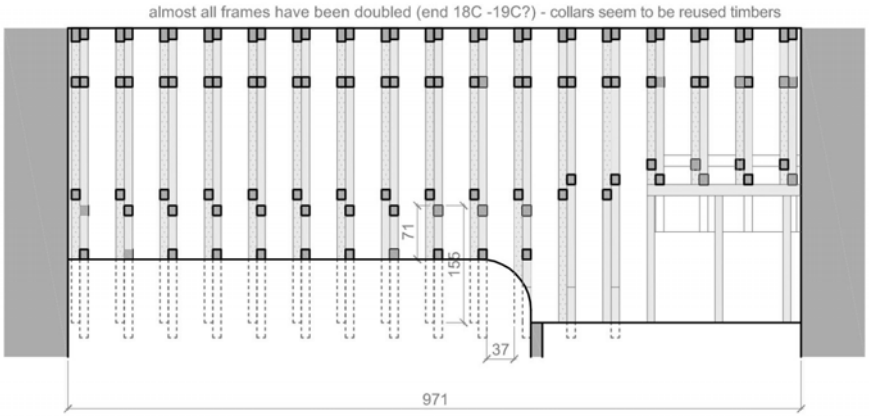
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** ROYSTON HOUSE | **Roof location** 1: W range

Survey date(s) 30/07/2015 | See drawing: RH-W-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.4 | Roof Height [m]: 3.9

Roof Pitch/es [°]: 45 | Roof Length [m]: 9.7

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.47

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1683 To 1696 | Identified by: Estimated

Roof General Description: Two-pitch gabled roof composed of 17 frames with two collars and rafter feet. Frames on North side have plaster ceiling underneath. Frames on South side have a later extension for staircase and remains of plaster on rafters and lower collars (it clearly used to be a room). Almost all frames have been doubled. All timbers are full logs roughly hand axed with some bark left on the corners.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 15 | B: 13 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg flush, Timber peg not flush

Joints description: Rafters' apex: mortice and tenon with timber peg not flush. Between rafters and collars: lapped with metal nail. In rafter foot all mortice and tenon with timber pegs flush.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Most of them are not visible, those which are visible are not in sequence.

Signs of reused timbers: Double collars seem to be reused timbers

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



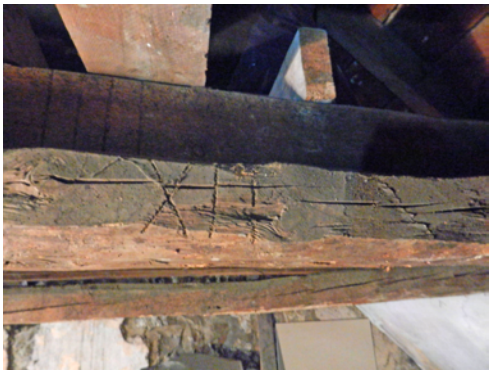
Connection with wall | link I:\Arch\A



Timber elements' dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: original plaster ceiling under frames on north side

Unfavourable conditions:

Accessibility limitations: Frames on north side couldn't be closely inspected because of plaster ceiling underneath.

Past interventions: Double rafters and collars added (end 18C-19C?). Sarking replaced probably in the same period. Lower pitch on east side added later (19C?) to cover staircase.



Past interventions | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: link

Other Notes:

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link

SAILOR'S WALK

Location: FIFE | KIRKCALDY AND DYSART

X coordinate: 328446 Y coordinate: 692059

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC

Protection status: NATIONAL

HS Listing: A Rcahms ID: 94225

Original Use: Residential

Current Use: Not in use

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1670	1679	BASED UPON STYLISTIC DETAILS - INCORPORATING EARLIER 15TH CENTURY FABRIC	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1954	1959		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2000		DATE NOT SURE	JOHN ADDISON

People involved:

Last Name	First Name	Role	Attributed
ADDISON	JOHN	ENGINEER	☐

Intervention type:	From:	To:	Description:	Reference:
SURVEY	2006			NTS

People involved:

Last Name	First Name	Role	Attributed
ADDYMAN ARCHAEOLOGY		ARCHAEOLOGIST	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
ADDYMAN ARCHAEOLOGY	2006	☑	SAILOR'S WALK, 443-449 HIGHT STREET, KIRKCALDY, FIFE - ANALYTIC ASSESSMENT AND HISTORIC BUILDING SURVEY FOR THE NATIONAL T SCOTLAND	
GIFFORD J.	1988	☐	THE BUILDINGS OF SCOTLAND COLLECTION: FIFE	
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	15

ARCHIVAL REFERENCES

Archive: Royal Commission on the Ancient and Historical Monuments of Scotland Doc.Num.: FID/114/2 Folios:

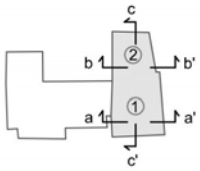
Title: Elevations: front and back; East elevation and sections (also adjoining cottages), Sailor's Walk, Kircaldy Insc. W. Williamson and Hubbard

Suggestions for further research:

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

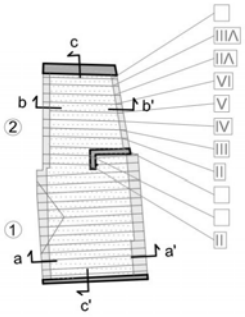
Archive	Royal Commission on the Ancient a	Doc. Num.	FID/114/2	Folios	
Title	Elevations: front and back; East elevation and sections (also adjoining cottages), Sailor's Walk, Kircaldy Insc. W. Williamson and Hubbard	Date: from	1935	to	
Contents					
Summary and comments					



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

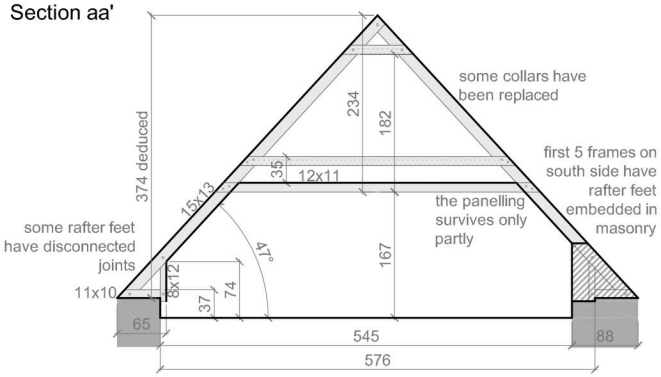
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



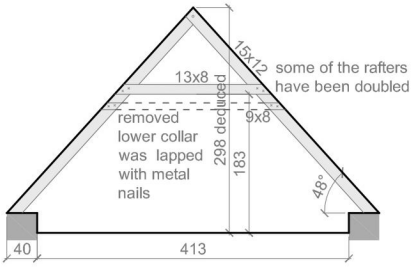
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa'



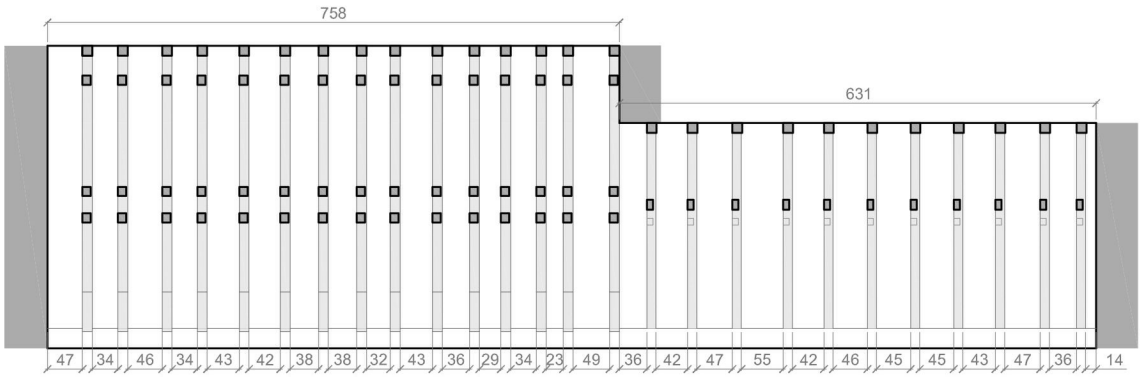
Section bb'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section cc'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** SAILOR'S WALK | **Roof location** 2: E range

Survey date(s) 11/09/2014 | See drawing: SW-E-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 4.13 | Roof Height [m]: 2.98

Roof Pitch/es [°]: 48 | Roof Length [m]: 6.3

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables:

Roof Construction Period: From 1670 To 1679 Identified by: Estimated

Roof General Description:

Building dated to 1670s based on stylistic considerations. The East range is the only one that could be surveyed; it has a two-pitch gabled roof, divided in two parts. The North section is composed of closely spaced rafter couples connected trasversally by one collar in and longitudinally by sarking boards only. The rafters simply sit on the wall-head. The timbers are all full logs roughly hand axed and numbered with big sawn roman numerals and unusual carpentry marks.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Round, Square with wanes

Rafter Scantling [cm] H: 15 B: 12 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed) Bark ☐

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters' apex: mortice and tenon with timber peg. Between rafters and collar: half lapped with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description:

Roman numerals in sequence: visible ones go from II to VIII from south to north

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure link I:\Arch\A



Dressing and carpentry marks link I:\Arch\A



Joints: rafter and collar link I:\Arch\A



Joints: rafter and original collar link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Some sarking replaced. Most rafters' ends strengthened with additional timber elements and a couple of frames have additional medium collars. Most lower collars doubled, some upper collars replaced. Some rafters doubled.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack in rafters, not sure if active



Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

INITIAL SURVEY | **Building name** SAILOR'S WALK | **Roof location** 1: E range

Survey date(s) 11/09/2014 | See drawing: SW-E-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.76 | Roof Height [m]: 3.74

Roof Pitch/es [°]: 47 | Roof Length [m]: 7.6

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1670 To 1679 | Identified by: Estimated

Roof General Description:

Building dated to 1670s based on stylistic considerations. The East range is the only one that could be surveyed; it has a two-pitch gabled roof, divided in two parts. The South section is composed of closely spaced rafter couples connected trasversally by three collars (two added later) and longitudinally by sarking boards only. The connection with the wall is provided by rafter feet partly embedded in masonry. The timbers are all full logs roughly hand axed and numbered with big sawn roman numerals. On the West side there is an intersecting roof. Part of painted timber panelling remains attached to rafters and lower collars

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Round, Square with wanes

Rafter Scantling [cm] H: 15 | B: 13 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg flush

Joints description:

Rafters' apex: mortice and tenon with timber peg. Between rafters and upper collar: half lapped with timber peg. Between rafters and lower collar: half lapped with metal nails. In rafter feet arrangement all mortice and tenon with timber pegs flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure: south | link I:\Arch\A



Roof Structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features: Part of painted timber panelling attached to rafters and lower collars

Unfavourable conditions:

Accessibility limitations:

Past interventions: Some sarking replaced. Most rafters' ends strengthened with additional timber elements and a couple of frames have additional medium collars. Most lower collars doubled, some upper collars replaced. Some rafters doubled.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack in rafters, not sure if active



Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage	Disconnection	Active	



Damage: disconnections | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☑
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: Almost all the mortice and tenon joints of the ashlar posts are opening.

link

Other Notes:

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link | I:\Arch\A

STIRLING TOLBOOTH

Location: STIRLING | STIRLING
X coordinate: 279307 Y coordinate: 693696
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A Rcahms ID: 46229

Original Use: City Council
Current Use: City Council, Theatre

Freestanding ☐ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1400	1499		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
RECONSTRUCTION	1703	1705		BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT	☐
CHRISTIE	JOHN	WRIGHT	☐
LIVINGSTONE	HARRY	MASTER MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1785		3 BAYS EAST	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
GRAY	GIDEON	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1808	1810	COURT HOUSE	

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1999	2001		BUILDINGS OF SCOTLAND COLLECTION

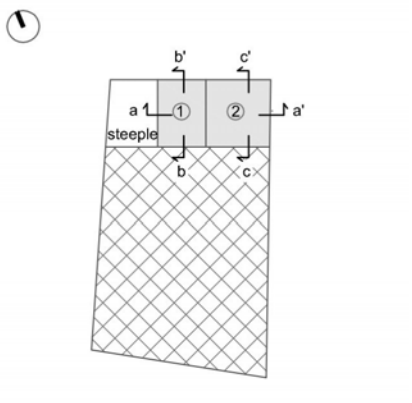
People involved:

Last Name	First Name	Role	Attributed
SIMPSON & BROWN		ARCHITECT	☐

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	120
GIFFORD J.	2002	☐	THE BUILDINGS OF SCOTLAND COLLECTION: STIRLING AND CENTRAL	
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	19

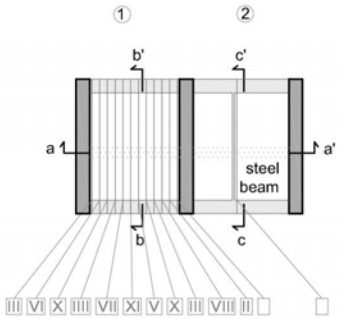
Suggestions for further research: NRS: miscellaneous papers 1710/39 (GD112/17/1/10)



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

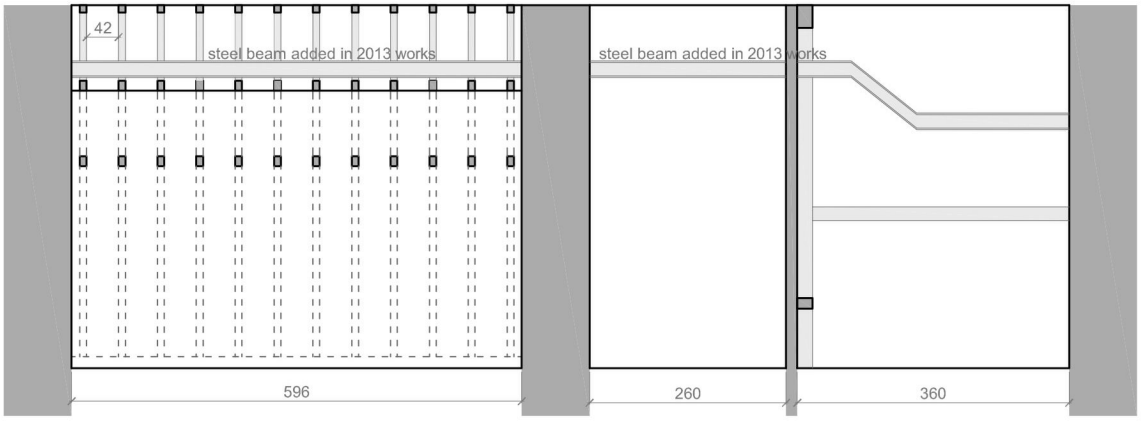
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

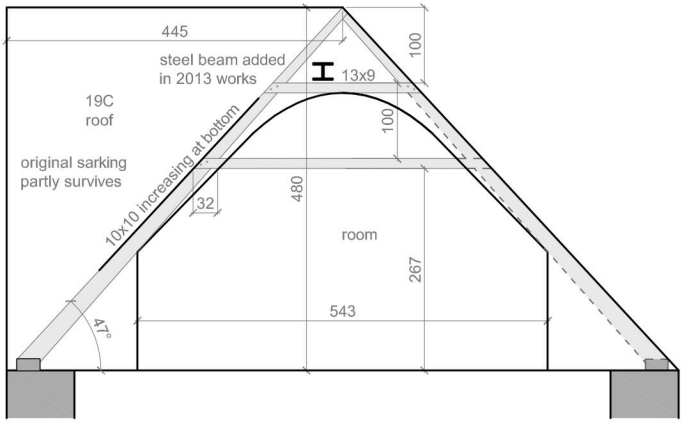
Section aa': ROOF ① and ②



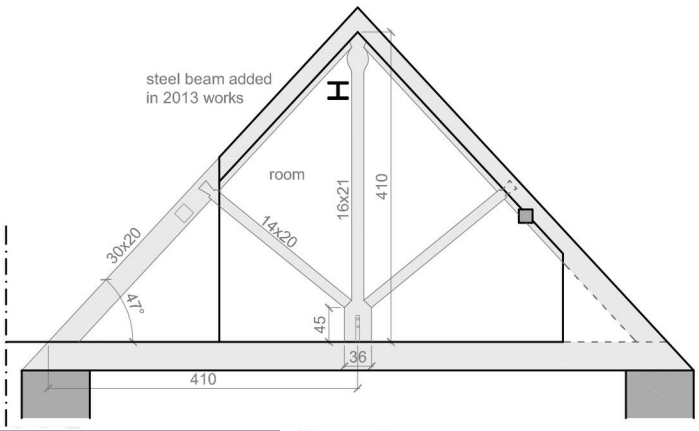
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb': ROOF ①



Section cc': ROOF ②



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** STIRLING TOLBOOTH | **Roof location** 2: E extension

Survey date(s) 30/09/2014 | See drawing: ST-E-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 8.2 | Roof Height [m]: 4.4

Roof Pitch/es [°]: 44 | Roof Length [m]: 3.6

Type of Primary Structure: 2D framing

Truss ☑ KING-POST

Frame ☐

Average Distance in between Primary Structure [m]: 3.5

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1785 To | Identified by: Estimated

Roof General Description:

Two-pitch gabled roof divided in two parts. The West section is supported by a king-post truss with one butt-purlin on each side and probably common rafters (they are not visible because they are behind the plaster, the roof space is used as office). A slanted strut on each side of the king post supports the rafters. The timbers are well dressed, hand sawn.

Roofing Material: slate

Roofing Material Fixing: Unknown

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 30 B: 20 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: bulb shaped joggle, dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal strap

Joints description:

Rafters apex: mortice and tenon with rounded joggle; between struts and king-post: mortice and tenon with joggles; between struts and rafters dovetail notched. Fasteners not visible, except for metal strap at bottom of post.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description: Not visible

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Joints: rafters apex | link I:\Arch\A



Joints: rafter and strut | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Secondary structure only partly visible. Connection with wall not visible.

Past interventions: Steel beam recently inserted beside the king-post. Purlin cut on south side.



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes: Not clear what the is the structural funtcion of the new steel beam

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui link

INITIAL SURVEY | **Building name** STIRLING TOLBOOTH | **Roof location** 1: E range

Survey date(s) 30/09/2014 | See drawing: ST-E-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 8.2 | Roof Height [m]: 4.4

Roof Pitch/es [°]: 47 | Roof Length [m]: 5.96

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables:

Roof Construction Period: From 1703 To 1705 | Identified by: Estimated

Roof General Description: Two-pitch gabled roof divided in two parts. The East section is supported by closely spaced rafter couples connected transversally by two collars and longitudinally by sarking boards only. Not much of the structure is visible since the spaced is plastered and used as office. A steel beam has been inserted in the upper part of the roof.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes, Square with wanes

Rafter Scantling [cm] H: 10 B: 10 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: lapped

Fasteners Types: Metal nail

Joints description: Rafters' apex's not visible. Joints between rafter and collars: lapped with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Not in sequence, probably because they have been moved and jointed to the new rafters

Signs of reused timbers: One of the lower collars has a redundant joint

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



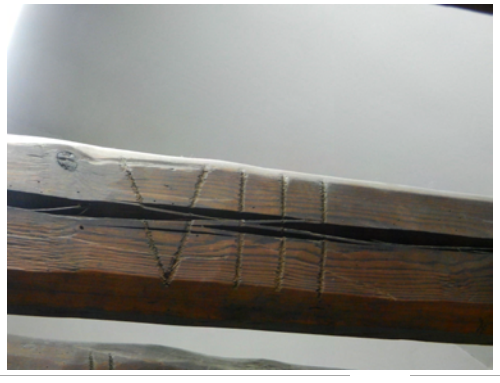
Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourablec onditions

Accessibility limitations: Structure not visible on north side

Past interventions: Rafters doubled, and some upper collars too, maybe in 19C when extensions were made to south. Original collars moved and jointed to the new rafters. Insulation and new plasterboards recently added. Steel beam recently inserted above the upper collar.



Past interventions | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☐

Humidity stains on sarking and rafters



Humidity stains | link I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage: | link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes: Not clear what the is the structural funtcion of the new steel beam

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

TWEEDDALE HOUSE

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)
X coordinate: 326123 Y coordinate: 673633
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: B Rcahms ID: 262755

Original Use: Residential
Current Use: Offices, Residential

Freestanding ☐ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1576		DATE ON A DOOR INSIDE THE ORIGINAL N HOUSE WALL	HS

People involved:

Last Name	First Name	Role	Attributed
LAING	NEIL	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1595	1605	CONVERTED TO A DOUBLE PILE BY EXTENDING TO THE N	HS

People involved:

Last Name	First Name	Role	Attributed
LAING	JOHN	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1664		HS SAYS "RECAST"	HS

People involved:

Last Name	First Name	Role	Attributed
BRUCE	SIR WILLIAM	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1671	1674	EXTENSIVE REPAIRS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BAINE	JAMES	MATERIAL SUPPLIER, PLASTERER, WRIGHT	☐
HOOMS	GEORGE	MASON	☐
HAY	JOHN 1ST MARQUES	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1687		RECAST	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
HARRWAY	JOHN	MASON	☐
HAY	ALEXANDER	WRIGHT	☐
HAY	JOHN 1ST MARQUES	COMMISSIONERPATRON	☑

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1692	1693	MASON WORK, SEE YESTER PAPERS	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1742	1749	REPAIRS	NLS MS 14551

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☐
NEILSON	SAMUEL	MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1750	1756	HEAVILY REPAIRED - THE ROOF WAS REDONE COMPLETELY	NLS MS 14665 F. 64

People involved:

Last Name	First Name	Role	Attributed

HAY	JOHN 4TH MARQUES		☐
ADAM	JOHN	ARCHITECT	☐
MACK	CHARLES	MASON	☐
DUNLOP	THOMAS	CONTRACTOR, WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1783		FIVE-STOREY TENEMENT TO EAST	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
BRODIE	WILLIAM	WRIGHT	☐
BUTTER	WILLIAM	WRIGHT	☐
GILES	ARTHUR	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1791	1807	ROMAN DORIC PORCH WAS ADDED AND THE BUILDING EXTENDED TO THE W, INTERIORS ALTERED TO CREATE LARGER WORKSHOPS	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1800		ROOF ABOVE OTHER ONE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	205

ARCHIVAL REFERENCES

Archive	National Library of Scotland	Doc.Num.	MS 14665	Folios	64
Title	Account of work by Thomas Dunlop for the Marquis of Tweeddale 1756				
Archive	National Library of Scotland	Doc.Num.	MS 14680	Folios	
Title	Works at Tweedale House				
Archive	National Library of Scotland	Doc.Num.	MS 14637	Folios	73
Title	Account of timber work for the Earl of Tweeddale by James Baine				
Archive	Royal Commission on the Ancient and Historical Monuments of Scotland	Doc.Num.	DC 3496	Folios	
Title	Tweeddale Court, 14 High Street, Edinburgh -Section A-A				
Archive	Private: Tweeddale House	Doc.Num.	Uncatalogued	Folios	
Title	Drawings and pictures of survey and repair works carried out in 1980s at Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	109
Title	Contract between William Adam and the Marquis of Tweeddale for works at Yester House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	115
Title	Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	116
Title	Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	126
Title	Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	128
Title	Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	130

Title	Account of repairs done by John Adam probably at Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	137
Title	Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House				
Archive	National Library of Scotland	Doc.Num.	MS 14665	Folios	70
Title	Account of work by Thomas Dunlop for the Marquis of Tweeddale				
Archive	National Library of Scotland	Doc.Num.	MS 14665	Folios	69
Title	Account of work by Thomas Dunlop for the Marquis of Tweeddale				
Archive	National Library of Scotland	Doc.Num.	MS 14665	Folios	
Title	Account of work by Thomas Dunlop and timber from William Caddell for the Marquis of Tweeddale				
Archive	National Library of Scotland	Doc.Num.	MS 14637	Folios	67
Title	Account of work by James Baine at a stable in Edinburgh and one in Yester for the Marquis of Tweeddale				

Suggestions for further research	

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive National Library of Scotland Doc. Num. MS 14665 Folios 64

Title Account of work by Thomas Dunlop for the Marquis of Tweeddale 1756 Date: from to

Contents (outside - partly missing) *Accompt The Most Hon.ble The Marquis of Tweddale To Tho.s Dunlop wright for work done [...] 1754 [...] 160:7:10 1756*
at the House in Ed[...] Paid from the Year [...] 1750 to 1756 for [...] Repairs to Tweeddale House in Edinburgh [...] to Deacon Dunlop Carp[...] as instructed by the ???[...] accompt amounting to [...]
£ 540 - carpenters acct
£ 577 - masons acct

£ 1117 exclusive of slaters [...] smyth glazier and [...] painters accts & [...] an acct paid to mr adam [...] of upwards of £ 100 for [...] marble chimneis jambs and slabs
(inside) *The Most Honourable the Marquise of Twaddale 1750 to Thomas dunlop wright*
transporting furniture from the *Abbay*, double and single flooring with plansher nails and door nails, furniture, closing window, lining window, taking down lining/shelves/partitions, taking out books from library
[...] *to 5 days work of 6 men taking down the roof of the towr & stair ??? as ned it fall £ 1.15*
to 4 days work of 4 men taking of the roof of the south side of the house al Do per day £ 0.18.8
to 4 men 5 days seporting the south side of the house al Do per day £ 1.3.4
to 4 men 4 days taking of the roof of the north side al Do per day £ 0.18.8
to 3 days of 4 men al Do seporting Do £ 0.14 [...] lining, plaster lime to point the walls
[...] *to 16 hutts? Do [of plaister lime] & 4 clifts of dals with 100 naills furnished for mending the plaster of the* [...]
deals used for furniture (presses and closets) and for windows
mending plaster in various rooms
[...] *to 12 clifts of sawen dals with 500 plansher naills & o hutts plaster lime with 3 days work of 3 men putting up scaffolding to mend the plaster & lath at the back of Lord Charles room and room below Do £ 1.8.8*
[...] cutting the floors and *making borders for 3 rooms*, *boxing the hearth stone*, mending panels in rooms, cheeks for *skie lights*
[...]
to 6 long dals furnished for mending the sarking of that roof 660 double flooring & 4 days work of two men £ 3.6.9
[...] mending the attic floors [...]
to taking of the landrie roof £ 0.3
to 2 days of 3 men putting one Do roof £ 0.7
to 32 cutts of sawn trees at 8 foot long for the roof 294 garron naills £ 1.9.10
to 6 single trees for backs to the couples 64 garron naills 3 days of two men for pa?ing and nailling Do £ 1.9
to 46 thick dals for casing and sarking and tyle lath & filliting £ 3.9
[...] tresses for the masons [...]
to 3 double trees & 10 dals for the roof at the back of the kitchen 12 garron nalls & 160 double flooring 2 days of 2 men £ 1.9.3
to 120 dals for scaffolding to the masons of which 15 of Do broke? & 20 trees & 6 of Do trees cutt 160 garron naills 1060 double floorings 300 double double & 8 days work of two men making and altering the scaffolding & ganys?
£ 4.9
[...] toubs and barrows for masons, deals for spouts, partitions, gantries, tables [...]
to 6 days of 4 men taking down the old houses & carrying Do to the backside £ 1.8
[...] elm and walnut trees used for furniture with glued (*gleu*) nails, cleaning rubbish [...]
to 457 yds 7 foot of rooffing and sarking one maine body of the house at 5pr yd £ 112.18.10 1/3
to 70 yds 5 foot one the to fall at 3pr yd £ 10.11
to 12 yds one the platform at 4pr yd £ 2.8
to 7 yds 4 ft one the east nefseray house £ 0.18.73
[...] whole deals or swn deals for lining (panelling?), naked flooring (only structure?), folding doors, *making a frame for carrying a fine screen to yester*, gate, dighting the floors, locks to doors, casway laying, cash for measurer
tot £ 505.10.6
deduct for old wood £ 5
plus other account £ 547.04.3
house rents to be deducted £19.12.2

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14637 Folios 67

Title Account of work by James Baine at a stable in Edinburgh and one in Yester for the Marquis of Tweeddale Date: from 1669 to

Contents (one side) *1669 ane acoumpt of furnitoe and workmanship for ane stable to the Earle of Tweddall at Edr furnished be James Baine wright and ane stabl at yestere*
Item in the ??? copalis & 16 ??? treis for syds and ??? per pair at 1£ 04s. £ 84

[Kate N. says *copalis* may be roofing couples]
Item for carting of tree caring of the ??? treis from leith 16 per pair at 3s. £ 10.04
Item for ??? ??? singl treis for barbs and hinging ??? per pair ??? ??? carting 12 £ 22.16
Item for ??? ??? twa treis for yester? 16? per pair ??? £ 48
Item for ten treis for stanards? and ??? for the stable per pair ??? £ 15
Item for hom? carting ??? ??? treis is £ 1.1
Item for twa sallentris? and on for the for syd of ??? pris per pair w.t hom? carting and salling 1.28 £ 5.08
Item for four treis for warping the partichand wall is £ 6
Item for ??? lintalls is £ 4
Item for the great dorman treis with the stanards? for the cath dore head £ 20
Item for four hunder and theitie ??? daills is at per 100 48 £ 192
Item for twa hunder of other daills per 100 at £40 £ 80
Item for carting of ??? hunder and theitie ancht? daills £ 15
Item for tria hunder and theitie singl garam nells is at per pair at 6d. £ 3.75
Item for ancht thousand 8 hunder of floring nells is per hunder at 12 £ 52.76
Item for twa dors w.t ther locks and bands is £ 7
Item for laying of the cassis £ 14
Item for caring away the rubesh £ 54
Item for caring away the rubesh out of the stables and ordering the rubesh about the dors is £ 5
Item for the maission work and furnishing lyme and sand is £ 300
Item for seavine thousand sllats being yor 1000 w.t the ??? carting £44 £ 308
Item for seavin thousand fyv hunder sllat nells per hunder is at 12 £ 45
Item for lym and sand for sllating is £ 20
tot £ 1312.09
(other side) *Item for the sllater worke is ane hunder and fortie marks £ 93*
Item ???????????
Receipt from James Baine. Received the sum of one thousand nine hundred and 25 pound scots money and seven shillings. Full payment for workmanship and furnishing of one stable and coach house at Edinburgh and repairing of one stable at Yester. 22 June 1669. James Baine

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14637 Folios 73

Title Account of timber work for the Earl of Tweeddale by James Baine Date: from 1675 to 1684

Contents
1675 one account ???? be? the Earl of Tweeddale to James Baine wright for timber and slates
Four daills for mending the C?? shop?
?One hndred floorin gnails
One man at that time for …?

8 febr 1676 two boxes for carrying of two looking glasses
Half a hundred plancher nails for rafter work in the Lodging
Two boxes for carrying of ??? to London

1677 for two chimney pieces
Two door ? pieces
Seven daills for ?? in the yard
??
One hundred of flooring nails
For work at that time
For the lining of two windows and one chimney port of the east end of the Low hall
One case and broads [shutters] *to the kitchen window*
1678 One coumed frame for the coffering/enclosing? The head of one bed one Coothead at the ??
4000 blue slates
??800 blue slates
Half a daill for filling/fitting to the slater
One hundred of Drunton (Trondheim) daills
1679 Two hundred and fifteen drunton daills
1680 Pinky?? 1200 slates
1681 1500 slates
1681 1800 slates

One account to my Lord Yester
Item 3000 blue slates
Forty four brod ??? daills
900 blue slates
Six merchant daills
26 daills for Pinky?

Reverse:
Comments and summary of payment made to James Baine by Tweeddale 1684

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14665 Folios

Title Account of work by Thomas Dunlop and timber from William Caddell for the Marquis of Tweeddale Date: from 1735 to 1753

Contents **f. ??**
january to september 1750 William Cadell merchant in Haddington
tot £ 42 for dealls with different prices
f. ??
march to november 1751 William Cadell merchant in Haddington
tot £ 93 for dealls with different prices, logs, iron bars, double trees, oak clapboards, wainscot 1/2 thick planks, scaillie
f. ??
april to november 1753 William Cadell merchant in Haddington
tot £ 56 for dealls with different prices, scaillie, logs, sawing
f. ??
1735 account to Thomas Dunlop
f. ??
1739 account to Thomas Dunlop

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 109

Title Contract between William Adam and the Marquis of Tweeddale for works at Yester House Date: from 1742 to 1749

Contents *Dr? The most Hon.ble Marques of Tweeddale to William Adam Architect for repairs done to his house in Edinburgh*
Decem 28 1742 – October 31 1749
chimneys, plasterwork, pointing, lead, hewn pavement for servant attic, …
TOT £ 11.76

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 116

Title Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House Date: from 1750 to

Contents *My Lord,*
I take the liberty to send to your lord inclosed a sketch for the different storeys of a little new house to be built in place of the old one in Edinburgh. It is such as I dare say your lord will not find fault with, wither for the dimentions of the rooms, or for the outward size of the whole, being only 47 by 49 feet over walls. I think it is conveniently disposed of, to answer what your lord proposes, but I thought it was best to send the rough draught to undergo the marques and his wife's examination before doing good drawings. […]
John Adam
20 August 1750

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 115

Title Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House Date: from 1750 to

Contents *[…] I also lookt at your lord's house with great attention, & can assure your lord it is in a very melancholy way. There is not one single thing within the doors of it that can be of use in the repairs, or can be allowd to stand as they are.* ***The roof is so bad, that a new one must inevitably be put on next spring****, and the floors, ceilings, doors, sashes, shutters & every thing must be made new, so that nothing in the world would be saved but the walls. This I confess is something, but not so much as your lord is apt to imagine as there is not a room in the house that has a door or a window properly placed in it, so that by rights these should be slap't & in that case I were almost as good to build them new. But supposing that your lord could comport with these as they are, it is my sincere opinion from the large size of the present house that if your lord once puts hand to the repairs of it, it must turn out as dear as building a little house from the foundation. I hope your lord will forgive my liberty on this head. I have no other view in it the to forwarn your lord of the expense that inevitably will follow if the repairs are once begun to, that so your lord may judge wether you would incline to bestow it or not. I shall send by the carrier the plans of the house as they presently are & as it was proposed to be alter'd that your lord may consider them.*
John Adam
26 June 1750

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 130

Title Account of repairs done by John Adam probably at Tweeddale House Date: from 1750 to

Contents Accounts for repairs in Edinburgh House Mr Adam £ 11.76 - 30th September 1750

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14665 Folios 69

Title Account of work by Thomas Dunlop for the Marquis of Tweeddale Date: from 1750 to 1753

Contents (outside) *House rents of small houses in the marquiss of Tweeddale's Close in Edin.re on the Right Hande going down set by*

Deacon Dunlop Carpenter for 3 years frome 1750 to 1753 £ 20.13.6
(inside) *Accompt of chairg and dischairg betwext Charls Hay of Hopps Ed.re and Thomas Dunlop for the markous of Twaddelles houses in Ed.re from whotsonday 1750 to whatsonday 1753*
he takes rent from people living in the Marquess houses and does some repairs in them
Itt give out for warning away the tennants when the houses was to take down [….

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 128

Title Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House Date: from 1753 to

Contents *[…] the laundry in your lord's house in town is 20 foot long, 16 foot broad & 9 foot high. The dining room is 27 foot long, 20 foot broad & 11 feet high. The plaister work of your lord's house is now begun & Mr Dunlop promises that it shall meet with no interruption from the wrights but that every thing shall be ready for him in due time. The other part of the work comes pretty well on. […]*
7 June 1753
John Adam

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 126

Title Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House Date: from 1753 to

Contents *My lord,*
Soon after my brother & I return'd to Town from Yester, ***we went to your lord's house along with Mess.rs Mack and Dunlop, & concerted every thing with them on the spot, in terms of what your lord directed****, so that they are now going on.* ***We are also making out for them Memorandums of the several things with drawings of the particular parts so as they may committ no mistake****. But one thing occurred to us, as a considerable improvement , th's we would not adventure to do it without your lord's leave, & that is to turn the present entry door from the court to the hall into a window & to change the east window of the present latter meat room into the entry door, & then to take away the wall which divides between the latter meat room & the hall, so as to throw them into one; By this means the hall will get light at the west end, which at present it wants, & the draught of air from the door is not directly opposite to the new door of relief, to the low drawing room. […]* he talks about other walls that could me moved
John Adam
15 March 1753

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14551 Folios 137

Title Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House Date: from 1755 to

Contents *[…] I have made out directions in writing for Mr Dunlop & the other people that they may get every thing done directly & without confusion.* problems with stove that has been put up in the wrong position and smoke in the lord's room. the lord put "Mr Auchinleck's machine" to get rid of the smoke!
13th October 1755
John Adam

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14665 Folios 70

Title Account of work by Thomas Dunlop for the Marquis of Tweeddale Date: from 1755 to 1756

Contents (outside) *Accompt the most honorable the markous of twddall to Tho: Dunlop 1755-56 £ 41.13.1*
(inside) *Accompt the most honorable the merkous of Twdal to Thomas Dunlop sinc 16 octobr 1755 and sinc the accompt was given in str*
[...] tables, chairs, windows, doors, presses, plaster, beds, shelves - talks about stables[...]
Itt in the washing hous two tries and 6 long spars put up [...]
[...] *to coot the floor and rouff to let up the vent* [...]
lintels for windows, table for Mrs Martine [...]
Itt to 24 long deals 16 penc pr pice lead in the garret to lay lumber on with work and nails to nail them £ 1.14
Itt to two broad firr planks in the ??? and to make borders to the hampers £ 0.6
[...] mending the drawing room

Summary and comments

Archive National Library of Scotland Doc. Num. MS 14680 Folios

Title Works at Tweedale House Date: from 1779 to 1782

Contents

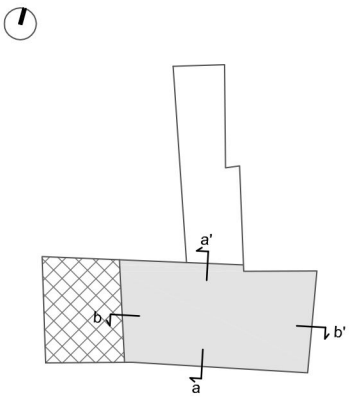
Summary and comments

Archive Private: Tweeddale House Doc. Num. Uncatalogued Folios

Title Drawings and pictures of survey and repair works carried out in 1980s at Tweeddale House Date: from 1980s to

Contents

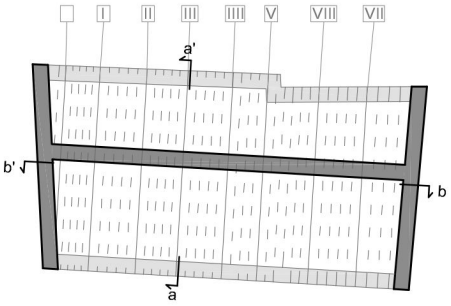
Summary and comments					
Archive	Royal Commission on the Ancient a	Doc. Num.	DC 3496	Folios	
Title	Tweeddale Court, 14 High Street, Edinburgh -Section A-A			Date: from	1984 to
Contents					
Summary and comments					



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

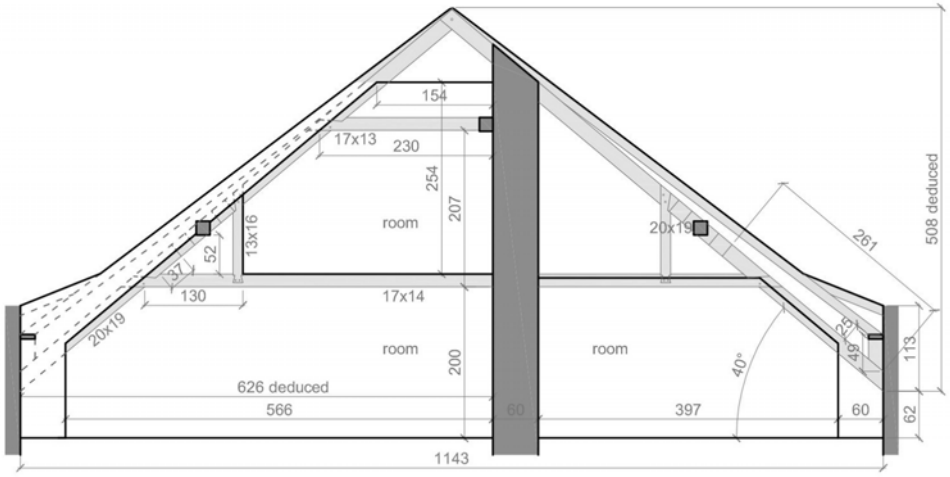
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

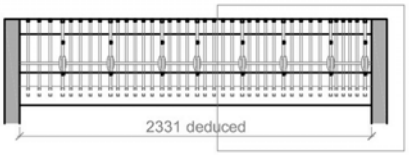
Section aa'

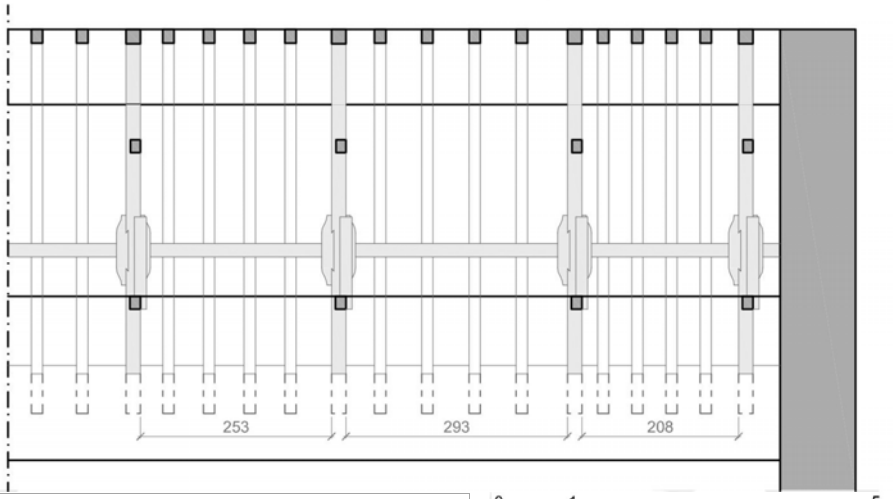


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



INITIAL SURVEY | **Building name** TWEEDDALE HOUSE | **Roof location** Main block

Survey date(s) 13/10/2014 11/12/2014 | See drawing: TWH-MB-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.26 | Roof Height [m]: 5.08

Roof Pitch/es [°]: 40 | Roof Length [m]: 23.3

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 2.2

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables: purlins

Roof Construction Period: From 1750 To 1756 Identified by: Estimated

Roof General Description: House reroofed in 1750-6 and repairs done in 1779/82 and 1791. Two-pitch gabled roof supported by intermediate longitudinal wall. Frames divided in principal and secondary frames. One butt-purlin on each side connects the principal frames together. A vertical strut on each side connects rafters and lower collars. Original sarking was secured with timber pegs.

Roofing Material: slate

Roofing Material Fixing: Metal nails, Timber Pegs

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 20 B: 19 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☑

Joint Types: cleat, dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg flush, Timber peg not flush

Joints description: Rafters' apex not well visible, could be mortice and tenon or lapped with timber pegs flush. Between rafters and collars/struts: dovetail lapped with metal nails. Bwteen rafters and purlins: mortice and tenon with cleat and timber pegs not flush.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Mostly in sequence

Signs of reused timbers: Some bark on collars, roughly shaped: they could be reused timbers from medieval roof. Archive documents record 5£ deducted from wrights' account for reused timber

Timber Treated ☐

Other Materials: Few iron straps between collars and rafters. Steel bolts added in 1980s to reinforce cleats and purlins.

Dendrochronology:



Roof structure link I:\Arch\A



link I:\Arch\A



Timber dressing link I:\Arch\A



Joints: strut and purlin link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall on south side not visible

Past interventions: Works in 1790s: rafters doubled with lower pitch; iron straps added between some collars and rafters. Works in 80s: some sarking replaced; some rafters and struts replaced partly or completely; hangers added; steel bolts added.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack on some collars, some looks old some new

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Material degradation | link | I:\Arch\A

Description of visible damage

Other Notes: Whilst purlins are normally employed in trussed roofs, cleats seem to be a more common feature in Italy, in both buildings and treatises.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link | I:\Arch\A

YESTER HOUSE

Location: EAST LOTHIAN | YESTER
X coordinate: 354348 | Y coordinate: 667161
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Protection status: NATIONAL
HS Listing: A | Rcahms ID: 56117

Original Use: Residential
Current Use: Residential

Freestanding: ☑ | N. of floors above ground level: 2 | Location link: I:\Arch\AD | Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1582		4 STOREYS TOWER-HOUSE CLOSE TO THE SITE WHERE THE PRESENT MANSION STANDS	DUNBAR 1972

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1600	1699	WINGS ADDED ON EACH SIDE OF TOWER-HOUSE	DUNBAR 1972

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1666	1669	WRIGHT WORK	CANMORE

People involved:

Last Name	First Name	Role	Attributed
SAMPSON	ROBERT	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION, LANDSCAPE	1670	1674	WRIGHT WORK INCLUDING FURNITURE + LAYING OUT OF THE PARK DESIGNED BY THE EARL	CANMORE

People involved:

Last Name	First Name	Role	Attributed
BAINE	JAMES	MATERIAL SUPPLIER, PLASTERER, WRIGHT	☐
MACKIE	CORNELIUS	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1686		JAMES SMITH PAID FOR FOUR STONE PEDESTALS FOR LEAD STATUES	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION, DEMOLITION, LANDSCAPE	1699	1715	NEW HOUSE CLOSE TO OLD ONE - OLD HOUSE WAS PROBABLY DEMOLISHED AROUND 1705	HS

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	ARCHITECT	☐
MCGILL	ALEXANDER	ARCHITECT	☐
RAE	DAVID	WRIGHT	☐
JOHNSTON	JOHN	WRIGHT	☐
BRUCE 1	SIR WILLIAM 1	ARCHITECT	☑
FINLAYSON	GEORGE	MASTER MASON	☐
SYME	JAMES	SLATER	☐

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1715	1728	CONSTRUCTION OF HOUSE CONTINUES	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
HAY	JOHN 4TH MARQUES	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1729	1748	NEW LEAD PLATFORM ROOF OVER DOUBLE-PITCHED SLATE ROOF. COLUMNS ADDED ON THE FACADES AND IMPOSING DOUBLE STAIRCASE TO ACCESS GROUND FLOOR + ADJUSTMENT OF FLOOR LEVELS	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT, MATERIAL SUPPLIER	☐
LOW	JOHN	OVERSEER	☐
ENZER	JOSEPH	PLASTERER	☐
NICOLS	FRANCIS	PLASTERER	☐
ROBERTSON	PHILLIP	PLASTERER	☐
NORIE	JAMES	PAINTER	☐
DOUGLAS	CHARLES	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION, LANDSCAPE	1750	1761	EAST PAVILION ALTERED TO PUT IN NURSERY - GARDENS ALTERED - LODGES AND GATEWAY TOWARDS GIFFORD VILLAGE - PLASTERWORK IN THE SALOON	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
HAY	GEORGE 7TH MARQ	COMMISSIONERPATRON	☐
ADAM	ROBERT	ARCHITECT	☐
ADAM 1	JAMES 1	ARCHITECT	☐
DAWSON	JOHN	PLASTERER	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1788	1790	APPROACH RAMP, DRAWING ROOM, FRONT AND REAR ELEVATIONS - ROOF ALTERATIONS TO INSERT WINDOWS FOR SALOON	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
ADAM	ROBERT	ARCHITECT	☐
HAY	GEORGE 7TH MARQ	COMMISSIONERPATRON	☐
HAY	JOHN	CONTRACTOR	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1793	1794	REPLASTERING THE STAIRCASE CUPOLAS + WRIGHT WORK IN UPPER DRAWING-ROOM AND ADJOINING ROOMS	DUNBAR 1972

People involved:

Last Name	First Name	Role	Attributed
DONALDSON	WILLIAM	WRIGHT	☐
RUSSELL	THOMAS	PLASTERER	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1797		WEST WING REPAIRED AFTER FIRE DAMAGE	DUNBAR 1972

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1830	1839	REMOVED W PAVILION AND ADDED NEW PORTE COCHERE TO W, TRANSFERRING ENTRANCE TO SIDE POSITION - INTERIOR REDECORATION.	HS

People involved:

Last Name	First Name	Role	Attributed
HAY	GEORGE 8TH MARQ	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1876	1878	ROOF AND CEILINGS	DUNBAR 1972

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	15

Author	Year	Unpubl.	Title	Pages
RYKWERT J.	1985	☐	THE BROTHERS ADAM. THE MEN AND THE STYLE	210
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 25-30
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	25-31

ARCHIVAL REFERENCES

Archive	National Library of Scotland	Doc.Num.	MS 14637	Folios	74
Title	Account of timber work at Yester House by James Baine				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	22
Title	Contract between William Adam and the Marquis of Tweeddale for works at Yester House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	24
Title	Contract between William Adam and the Marquis of Tweeddale for works at Yester House				
Archive	National Library of Scotland	Doc.Num.	MS 14551	Folios	112
Title	Account of timber furnished by William Adam for Yester House				
Archive	National Library of Scotland	Doc.Num.	MS 14637	Folios	66
Title	Account of work by James Baine for the Marquis of Tweeddale				
Archive	National Library of Scotland	Doc.Num.	MS 14637	Folios	67
Title	Account of work by James Baine at a stable in Edinburgh and one in Yester for the Marquis of Tweeddale				
Archive	National Library of Scotland	Doc.Num.	MS 14637	Folios	68
Title	Account of work at Yester				

Suggestions for further research: NLS: Hay papers

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: National Library of Scotland | Doc. Num.: MS 14637 | Folios: 66

Title: Account of work by James Baine for the Marquis of Tweeddale | Date: from 1668 to

Contents:
(one side) *Comptt and rectt James Baine wright for ??? yester and pan cratch to ??? 9th 24tt ???*
(other side) 1668 May tot £ 24.18

Summary and comments:

Archive: National Library of Scotland | Doc. Num.: MS 14637 | Folios: 68

Title: Account of work at Yester | Date: from 1669 to

Contents:
Agust 1669 ane acoumpt of timber and workmanship for yester
Item for sixtaine? ockane treis is at ??????? £ 40.12
Item for ane long great tri that was 33 foot of length £ 12
Item for the sawing of that tri from the on end to the other £ 1.04
Item for ane other short great trie is at £ 4.7
Item for ane hunder and anchtie dalls at 8 per peic is £ 80
Item for ane other hunder of dalls is £ 48
Item for twentie sex ockane garrons is per peic £ 15.72
Item for twa wainscot per peic at ??? £ 9
Item for ancht double tris at per piec 7£ 4p. £ 9.72
Item for four scor [80] *of daills is at per peic 6p. 8s. £ 26.13.8*
Item for thri thousand sllat nells to yester is £ 18
Item to neidpeath? ane thousand floorings is £ 6
Item to neidpeath? ancht hunder of slating? nells is £ 4
John Baine, ???, James pitlour?, Hobert ???drack, John Waterspun, John Baine Younger
tot £ 1925.07

Summary and comments:

Archive: National Library of Scotland | Doc. Num.: MS 14637 | Folios: 67

Title: Account of work by James Baine at a stable in Edinburgh and one in Yester for the Marquis of Tweeddale | Date: from 1669 to

Contents:
(one side) *1669 ane acoumpt of furnitoe and workmanship for ane stable to the Earle of Tweddall at Edr furnished be James Baine wright and ane stabl at yestere*
Item in the ??? copalis & 16 ??? treis for syds and ??? per pair at 1£ 04s. £ 84
[Kate N. says *copalis* may be roofing couples]
Item for carting of tree caring of the ??? treis from leith 16 per pair at 3s. £ 10.04
Item for ??? ??? singl treis for barbs and hinging ??? per pair ??? ??? carting 12 £ 22.16
Item for ??? ??? twa treis for yester? 16? per pair ??? £ 48
Item for ten treis for stanards? and ??? for the stable per pair ??? £ 15
Item for hom? carting ??? ??? treis is £ 1.1
Item for twa sallentris? and on for the for syd of ??? pris per pair w.t hom? carting and salling 1.28 £ 5.08
Item for four treis for warping the partichand wall is £ 6
Item for ??? lintalls is £ 4
Item for the great dorman treis with the stanards? for the cath dore head £ 20
Item for four hunder and theitie ??? daills is at per 100 48 £ 192
Item for twa hunder of other daills per 100 at £40 £ 80
Item for carting of ??? hunder and theitie ancht? daills £ 15
Item for tria hunder and theitie singl garam nells is at per pair at 6d. £ 3.75
Item for ancht thousand 8 hunder of floring nells is per hunder at 12 £ 52.76
Item for twa dors w.t ther locks and bands is £ 7
Item for laying of the cassis £ 14
Item for caring away the rubesh £ 54
Item for caring away the rubesh out of the stables and ordering the rubesh about the dors is £ 5
Item for the maission work and furnishing lyme and sand is £ 300
Item for seavine thousand sllats being yor 1000 w.t the ??? carting £44 £ 308
Item for seavin thousand fyv hunder sllat nells per hunder is at 12 £ 45
Item for lym and sand for sllating is £ 20
tot £ 1312.09
(other side) *Item for the sllater worke is ane hunder and fortie marks £ 93*
Item ???????????
Receipt from James Baine. Received the sum of one thousand nine hundred and 25 pound scots money and seven shillings. Full

payment for workmanship and furnishing of one stable and coach house at Edinburgh and repairing of one stable at Yester. 22 June 1669. James Baine

Summary and comments

Archive National Library of Scotland | Doc. Num. MS 14637 | Folios 74

Title: Account of timber work at Yester House by James Baine | Date: from 1675 to

Contents:

Account the Earl of Tweeddale ??
James Bain His Majestys Master Wright..???? 1675

For four door ??? for mending the Cobbler his shop?
One deal for one tre????????
One hundred of flooring nails

For one man working of the above????
?????? in the house at Yester
For two boxes for carriage of looking glasses
Half one hundred of plancher nails
For two boxes for carrying of goods to London
For two chimney pieces with two frames above ??

Seven deals for boxing of the ??
??
One hundred of flooring nails
Work wrought at the???

For lining of two windows with one chimney piece in that chamber adjacent to the Laigh Hall ??
For one case with broads to the kitchen window
For one coumed/carved frame for the head of one ?
One coumed/carved head ?? in my Lords Chamber
1678 4000 blue slates ?
Per thousand ???? to James Murray
800 slates ??? with Musselburgh [Castle?]
???????
One hundred of drunton daills
Two hundred and fifteen drunton deallis
To Pinkie one thousand and two hundred slates
One thousand eight hundred and sixty slates
Att 44 pound per thousand??
20 May To yester? Three thousand blue slates ???
Forty four Christian (Oslo) deals??
?? hundred slates
Merchant? Deals
Six broad dealls

Summary and comments

Archive National Library of Scotland | Doc. Num. MS 14551 | Folios 22

Title: Contract between William Adam and the Marquis of Tweeddale for works at Yester House | Date: from 1729 to

Contents:

Edinburgh 20th December 1729 – contract between William Adam and the Marques of Tweeddale
the marquess of Tweeddale asks William Adam *architect in Edinburgh […] whereas the present roofe of Yester house being done after the forme commonly called a Happer roof which lodges a great quantity of snow in the winter season to the great prejudice of the said roofe And the said noble marques being designed to alter the same from a Happer roofe to a Plattform to lye betwixt the ridges of the present roof […] The east part of the said house all which to be said with sufficient* ***beams of firr wood*** *and* ***sarking deals*** *and to be* ***covered with lead*** *sufficiently cast and laid with the usual rolls and overlaps at eight pound weight each foot […] As also* ***the said noble marques designing to roofe*** *the middle part of the said house viz- that over the great hall and garden room bounded betwixt the forementioned two principall walls with a pediment roofe to be* ***covered with blue siaillie*** *Wherefore the said William Adam binds and obliges him his heirs executers and successors? to perform the foresaid articles of platt forming in beams sarking and lead, with the pediment roofe and siaillie work over the formentioned middle part of the said house in manner forsaid, and to furnish upon his own proper charges and expenses the whole material there to as also to reuse upon the*
signatures cancelled

Summary and comments

Archive National Library of Scotland | Doc. Num. MS 14551 | Folios 112

Title: Account of timber furnished by William Adam for Yester House | Date: from 1742 to 1748

Contents:

Account of W. Adam who **furnished timber to Yester House**
Oct 26 1742 – June 8 1748
TOT £ 113.2

Summary and comments

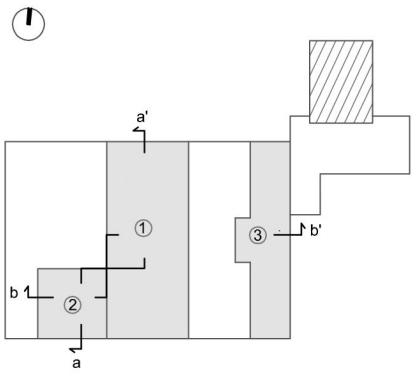
Archive National Library of Scotland | Doc. Num. MS 14551 | Folios 24

Title: Contract between William Adam and the Marquis of Tweeddale for works at Yester House | Date: from Undated to

Contents:

Another contract between the Marques and W. Adam
signatures cancelled
W. Adam is providing all the material: *all stons lyme and sand and to cause carry and lay down all lead and* ***timber from the port of portseaton*** *to the plane of yester and to lay down the same within the court at yester The said William Adam having the timber in readiness at the said port of portseaton so as may be ready to be carried to yester […] And is hereby declared that all the timber lead and siaillie now upon the house whilst? will or maybe altered by this new design shall be deemed the property of the said William Adam in so far as he shall*
The same in the alterations to be made on the present roofe but if any of the old timber lead and siaillie remains after the house is finished the same is to belong to the said noble marques And the said noble ***marques oblidges him to cut and squair two rows of the firr trees now growing in the garden from the cannall to the trongate and to furnish the same to the said William Adam for scaffolding*** **and for hand or horse machines that W. Adam might need to carry the materials to the top of the house**
they get some lead from the Duke of Queensbeery – W. Adam pays for it

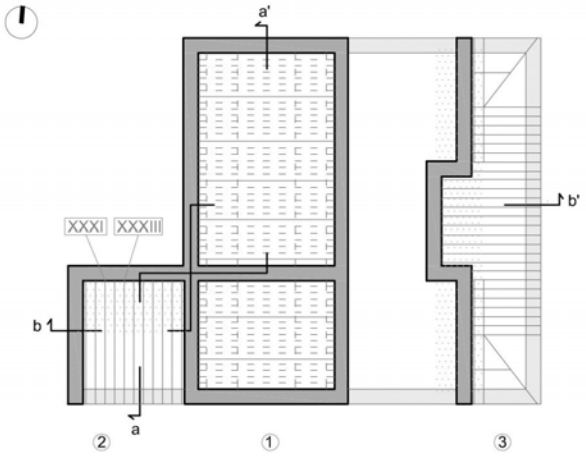
Summary and comments



Legend (plans):

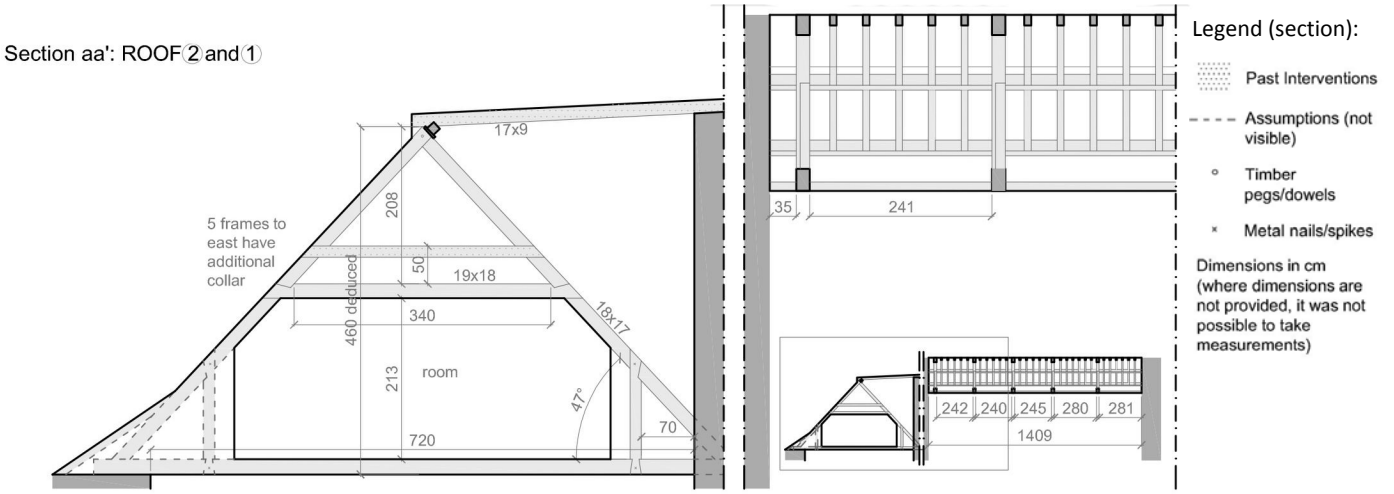
Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

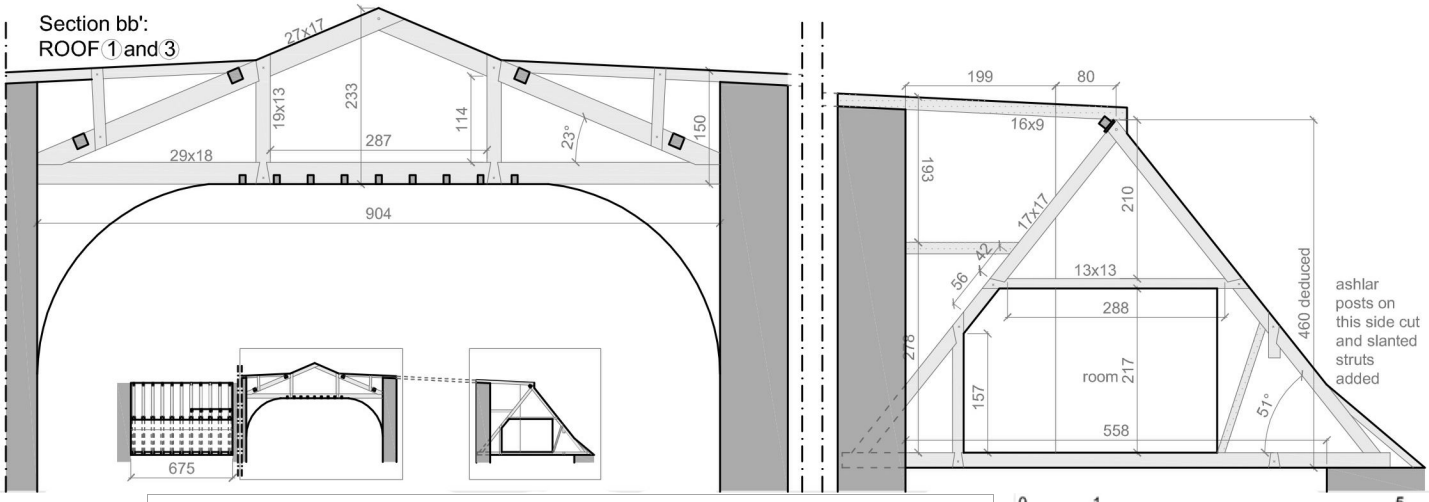
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



Roof 1 from outside I:\Arch\A



Roof 2 from outside I:\Arch\A

INITIAL SURVEY | **Building name** YESTER HOUSE | **Roof location** 3: E part of main block

Survey date(s) 26/08/2015 | See drawing: YH-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 5.6 | Roof Height [m]: 4.6

Roof Pitch/es [°]: 51 | Roof Length [m]:

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.52

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm]: | thickness [cm]: 3

Connection with lateral walls: Tie-beam

Connection with gables: rafters

Roof Construction Period: From 1699 To 1729 Identified by: Estimated

Roof General Description:

Late 17C gabled roof with simple frames with two collars transformed into a platform roof in early 18C. Ashlar post probably added when platform roof was put on top.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 16 B: 16 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed) Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters' apex: mortice and tenon with timber peg not flush. Between rafters and collars/struts: dovetail lapped (struts have metal nails, collar joints are not well visible).

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: runic marks

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure link I:\Arch\A



Roof structure link I:\Arch\A



Timber dressing link I:\Arch\A



Joints: rafter and collar link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Some ashlar posts on east side cut and replaced with slanted struts



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains and fungi attack on sarking and rafters. Looks active.



Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Fungi attack | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** YESTER HOUSE | **Roof location** 2: SW part of main block

Survey date(s) 26/08/2015 | See drawing: YH-MB-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 7.2 | Roof Height [m]: 4.6

Roof Pitch/es [°]: 47 | Roof Length [m]: 6.7

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.5

Type of Secondary Structure: sarking | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Tie-beam

Connection with gables:

Roof Construction Period: From 1699 To 1729 | Identified by: Estimated

Roof General Description: Late 17C gabled roof with simple frames with two collars transformed into a platform roof in early 18C. Ashlar post probably added when platform roof was put on top.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes, Square with wanes

Rafter Scantling [cm] H: 18 | B: 17 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: mortice and tenon with timber peg not flush. Between rafters and collars/struts: dovetail lapped (struts have metal nails, collar joints are not well visible).

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals, runic marks

Carpentry Marks Description: Only few visible

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

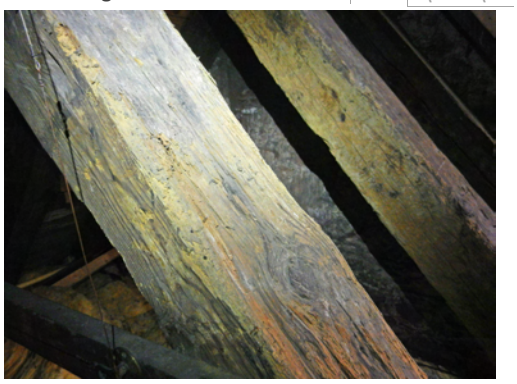
Unfavourable conditions

Accessibility limitations: Connection with wall on south side not visible, and only partly visible on north side.

Past interventions: Some sarking replaced.



Material degradation | link | I:\Arch\A



Material degradation | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Insect attack on rafters, not sure if active

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** YESTER HOUSE | **Roof location** 1: central part of main block

Survey date(s) 26/08/2015 | See drawing: YH-MB-1

Roof Geometry: Flat, Two-pitch gabled

Roof Max Span [m]: 9 | Roof Height [m]: 2.33

Roof Pitch/es [°]: 23 | Roof Length [m]: 22.3

Type of Primary Structure: 2D framing

Truss ☑ OTHER

Frame ☐ Struts

Average Distance in between Primary Structure [m]: 2.45

Type of Secondary Structure: common rafters, purlins, sa | Plane: roof plane

Sarking boards: width [cm] | thickness [cm]: 4

Connection with lateral walls: Tie-beam

Connection with gables: purlins

Roof Construction Period: From 1729 To 1748 | Identified by: Estimated

Roof General Description:

Gabled roof supported by 7 trusses, each composed of a tie-beam, 2 rafters and two vertical struts. Two purlins on each side support the common rafters and the sarking. A lower pitch is added on the sides to link with the platform on the other sides.

Roofing Material: lead

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 27 | B: 17 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal nail, Timber peg flush

Joints description:

Between rafters and tie-beam and at rafters' apex: mortice and tenon (rafters' apex also have timber peg flush). Struts are secured with dovetaill lapped joint with a metal nail.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: runic marks

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: tie-beam and strut | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features: Original plaster ceiling underneath

Unfavourable conditions: poor ventilation

Accessibility limitations:

Past interventions: Some common rafters replaced. Purlin end reinforced with steel plates and timber struts.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☐

Humidity stains in sarking and common rafters, insect attack in common rafters, not sure if active.



Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks	Unknown	
Connection Damage	Disconnection	Unknown	



Damage: opening of joints | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient joints
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: crack in rafter | link | I:\Arch\A

Description of visible damage: Joints between rafters and tie-beams are opening, as if the rafters were sliding outward. Not sure if movement is still active. One rafter on west side is cracked.

Other Notes:

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

APPENDIX F

STRUCTURED FORMS OF THE CASE STUDIES

COCKENZIE HOUSE.....719
HOLYROOD PALACE.....766
NEWHAILES HOUSE.....838
PINKIE HOUSE.....865
ST ANDREW'S & ST GEORGE'S CHURCH.....913
ST ANDREW'S IN THE SQUARE CHURCH.....930
STIRLING CASTLE.....946
TOUCH HOUSE.....1039

COCKENZIE HOUSE

Location: EAST LOTHIAN | TRANENT
X coordinate: 340022 Y coordinate: 675641
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Rcahms ID: 53644
HS Listing: A

Original Use: Residential
Current Use: Hospital

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1680	1683	MAYBE INCORPORATING EARLIER FABRIC	JOE ROCK

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	ARCHITECT	☐
SETON	GEORGE 4TH EARL O	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1700	1725	WAREHOUSE TO WEST	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1750	1799	PILASTERED PORCH AND OTHER	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1845	1902	TO THE NORTH FRONT	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION, DAMAGE	1980	1989	FIRE IN NORTH WING, WHICH HAD TO BE REROOFED	TENANTS

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
ROCK J.	2015	☑	COCKENZIE HOUSE - NEW RESEARCH	
WALKER D.	1976	☑	HISTORIC BUILDINGS REPORT	

ARCHIVAL REFERENCES

Archive: National Records of Scotland Doc.Num.: E661/107 Folios: 3, 6, 10 and 3 folios un-numbered

Title: Forfeited Estates: Winton: Estate papers and vouchers prior to forfeiture: Accounts for timber bought for the earl of Winton by David Balfour, his chamberlain, 1681

Suggestions for further research:

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive	National Records of Scotland	Doc. Num.	E661/107	Folios	3, 6, 10 and 3 folios un-numbered

Title: Forfeited Estates: Winton: Estate papers and vouchers prior to forfeiture: Accounts for timber bought for the earl of Winton by David Balfour, his chamberlain, 1681

Date: from 1681 to

Contents

3
Leath 7th May 1681
Received from William Taitt carpinter in Leath upon the accompt of the Earle of Wintone ane? paire of wood of twentie two feets long and twelve inches squair bought be me att eyhtanie shillings per foots as also a paire of wood called a Knight [...]
D. Balfoure
Other merchants are paid: John Memeres?, Andrew Myrtime?, William Wilson, George Clark

6
Accompt & receat Normand Blaikson? 1681
40 single trees at 10s. per tree
four deals at 8s. per deal
20 single trees at 10s per tree
tot 41£

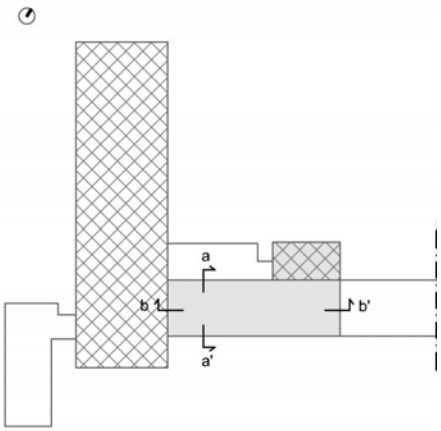
10
An accompt of timber received be James Steven wright from James Cockburn for the use of the Ealre of Wintons saltyarns in Cockenie & coall sinck ther, from the 19th of January 81 to the ???
12 double trees and 8 single trees for John Mathisons panroofe
1 double tree for Richard Bools Coop
many more double trees, and double doubles

no number
An accompt what timber Mr David Ballfour has gotten from Ja. Cockrane for my lord winton his use for the call work at tranent & the sinke at corkenny? lime our cast claying which was in april 23 ???
double trees
single trees
deals

no number
An accompt of what timber [missing] *recevid from James Cockburn by my lords order for the use of his gien? at tranent in No.br the 19 1680 a fokouth?*
3 double doubles
4 double trees
another double tree

no number
Accompt off timber receave be James Trotter? from James Cockburne for my lord winton ??? ??? ??? for Cokeney: sink and the coall works at tranente from the 24 jany 1681 to the 20 of Apryll ditto
double doubles
double tresses
single tress

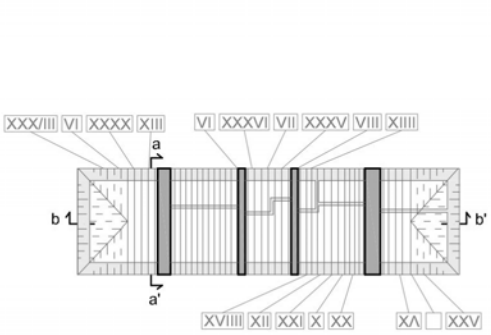
Summary and comments: 1681 timber bought by the Earl of Winton. Cockenzie and Tranent are mentioned, thus it could be timber used for Cockenzie House, but it is not sure.



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

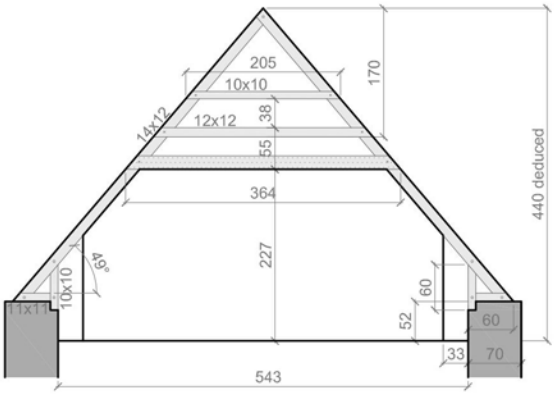
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

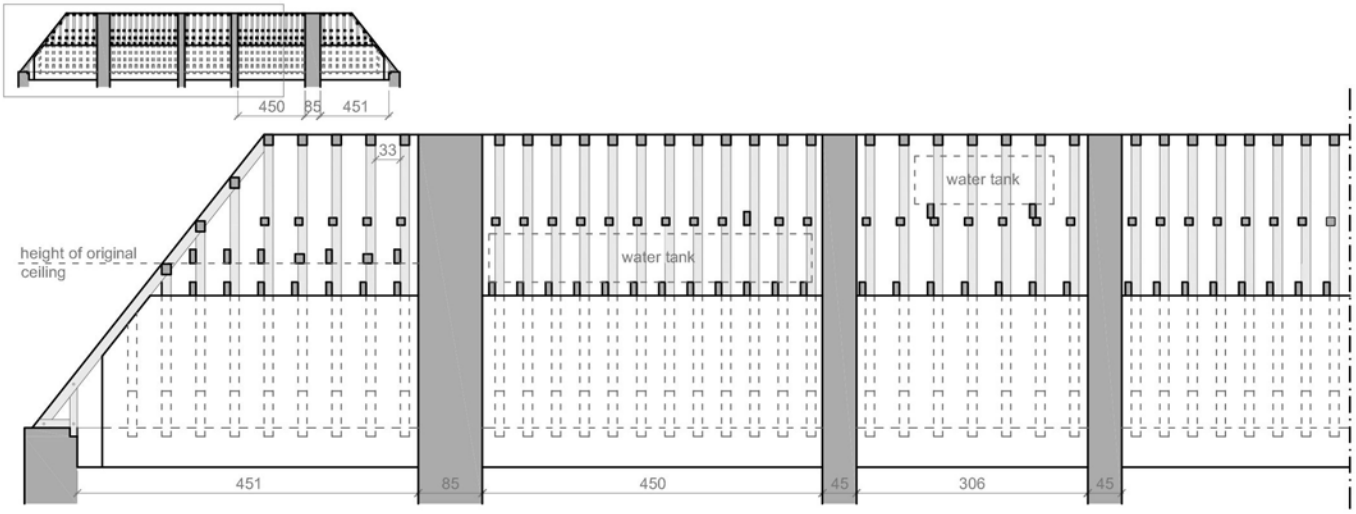
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** COCKENZIE HOUSE | **Roof location** E range

Survey date(s) 10/11/2015 | See drawing: COH-E-1

Roof Geometry: Hipped

Roof Max Span [m]: 5.43 | Roof Height [m]: 4.4

Roof Pitch/es [°]: 49 | Roof Length [m]: 23.7

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking

Sarking boards: width [cm] | thickness [cm]: 2

Connection with lateral walls: Rafter foot

Connection with gables: sarking interrupted (chimney)

Roof Construction Period: From 1680 To 1683 Identified by: Estimated

Roof General Description:

Hipped roof supported by simple frames with two collars and rafter feet with the ashlar post extended downwards on the masonry (visible only in a few points). Most of the lower collars have been removed and replaced at a lower height (the ceilings are in fact not original). All elements are full logs roughly squared with some bark retained. There are 4 intermediate gables: the external ones are thicker and house chimneys, thus the roof structure here is interrupted; the inner ones are thinner and more recent.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 14 B: 12 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed) Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg flush, Timber peg not flush

Joints description:

Rafters' apex: lapped with timber peg not flush. Between rafters and collars: lapped with hint of dovetail and metal nail. Rafter feet: mortice and tenon with timber pegs flush.

Wood Species:

All elements, including sarking and pegs securing the joints: pinus sylvestris

Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Not all elements have visible numbers and the visible ones are not in sequence

Signs of reused timbers:

Some redundant lap joints on collars.

Timber Treated ☑ in E part, probably for insects

Other Materials:

Dendrochronology:



Roof structure link I:\Arch\A



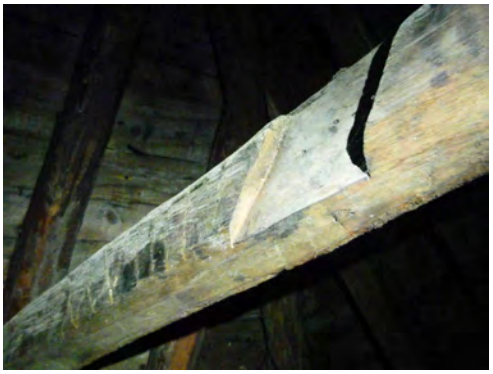
Connection with the wall link I:\Arch\A



Timber dressing link I:\Arch\A



Joint: collar and rafter link I:\Arch\A



Redundant joint & carpentry marks link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance, poor ventilation, presence of water tank

Accessibility limitations: The connection with the wall is visible only in two sections of the roof

Past interventions: Some collars have been removed, some others replaced. The ceiling has been lowered and new collars support it. Water tanks have been inserted and are supported by the original rafters.



Past interventions | link | I:\Arch\A



Open air water tank in roof | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☑

Brown rot in one of the visible rafter feet. Insect attack in other visible rafter feet and in a few rafters. All the timbers in the upper part, where the water tanks are, are very wet and damp.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



Brown rot in rafter feet | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Insect attack in rafter feet | link | I:\Arch\A

Description of visible damage

Other Notes: The inner walls are thicker than the outer, which suggests that the core of the house is of earlier date. In any case the roof structure is homogeneous thus it must have been replaced when the house was extended. There is evidence for reused timbers, which could have been taken from the earlier roof.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

DETAILED SURVEY **Building name** COCKENZIE HOUSE **Roof location** E range

Survey date(s) 22/01/2016 05/02/3016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings COH-E-1, COH-E-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
rafter	495*	square with wanes and bark	bending, compression	pinus sylvestris	hand axed
upper collar	200	square with wanes and bark	bending, compression	pinus sylvestris	hand axed
intermediate collar	270	square with wanes and bark	bending, compression		original ones are hand axed
lower collar	365	square with wanes and bark	bending, compression		original ones are hand axed
sole piece	50	square with wanes and bark	shear, tension	pinus sylvestris	hand axed
ashlar post	60	square with wanes and bark	compression, shear		hand axed
sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

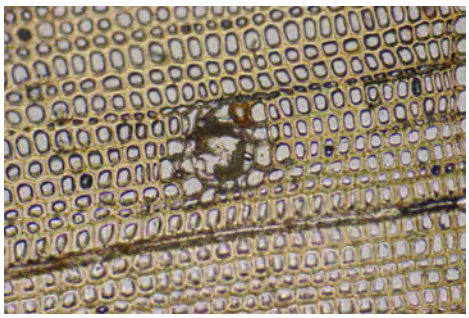
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings COH-E-1, COH-E-2

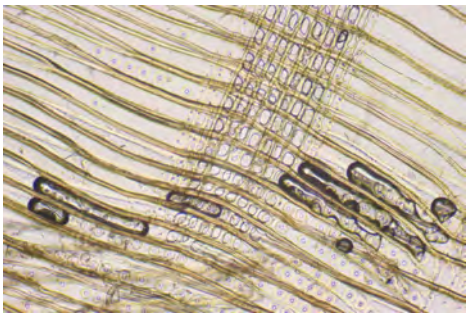
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner halved	compression	wooden pegs	pinus sylvestris
rafter & collar	Encounter halved	compression	nails	
rafter & sole piece	Corner mortice & tenon	compression, shear	wooden pegs	
rafter & ashlar post	Encounter mortice & tenon	compression, shear	wooden pegs	
sole pice & ashlar post	Encounter mortice & tenon	tension	wooden pegs	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

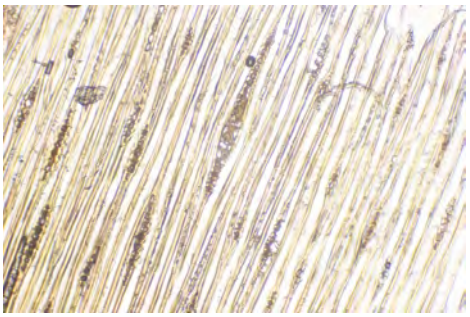
Microscopic identification of the timber species See drawings COH-E-2



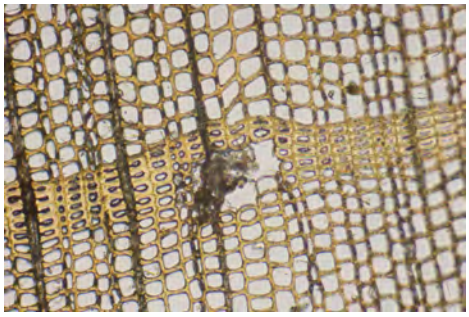
Sarking: transv. section x100 I:\Arc



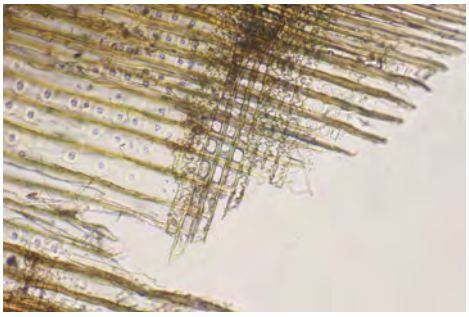
Sarking: radial section x 100 I:\Arc



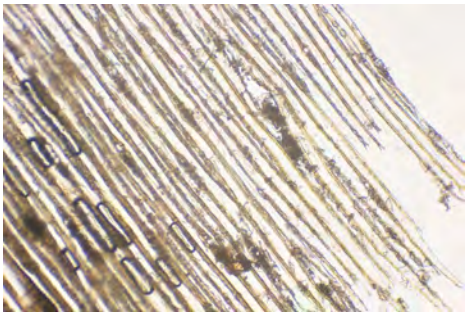
Sarking: tang. section x100 I:\Arc



Sole piece: transv. section x100 I:\Arc



Sole piece: radial section x100 I:\Arc



Sole piece: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawings COH-E-1, CH-E-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	W side	22/01/2016	12:40 am	9.8	82
attic space	W side	22/01/2016	12:20 am	9.8	77.7

roof space	W centre	22/01/2016	12 am	10.4	78.7
attic space	W centre	22/01/2016	11:40 cm	10.3	73
roof space	centre	22/01/2016	11:20 am	9	81.5
attic space	centre	22/01/2016	11 am	9.5	79
roof space	E centre	22/01/2016	10:40 am	84	87
attic space	E centre	22/01/2016	10:20 am	9.5	79
attic space	E side	22/01/2016	9:40 am	9.7	78
roof space	E side	22/01/2016	10:00 am	9	80

Frame/Truss name XX

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack: N rafter

Other: all timbers very wet

Element name A collar

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 12x10 | min. size (hxb) [cm]: 11x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 5 tangential

Knots [min d/section h]: 4/9 group | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

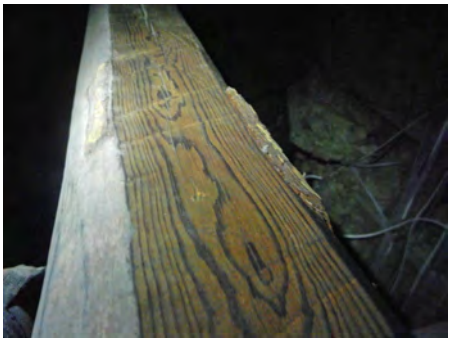
Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other



bark | I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name B north rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 9.7x9.5 | min. size (hxb) [cm]: 9.5x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 6 tangential

Knots [min d/section h]: 4/10 single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Element name C south rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x11.2 min. size (hxb) [cm] 13x11 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 3.5/11.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Frame/Truss name non visible 16

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 12.7x10 | min. size (hxb) [cm]: 12x9.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 4 | tangential

Knots [min d/section h]: 2.5/10 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ | Type: | Status:

Way of identification:

Fungi attack ☐ | Type: | Status:

Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage: | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: | Way of identification:

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Element name B north rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 12x10.2 | min. size (hxb) [cm]: 11x9.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 6 | tangential

Knots [min d/section h]: 4/12 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ | Type: | Status:

Way of identification:

Fungi attack ☐ | Type: | Status:

Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type | Status | Role



knots | I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name C south rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 11.5x10.5 min. size (hxb) [cm] 11x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential
Knots [min d/section h] 3/11 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Frame/Truss name non visible 17

Missing elements
Elements with defects in critical area
Joints with decayed peg
Insect attack
Failed joints
Fungi attack
Other all timbers very wet

Element name A collar

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12x9.7 min. size (hxb) [cm] 12x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential
Knots [min d/section h] 2/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10x10 min. size (hxb) [cm] 10x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 1/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification



knots and diffuse insect exit holes I:\Arc

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name C south rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10x9 min. size (hxb) [cm] 9x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 1.5/9 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Frame/Truss name non visible 18

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x9.7 min. size (hxb) [cm] 13x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name B north rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 10.2x9.7 min. size (hxb) [cm] 9.5x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] 2/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name C south rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 10.2x10 min. size (hxb) [cm] 10x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential
Knots [min d/section h] 3/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Frame/Truss name non visible 19 See drawing COH-E-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11x9.2 min. size (hxb) [cm] 11x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] 2/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 23 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 24.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse redundant lap joint below joint with collar

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.7x11.5 min. size (hxb) [cm] 11.5x11 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 4/15 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 22 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 26.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse redundant lap joint below joint with collar

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x11.5 min. size (hxb) [cm] 12x11 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 2.5/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



redundant lap joint I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 23.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 22.8	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name non visible 20

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack S rafter

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.5x9.5 min. size (hxb) [cm] 10x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 1/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name B north rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 9.5x8.7 min. size (hxb) [cm] 9x8.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] 1.5/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name C south rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12.2x10 min. size (hxb) [cm] 11.5x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 10 tangential
Knots [min d/section h] 3/13 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II



insect attack close to upper end | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated

Fungi attack ☐ Type: Status:
Way of identification:

Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: Way of identification:

Estimated causes of primary damage
Poor design ☐ Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐ External actions ☐ Other ☐

Frame/Truss name XVIIII

Missing elements: Elements with defects in critical area:
Joints with decayed peg: Insect attack
Failed joints: Fungi attack
Other: all timbers very wet

Element name A collar

Dating: original construction Signs of reuse:
Timber treated ☐ Accessibilityissues:
Past interventions:
Differences compared to other elements of the same type:
Section: nominal size (hxb) [cm]: 9.7x8 min. size (hxb) [cm]: 9.5x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 3 tangential
Knots [min d/section h]: 1/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects:

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ Type: Status:
Way of identification:

Fungi attack ☐ Type: Status:
Way of identification:

Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: Way of identification:

Estimated causes of primary damage
Poor design ☐ Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐ External actions ☐ Other ☐

Element name B north rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 12.5x11.5 | min. size (hxb) [cm]: 12x11 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 12 | tangential

Knots [min d/section h]: 2/11 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ | Type: | Status: | Way of identification:

Fungi attack ☐ | Type: | Status: | Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage: | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: | Way of identification:

Element name C south rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 11x9.2 | min. size (hxb) [cm]: 10x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 3 | tangential

Knots [min d/section h]: 1/9 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:



Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ | Type: | Status: | Way of identification:

Fungi attack ☐ | Type: | Status: | Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role

knots | I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Frame/Truss name XXII See drawing COH-E-3

Missing elements
Elements with defects in critical area
Joints with decayed peg
Insect attack
Failed joints
Fungi attack
Other all timbers very wet

Element name A collar

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12.5x9.7 min. size (hxb) [cm] 12x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] 2/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 20.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 19.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction
Signs of reuse redundant lap joint below joint with collar
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.5x9.7 min. size (hxb) [cm] 12x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 4 tangential

Knots [min d/section h] 3/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 20.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 21.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse redundant lap joint below joint with collar

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.5x10.5 min. size (hxb) [cm] 9x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] 1/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other



diffuse insect exit holes I:\Arc

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 22.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 24.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name non visible 15 See drawing COH-E-3

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.5x8.5 min. size (hxb) [cm] 10x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] 3/10 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 25.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 24.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.5x9.7 min. size (hxb) [cm] 10x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 12 | tangential

Knots [min d/section h] 6/10 | group | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 25.3 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 26 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction | Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.7x9.2 | min. size (hxb) [cm] 12x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 6 | tangential

Knots [min d/section h] 2/9 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 27.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 34.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name X

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction | Signs of reuse redundant lap joint close to centre

Timber treated ☐ | Accessibilityissues | Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.5x10.5 | min. size (hxb) [cm] 12x10 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 7 tangential

Knots [min d/section h] 1/12 single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Element name B north rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues | Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x10.5 | min. size (hxb) [cm] 12x10 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 3 tangential

Knots [min d/section h] 3/10 single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Element name C south rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.5x11 min. size (hxb) [cm] 12x11 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 4 tangential

Knots [min d/section h] 3/11 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Frame/Truss name XXV See drawing COH-E-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A upper collar

Dating original construction | Signs of reuse | Timber treated ☐ | Accessibilityissues | Past interventions | Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] | Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects | Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐ | Cracks ☐ | Crushing ☐ | Other ☐

Estimated causes of primary damage: Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Measurement Point a

Moisture Content [%] 22.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 22.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name B lower collar

Dating original construction | Signs of reuse | Timber treated ☐ | Accessibilityissues | Past interventions | Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] | Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects | Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 19.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 20 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C north rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Measurement Point b
Moisture Content [%] 22.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D south rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Measurement Point b

Moisture Content [%] 19 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name non visible 21 See drawing COH-E-3

Missing elements collar Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A north rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.5x8.7 min. size (hxb) [cm] 10x8.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 2.5/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 28 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 23.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B south rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 10.2x8.7 min. size (hxb) [cm] 9.5x8 Single piece ☑ Jointed element ☐

Strength affecting defects
Pith location centre Slope of grain [%] 6 tangential
Knots [min d/section h] 2/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation
Insect attack ☐ Type Status Way of identification
Fungi attack ☐ Type Status Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage
Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 26.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 24.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name XX/III See drawing COH-E-3

Missing elements Elements with defects in critical area
Joints with decayed peg Insect attack
Failed joints Fungi attack
Other

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 18.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 17.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☑ probably for insects Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 21.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 20.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name A south rafter

Dating original construction
Signs of reuse
Timber treated ☑ probably for insects
Accessibilityissues lower half not accessible
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects
Pith location centre
Slope of grain [%]
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation
Insect attack ☐ Type Status Way of identification
Fungi attack ☐ Type Status Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage
Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 22.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 22 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name non visible 1 See drawing COH-E-3

Missing elements
Elements with defects in critical area
Joints with decayed peg
Insect attack
Failed joints
Fungi attack
Other

Element name A collar

Dating: original construction | Signs of reuse:

Timber treated: ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: | min. size (hxb) [cm]: | Single piece: ☑ | Jointed element: ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]:

Knots [min d/section h]: | Knotty element: ☐ | Defects in critical area: ☐ | Deep checks on both sides of element: ☐

Other defects:

Estimated Strength Class according to UNI 11119:

Material degradation

Insect attack: ☐ | Type: | Status: | Way of identification:

Fungi attack: ☐ | Type: | Status: | Way of identification:

Corrosion: ☐ | Wet surface: ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design: ☐ | Poor construct.: ☐ | Degradation: ☐ | Poor maintenance: ☐ | Past interv.: ☐ | External actions: ☐ | Other: ☐

Estimated level of damage: | Emergency interv. needed: ☐

Mater.Degr. and Damage Extent: | Way of identification:

Measurement Point a

Moisture Content [%]: 26.1 | Visible Material Degradation: ☐ | Not Accessible for: hygrometer: ☐

Measurement Point b

Moisture Content [%]: 26.8 | Visible Material Degradation: ☐ | Not Accessible for: hygrometer: ☐

Element name B north rafter

Dating: original construction | Signs of reuse:

Timber treated: ☑ probably for insects | Accessibilityissues: lower half not accessible

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: | min. size (hxb) [cm]: | Single piece: ☑ | Jointed element: ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]:

Knots [min d/section h]: | Knotty element: ☐ | Defects in critical area: ☐ | Deep checks on both sides of element: ☐

Other defects:

Estimated Strength Class according to UNI 11119:

Material degradation

Insect attack: ☐ | Type: | Status: | Way of identification:

Fungi attack: ☐ | Type: | Status: | Way of identification:

Corrosion: ☐ | Wet surface: ☐ | Other:

Mechanical Damage

Type	Status	Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 22 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 21.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse
Timber treated ☑ probably for insects
Accessibilityissues lower half not accessible
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 23.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 22.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse
Timber treated ☐
Accessibilityissues lower half not accessible
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12.7x8.5 min. size (hxb) [cm] 11.5x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 3 | tangential

Knots [min d/section h]: 2/8.5 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: active

Way of identification: Estimated

Fungi attack ☐ | Type: | Status:

Way of identification:

Corrosion ☐ | Wet surface ☑ | Other:

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage: | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: | Way of identification:

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐

Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a			
Moisture Content [%]	21.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	21.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	21.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name Vibis | See drawing COH-E-3

Missing elements: | Elements with defects in critical area:

Joints with decayed peg: | Insect attack

Failed joints: | Fungi attack

Other:

Element name A collar

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: | min. size (hxb) [cm]: | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]:

Knots [min d/section h]: | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119:

Material degradation

Insect attack ☐ | Type: | Status:

Way of identification:

Fungi attack ☐ | Type: | Status:

Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type | Status | Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 26.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 23.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status Way of identification
Fungi attack ☐ Type Status Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 23.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 21.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a		
Moisture Content [%] 21.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 21.2	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name XXXV See drawing COH-E-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 25.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 21.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 24.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 24.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a		
Moisture Content [%] 22.8	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%]	Visible Material Degradation ☐	Not Accessible for: hygrometer ☑

Frame/Truss name non visible 14 See drawing COH-E-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 22.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 22.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 24.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 22.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a		
Moisture Content [%] 22.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 19.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name non visible 22 See drawing COH-E-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 30.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 28.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 22.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 23.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south rafter

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a		
Moisture Content [%] 21.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 26.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name XXI

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack S rafter

Failed joints Fungi attack

Other all timbers very wet

Element name A collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11x8.5 min. size (hxb) [cm] 10x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 1.5/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name B north rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12x10 min. size (hxb) [cm] 12x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] 1/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name C south rafter

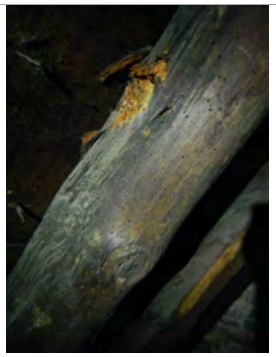
Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues lower half not accessible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12.7x10.5 min. size (hxb) [cm] 12.5x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential
Knots [min d/section h] 3/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



insect attack close to upper end I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage

Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

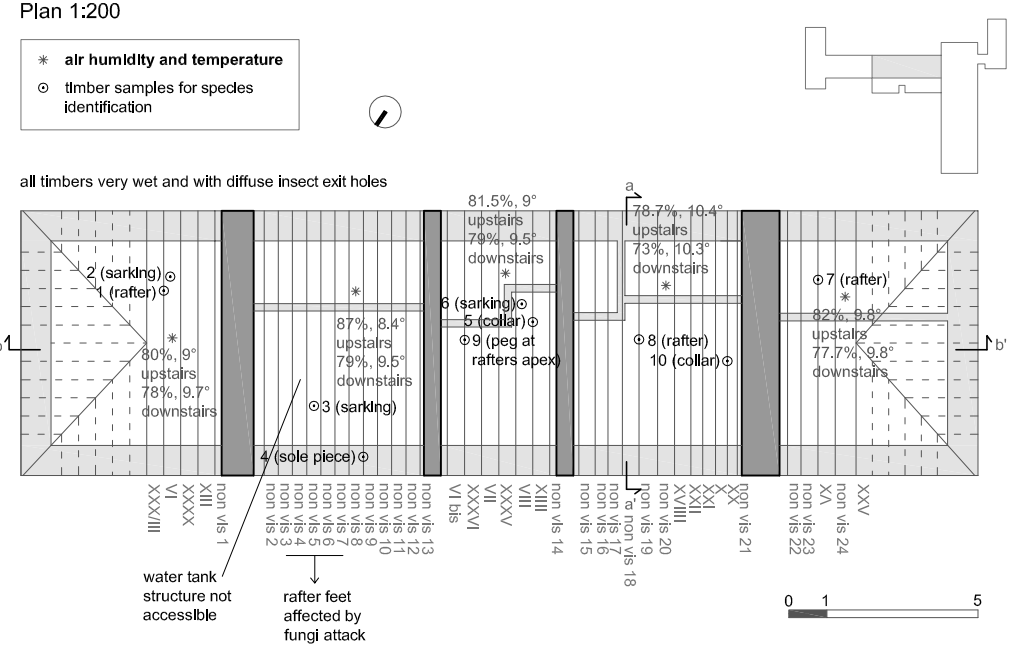
Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

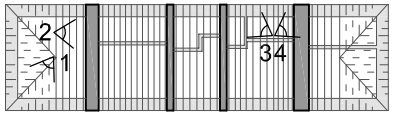
Other ☐

Plan 1:200

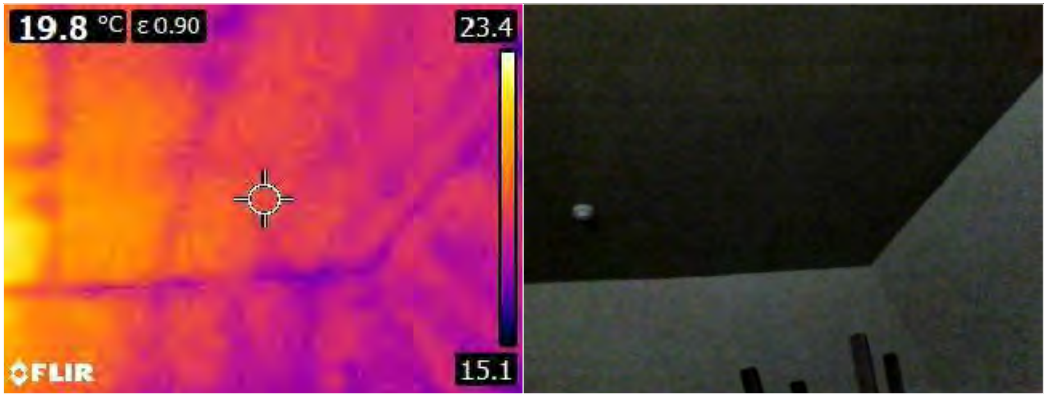


Themographic images

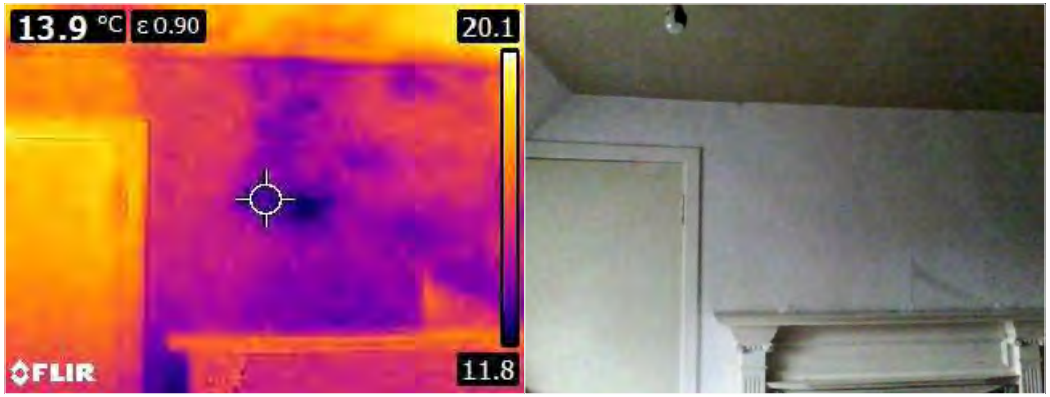
Plan 1:500



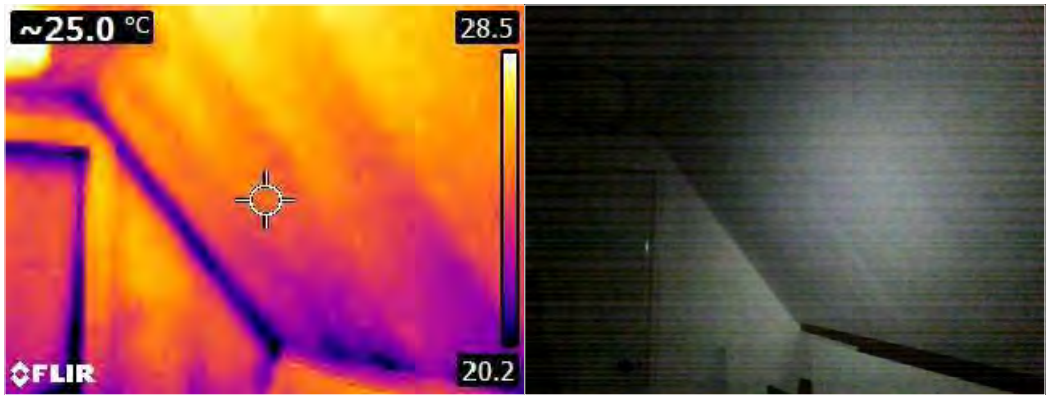
1: areas with lower temperature identifythe position of rafters and collars behind the plaster



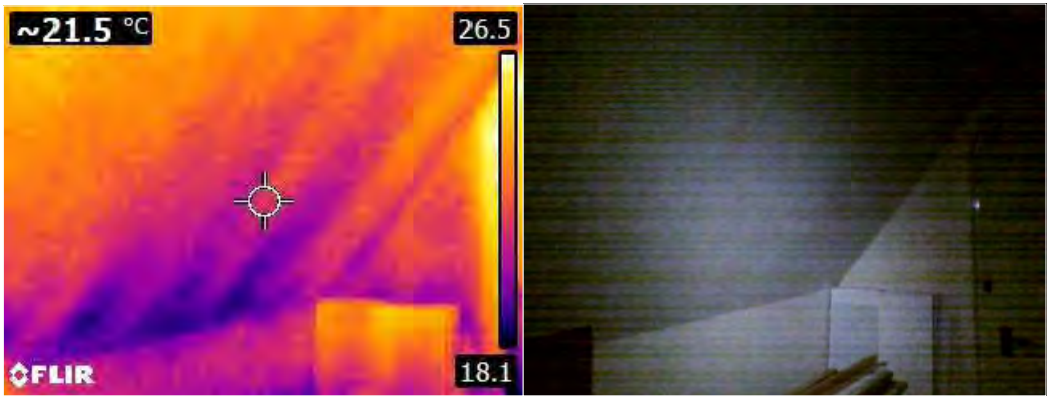
2: areas with lower temperature identify humidity on the gable probably due to deficiencies in the flashings



3: areas with lower temperature identify deficiencies in the flashings

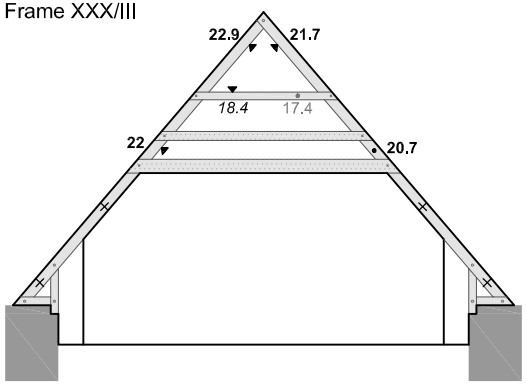


4: areas with lower temperature identify deficiencies in the flashings

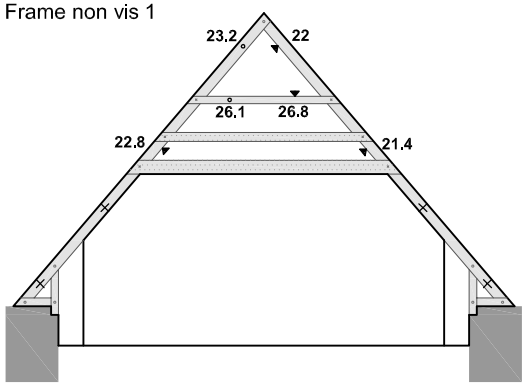


Sections looking West 1:100

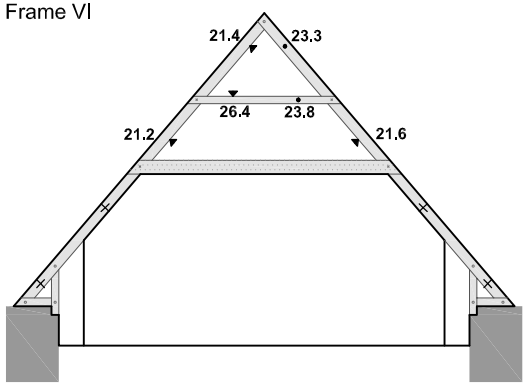
Frame XXX/III



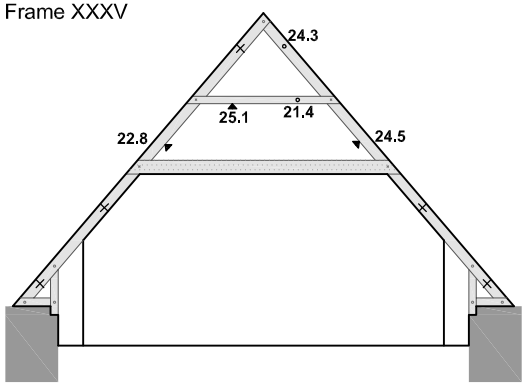
Frame non vis 1



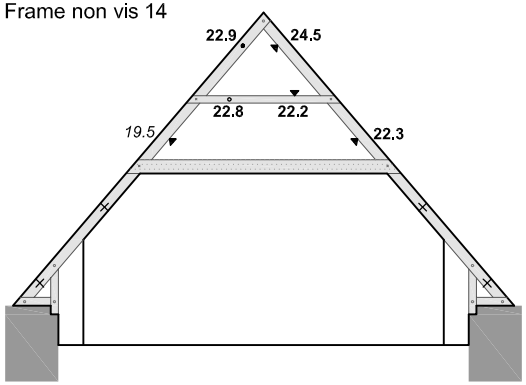
Frame VI



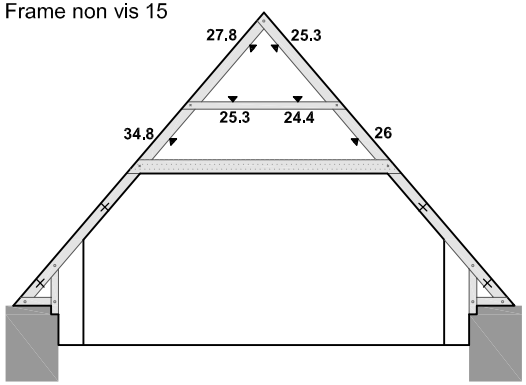
Frame XXXV



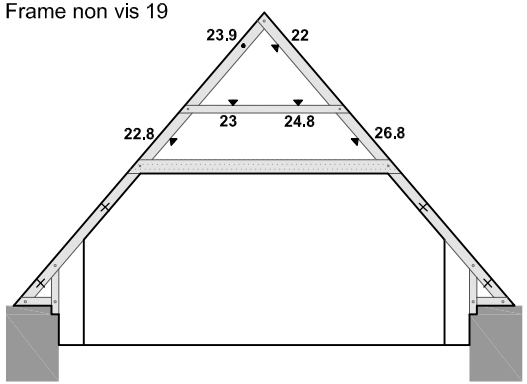
Frame non vis 14



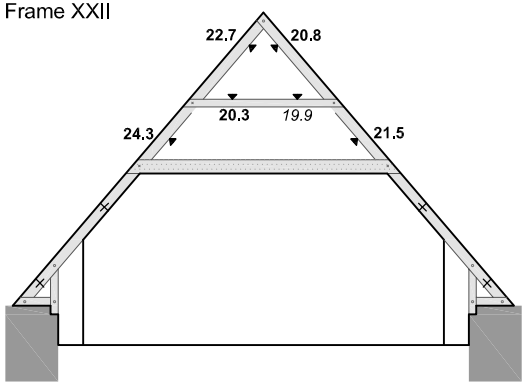
Frame non vis 15



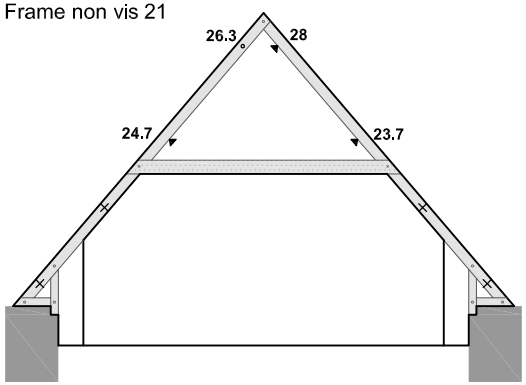
Frame non vis 19



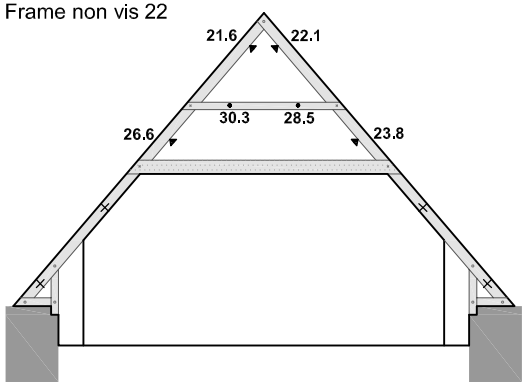
Frame XXII



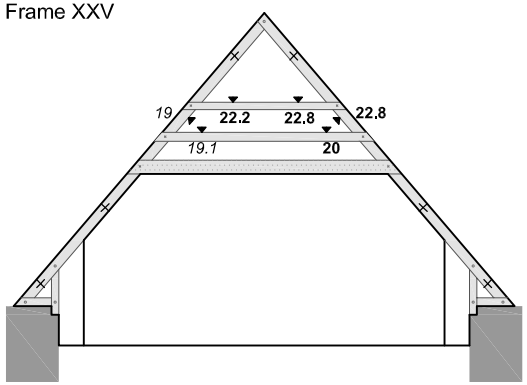
Frame non vis 21



Frame non vis 22



Frame XXV



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- × not accessible

readings <18
readings >18
readings >20

0 1 5

Sections looking West 1:100

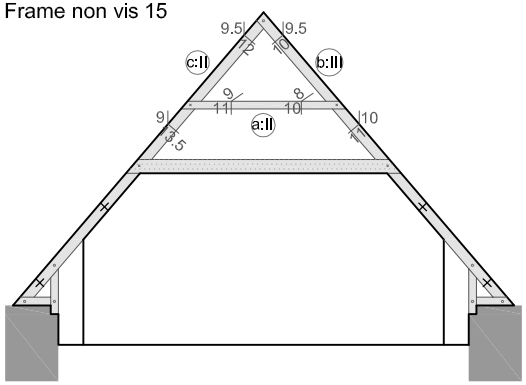
Visual inspection: many small knots & diffuse insect exit holes on most timbers

x:x element name : estimated strength class (na=less than 2 faces visible)

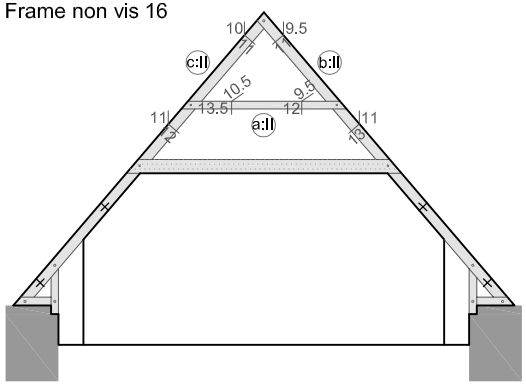
insect attack

fungl attack

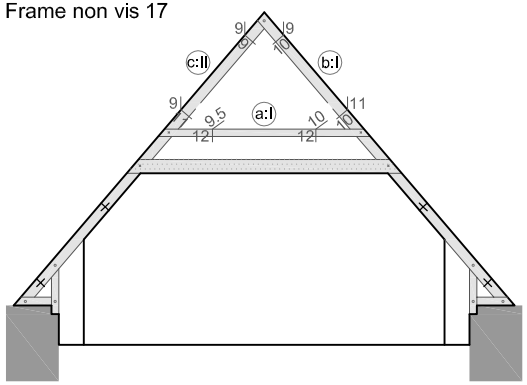
Frame non vis 15



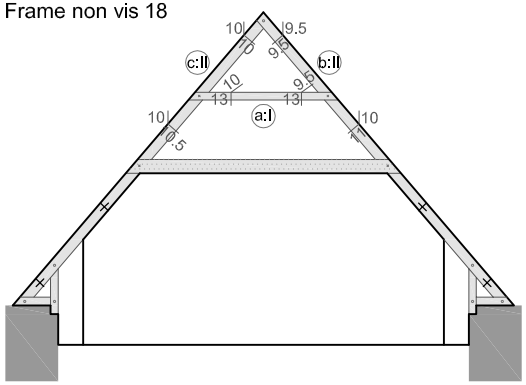
Frame non vis 16



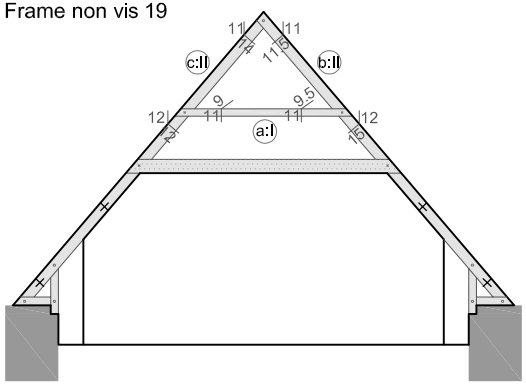
Frame non vis 17



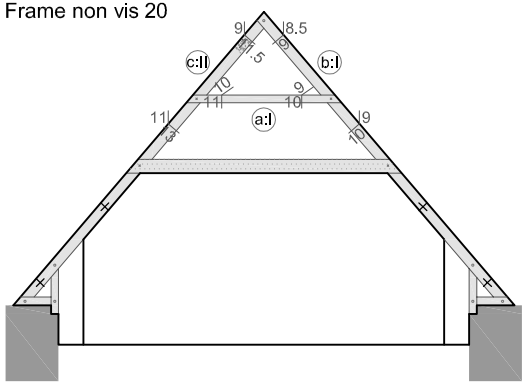
Frame non vis 18



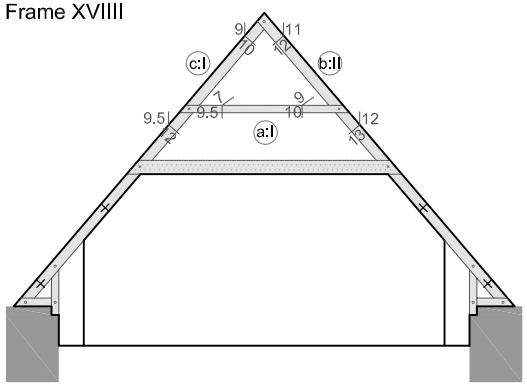
Frame non vis 19



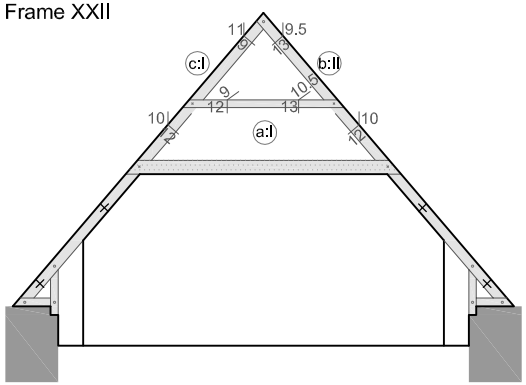
Frame non vis 20



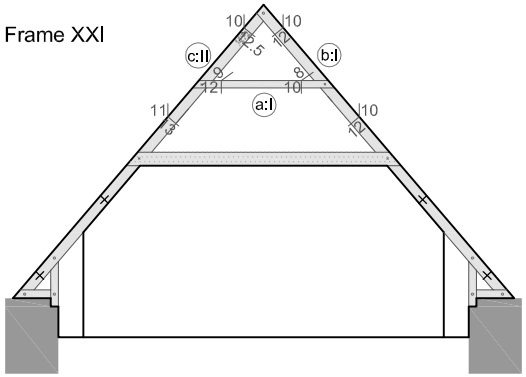
Frame XVIIII



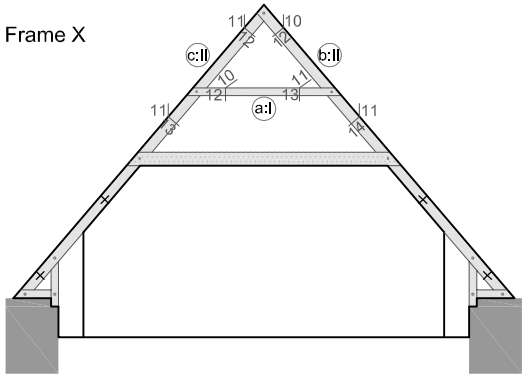
Frame XXII



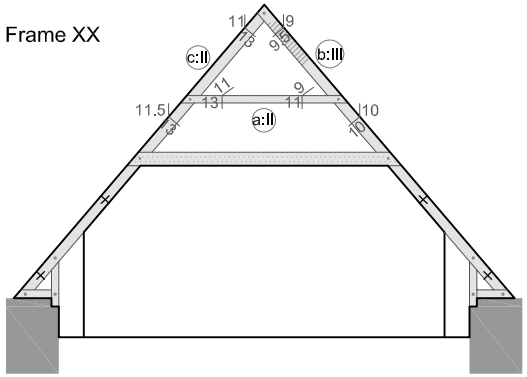
Frame XXI



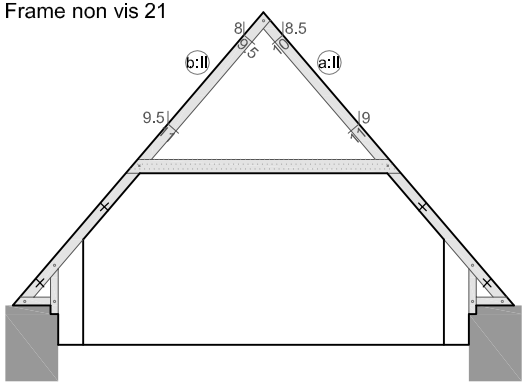
Frame X



Frame XX



Frame non vis 21



0 1 5

HOLYROOD PALACE

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)

X coordinate: 326896 Y coordinate: 673919

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE

Rcahms ID: 52380

HS Listing: A

Original Use: Residential

Current Use: Museum, Offices

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
ALTERATION, RECONSTRUCTION	1501	1505	S TOWER, CHAPEL, GALLERY, ROYAL APARTMENTS AND GATEHOUSE BUILT: A QUADRANGLE WEST OF THE ABBEY CLOISTER	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role
KING OF SCOTLAND	JAMES IV	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1528	1532	NW TOWERHOUSE ADDED TO NORTH RANGE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role
KING OF SCOTLAND	JAMES V	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
ALTERATION, RECONSTRUCTION	1535	1540	WEST AND SOUTH RANGES REBUILT OR REMODELLED. NEW CHAPEL IN SOUTH RANGE, THE OLD CHAPEL BECOMES THE COUNCIL CHAMBER. LONG GALLERY BUILT (NOT NECESSARILY ON SITE OF PRESENT LONG GALLERY).	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1544		PILLAGED AND BURNED BY INVASORS. PALACE STILL HABITABLE BUT NOT CONSIDERED 'FIT FOR LADIES'.	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1554	1566	UNSPECIFIED WORKS, MAYBE RECONSTRUCTION OF NORTH AND EAST RANGES	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1574		REPAIRS	CRAE UNPUBL.

People involved:

Last Name	First Name	Role
MCDOWGALL	WILLIAME	MASTER OF WORKS

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1616	1617	CHAPEL IN S RANGE RECAST AND REDECORATED. ROOF & PART OF STONEWORK TO CHANCELLOR'S LODGING REBUILT AND REPAIRS TO MANY APARTMENTS & SERVICE ROOMS	BUILDINGS OF SCOTLAND COLLECTION & ACCOUNTS OF THE MASTERS OF WORKS VOL.2

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1622	1623	CHANCELLOR'S LODGING IN THE COURT TO THE SOUTH ENLARGED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1633		REPAIRS TO CHURCH AND PALACE	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1650		FIRE IN EAST RANGE DURING OCCUPATION BY CROMWELLIAN TROOPS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1658	1659	WEST RANGE RECONSTRUCTED AND HEIGHTENED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION, CONSERVRESTOR	1662	1663	REPAIRS TO CHAPEL ROYAL, STABLES & COUNTERGUARD BUILT AND N QUARTER REBUILT - PROBABLY SOME MATERIALS REUSED	NRS E78/11 &

People involved:

Intervention type:	From:	To:	Description:	Reference:
SURVEY	1663			BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role
MYLNE	JOHN JUNIOR (3)	ROYAL MASTER MASON

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1671	1678	ALL RANGES REBUILT EXCEPT FOR W RANGE AND NW TOWER - SW TOWER ADDED - SOME TIMBER BOUGHT FROM NORWAY, OTHER FROM LINLITHGOW MILL	BUILDINGS OF SCOTLAND COLLECTION & NRS GD29/100 & NRS E36/30 & NRS GD29/94

People involved:

Last Name	First Name	Role
DUNSTERFIELD	GEORGE	PLASTERER
DE WET	JACOB	PAINTER
BRUCE	SIR WILLIAM	ARCHITECT
MYLNE 1	ROBERT 1	ROYAL MASTER MASON
SMITH 1	JAMES 1	CONTRACTOR, MASTER MASON
BAINE	JAMES	WRIGHT
EIZAT	ALEXANDER	WRIGHT
MCFARLAND	JAMES	WRIGHT

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1682	1686	WORKS TO FINISH AND REPAIR SOME INTERIORS AND ROOFS, WORKS AT COUNCIL CHAMBER, PRIVY CHAMBER AND ORATORY	EUL LA II 87 & NRS E37/24

People involved:

Last Name	First Name	Role
STIRLING	GEORGE	MATERIAL SUPPLIER
MCCLELAND	JAMES	WRIGHT
HAMILTON	JOHN	WRIGHT
DUNBAR	JAMES	MATERIAL SUPPLIER
BAINE	JAMES	WRIGHT
SMITH 1	JAMES 1	MATERIAL SUPPLIER, OVERSEER
MYLNE 1	ROBERT 1	ROYAL MASTER MASON

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1686	1687	THE DUKE OF HAMILTON DESCRIBES A FIRE IN THE GARRETS OF THE PALACE, POSSIBLY IN THE NE CORNER	EUL LAII87 1A & CRAE UNPUBL.

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1695		LORD JOHN HAMILTON DESCRIBES ROOF REPAIRS DUE TO FLOODING IN THE EARL OF ARRAN'S ROOMS (NW TOWER & W RANGE) CAUSED BY MELTING SNOW	CRAE UNPUBL.

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1721	1740	DUKE OF HAMILTON APARTMENT & OTHER INTERNAL ALTERATIONS - WORKS ON ABBEY ROOF	FLEMING 1962 & EUL LA II 88

People involved:

Last Name	First Name	Role
ADAM	WILLIAM	ARCHITECT, MATERIAL SUPPLIER
CLAYTON	THOMAS	PLASTERER
NORIE	JAMES	PAINTER

MOWBRAY	ROBERT	WRIGHT
SYME	JAMES	SLATER
CARNABY	WILLIAM	PLUMBER
WILSON	JAMES	SMITH
CHALMERS	RODERICK	PAINTER
BURTON	ALEXANDER	GLAZIER
BUTTER	WILLIAM	WRIGHT

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1755		NOT SPECIFIED	EUL LA II 88

People involved:

Last Name	First Name	Role
HAMILTON	JOHN	WRIGHT
DOUGLAS	JOHN	ARCHITECT
MACPHERSON	JAMES	MASON

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1791	1806	REPAIRS TO ROOF OF LIMITED EXTENT - REPAIRS TO LORD DUMMERES & DUKE OF HAMILTON & DUKE OF PORTLAND LODGINGS - REPAIRS TO ABBEY - OTHER UNSPECIFIED WORK	EUL LA II 88

People involved:

Last Name	First Name	Role
GORDON	GEORGE	WRIGHT
SALISBURY	JAMES	WRIGHT
BUTTER	HENRY	WRIGHT

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1824	1834	CLEARANCE OF BUILDINGS S OF THE PALACE AND REMOVAL FROM NW TOWER OF THE 1676 N ADDITION (LORD ROBERT STEWART HOUSE) - S FRONT REFACED IN ASHLAR - SE CORNER REBUILT	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role
REID	ROBERT	ARCHITECT
MATHESON	ROBERT	ARCHITECT

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1856	1880	S WING: INTERIORS, EXTERIORS AND ROOFS	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1879	1881	ROOF REPAIRS, EXTENT UNKNOWN	CRAE UNPUBL.

People involved:

Intervention type:	From:	To:	Description:	Reference:
DAMAGE	1900		FIRE IN S RANGE: CHARRED TIMBERS FOUND DURING REMOVAL OF PLASTER CEILING IN 1982	CRAE UNPUBL.

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CRAE J.		☑	PALACE OF HOLYROODHOUSE ROOFS	
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL FROM THE TWELFTH TO THE EIGHTEENTH CENTURY	130-138
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	77, 84
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	77-78
GONZÁLEZ LONGO C.	2012	☐	JAMES SMITH AND ROME	80-81
MICHAELSON K.	1984	☐	SCOTTISH ARCHITECTURE IN THE SEVENTEENTH CENTURY	12

Author	Year	Unpubl.	Title	Pages
SCOTTISH ARTS COUNCIL	1970	☐	SIR WILLIAM BRUCE, 1630-1710	11
WILLIAM A. (SIMPSON J.)	2011	☐	VITRUVIUS SCOTICUS. PLANS, ELEVATIONS, AND SECTIONS OF PUBLI BUILDINGS, NOBLEMEN'S AND GENTLEMEN'S HOUSES IN SCOTLAND	PLATE 1-5

ARCHIVAL REFERENCES

Archive	National Records of Scotland	Doc.Num.	GD124/15	Folios	471
Title	Letter to the Earl of Mar from Mr James Smith, surveyor of Her Majesty's works, in Edinburgh. He describes the dismal state of the Palace of Holyroodhouse and the Castle of Stirling.				
Archive	National Records of Scotland	Doc.Num.	E37/24	Folios	
Title	Estimate of materials required for reparation of Holyroodhouse, with notes of unfinished rooms their work to be done by Robert Mill under contract and of buildings and repairs necessary at Stirling Castle				
Archive	National Records of Scotland	Doc.Num.	GD29/100	Folios	
Title	Two copies of an order signed by Lauderdale terminating Sir William Bruce's appointment as Surveyor General, the building and repairing of Holyrudhouse [Holyroodhouse, Edinburgh] being completed - 30 May 1678				
Archive	National Records of Scotland	Doc.Num.	GD29/94	Folios	
Title	Contract between Sir William Bruce of Balcaskie, Surveyor General, Sir William Sharpe of Stainiehill, the King's Cash-keeper, and Robert Mylne, the King's Master Mason, for the building and repair of Halyrudehouse				
Archive	National Records of Scotland	Doc.Num.	GD29/95	Folios	
Title	Warrant by the Lords Commissioners of the Treasury to Sir William Bruce of Balcaskie, as Surveyor General to repair the Lord Chancellor's and the Duke of Hamilton's lodgings in Holyrudhous. Signed by the Lord Commissioners - 6/8/1673				
Archive	National Records of Scotland	Doc.Num.	E36/30	Folios	
Title	Sir William Bruce of Balcoskie: Holyrood, Stirling, Edinburgh, the Bass, 4 Mar. 1671-18 Jan. 1674, rendered 9 July 1674				
Archive	National Library of Scotland	Doc.Num.	Ms 14493	Folios	37
Title	Transcription by Aonghus Mackechie				
Archive	National Library of Scotland	Doc.Num.	Ms 14493	Folios	38
Title	Transcription by Aonghus Mackechie				
Archive	Edinburgh University Library	Doc.Num.	La II 88	Folios	1/8
Title	Accompt of large tree beams furnished to the roof of Holyrood 1733-4				
Archive	Edinburgh University Library	Doc.Num.	La II 88	Folios	3
Title	Note of money paid for repairs on Holyroodhouse since the union 28th Sept. 1806				
Archive	Edinburgh University Library	Doc.Num.	La II 88	Folios	2
Title	Accounts of several artificers employed in repairing Holyroodhouse 1733				
Archive	Edinburgh University Library	Doc.Num.	La II 88	Folios	1/1
Title	Accompt of Carpenter work performed at the Abbay of Holyroodhouse by Robert Mowbray wright 1733-4				
Archive	Edinburgh University Library	Doc.Num.	La II 87	Folios	1A
Title	Holyroodhouse, Stirling Castle, Dumbarton Castle, Edinburgh Castle Vouchers of expenditures on works (1684-86)				
Archive	Edinburgh University Library	Doc.Num.	La II 87	Folios	2
Title	Repairing Holyroodhouse for reception of the High Commissioner (8 vouchers)				
Archive	Edinburgh University Library	Doc.Num.	La II 87	Folios	3
Title	Timber for Holyroodhouse (1 voucher)				
Archive	Edinburgh University Library	Doc.Num.	La II 87	Folios	6
Title	Wright work at Holyroodhouse and Stirling Castle (4 vouchers)				
Archive	Edinburgh University Library	Doc.Num.	La II 87	Folios	7
Title	Timber for Holyroodhouse and fees of carvers (4 vouchers)				
Archive	Edinburgh University Library	Doc.Num.	La II 87	Folios	8
Title	Works at council chamber, privy chamber and oratory at Holyroodhouse (2 items)				

Suggestions for Further documents in Manuscripts Collections at NLS and Sir W. Bruce's accounts in NRS (E 36/31)

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: National Library of Scotland | Doc. Num.: Ms 14493 | Folios: 38

Title: Transcription by Aonghus Mackechie | Date: from | to

Contents:
Off the counsell roome as follows
A thousand daills or therabout of 14 foot of lenth
2 formes for carpenters and on tressell
Some ???hes for playstering for sclaiters with trie? for slaiting and foot ganges
Above 5000 sclait ??? for nailing one
300 broad peises that came out of berwik
600 of uther lang jeists yt came be thomas mylne
500 of new dails [letter deleted?] *restand in pyls of the chapple*
scaffeling & uther materials for scaffling
22 laid of lyme in the stables
Of joists & scaffling to the stables
the chaple rigging stons all drest
All the pavement stones in the guard hall & presence
[The] *Materials that went doun to Leith by* [Cnall Murgen] *in Generall Monks tym wt? the wholl iron wark except doors & casements ??? the iron wark turned bak again by the Chanclers orders delivered to John Mylne Master masson*
Item the rest of all the timber wark of 900 joists and uther materials in the maister of work his hand & his servants yt was left since my lo| midletons tyme.'
[In margin on second page] *al this* afors[ai]d *was left in gnall monk his tym*

Summary and comments: materials for works in the council room - undated

Archive: National Library of Scotland | Doc. Num.: Ms 14493 | Folios: 37

Title: Transcription by Aonghus Mackechie | Date: from 1660 | to

Contents:
Holyrood [c.1660 – says catalogue]
[outside] *List Materials left in the Abay of Hollyrud's By General Monck given in by Mathew Hamiltoune*
[inside] *A memorandum of things or materials left be Generall monk of the abbay of holyrudhous for its repairing*
glass bands, iron bands for casements, *cross tailed garnes*? For ??? windows unturned *great bell nails for gates*, door hinges, locks, cross bands, blocks and tackle, scaffolding, , ???es for plastering, for slaters
5 ??? with their furnishing for the geates or: yeates
23 pair of great handles ??? for doors
68 pair of the best sort of all furnished
14 crosse bands for the chappill window
2 ??? for the new roofe
4000 nailes of severall sorts
53 chamber braises
ane great iron window with a ???esse on
3 new kithin? braises with ane old ane
60 laid of lyme…in tua voults
33 pains of glaisse received from Jon Brooks?
2000 plained boords in thrie? pyls
2400 of unplayned dails into thrie pyls in the pump? close
77 new doors not fixed nor ???thed
75 new windows wt caisments
6 great peace? of wainscot in the inner close
On barrell of thik tarre
36 thinne wainscot boords sawne great or small
25 jeists & 2 great? cons in twa pyls in the utter close
7 takells and 5 blocks
14 hurlebarrous & twa ledders
4 pickaxes & 3 schools?
ane suver for the pump
28 caisments & shutters for the windows

Summary and comments: In 1660 some deals and 2 other things 'for the new roof' have been left in Holyrood Palace and probably reused in the 1670s works.

Archive: National Records of Scotland | Doc. Num.: E36/30 | Folios:

Title: Sir William Bruce of Balcoskie: Holyrood, Stirling, Edinburgh, the Bass, 4 Mar. 1671-18 Jan. 1674, rendered 9 July 1674 | Date: from 1671 | to 1673

Contents

Hallyroodhouse 4 March 1671
Discharge
Imprs: paid to pitcairlis secret? for writeing two Charter parties betwixt Sr Wm Bruce & James Cook skipper in pittenween? upon ane Norway voadge? to be made by him for bringing home a loading of timber for the said works 2:R dollars £5 16s.
It paid for writing a contract betwixt the said Sr Wm Bruce & Thomas Mill indweller? in Leith upon acct of a quantity of timber to be bought from Norway for these works a half crown £1 10s.
[...]
Holyroodhous 16 June 1671
Imprs: paid to James Cook skipper in Pittenweem as followes for 800 long dailles bought by him at Norway at 13 1/2 doll. the 100 £313 4s.
for 1000 short dailles at 8 1/2 dolls the 100 £239 5s.
for 1300 dailles at 8 1/2 dolls the 100 £312 6d.
for 1000 short dailles at 8 1/2 dolls the 100 £246 10s.
[tot] *£1109 19s. 6d.*
It paid to provost mill of Linlithgow for great ??? trees bought from him for the use of the said works as followes
ffirst for 69 great trees 26 & 30 foot long & 14 inches square at 15£ each tree is 1035
It for 120 smaller trees 22 & 24 foot long 10 & 12 inches square at 8£ the piece (n. 9) 0880 [tot] *£1915*
It paid to James Baine wright for dailles bought from him for the use of the said works 50£ conforme to his accompt attested by the storekeeper that he received the same as followes
ffirst 400 dailles at 50£ the 100 £200
It 580 dailles at 54£ the 100 £306
[tot] *£ 506*
[...]
Holyroodhous 22 Julio 1671
[...] *It payed to the orge Rriffell? skipper in pittenweem 623£ for a loading of dealls & trees bought form him for the use of his Mayties works at holyroodhous as by particular accompt porder & received (n.17) £623*
Patrick Fyfe for knaple and wainscot
8 September 1671
Stones from Rotterdam
15 April 1672
Lead from Newcastle
It paid upon the 4 august 1671 to Robert Simpson skipper in Dysart thirteen hundreth nyntie ane pound fifteen shillings scots money in full & compleet payment of a loading of timber bought & receaved from him for the use of his Mayties works as accompt & receipt n. 55 £1395 15s.
16 June 1672
Imprs paid to William Bining? merchant in Edinburgh the sume of two thousand twenty three pounds ten shillings scots for a quantity of trees & dailles bought and receaved from him [...] £2023 10s.
Thomas Mill in Leith for deals and trees £273 8s.
7 September 1672
James Brune? merchant for deals and trees £2987 8s.
William Bining merchant 7000 deals £3220
18 October 1672
Bay Liverame dutch skipper 834 deals £380 18s.
Dutch plasterer
28 November 1672
James Tailrieser? 100 fir planks £435
John Veever? skipper in Lukestat? 1500 good deals £716
22 January 1673
Thomas Mylne indweller nine scoir? seventeen great shafts? £1595
Thomas Mylne greater and smaller shafts, fir planks, deals £2568 10s.
18 February 1673
Gibson Murray of Pittkeirie 7900 ordinary mert deals £3476
Sawing of 45 great shafts £45
25 July 1673
Sawing of trees £19 16s.
Many carters bringing timber and other materials from Leith to Holyrood
lead, tiles, plaster lime, hair for the plaster, ropes, nails, candles, sand, stones, ...
22 November 1673
Robert Mylne provost in Linlithgow planks, wainscot, deals £4142 16s.

Summary and comments: 1671-3 account of timber & other materials for the Palace works - the timber is brought from Norway and from the mill of Linlithgow. Some is bought by James Baine as well, and other merchants in Edinburgh/Leith. Not all of the purchases are detailed, but those which are reflect a big quantity of timber material (thousands of deals of different types, great trees of different lengths and scantlings, planks, shafts) suitable for the major works carried out by Bruce & Mylne in those years.

Archive: National Records of Scotland | Doc. Num.: GD29/95 | Folios:

Title: Warrant by the Lords Commissioners of the Treasury to Sir William Bruce of Balcaskie, as Surveyor General to repair the Lord Chancellor's and the Duke of Hamilton's lodgings in Holyrudhous. Signed by the Lord Commissioners - 6/8/1673

Date: from 1673 to

Contents

Summary and comments: No details on works

Archive: National Records of Scotland | Doc. Num.: GD29/100 | Folios:

Title: Two copies of an order signed by Lauderdale terminating Sir William Bruce's appointment as Surveyor General, the building and repairing of Holyrudhouse [Holyroodhouse, Edinburgh] being completed - 30 May 1678

Date: from 1678 to

Contents

Summary and comments: No details on works

Archive: National Records of Scotland | Doc. Num.: GD29/94 | Folios:

Title: Contract between Sir William Bruce of Balcaskie, Surveyor General, Sir William Sharpe of Stainiehill, the King's Cash-keeper, and Robert Mylne, the King's Master Mason, for the building and repair of Halyrudehouse

Date: from 1679 to

Contents:
[outside] *Contract betwixt Sr William Bruce & Sr William Sharpe And Robert Mylne 1673* [...]
[inside] [...] *by his Majesty speciall order and appointment that his Majestys ryall palace and house at Holyrude house Be furtwith? repaired and builded in maner ??? And according to the designes and mappe therof both in plane and perspective exhibited and presented be the Surveyor generall to and approven be his Majestys* [...]
Robert Mylne needs to follow drawings presented by S. W. Bruce and agreed with the King - he shall furnish all materials necessary including *dailles and treesfor scaffolding and for centries and devalling? of the vaults* [...] *nailles*
Robert Mylne binds and obliges him and his forfes? to take doune and demolish the whole old pale? of building noe designed to be rebuilt and all other old works necessare to be takine dwne [...]
[...] *the inner court is to be enlarged as is designed to the space of sixty? ane foot and ane halfe squaire and to reddo the ground and fitt the samyne for sufficient and solide founding and to found and build therupon ane great towre upon the south pairt of the front of the palace equidistant from the ??? entrie ??? ??? front with the old tower ??? built opon the north pairt therof and that of lyme smooth and good ??? worke existing soe much as sower? for a gavell to ym lord chancelloire house and faills within the rooffe therof which is to be done in good sufficient cleared? rugh? work and every way to finish it in height breaith length shape doores rowmes and windows accoridng to the order and dimensiones in forme and maner lyke unto the old tower* [...]
[...] *according to the wrought and modell therof done and wrought in timber as? the samyne is designed be the Sr William Bruce* [...]
[...] *the said Robert Mylne binds and obliges him and his forfes? to take downe the stone worke of the gavells? of the rooffe above the Lobby and to build up ane syde wall in place therof of good aislar worke Also good and joyneing with the worke latlie? built above the old allering and raife? and joyne the samyne to the tower alse? high as the said new worke and soe continue up same from the south and of the said new worke and to joyne the samyne with the south tower now to be built and to finish the same with the doores windowes chimenys and entries according to the said draught*
kitchen court
garden walls
[...] *lykewaye the said Robert Mylne binds and obliges him and his forfds? to take downe the old worke betwyxt the north tower and the kirke and rebuild the samyne in good aisler worke with windowes conforme to and exactle according to the aisler of the tower and the worke of the windowes and tabling of the samyne excepting the uppermost tabling whereupon* [blank space] *rests which is to be a fyne cornish*
[...] *the aisler exactlie joyned and perfectlie smoothed ??? worke and other walls all off them with out band and in band stones compleatlie frtified for ther severall uses especiaillis for the supporting of rooffes and doors to the satisfactione of the said surveyore*

Summary and comments: 1679 detailed description of works to be carried out by Robert Mylne according to the design of Sir William Bruce, including the rebuilding of the North range – no details on roofs

Archive: National Records of Scotland | Doc. Num.: E37/24 | Folios:

Title: Estimate of materials required for reparation of Holyroodhouse, with notes of unfinished rooms their work to be done by Robert Mill under contract and of buildings and repairs necessary at Stirling Castle

Date: from 1682 to

Contents:
[outside] *Estimat of materialls to be provyded for the use and towards the reparation of his Ma.ties Palace of Holyroodhouse As also ane nott of such roumis as ar yet unfinished in the said Palace. Lykwayis A Particular nott of Buildings & Reparationis necessar at his Ma.tis Castle of Stirling*
18th July 1682
[inside] *Estimat of materialls to be provyded for the use, and towards the reparation of his Ma.ties Palace of Holyroodhouse, to be presently done, as follows viz*
lime for mason work & plaster in Duke of Hamilton and Treasurer and Lord Registers apartments
sand
rebats to make two arches in the Duke of Hamilton kitchen and a door in the Treasurer's apartment
stone plaster hair
door nails
[...] *whytning or spanish whyt?* [...] *for whytning of rooffs &syd? walls which stand in wood*
[...] *1000 daills* [...] *towards these reparations for sarking below the leaid work within the ??? Palace 48£ per 100* £480
[...] *half hundred double treis for the rofe of the work 18p. peece* tot. 54£
[...] *100 single trees at 9s. peece* £45
[...] *20 great trees for sawing at 2£ 10s. peece* £30

[...] *knappill for making new casem.ts*
[...] *5000 double floorings* [...] *for the rofe of the work at 10£ 1000* £50
single flooring
blind flooring
planshers
windows
[...] *1000 stones of lead [...] for helping of the main rooff & the infys of the wallheads & outfys of the ??? Palace*
[...] *half hundred great trees needful for making of garrons to lay upon the wallheads of the lead* [...] *at 1£ 10s. peece* £90
[...] *30 oak planks needful for going along the fare of the cornice whereupon the lead is to be layid at 1£ 10s. peece* £45
[...] *6000 scailie naills needful for putting on the slaits, that must be taken off the easing? in the infys of the Palace to get the lead*
[...] *layid in bilowit? at 5£ 1000* £30
[...] *100 prick? batts for putting on of the oak planks which project above the fare of the cornice at 4£ p.* £20
[...] *hogsheads of trass or pan cratch for pointing the alloring upon the wallheads & round the old tower?*
window nails
A particular nott of such roumes in the Palace of Holyroodhouse & others that are not yet finished nor completed viz.
[...] the rooff and the walls of the Pratches? from the great stairs to the door of the entrie of the Duke of Hamiltons lodgings is not yet plaistered
mason work that Robert Mill didn't do yet
A particular nott of Buildings & Reparations necissar at his Ma.tis Castle of Stirling as followes
[...] *Item the gallery or Transe w.ch enters the great hall being ane hundred feet long & thirten feet wyde wants the rooff and must be sarked and slated.*
[...] *Item the slait rooff of this Palace must be pointed & helped in severall of the flankers, or run rooff, as lykways the Bartisan covered with lead, together with the slait rooff and Bartisan of the great hall.*
Item the one side of the slait rooff of the Chappill became ruinous this last winter, and must newly sarked with dailles and newly slaites on that side; wheter the rooff y.rof be faulty or not cannot be known till the slaits & old sarken be taken off.
[...] *the slait rooffs of the whole castle would be pointed and a bargan made with a slaiter to maintain ym. yearlie hereafter upon a rentan yearly pension or sallarie.*
[...] *It is necessar all this work above mentioned be presently gone about* [...] *and for this effort it is necessar that money be provided for buying of materialls & payment of workmen* [...]
As to the particular Estimat, what these buildings and Reparations will cost at Stirling Castle it cannot be exactly sett doune without measuring of the dimensions of the places & rooffs to be built and repaired, w.ch must be done upon the place. [....

Summary and comments: 1682 materials needed to finish and repair Holyrood Palace: slates, sarking and lead but also some single, double and great trees – some are specifically for the 'roof of the work', thus it seems that some roof works were still ongoing at this time.

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 6

Title: Wright work at Holyroodhouse and Stirling Castle (4 vouchers) | Date: from 1684 to 1686

Contents:
1
[outside] *Accompt of wright work at the Palace of Holyroodhouse 1685 be James Mcleland £ Scots 1144 14s.*
[inside] [...] *December 1684 to Jully 1685*
Frames for paintings, windows, casements, new coach house, repairs to guard stables, tables, benches, beds, shelves, press, partitions, doors, ladders, ...
TOT £1144 15s. 8d.
2
[outside] *Accompt of wright work at Stirling Castle 1685 be James Mcland Scots £655 16s. 06d.*
[inside] *Accompt of wright work wroght at the Castle of Stirling Be James Mcleland frae 29 of May to 24 of September 1685 conforme to agreeement*
Lining floors and windows and walls, making shelves, barrowes, ladders, tresses, boxes, casements, garrones, partitions, doors, ...
For making & ane putting ane new roof on the maine gaird ??? of 27 couple & sarking of the??? £48 12s.
TOT £655 16s. 06d.
3
[outside] *Accompt of wright work Be James Mcleland at the Palace of Holyroodhouse fra Jyllu 1685 to March 1686 Scots £1031 2s.*
[inside] lining, flooring, casements, tables, presses, doors, shelves, windows, stairs, partitions, beds, replacing roof of stables and other repairs, ...
4
[outside] *Receipt Jon Hamiltone wright to Mr Jas Smith £6 7s, 5d. for reparatione in the foot guard. Hollyrudhous Scots £76 9s.*
6
[outside] *Instructions for the 8 article by the Abbreviat Acct.*
James McClealand and accompt for wright worke done at stirling and the abay £2879 10s. 6d.
[outside] *Abbreviat accompt of wright worke by James McCleland wright for worke done at the palace of Holyroodhouse and Castle of Stirling from december 1684 to march 1686*
Frames for paintings, High Commissioner accommodation, girnels, platforms, repairs at stables, benches, ...
TOT £2908 10s. 6d.

Summary and comments: Nothing related to roof structures

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 2

Title: Repairing Holyroodhouse for reception of the High Commissioner (8 vouchers) | Date: from 1684 to 1685

Contents: 1684-5 Reparations in the stables, plaster in King's room & oratory, partitions, doors, lathing the coach house

Summary and comments: Nothing related to roof structures

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 1A

Title: Holyroodhouse, Stirling Castle, Dumbarton Castle, Edinburgh Castle Vouchers of expenditures on works (1684-86) | Date: from 1684 to 1687

Contents:
[outside] Missing part
Mr James Smith
By
An accompt of money payed to severall persons for work & materialls furnished for the use of his Maj Palace & Castles from 14 Aprile 1684 to 1 of March 1686
[inside] *By an accompt of money payed to Mr James Smith overseer to his Mties works, and to his orders by Hugh Wallace of Inglistoun his Majesties cashkeeper from 14 Aprile 1684 to 1 March 1686*

1. Clearing casway-layers and others in Edinburgh Castle £360
2. Not specified £7704 4s.
3. To pay workers £4093 11s. 10d.
4. Not specified £657 15s.

TOT £12814 10s. 10d.

Received by J. Smith
By an accompt of money debursed by Mr James Smith overseer to his Mties works to the particular persons after mentioned for work don and wrought by them at his Maties Palace and Castles conform to the particular instructions afterspecified from 14 Aprile 1684 to March 1 1686

1. Casway men, levellers, sandmen, workmen and others to carry sand and stones and levelling the ground at Edinburgh Castle £1481 9s.
2. *It. to several persons for workmanship and furniture in repairing the Palace of Holyroodhouse for the reception of his royal highnes* […] *and afterwards continued for his Grace the Duke of Queensbury* […] *his accommodation anno 1685* […] £1002 18s.
3. Other people for works at Holyrood £1060
4. James Alexander and Mr Kikeus for painting at Holyrood and Edinburgh Castle £705
5. *To Robert Marshall wright in Dumbarton and others at Stirling* for defenses £720 18s.
6. *To James Mccleland & John Hamilton wrights for work don at the Palace of Holyroodhous & Castle of Stirling as the accompts & recepts from Dec. 1684 to March 1686* […] £ 2908 10s.
7. To James Dunbar merchant for deals and trees and two carvers brought from London to carve his Majestys statue in marble to be set up in the middle of the court of Holyrood £ 2321 16s.
8. To James Baine wright and John Callander smith for work at the Councill Chamber and windows of the privy chamber & oratory at Holyrood £629
9. Alexander Chambers for clensing walls at Edinburgh Castle £97
   James Smith for visits to Blacknes, Dumbarton, Stirling Castles and the Bass £120
10. *To severall persons who were active in smothering & suppressing the fire in his Ma. Palace of Holyrood hous Feb. 1686* […] £173 4s. 4d.
11. John Mastertoun glass work at Holyrood and Edinburgh Castle 1683-4-5-6 £1130 14s.
12. *To severall persons for reparations don at his Ma. Palace of Holyroodhous in the latter end of 1685 and beginning of 1686 about the stables and other office houses* […] £463

TOT £12814 10s. 10d.

Summary and comments: Abstract of specific accounts of James Smith surveyor general between 1684 and 1686 at Edinburgh Castle, Dumbarton Castle, Stirling Castle, Holyrood Palace. Repairs are carried out at Holyrood Palace for the reception of the king, in particular works are carried out at the Councill Chamber, the Privy Chamber and the Oratory. The wrights James Mccleland, John Hamilton, James Baine, and the merchant James Dunbar are paid for timber work and materials.

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 8

Title: Works at council chamber, privy chamber and oratory at Holyroodhouse (2 items) | Date: from 1684 to

Contents:
[outside] *Accompt and receipt James Baine for by works at the Abay for £567*
[inside] *Instructions for the 8 article relative to worke done by James Baine inm the Coucnell Chamber & privie chamber & others in His Maties palace of Holyroodhouse over & above the ??? he had done there by contract in the years 1684*
furniture

Summary and comments: Nothing related to roof structures

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 3

Title: Timber for Holyroodhouse (1 voucher) | Date: from 1685 to

Contents: 1685 George Stirling 1200 deals from timber bush in Leith £480

Summary and comments: Deals probably for works carried out by J. Macleland in 1684-5

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 7

Title: Timber for Holyroodhouse and fees of carvers (4 vouchers) | Date: from 1686 to

Contents: [outside] *Instructions for the seventh article relative to timber bought & the fee of two carvers*

Scots 2321 16s..
[inside] […] James Dunbar merchant in Inverness for a loading of timber £701 8s.
Custom house, carriage, carvers to make the king's statue in marble
(1)
[outside] *Receipt James Dunbar mert. In Inverness for £ 58 9s. £701 8s.*
[inside] *Ane accompt of timber bought be Mr James Smith from James Dunbar mert. In Inverness the 16th Janry 1686*
1100 Bergen deals, 9 dozen long deals halved, 12 dozen double trees, 10 single trees, 8 dozen fire planks, 2 other dozen deals
TOT £58 9s.

Summary and comments: Deals, trees and planks probably for works carried out by J. Macleland in 1684-6

Archive: National Records of Scotland | Doc. Num.: GD124/15 | Folios: 471

Title: Letter to the Earl of Mar from Mr James Smith, surveyor of Her Majesty's works, in Edinburgh. He describes the dismal state of the Palace of Holyroodhouse and the Castle of Stirling.

Date: from 1707 to

Contents:
Mr Ja. Smith concerning the Abie of Halarudhouse & Stirling Castle
Novemb. 6 1707
My Lord
since I have been preferred to be surveyor of Her Ma.tis works, I ame bound in duty to informe that unless some serious settled measure be laide doune for keeping her Ma.tis palace castles and forts in repaire they'l infallibly go all to ruine.
My lord the palace of holyroodhouse is in so dismail a conditione both in the roof & windowes that I ame ashamed to write of it, but ther is ane absolute necessitie of keeping it in repaire otherways it will inevitably perish if 500£ be bestoned by the housekeeper as I shall advise and the bond? made sune? it may be? more than a thousand pounds laide out in the ordinaire maner. What I say of the palace of holyrodhouse I may say meane? the same of the castle of stirling with the additione that the platforms and embrasures are all ruined the half being all ??? doune with the flashes of ??? and the other rotten having been made only of firr wals many years agoe but I ??? not head farr. I ought to medle? in this affaire, it being properly I being properly the Mr of Ordonance his post to judge of and ordar these things and if any thing ??? a ??? of artiglarie be kept in thy place (of which I doubt) the master of the ordnance may order me or ??? of ane under him to represent the thing for there is ane absolute necessitie of looking after ??? in all the branches both in ??? Castle ??? Stirling as for ??? ??? not but Major Grall Maitland has given informatione since his affairs ??? ane but in a maner a doing wants greate support.
My lord wherin I am short or out of the ??? I hope will be pardoned when it is considered of preceeeding from My Lo
your most obliged dutifull most humble servt Smith

Summary and comments: In 1707 James Smith, the King's Surveyor General, says that the roof of Holyrood Palace and Stirling Castle are in bad conditions – it is not clear if his evaluation is limited to the slates and sarking, or comprises the structure as well.

Archive: Edinburgh University Library | Doc. Num.: La II 88 | Folios: 3

Title: Note of money paid for repairs on Holyroodhouse since the union 28th Sept. 1806

Date: from 1721 to 1805

Contents:
[outside] *Note of money paid for repairs on Holyroodhouse since the union 28th Sept. 1806*
£23646
[inside] *Note on Money paid for repairs on Holyroodhouse since the union*
1721
Robert Moubray wright £80
Joseph Forester plumber £80
Gilbert Smith mason £12
Alexander Burton glazier £40
James Wilson smith £10
James Syme slater £40
TOT £262
1722
Same + Alexander Syme painter
TOT £646
1723
same
TOT £993
1733
Same + William Adam
TOT £3000
1735
William Adam £100
1754
W. Moncrieffe for paying workmen £400
1755
W. Moncrieffe for paying workmen £450 (John Douglas architect, William Hamilton wright-paid £380-, James Mcpherson mason, Mr Richardson smith, John Lamb smith)
1762
Clock repairs £21
1771
W. Moncrieffe for paying workmen £50
1772

W. Moncrieffe for paying workmen £17
1774
W. Moncrieffe for paying workmen £10
1777
Repairs of apartments £7
1779
Duke of Hamilton for repairs on Holyrood £450
1780
James Reid for building a wall at the watergate £10
1791
Ramsay slater £91
James Salisbury for repairing roof £10
1792
Marshall Armstray plumber £89
Archibald Ramsay slater £11
1793
Clock £50
1794
Henry Butter carpenter for repairs of Lord Dummeres? Lodgings £52
James Gordon for cutting drains £60+71
??? £126, £35, £150
Adam £1442
Marshall Armstray plumber £100
??? £14
Charles Hamilton for repairs of Duke Hamilton's lodgings £29
??? £80
??? carreyer £53 + £20 + £70
Marshall Armstrong plumber £49
George Gordon Carpenter £23
1795
Mr Butter wright £6
??? £21
Glazier £2
Repairing paintings £25
William Archibald mason £198
George Wilsh for causewaying £366
John Butcher slater £30
Marshall Armstray plumber £120
George Gordon carpenter £9 + £43
??? clockmaker £16
W. Lauson plasterer £36
John Medina painter £30
1796
??? £27
Duke of Portland apartments £1000 + £1500 +£4000
William Sibbald mason £650
1797
Royal apartments £700
1798
Duke of Portland apartments £400
??? mason and other workmen £600
1799
??? £600
1801
Repairs on abbey £400 + £182
Archibald Ramsay slater £5
John Baron painter £4
1802
Repairs £2000 + £200 + 1000
1803
Repairs £300 + £300
1805
Repairs £200 + £150 + £150
TOT £23646

Summary and comments	No details of works but the sums paid for carpentry works are limited, thus no extensive works were probably carried out during the 18th century on the roof structures.

Archive	Edinburgh University Library	Doc. Num.	La II 88	Folios	1/1

Title	Accompt of Carpenter work performed at the Abbay of Holyroodhouse by Robert Mowbray wright 1733-4	Date: from	1733	to	1734

Contents [outside] *Accompt of Carpenter work performed at the Abbay of Holyroodhouse by Robert Mowbray wright 1733 & 1734*
[inside] *Accompt fo carpenter work performed at the Pallace of HolyRood House by Robert Mowbray His Majestys Master Carpenter in Scotland between the 19th July 1733 and.*
To 2485 yards of roofing and sarking including the taking up of the old sarking & rotten timbers of the roof, sawing new sweeps out of great beams, furnishing nails thereto, the sarking being jointed and seemed, also the battons on the ridge of the roof & peans of the angles & garret windows at 2sh. Pr. Yd. £248 10s.
Doors £3
To making a crane to hoist up the great timbers & sheet lead from the court to the platform above the Duke Hamilton's lodging £2
To making a scaffold and gangway between that platform & the main Roof for carrieing the lead ecc £1
Table & other tools for plumber £1 15s.
To making a strong frame 48 feet long & 6 deep of square timber to support the couples of the roof on the south side of the church wt. nails ecc £4 10s.
To repairing all the sarking of the 4 garrets in the front & making scaffolds on them for the wrights and sclaters £9 2s.
Other tools for plumbers £9
Scaffold for the masons £1 3s.
Moulds and rules for masons 18s.
Lodge for masons £1 15s.
To mending a floor in the Duke of Argyles appartment that was rotten by the rain that came through the roof £10 10s.
Door £9
Door £4
Door £5
Windows £1 12s.
Locks £7
Scaffolds £7 3s.
Clock £1 10s.
Lath and plaster in garret £16 8s.
Demolishing stable £18
Lining £9
Mason putting ducks in the stone wall £ 1
Nails £3
Mouldings £11
Mouldings & panelling £7
Tables and shelves 15s.
Painting 3s. 6d.
Ladders 7s.
TOT £316 6s. 6d.
Work measured by James Buchanan and William Adam and paid

Summary and comments 1733/34 works at the Abbey roof carried out by carpenter Robert Mowbray.

Archive Edinburgh University Library Doc. Num. La II 88 Folios 1/8

Title Accompt of large tree beams furnished to the roof of Holyrood 1733-4 Date: from 1733 to 1734

Contents [outside] *Accompt of timber to the Abbay 1733 & 1734*
[inside] *Accompt of large tree beams furnished to the rooff of the Abbay from 31 July 1733 to 24 September 1734 both inclusive*
[…] *To 328 largest choiced firr beams mostly 26 foot long from 10 to 16 inches square being cutt out for new framing the sides of the rooff and storm windows, also in replacing severall of the principall beams of the rooff which were rotten by the rain watter coming in upon the timbers, each new beam att £? £410*
Accompt of planks & dealls furnished to the above rooff
Broad fir planks 15, 16, 17, 18, 24 feet long – some 4 inches thick, some just *thick* or *thinner* (some from Portseaton)
Double 10, 12 feet deals – some 2 inches thick, some just *thinner* (some from Norway)
Single deals 9 feet long
Large slabbs for cleats?
Large double trees
TOT £874 13s. 6d.
Furnished by William Adam

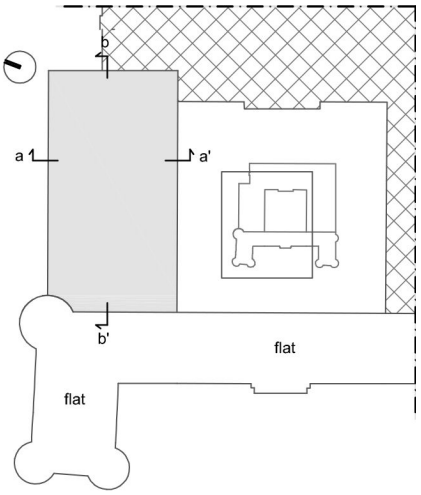
Summary and comments 1733/34 William Adam furnishes timber for the works at the Abbey roof.

Archive Edinburgh University Library Doc. Num. La II 88 Folios 2

Title Accounts of several artificers employed in repairing Holyroodhouse 1733 Date: from 1735 to 1736

Contents [outside] *Abstract*
Workmen's acct. for repairing the Abbey signed by Mr Philp
26th ??? 1735/6
???gned precepts for paying the ballances
[inside] *An abstract of the accounts of the several artificers employed in repairing his Majesty's Palace of Holyroodhouse, pursuant to his Majestys Royal Sign manual dated the 10th day of August 1733*
Robert Moubray wright £316 6s. 6d.

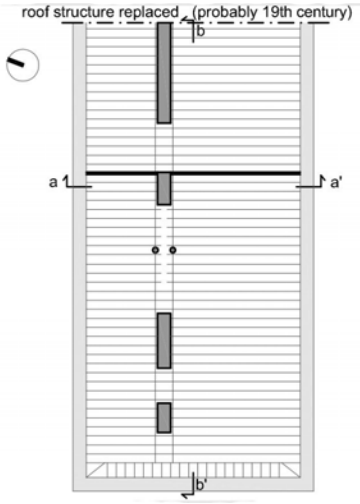
	James Syme slater £191 15s. 6d. William Carnaby plumber £260 William Adam architect £2210 2s. 1 5/12d. mainly for materials furnished (slates, timber, lead, stone) but also for the smith's, clock maker's account, painter's and glazier's accounts
Summary and comments	No details of works, but it's probably related to the 1733/34 works at the Abbey roof.



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



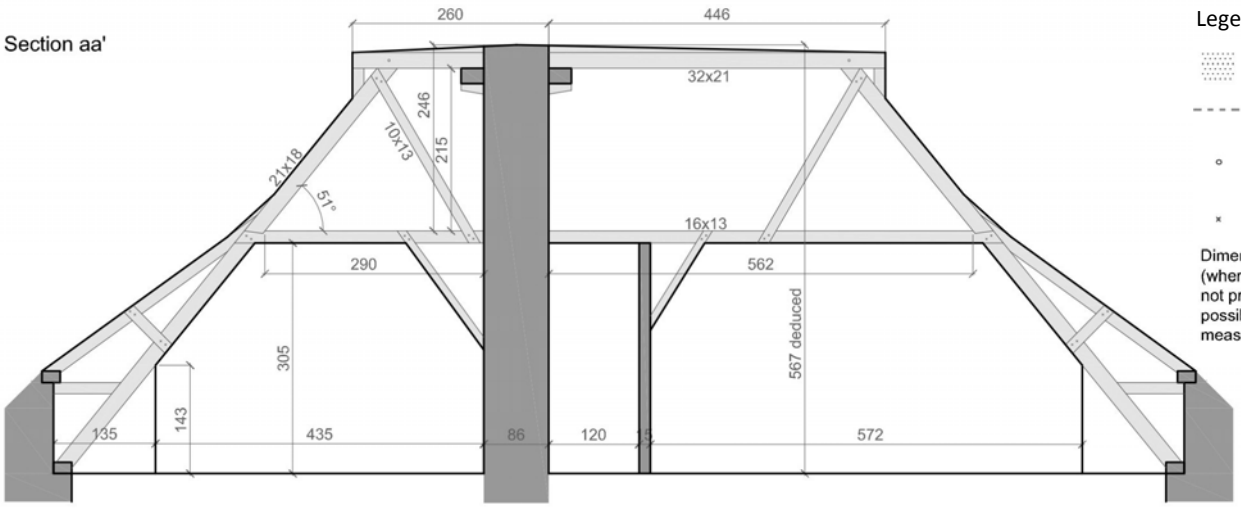
Carpentry marks from west to east:

IIII	XXII	XXXIX
V	XXIII	⌐IX
VI	XXIIII	XΓI
VII	XXV	XΓ II
VIII	XXVI	XLIII
VIIII	II/XX	XXXXIV
X	XXVIII	XXXXV
XI	XXVIII	XXXXVI
XII	XXX	XXXXVII
XIII	XXXI	XXXXVIII
XIIII	IIXXX	XXXXIX
XV	XXXIII	XXXXX
IAX	XXXIIII	not visible
XVII	XXXIV	not visible
XVIII	XXXV	
XVIIII	XXXVI	
XX	XXXVII	
XXI	XXXVIII	

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

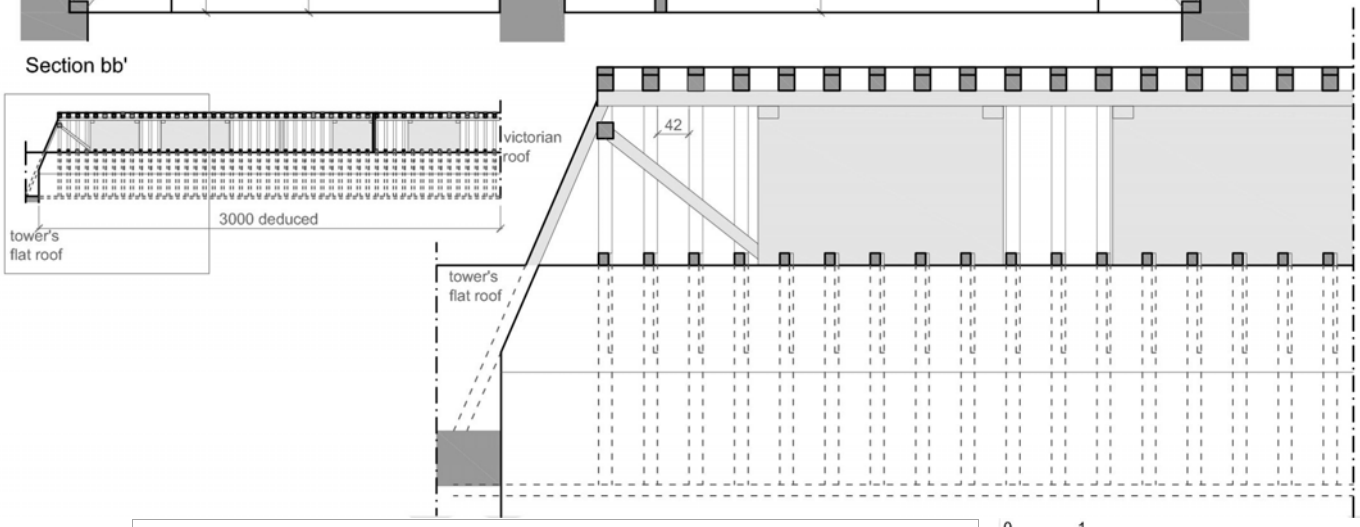
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** HOLYROOD PALACE | **Roof location** N range

Survey date(s) 08/09/2014 | See drawing: HP-N-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 8.2 | Roof Height [m]: 4.8

Roof Pitch/es [°]: 54 | Roof Length [m]: 30

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Other

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking

Sarking boards: width [cm]: 26 | thickness [cm]: 2.5

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1671 To 1679 | Identified by: Estimated

Roof General Description: Only N range retains original roof structure. It incorporates the 16C palace and chapel royal. Hipped platform roof supported by an intermediate longitudinal wall. Timber beams span transversally and sit on this wall - they are connected on the sides to the rafters. Lower beams span from the rafters to the intermediate wall and support the ceiling of the attic rooms. Rafters and lower beams are connected by struts. All timbers are hand-axed whole logs. Struts are smaller and roughly dressed.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 21 | B: 18 | Or Purlin - H: | B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Between upper beams and rafters: mortice and tenon with timber pegs not flush; between rafters and struts: half lapped with metal pins; between rafters and lower beams dovetail lapeed with metal nails.

Wood Species: All elements, including sarking: Pinus sylvestris) - Pegs securing joints between elements: oak

Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: In sequence, numbered from IIII to XXXXX from west to east. First 3 frames removed?

Signs of reused timbers: A few elements on the west side have redundant joints.

Timber Treated ☑ some timbers have been treated with insecticides in 1960s

Other Materials:

Dendrochronology: dendrochronology done by Anne Crone on timber doors but inconclusive



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joint: rafter and upper beam | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation

Accessibility limitations: The lower beams are beneath the insulation sheets and are therefore inaccessible for inspection

Past interventions: Some rafter ends, close to the walls, reinforced with timbers on the sides bolted together. The sarking is probably not original. In 1960s timber treated for woodworm. 8 years ago redone all the wiring and put partitions for fire safety.

Material Degradation: Fungi attack ☑ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☑

Some humidity stains, but mostly seem old. Some timbers feel wet though. Diffuse insect exit holes on most timbers, probably corresponding to past insect attack confined to the sapwood. Localized insect attack on some timbers. 'Wounds' (injuries suffered by the living tree,) on a few timbers. Fungi attack in a few locations.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage	Disconnection	Unknown	

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient joints
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☑ insect attack
- Past interventions ☐
- Extreme actions ☐
- Other ☐

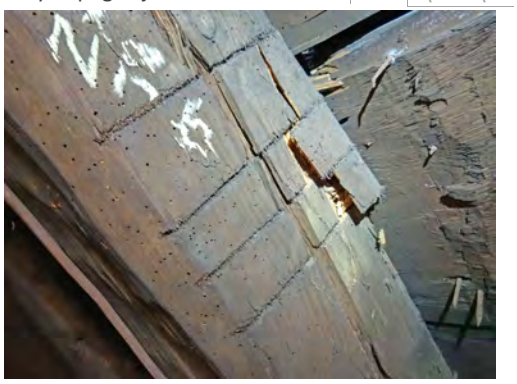
Description of visible damage: Some joints between rafters and upper beams have opened/partly failed, because the timber peg has decayed or broken, or because the mortice or tenon have failed.

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui



Decayed peg in joint | link I:\Arch\A



Insect attack on rafter | link I:\Arch\A



Unidentified fungi attack | link I:\Arch\A



Damage: disconnection | link I:\Arch\A



Damage: disconnection | link I:\Arch\A

DETAILED SURVEY **Building name** HOLYROOD PALACE **Roof location** N range

Survey date(s) 12/02/2016 02/06/2016 15/06/2016 28/06/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings HP-N-1, HP-N-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafters	650*	rectangular with wanes	bending, compression	pinus sylvestris	hand axed
South upper beams	500	rectangular with wanes	bending	pinus sylvestris	hand axed
North upper beams	225	rectangular with wanes	bending	pinus sylvestris	hand axed
South lower beams	635*		bending, tension		not visible
North lower beams	360*		bending, tension		not visible
Struts	270	rectangular with wanes and bark	bending, compression	pinus sylvestris	hand axed
Sprocket Rafters	340	rectangular	bending		hand axed, only a few hand sawn
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

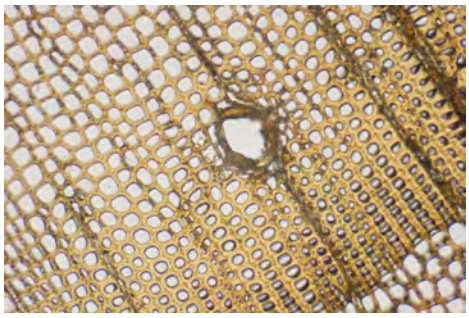
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings HP-N-1, HP-N-2

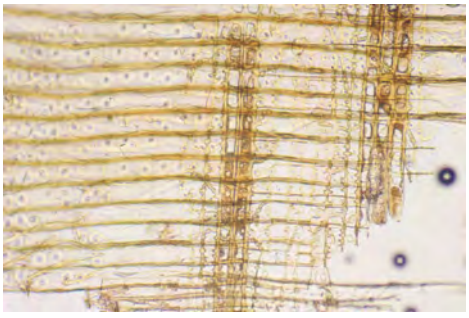
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & upper beam	Encounter mortice & tenon	compression, shear	wooden pegs	quercus sp.
rafter & lower beam	Encounter dovetail	tension	nails	
rafter & strut	Encounter halved	compression, shear	nails	
strut & lower beam	Encounter dovetail	compression, shear	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

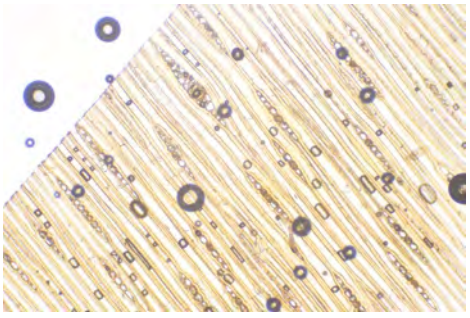
Microscopic identification of the timber species See drawing HP-N-2



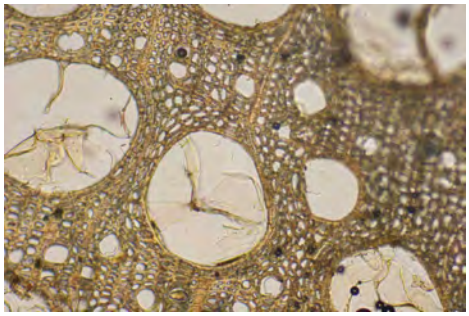
Rafter: transv. section x100 I:\Arc



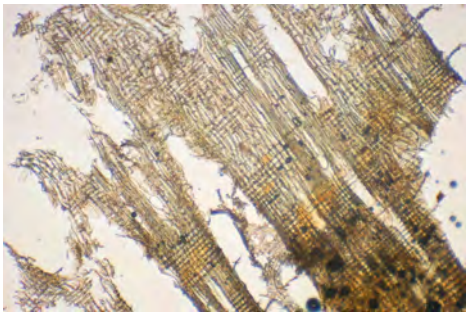
Rafter: radial section x100 I:\Arc



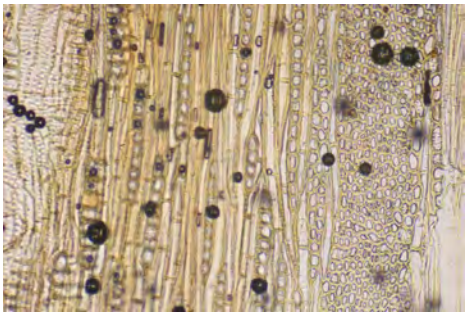
Rafter: tang. Section x50 I:\Arc



Peg: transv. Section x100 I:\Arc



Peg: radial section x50 I:\Arc



Peg: tang. Section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing HP-N-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	Close to frame XXXXV	12/02/2016	11 am	11.7	56.5

roof space	Close to frame XXX	12/02/2016	10:30 am	10.9	59.5
roof space	Close to frame XV	12/02/2016	10 am	11	59.7
roof space	Close to frame XV	02/06/2016	3 pm	21.4	52.5
attic space	Close to frame XLIII on North side	02/06/2016	11:20 am	19	56.8
attic space	Close to frame XLIII on South side	02/06/2016	12 am	22	46.9
attic space	Close to frame XX on North side	02/06/2016	10:40 am	18.9	47
attic space	Close to frame XX on South side	02/06/2016	12:40 pm	20	48.5
attic space	Close to frame X on North side	02/06/2016	10 am	18.9	52
attic space	Close to frame XI on South side	02/06/2016	1:10 pm	19	60
roof space	Close to frame XV	15/06/2016	10 am	16.9	65

Frame/Truss name XX — See drawings HP-N-2, HP-N-9

Missing elements

Elements with defects in critical area: S rafter

Joints with decayed peg: between N & S upper beam and rafter

Insect attack: N upper beam

Failed joints

Fungi attack

Other: 6cm deep check on one side of S rafter

Element name A north upper beam

Dating: original construction

Signs of reuse

Timber treated: ☑ insecticides, in the 1960s

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 16.5x14 — min. size (hxb) [cm]: 12.5x13 — Single piece ☑ — Jointed element ☐

Strength affecting defects

Pith location: centre — Slope of grain [%]

Knots [min d/section h] — Knotty element ☐ — Defects in critical area ☐ — Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack, probably old — I:\Arc

Material degradation

Insect attack ☑ — Type: Anobium Punctatum — Status: non-active

Way of identification: Estimated

Fungi attack ☐ — Type — Status

Way of identification

Corrosion ☐ — Wet surface ☐ — Other

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage — Emergency interv. needed ☐

Mater.Degr. and Damage Extent: in point A section reduced 8cm in height - in point B section reduced 2cm all around

Way of identification: NDT/SDT, visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ — Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

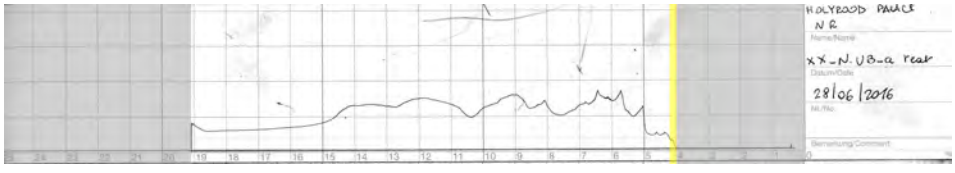
Moisture Content [%]: 14.4 — Visible Material Degradation ☑ — Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] — Higher voltage ☐ — Higher gain ☐ — Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]: 1.2

Link to Micro-drill graph: I:\Arc



LEGEND — Zero resistanc — Low resistance — High resistance (knot — Out of timber

Measurement Point b

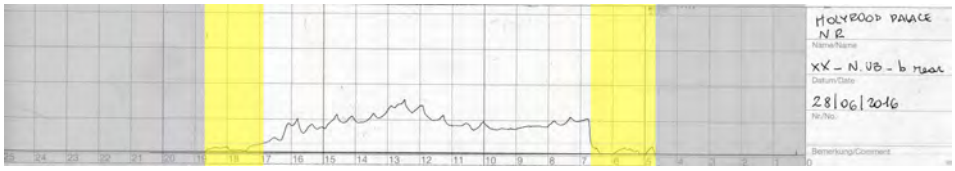
Moisture Content [%] 13.5 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 24.8

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

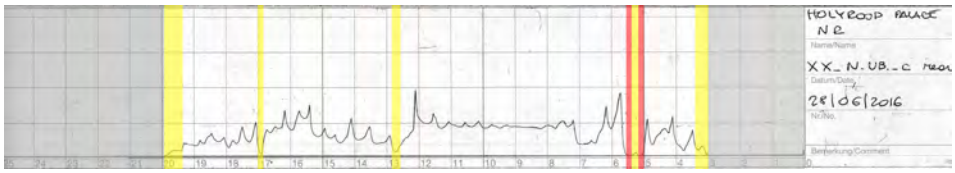
Moisture Content [%] 14.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 2.5

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name XIV — See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg between N upper beam and rafter | Insect attack

Failed joints between N upper beam and rafter | Fungi attack

Other old humidity stain on S upper beam

Connection name between N upper beam and rafter — FrameTrussCode HP-N-XIV

Mechanical Damage:	Type	Status	Role
Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary

Estimated causes of primary damage:

Poor design ☑ wrong geometry | Poor maintenance ☐

External actions ☐ | Material degrad. ☑

Poor construction ☐

Past interventions ☐

Other ☐

Description: decayed peg, completely missing, and joint open



joint open, peg missing | I:\Ar

Estimated damage level severe

Emergency intervention needed ☐

Frame/Truss name XIII — See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints between N upper beam and rafter | Fungi attack

Other small crack in S upper beam

Connection name between N upper beam and rafter — FrameTrussCode HP-N-XIII

Mechanical Damage: Type | Status | Role

Splitting: shear failure along grain	☑	unknown	primary
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☐		



joint open, peg undamaged | I:\Ar

Estimated causes of primary damage:

Poor design	☑ wrong geometry	Poor maintenance	☐
External actions	☐	Material degrad.	☑
Poor construction	☐	Description	joint open, probably broken tenon
Past interventions	☐	Estimated damage level	rupture
Other	☐	Emergency intervention needed	☐

Frame/Truss name XII | See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between N upper beam and rafter | Insect attack

Failed joints: between N upper beam and rafter | Fungi attack

Other

Connection name between N upper beam and rafter | FrameTrussCode: HP-N-XII

Mechanical Damage: Type | Status | Role

Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



I:\Ar

Estimated causes of primary damage:

Poor design	☑ wrong geometry	Poor maintenance	☐
External actions	☐	Material degrad.	☑
Poor construction	☐	Description	decayed peg and joint open
Past interventions	☐	Estimated damage level	medium
Other	☐	Emergency intervention needed	☐

Frame/Truss name XI | See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between S upper beam and rafter | Insect attack

Failed joints | Fungi attack

Other: old humidity stain on S upper beam -S rafter lower end strengthened

Frame/Truss name VIIII | See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between N & S upper beam and rafter | Insect attack

Failed joints: between N upper beam and rafter | Fungi attack

Other: old humidity stain on S upper beam - S rafter lower end strengthened

Frame/Truss name VIII | See drawing HP-N-2

Missing elements: S strut | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other: old humidity stain on S upper beam - S rafter lower end strengthened

Frame/Truss name VI | See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between S upper beam and rafter | Insect attack

Failed joints | Fungi attack: N upper beam

Other

Frame/Truss name X — See drawings HP-N-2, HP-N-4

Missing elements: N strut | Elements with defects in critical area: S strut, S rafter

Joints with decayed peg | Insect attack: N & S upper beam

Failed joints | Fungi attack: N upper beam

Other: N rafter wet close to wall - S rafter lower end strengthened

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: central part not visible

Past interventions: Rafter end close to wall strengthened with additional timber elements on the sides bolted together

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 16.1x13.4 | min. size (hxb) [cm]: 13x11 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 6 | tangential

Knots [min d/section h]: 3.5/14.5 | single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other



Rafter end strengthened | I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 13.3 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1355 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -0.8

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%] 13.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1543 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -8.1

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 13.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1068 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] 10.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 15.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2391 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -41.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 17.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1596 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -10

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 16.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1819 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -18.8

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B south strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 18.3x14 min. size (hxb) [cm] 14x14 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 2.4/11 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119: lower than III

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 15
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s]: 1492
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]: -5.8
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

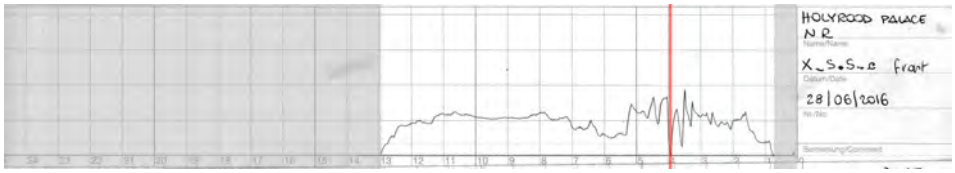
Measurement Point b

Moisture Content [%]: 14.5
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s]: 1670
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]: -12.9
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 15.2
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s]:
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 0.5
Link to Micro-drill graph: I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C south upper beam

Dating: original construction
Signs of reuse
Timber treated ☑: insecticides, in the 1960s
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 20.6x19.1 min. size (hxb) [cm]: 19.5x17 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 5 tangential
Knots [min d/section h]: 4/20 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



Insect attack, probably old I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum Status non-active
Way of identification Estimated
Fungi attack ☑ Type Unknown Status unknown
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type		Status	Role
Deformation	☐		
Cracks	☐		
Crushing	☐		
Other	☐		

Estimated level of damage Emergency interv. needed ☐

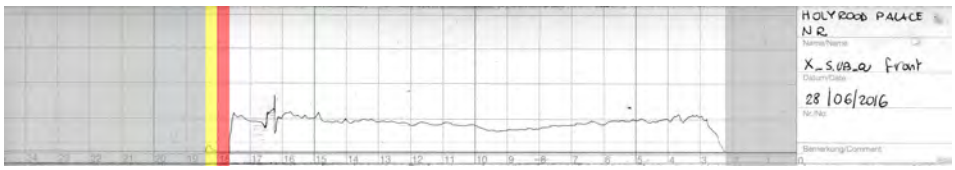
Mater.Degr. and Damage Extent: section reduced 1cm all around - in point D almost half section lost
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 13.8
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 4.3
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

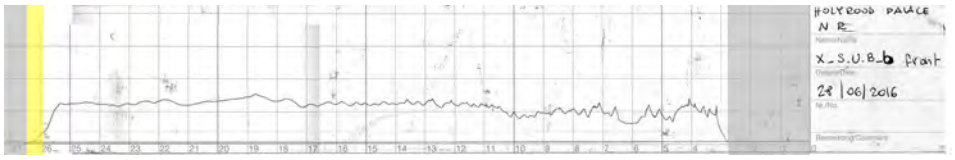


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 14.3
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 2.2
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 14.2
Ultrasonic velocity [m/s] 1767
Density loss based on ultrasonic test [%] -16.7
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

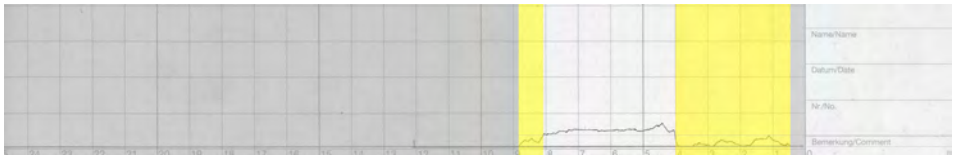
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 14.1
Ultrasonic velocity [m/s] 1309
Density loss based on ultrasonic test [%] 1.4
Material Degradation based on Micro-drill [%] 41.2
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name D south sprocket rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 15.5x12 | min. size (hxb) [cm]: 15x12 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 2 | tangential

Knots [min d/section h]: 2/15 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ | Type: | Status: | Way of identification:

Fungi attack ☐ | Type: | Status: | Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage: | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Measurement Point a

Moisture Content [%]: 14.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1537 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -7.6

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 13.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1330 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: 0.6

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name E north rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 16.8x14.3 | min. size (hxb) [cm]: 15x13 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 5 | tangential

Knots [min d/section h]: 2/15 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type		Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage

Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%]: 16.1

Ultrasonic velocity [m/s]: 1919

Density loss based on ultrasonic test [%]: -23.5

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 15.4

Ultrasonic velocity [m/s]:

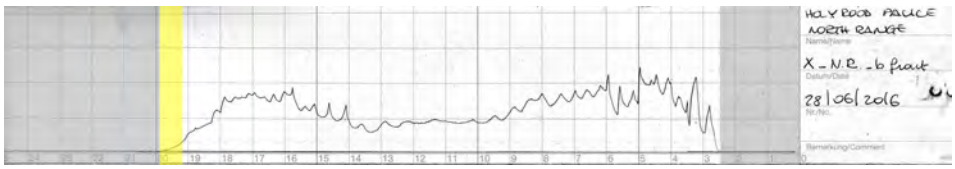
Density loss based on ultrasonic test [%]:

Material Degradation based on Micro-drill [%]: 4

Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 14.2

Ultrasonic velocity [m/s]: 1908

Density loss based on ultrasonic test [%]: -22.7

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%]: 16.2

Ultrasonic velocity [m/s]: 1712

Density loss based on ultrasonic test [%]: -15.5

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 16.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1517 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -8.1

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1450 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -5.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name F north upper beam

Dating original construction Signs of reuse

Timber treated ☑ insecticides, in the 1960s Accessibilityissues only end close to rafter is visible, the rest is enclosed in a rooflight

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17x9.5 min. size (hxb) [cm] 17x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



Insect attack, probably old I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum Status non-active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 4cm in height at the northern end

Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☑ | ultrasonic ☑ | micro-drill ☑

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name G north sprocket rafter

Dating later | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 21.25x11.5 | min. size (hxb) [cm] 20x11 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 5 | tangential

Knots [min d/section h] 2/12 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 1cm all around | Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

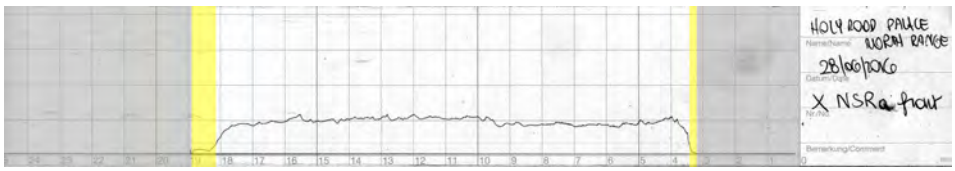
Moisture Content [%] 14.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] 1176 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] 5.7

Material Degradation based on Micro-drill [%] 5.8

Link to Micro-drill graph I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%] 17.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] 2032 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -28.1

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name XXXXVI — See drawings HP-N-2, HP-N-10

Missing elements | Elements with defects in critical area

Joints with decayed peg: between S upper beam and rafter | Insect attack: N rafter & N upper beam

Failed joints | Fungi attack

Other

Element name A north rafter

Dating: original construction | Signs of reuse

Timber treated ☑ insecticides, in the 1960s | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 16.5x14 | min. size (hxb) [cm]: 15x12.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



Insect attack, probably old | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum | Status: non-active

Way of identification: Estimated

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 1-3cm all around - internal decay up to 1cm wide but confined to sapwood

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

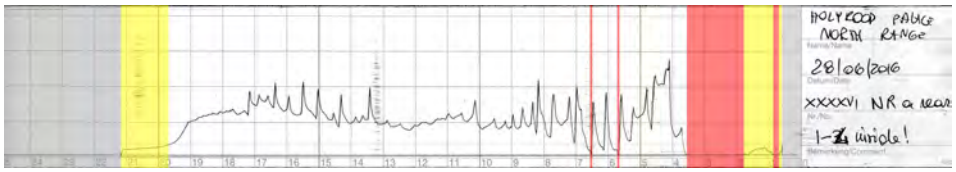
Moisture Content [%]: 13.8 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]: 21

Link to Micro-drill graph: I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

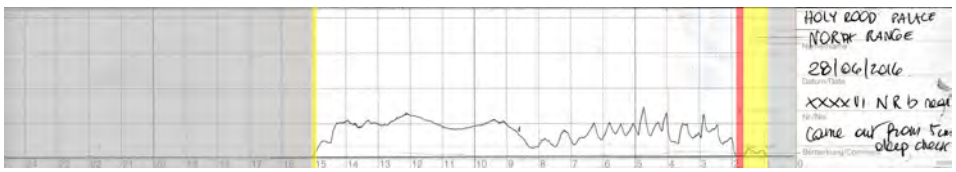
Moisture Content [%]: 15.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]: 7.5

Link to Micro-drill graph: I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

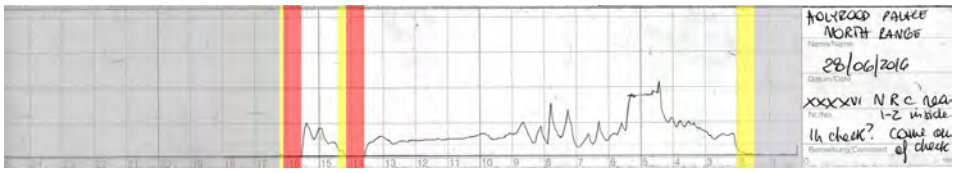
Moisture Content [%] 14.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 13.4

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

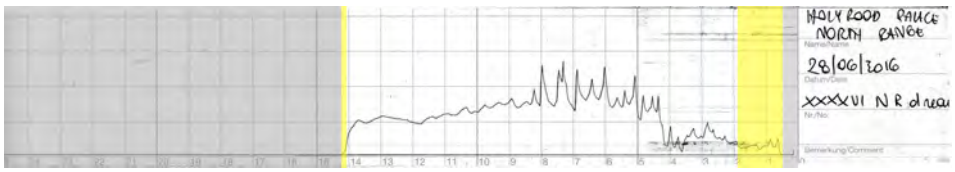
Moisture Content [%] 14 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 9.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name B north upper beam

Dating original construction | Signs of reuse

Timber treated ☑ insecticides, in the 1960s | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15x12.7 | min. size (hxb) [cm] 13.5x12.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack, probably old I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum | Status active | Way of identification Estimated

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 1cm all around - internal decay up to 1cm wide but confined to sapwood | Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

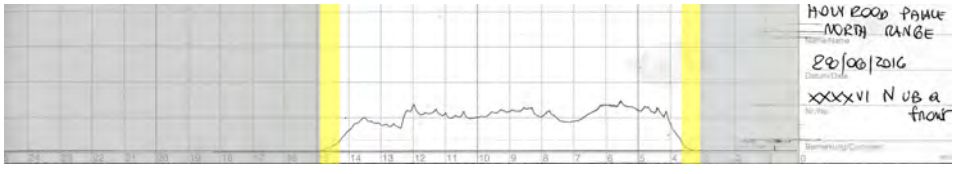
Moisture Content [%] 15.4 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 9.1

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

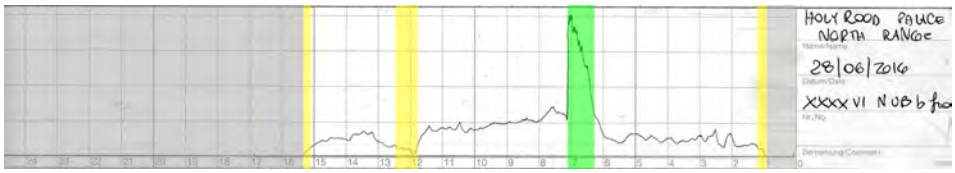
Moisture Content [%] 15.9 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 6.8

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

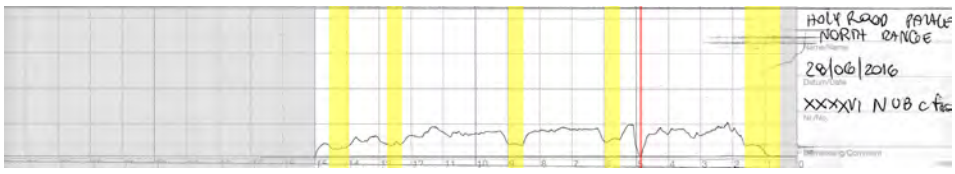
Moisture Content [%] 14.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 13.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Connection name between S upper beam and rafter | FrameTrussCode HP-N-XXXXVI

Mechanical Damage: Type | Status | Role

	Type	Status	Role
Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



insect attack affecting all joint | I:\Ar

Estimated causes of primary damage:

Poor design ☐ | Poor maintenance ☐

External actions ☐ | Material degrad. ☑

Poor construction ☐ | Description: decayed peg

Past interventions ☐

Other ☐

Estimated damage level severe

Emergency intervention needed ☐

Frame/Truss name XXIII | See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other rafters and upper beams different from others: bigger section and one sawn face

Frame/Truss name IIII | See drawings HP-N-2, HP-N-9

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack N rafter

Failed joints | Fungi attack

Other

Element name A north rafter

Dating original construction | Signs of reuse

Timber treated ☑ insecticides in 1960s | Accessibilityissues central part not visible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.7x17.1 | min. size (hxb) [cm] 16x15.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



Insect attack with new bore-dust | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated
Fungi attack ☐ Type: Status:
Way of identification:
Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type		Status	Role
Deformation	☐		
Cracks	☐		
Crushing	☐		
Other	☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 2cm all around
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%]: 15.4
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

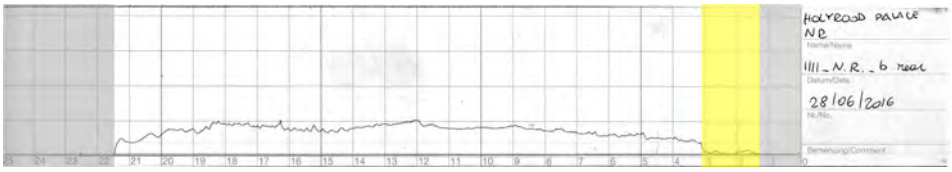
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 17.5
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 8.15
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 16
Ultrasonic velocity [m/s]: 1697
Density loss based on ultrasonic test [%]: -14
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

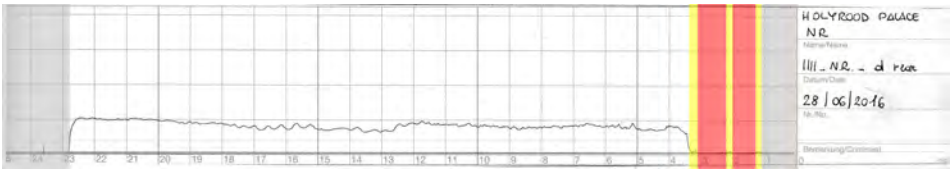
Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%]: 15.2
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 10.5
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XXXXIX — See drawings HP-N-2, HP-N-8

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack: S rafter

Failed joints | Fungi attack

Other: additional S strut - S rafter lower end strengthened

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☑ insecticides, in the 1960s | Accessibilityissues

Past interventions: Rafter end close to wall strengthened with additional timber elements on the sides bolted together.

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 15x12.2 | min. size (hxb) [cm]: 14.5x10.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: non-active | Way of identification: Estimated

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Insect attack, probably old | I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 2cm all around | Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

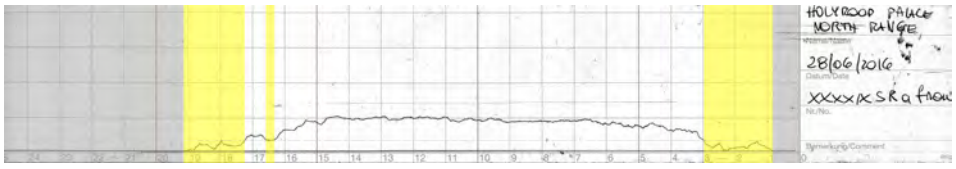
Moisture Content [%]: 13.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]: 19.8

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 14.3 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1577 | Higher voltage ☑ | Higher gain ☑ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -9.2

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

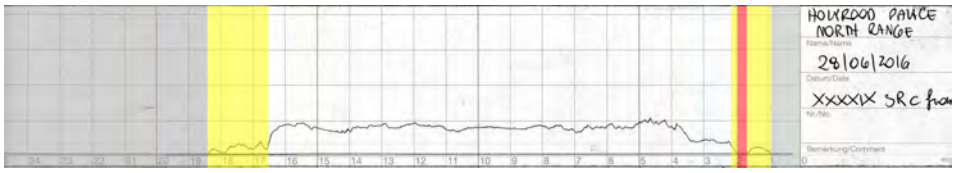
Moisture Content [%] 14.2 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 14.8

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

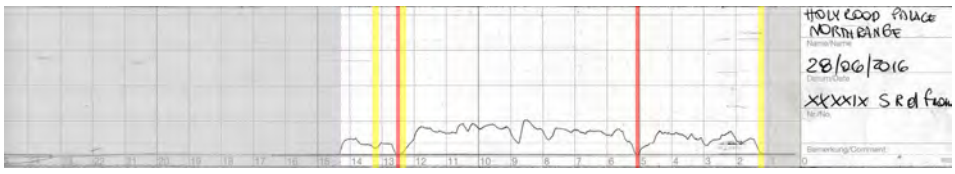
Moisture Content [%] 14 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 5.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Connection name between S upper beam and rafter | FrameTrussCode HP-N-XXXXIX

Mechanical Damage: Type | Status | Role

Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



decayed peg and tenon | I:\Ar

Estimated causes of primary damage:

Poor design ☐ | Poor maintenance ☐

External actions ☐ | Material degrad. ☑

Poor construction ☐

Past interventions ☐

Other ☐

Description: decayed peg and tenon

Estimated damage level: severe

Emergency intervention needed ☐

Frame/Truss name XXII | See drawings HP-N-2, HP-N-8

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack S rafter

Failed joints | Fungi attack

Other 6cm deep check and wound on one side of S upper beam - S rafter strengthened

Element name A south rafter

Dating original construction | Signs of reuse

Timber treated ☑ insecticides, in the 1960s | Accessibilityissues

Past interventions: Rafter end close to wall strengthened with additional timber elements on the sides bolted together.

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.3x15.1 | min. size (hxb) [cm] 14.8x14 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



Insect attack with new bore-dust | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated

Fungi attack ☐ Type: Status:
Way of identification:

Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 1-3cm on the sides

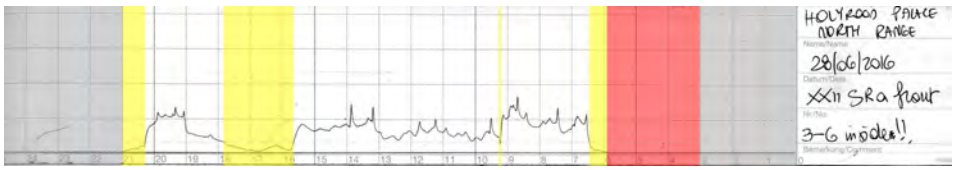
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 13
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 32.6
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

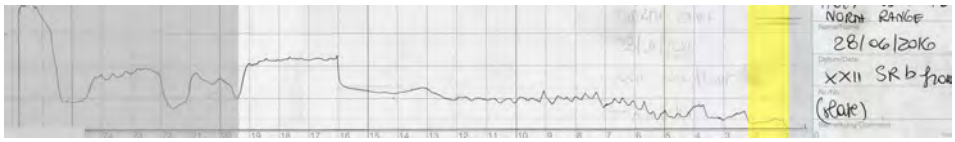


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 15.1
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 5.9
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

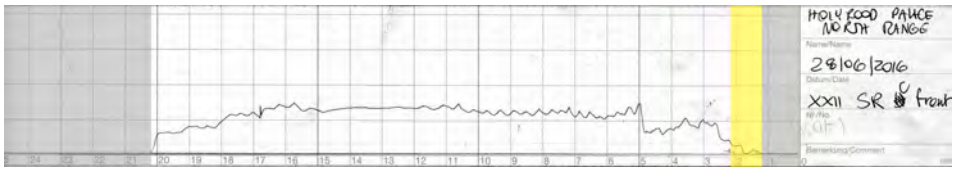


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 13.8
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 4.6
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

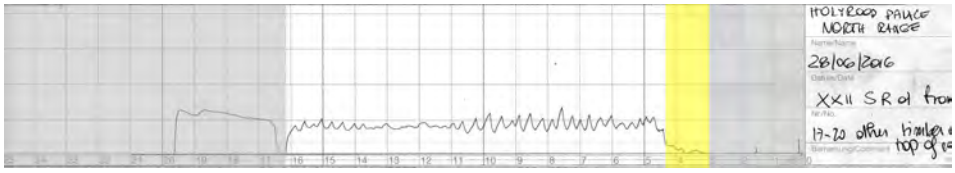


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%]: 13.7
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 9
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B south upper beam

Dating: original construction | Signs of reuse:

Timber treated: ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 17.1x16.9 | min. size (hxb) [cm]: 16.5x16.4 | Single piece: ☑ | Jointed element: ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]:

Knots [min d/section h]: | Knotty element: ☐ | Defects in critical area: ☐ | Deep checks on both sides of element: ☐

Other defects: wound (injury to living tree) and 6cm deep check on one side

Estimated Strength Class according to UNI 11119:



Material degradation

Insect attack: ☐ Type: | Status: | Way of identification:

Fungi attack: ☐ Type: | Status: | Way of identification:

Corrosion: ☐ | Wet surface: ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: | Emergency interv. needed: ☐

Mater.Degr. and Damage Extent: internal decay up to 1cm wide but confined to sapwood

Way of identification: NDT/SDT

Wound (injury to living tree) | I:\Arc

Estimated causes of primary damage

Poor design: ☐ | Poor construct.: ☐ | Degradation: ☐ | Poor maintenance: ☐ | Past interv.: ☐ | External actions: ☐ | Other: ☐

Measurement Point a

Moisture Content [%]: 13 | Visible Material Degradation: ☐ | Not Accessible for: hygrometer: ☐ ultrasonic: ☐ micro-drill: ☐

Ultrasonic velocity [m/s]: 1642 | Higher voltage: ☑ | Higher gain: ☑ | Signal not stable enough to take ultrasonic measur.: ☐

Density loss based on ultrasonic test [%]: -11.8

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

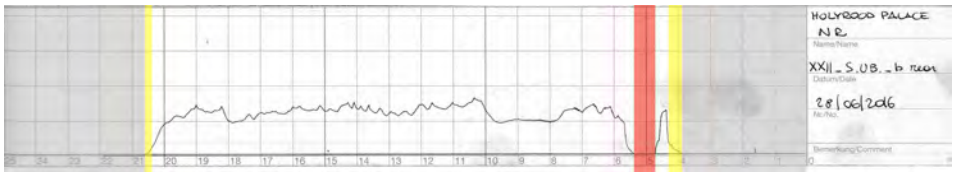
LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 12.4 | Visible Material Degradation: ☐ | Not Accessible for: hygrometer: ☐ ultrasonic: ☐ micro-drill: ☐

Ultrasonic velocity [m/s]: | Higher voltage: ☐ | Higher gain: ☐ | Signal not stable enough to take ultrasonic measur.: ☑

Density loss based on ultrasonic test [%]:



Material Degradation based on Micro-drill [%]: 8.4

Link to Micro-drill graph: I:\Arc

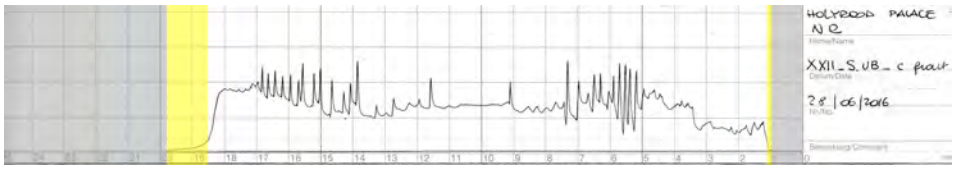
LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%]: 14 | Visible Material Degradation: ☐ | Not Accessible for: hygrometer: ☐ ultrasonic: ☐ micro-drill: ☐

Ultrasonic velocity [m/s]: | Higher voltage: ☐ | Higher gain: ☐ | Signal not stable enough to take ultrasonic measur.: ☑

Density loss based on ultrasonic test [%]:



Material Degradation based on Micro-drill [%]: 6.2

Link to Micro-drill graph: I:\Arc

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

Moisture Content [%] 13 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1861 | Higher voltage ☑ | Higher gain ☑ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -20.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name XXXXX | See drawings HP-N-2, HP-N-7

Missing elements | Elements with defects in critical area

Joints with decayed peg between N upper beam and rafter | Insect attack S upper beam

Failed joints | Fungi attack

Other joint between S rafter and strut more complex than others: dovetail and notched - 6.4cm deeop check on one side of S upper beam

Element name A south upper beam

Dating original construction | Signs of reuse

Timber treated ☑ insecticides, in the 1960s | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19.7x18.7 | min. size (hxb) [cm] 19.3x18 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects 6.4cm deep check on one side

Estimated Strength Class according to UNI 11119



insect attack, probably old | I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum | Status non-active | Way of identification Estimated

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 0.5-1.5cm all around - internal decay up to 0.5cm wide but confined to sapwood

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

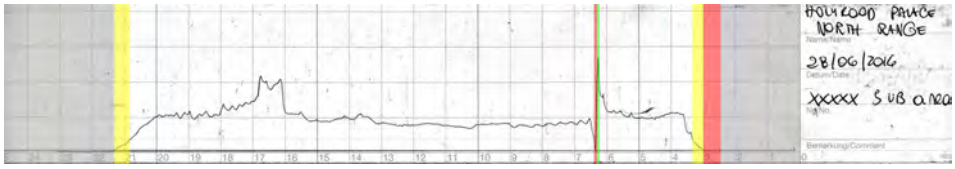
Moisture Content [%] 13.1 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 7.4

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

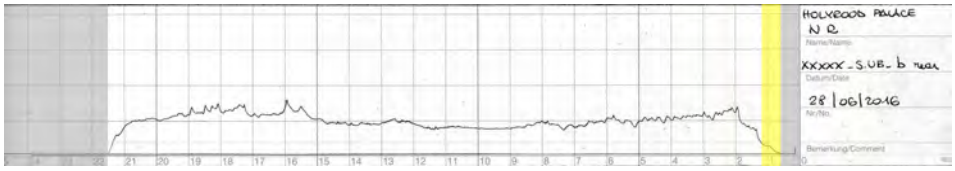
Moisture Content [%] 12.6 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1752 | Higher voltage ☑ | Higher gain ☑ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -16.1

Material Degradation based on Micro-drill [%] 2.3

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

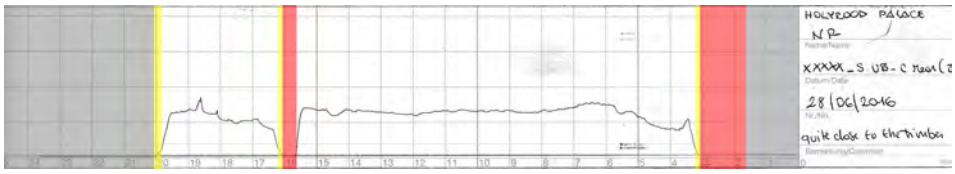
Moisture Content [%] 13.8 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1975 | Higher voltage ☑ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -25

Material Degradation based on Micro-drill [%] 13.3

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

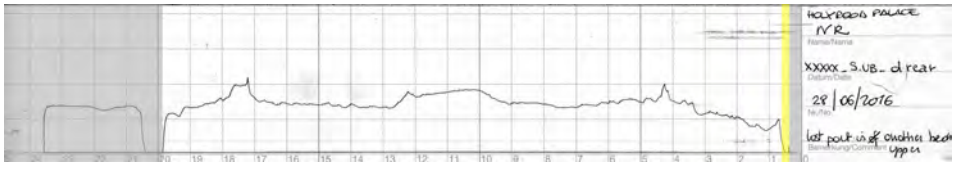
Moisture Content [%] 13.3 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1817 | Higher voltage ☑ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -18.7

Material Degradation based on Micro-drill [%] 1.1

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name XXXXVII | See drawings HP-N-2, HP-N-7

Missing elements S strut | Elements with defects in critical area

Joints with decayed peg | Insect attack N strut & N rafter

Failed joints | Fungi attack

Other redundant dovetail joint on N rafter - S rafter strengthened - efflorescence and wet sarking near N rafter

Element name A north rafter

Dating original construction | Signs of reuse redundant dovetail joint

Timber treated ☑ insecticides, in the 1960s | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 18.7x17.2 | min. size (hxb) [cm] 18.5x17 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☑ Type Anobium Punctatum | Status active

Way of identification Estimated

Fungi attack ☑ Type Unknown | Status unknown

Way of identification

Corrosion ☐ | Wet surface ☑ | Other efflorescence and wet sarking

Mechanical Damage

Type | Status | Role



Insect attack with new bore-dust I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: no section loss, rot is probably superficial

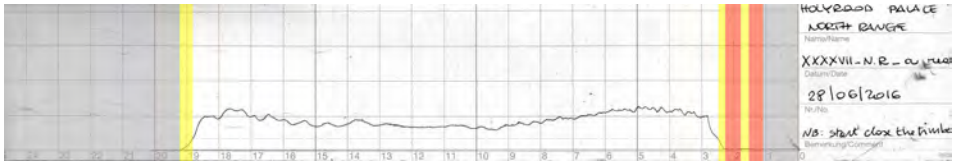
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 19.2
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 9.4
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

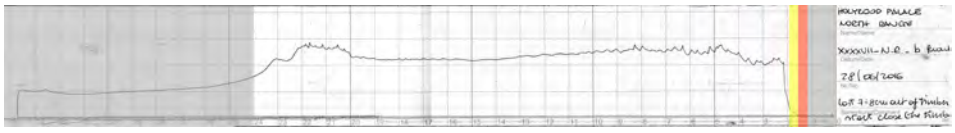


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 17.1
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 3.2
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

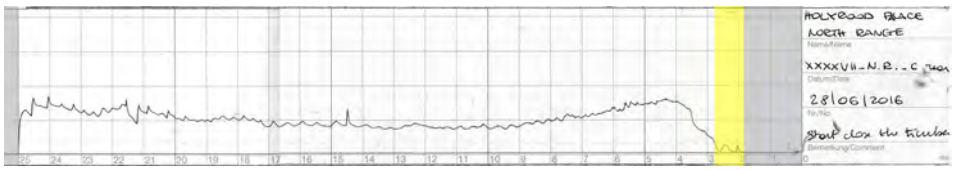


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 15.5
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 3.6
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north strut

Dating: original construction
Signs of reuse:
Timber treated ☑ insecticides, in the 1960s
Accessibilityissues:
Past interventions:
Differences compared to other elements of the same type:
Section: nominal size (hxb) [cm]: 10.6x9.3 min. size (hxb) [cm]: 10x8.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre
Slope of grain [%]:
Knots [min d/section h]:
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☑
Other defects:
Estimated Strength Class according to UNI 11119:

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated
Fungi attack ☐ Type: Status:
Way of identification:
Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type Status Role



Insect attack with new bore-dust I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced up to 2cm all round - internal decay up to 1.5cm wide but confined to sapwood

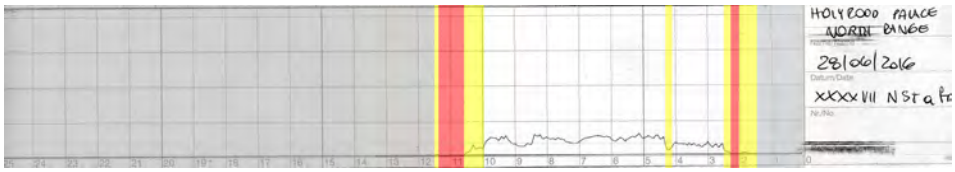
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 15
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 24
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

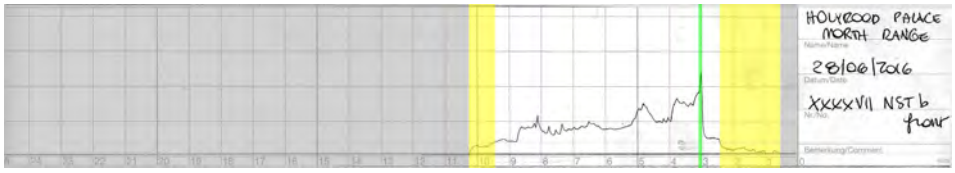


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 14.3
Ultrasonic velocity [m/s]: 1541
Density loss based on ultrasonic test [%]: -7.8
Material Degradation based on Micro-drill [%]: 25
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐

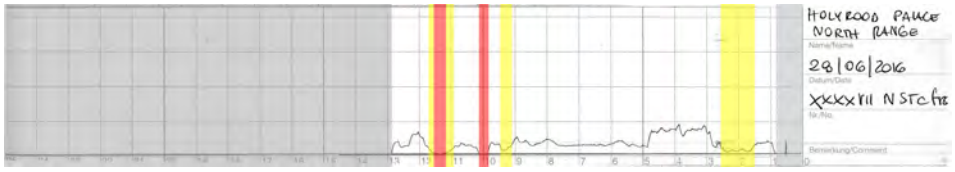


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 15.5
Ultrasonic velocity [m/s]: 1981
Density loss based on ultrasonic test [%]: -25.2
Material Degradation based on Micro-drill [%]: 17
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐

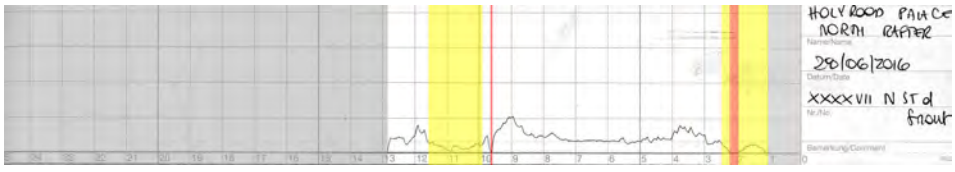


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%]: 16.2
Ultrasonic velocity [m/s]: 2130
Density loss based on ultrasonic test [%]: -31.1
Material Degradation based on Micro-drill [%]: 16.3
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XLIII — See drawings HP-N-2, HP-N-6

Missing elements
Elements with defects in critical area: N & S struts, S rafter
Joints with decayed peg
Insect attack: N & S struts and S upper beam
Failed joints
Fungi attack: N upper beam

Other: N & S rafter lower ends wet and efflorescence on sarking near their lower end - S rafter lower end strengthened

Element name A south rafter

Dating: original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions: Rafter end close to wall strengthened with additional timber

elements on the sides bolted together.

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.4x13.9 min. size (hxb) [cm] 17x12 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] 2.5/19.5 single Knotty element ☑ Defects in critical area ☑ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



Efflorescence near lower end I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other efflorescence on sarking next to lower end

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 12.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1529 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -7.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 13 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2004 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -26.1

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

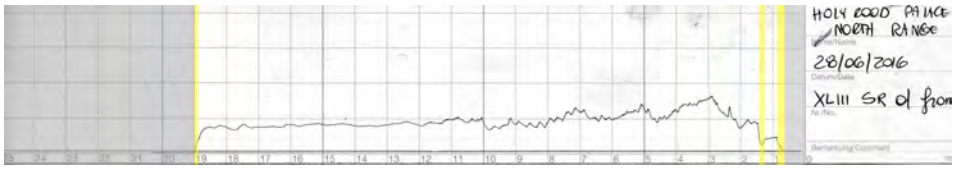
Moisture Content [%] 14.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1261 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] 3.3

Material Degradation based on Micro-drill [%] 2.9

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 14.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1650 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -12.1

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 11.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1886 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -21.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B south strut

Dating original construction Signs of reuse

Timber treated ☑ insecticides, in the 1960s Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.8x9.6 min. size (hxb) [cm] 10.5x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 2.1/11 single Knotty element ☑ Defects in critical area ☑ Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119 lower than III



Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type		Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent internal decay up to 1cm wide and section loss up to 40% (also due to presence of deep checks)

Way of identification NDT/SDT

Insect attack with new bore-dust I:\Arc

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 14.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1461 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -4.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

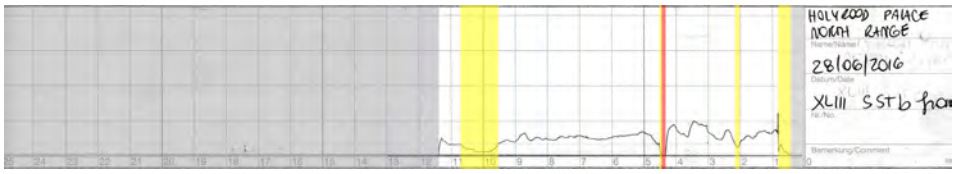
Moisture Content [%] 14 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1658 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -12.4

Material Degradation based on Micro-drill [%] 13.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

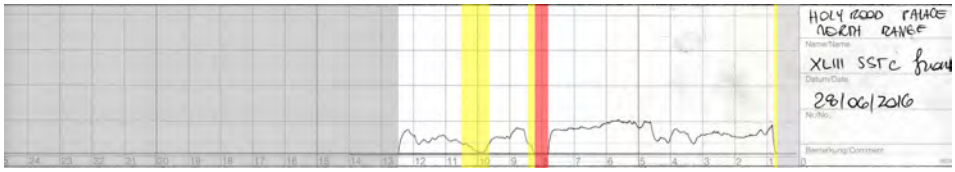
Moisture Content [%] 15.9 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1708 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -14.4

Material Degradation based on Micro-drill [%] 11.6

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C south upper beam

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 16.9x17 min. size (hxb) [cm] 14.5x14.1 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 12 tangential

Knots [min d/section h] 8/18.5 group Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other Section reduced near wall (4.5cm deep 46cm length)



Section reduced I:\Arc

Mechanical Damage

Type		Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2067 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -28.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 15.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1986 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -25.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 16 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1965 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -24.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 17 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2186 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -33.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name D south sprocket rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.2x11.7 min. size (hxb) [cm] 11x16.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 7 tangential

Knots [min d/section h] 2/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other efflorescence on sarking next to timber

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 17.6
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s]: 2361
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]: -40.3
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 17.6
Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s]: 1689
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]: -13.6
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name E north rafter

Dating: original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 20x16 min. size (hxb) [cm]: 15x16.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 12 tangential
Knots [min d/section h]: 5/16 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☑ Other: efflorescence on sarking next to timber

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 14.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2154 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -32

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 14.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2335 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -39.2

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 14.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2014 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -26.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 16.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2184 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -33.2

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 16.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1926 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -23

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1774 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -17

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name F north strut

Dating original construction Signs of reuse

Timber treated ☑ insecticides, in the 1960s

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.4x19.5 min. size (hxb) [cm] 12.1x19.1 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 1.3/11.5 single Knotty element ☑ Defects in critical area ☑ Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119 lower than III



Insect attack, probably old I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum Status non-active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: internal decay up to 2cm wide - in point B half section lost

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

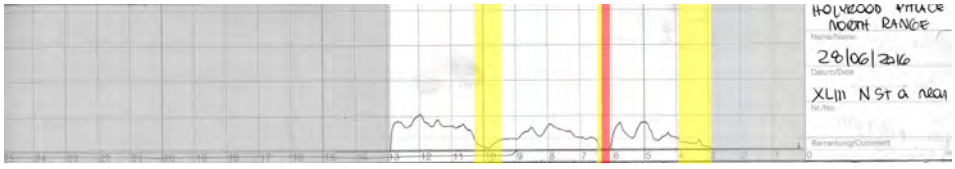
Moisture Content [%] 13.6 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1720 Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -14.9

Material Degradation based on Micro-drill [%] 17.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

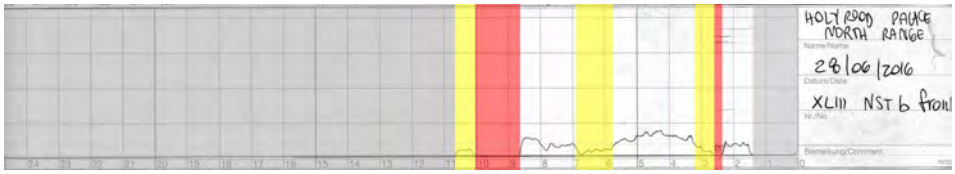
Moisture Content [%] 14.5 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1912 Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -22.5

Material Degradation based on Micro-drill [%] 50.3

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2570 Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -48.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name G north upper beam

Dating original construction Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.7x19.1 | min. size (hxb) [cm] 16.6x19 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 5 | tangential

Knots [min d/section h] 4.3/17.5 | group | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



Fungi attack | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☑ | Type Unknown | Status unknown | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: no section loss, fungi attack is probably superficial or at an early stage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

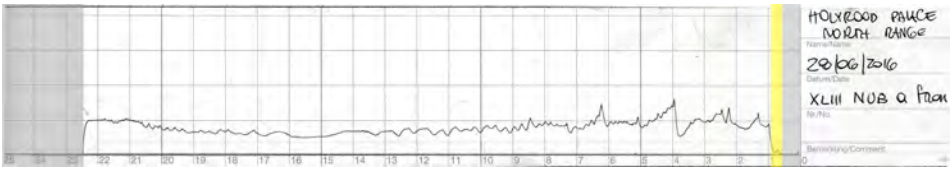
Moisture Content [%] 19.3 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] 2337 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -39.3

Material Degradation based on Micro-drill [%] 1.7

Link to Micro-drill graph I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

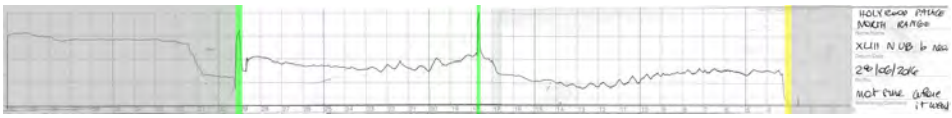
Moisture Content [%] 18.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] 2208 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -34.2

Material Degradation based on Micro-drill [%] 1.1

Link to Micro-drill graph I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name I north sprocket rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.2x11.7 | min. size (hxb) [cm] 10x18 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 5 | tangential

Knots [min d/section h] 3/12 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type | Status | Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

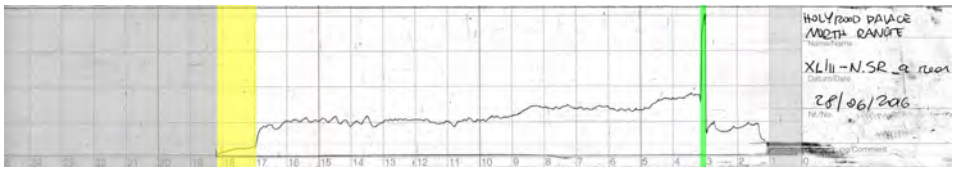
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Mater.Degr. and Damage Extent: No decay/damage
Way of identification: NDT/SDT

Measurement Point a

Moisture Content [%]: 20
Ultrasonic velocity [m/s]: 1733
Density loss based on ultrasonic test [%]: -15.4
Material Degradation based on Micro-drill [%]: 6.1
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

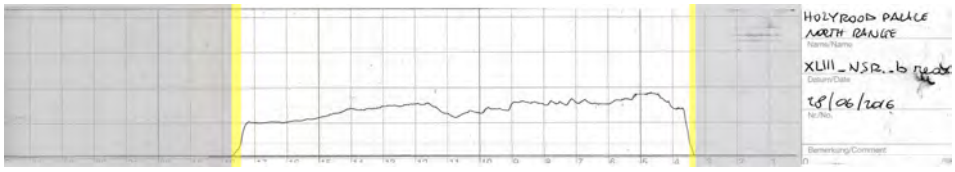


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 18.6
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]: 3.4
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XVIIII — See drawings HP-N-2, HP-N-5

Missing elements: S strut
Elements with defects in critical area: S rafter, S upper beam, N strut, N upper beam
Joints with decayed peg: between S upper beam and rafter
Insect attack: N upper beam
Failed joints
Fungi attack
Other: S rafter lower end strengthened

Element name A south rafter

Dating: original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions: Rafter end close to wall strengthened with additional timber elements on the sides bolted together.

Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 18.5x16.6 min. size (hxb) [cm]: 18x15.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 2 tangential
Knots [min d/section h]: 4/18 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II



strengthened lower end | I:\Arc

Material degradation

Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 11.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 2148 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -31.8

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 11.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1911 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -22.4

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%]: 12.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1765 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -16.6

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

Moisture Content [%]: 11.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1926 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -23

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point e

Moisture Content [%] 14.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2084 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -29.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 14.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2246 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -35.7

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B south upperbeam

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.4x16.4 min. size (hxb) [cm] 16x16 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 12 tangential

Knots [min d/section h] 4.5/18 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 1-3cm all around

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

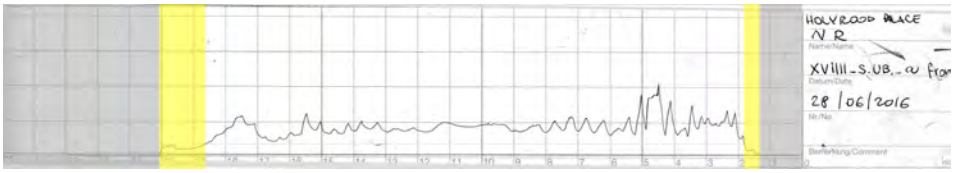
Moisture Content [%] 13.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 8.1

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

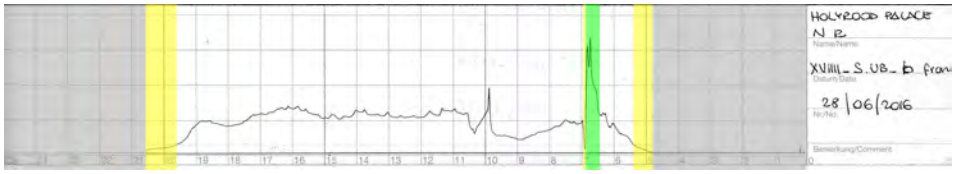
Moisture Content [%] 13.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 9.5

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

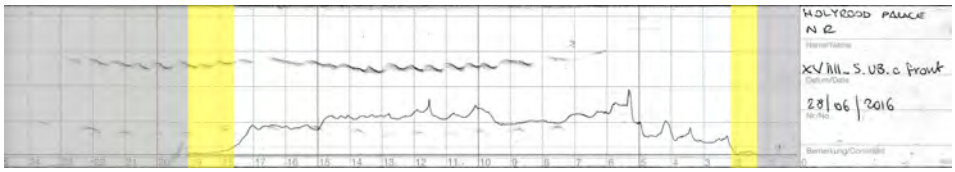
Moisture Content [%] 13.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 11.9

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

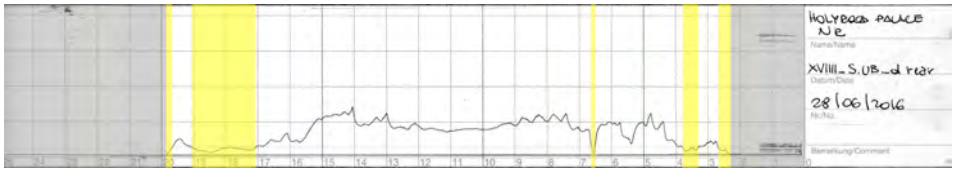
Moisture Content [%] 15.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 14.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name C south sprocket rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 14.8x10.5 | min. size (hxb) [cm] 13.5x10 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 5 | tangential

Knots [min d/section h] 2.5/14 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage | Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1458 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -4.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 14.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1502 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -6.2

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name D north rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.5x15.9 min. size (hxb) [cm] 16.5x15 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 8 tangential

Knots [min d/section h] 3/16.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification NDT/SDT

Measurement Point a

Moisture Content [%] 14.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1966 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -24.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2836 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -59

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 15.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2342 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -39.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 17.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1619 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -10.9

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1876 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -21

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1747 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -16

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name E north strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12x10.7 min. size (hxb) [cm] 11x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 6/12 group Knotty element ☑ Defects in critical area ☑ Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119: lower than III

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: internal decay up to 2cm wide but confined to sapwood

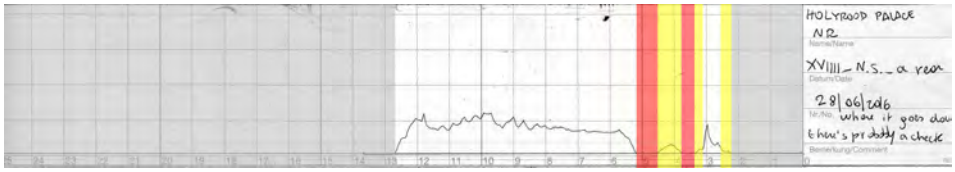
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 15.7
Ultrasonic velocity [m/s]: 1338
Density loss based on ultrasonic test [%]: 0.3
Material Degradation based on Micro-drill [%]: 20.8
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 15.3
Ultrasonic velocity [m/s]: 1629
Density loss based on ultrasonic test [%]: -11.3
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 14.9
Ultrasonic velocity [m/s]: 1848
Density loss based on ultrasonic test [%]: -19.9
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name F north upper beam

Dating: original construction
Signs of reuse
Timber treated ☑: insecticides, in the 1960s
Past interventions
Accessibilityissues: one face is close to the wall and is not well visible
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 19.2x18.5 min. size (hxb) [cm]: 18.5x18 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 6 tangential
Knots [min d/section h]: 3/17 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type		Status	Role
Deformation	☐		
Cracks	☐		
Crushing	☐		
Other	☐		

Estimated level of damage

Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced 3cm on one side and internal decay up to 1cm wide

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.6

Ultrasonic velocity [m/s]

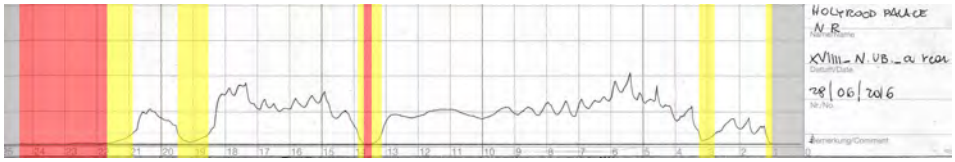
Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%] 23.6

Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]

Ultrasonic velocity [m/s]

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name G north sprocket rafter

Dating later Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 20x8.5 min. size (hxb) [cm] 19.5x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 4 tangential

Knots [min d/section h] 2/20 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 | I

Material degradation

Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 17.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1463 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -4.7

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

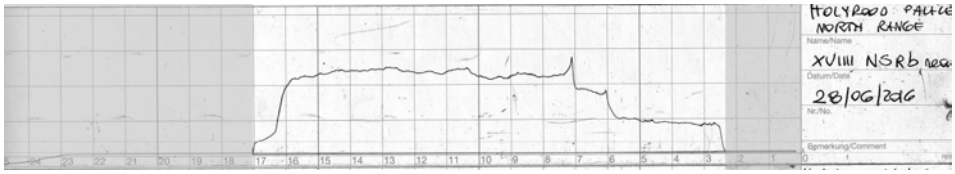
Moisture Content [%]: 18.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1705 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -14.3

Material Degradation based on Micro-drill [%]: 0

Link to Micro-drill graph: I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name XLII | See drawings HP-N-2, HP-N-10

Missing elements | Elements with defects in critical area: N strut

Joints with decayed peg | Insect attack: N strut

Failed joints | Fungi attack

Other: S rafter lower end strengthened - efflorescence on sarking close to upper end of N rafter

Element name A north strut

Dating: original construction | Signs of reuse

Timber treated ☑: insecticides, in the 1960s | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 11.3x9 | min. size (hxb) [cm]: 11x8.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119



insect attack, probably old | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: non-active
Way of identification: Estimated

Fungi attack ☐ Type: Status:
Way of identification:

Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type		Status	Role
Deformation	☐		
Cracks	☐		
Crushing	☐		
Other	☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: section reduced up to 40%, not only superficiallly (also due to the presence of deep checks)

Way of identification: NDT/SDT

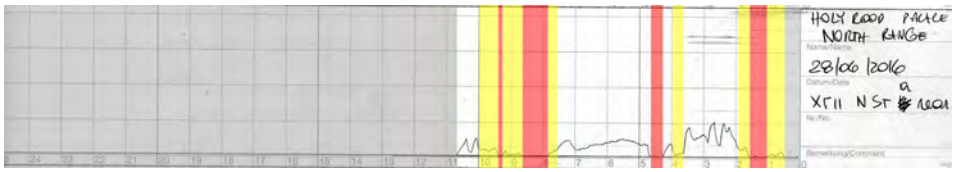
Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%]: 16.2
Ultrasonic velocity [m/s]: 1618
Density loss based on ultrasonic test [%]: -10.8
Material Degradation based on Micro-drill [%]: 40.3
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐

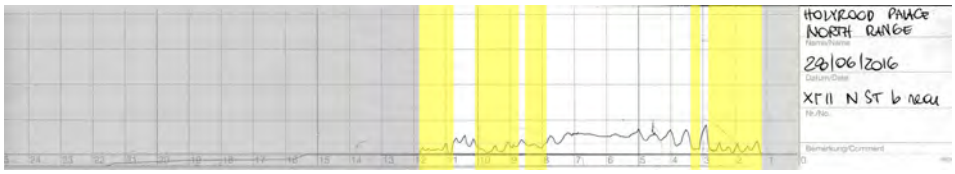


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 14.9
Ultrasonic velocity [m/s]: 1816
Density loss based on ultrasonic test [%]: -18.7
Material Degradation based on Micro-drill [%]: 32.3
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

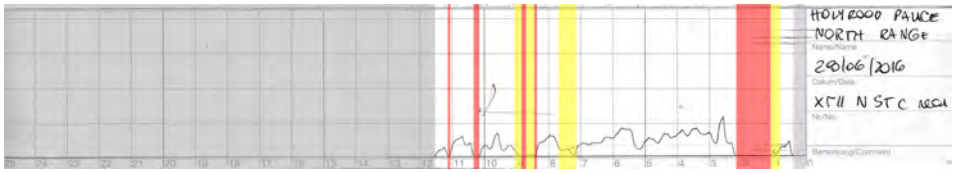


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 16
Ultrasonic velocity [m/s]: 1796
Density loss based on ultrasonic test [%]: -17.9
Material Degradation based on Micro-drill [%]: 24.2
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

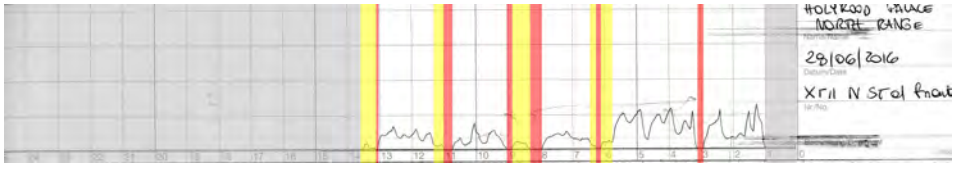


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%]: 15.7
Ultrasonic velocity [m/s]: 1577
Density loss based on ultrasonic test [%]: -9.2
Material Degradation based on Micro-drill [%]: 6.8
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XXXII — See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between N & S upper beam and rafter | Insect attack

Failed joints | Fungi attack

Other

Frame/Truss name not visible 1 — See drawing HP-N-2

Missing elements: S strut | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other: S rafter lower end strengthened - additional S strut

Frame/Truss name XXXXV — See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other: S upper beam partially strengthened

Frame/Truss name XXXXIV — See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between N upper beam and rafter | Insect attack

Failed joints | Fungi attack

Other: S rafter lower end reinforced and efflorescence on sarking next to it

Frame/Truss name XLI — See drawing HP-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between N upper beam and rafter | Insect attack

Failed joints | Fungi attack: S upper beam

Other: S rafter strengthened and efflorescence on sarking close to its lower end

Element name south upper beam

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



Material degradation

Insect attack ☐ | Type | Status

Way of identification

Fungi attack ☑ | Type: Unknown | Status: unknown

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role | unidentified fungi | I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: Probably superficial

Way of identification: visual inspection

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Frame/Truss name LX — See drawing HP-N-2

Missing elements
Elements with defects in critical area
Joints with decayed peg: between N upper beam and rafter
Insect attack
Failed joints
Fungi attack
Other: S rafter and upper beam twisted - S rafter lower end strenghtened - efflorescence on sarking near S rafter lower end

Frame/Truss name XXXIX — See drawing HP-N-2

Missing elements
Elements with defects in critical area
Joints with decayed peg: between N & S upper beam and rafter
Insect attack
Failed joints
Fungi attack
Other: wound on S upper beam

Connection name between S upper beam and rafter — FrameTrussCode: HP-N-XXXIX

Mechanical Damage:

	Type	Status	Role
Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary

Estimated causes of primary damage:
Poor design ☐
Poor maintenance ☐
External actions ☐
Material degrad. ☐
Poor construction ☐
Past interventions ☐
Other ☑ hammering

Description: broken peg



peg broken due to hammering | I:\Ar

Estimated damage level: rupture
Emergency intervention needed ☐

Frame/Truss name XXXVIII — See drawing HP-N-2

Missing elements
Elements with defects in critical area
Joints with decayed peg: between N upper beam and rafter
Insect attack
Failed joints: between S upper beam and rafter
Fungi attack
Other

Connection name between S upper beam and rafter — FrameTrussCode: HP-N-XXXVIII

Mechanical Damage: Type | Status | Role

Splitting: shear failure along grain	☑	unknown	primary
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☐		



open joint, peg too short | I:\Ar

Estimated causes of primary damage:

Poor design ☑ fastener too small
Poor maintenance ☐
External actions ☐
Material degrad. ☑
Poor construction ☐
Past interventions ☐
Other ☐

Description: joint open probably because peg is too short

Estimated damage level: rupture
Emergency intervention needed ☐

Frame/Truss name XV | See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg: between S upper beam and rafter | Insect attack
Failed joints | Fungi attack
Other

Frame/Truss name XXXV | See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg: between N upper beam and rafter | Insect attack
Failed joints | Fungi attack
Other: new S strut

Frame/Truss name XXI | See drawing HP-N-2

Missing elements | Elements with defects in critical area: S rafter
Joints with decayed peg: between S upper beam and rafter | Insect attack
Failed joints | Fungi attack
Other: 8cm deep check on one side of S rafter

Connection name between S upper beam and rafter | FrameTrussCode: HP-N-XXI

Mechanical Damage: Type | Status | Role

Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	unknown



broken peg | I:\Ar

Estimated causes of primary damage:

Poor design ☐
Poor maintenance ☐
External actions ☐
Material degrad. ☑
Poor construction ☐
Past interventions ☐
Other ☐

Description: broken peg

Estimated damage level: rupture
Emergency intervention needed ☐

Frame/Truss name XXXI | See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg: between N upper beam and rafter | Insect attack
Failed joints | Fungi attack
Other

Frame/Truss name XXX | See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: new S strut and additional vertical pole to support rooflight

Frame/Truss name XXVIIII — See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: old humidity stains on N upper beam - new S strut and additional vertical pole to support rooflight

Frame/Truss name XXVIII — See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: new S strut and additional vertical pole to support rooflight

Frame/Truss name IIVXX — See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: new S strut

Frame/Truss name XXVI — See drawing HP-N-2

Missing elements | Elements with defects in critical area: S rafter
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: 8cm deep check on one side of S rafter

Frame/Truss name XXIIII — See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: S upper beam slightly wet

Frame/Truss name XVI — See drawing HP-N-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack: N rafter
Other

Element name A north rafter

Dating: original construction | Signs of reuse
Timber treated ☐ | Accessibilityissues
Past interventions
Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location | Slope of grain [%] | Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☑ Type: Unknown | Status: unknown | Way of identification

Corrosion ☐ | Wet surface ☐ | Other



fungi attack unidentified | I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Frame/Truss name XXXVII | See drawing HP-N-2

Missing elements | Elements with defects in critical area

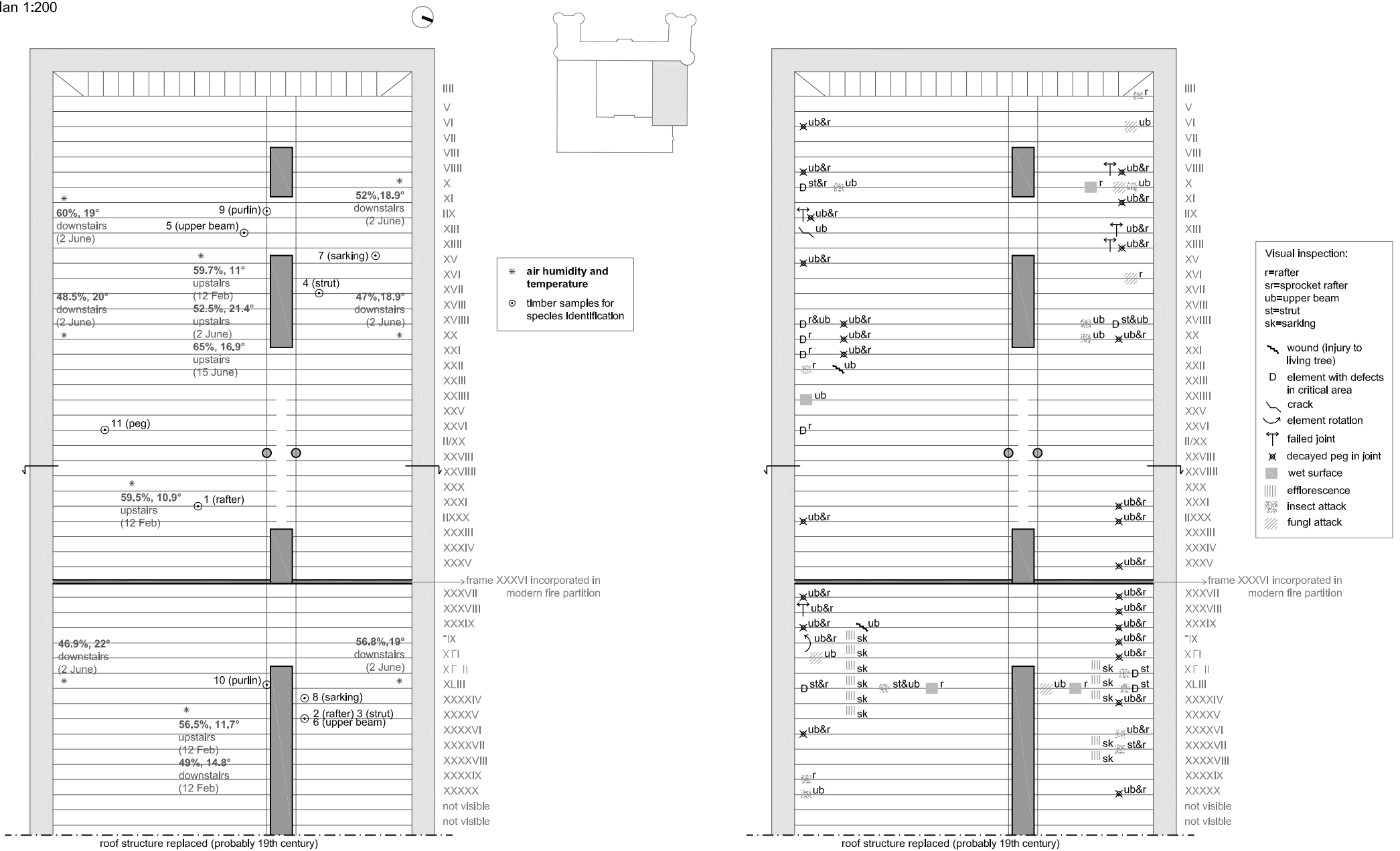
Joints with decayed peg: between N & S upper beam and rafter | Insect attack

Failed joints | Fungi attack

Other

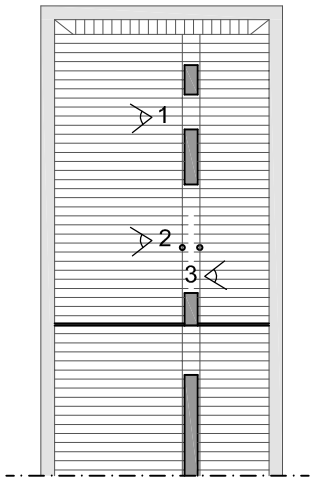
Building Name: Holyrood Palace
Drawing HP-N-2
Roof Location: N range
ANNA SERAFINI
PhD thesis
Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou
Architecture Department, University of Strathclyde
829

Plan 1:200



Themographic images

Plan 1:500



1: areas with higher temperature reveal where the insulation sheets are missing and therefore the heat come up from the attic spaces



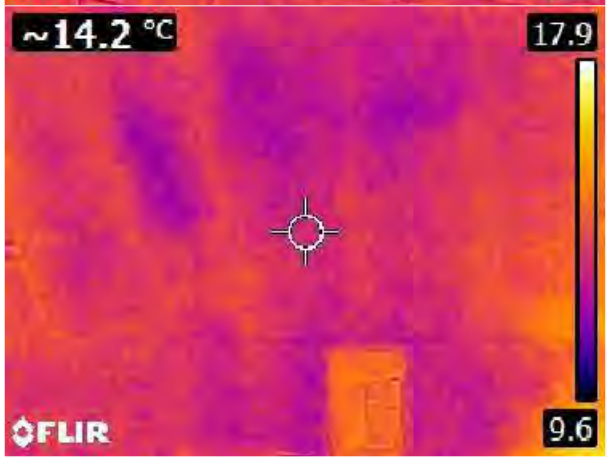


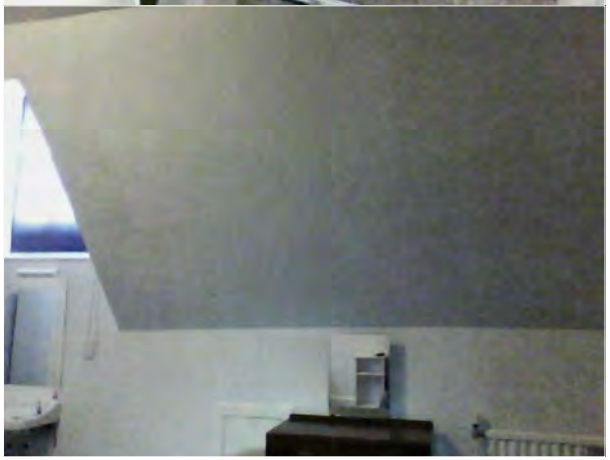
2: areas with higher temperature reveal where the insulation sheets are missing and therefore the heat comes up from the attic spaces





3: areas with higher temperature show the position of the rafters behind the plaster in the attic spaces

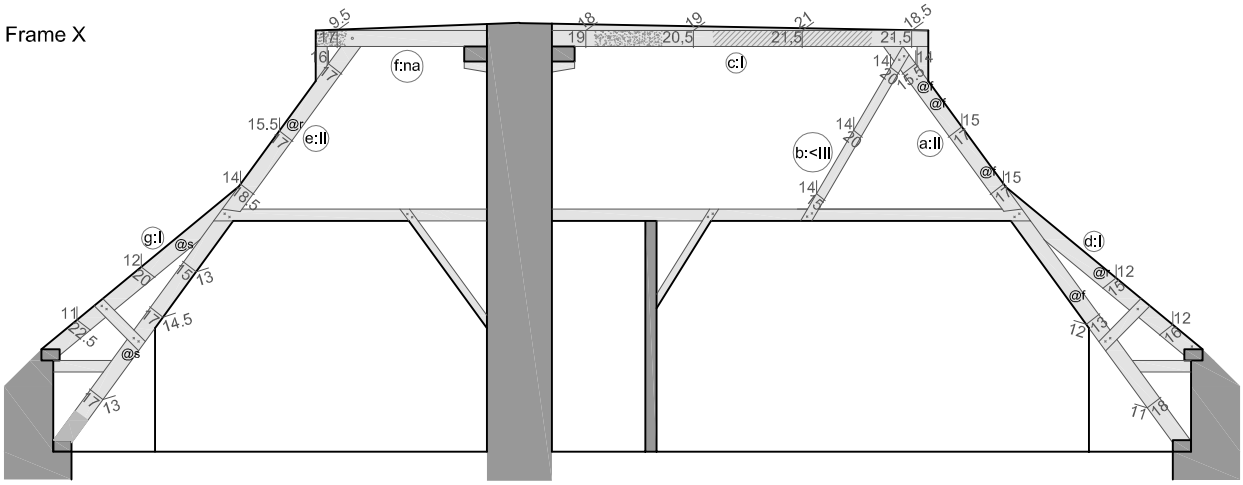




Sections 1:100 (looking East)

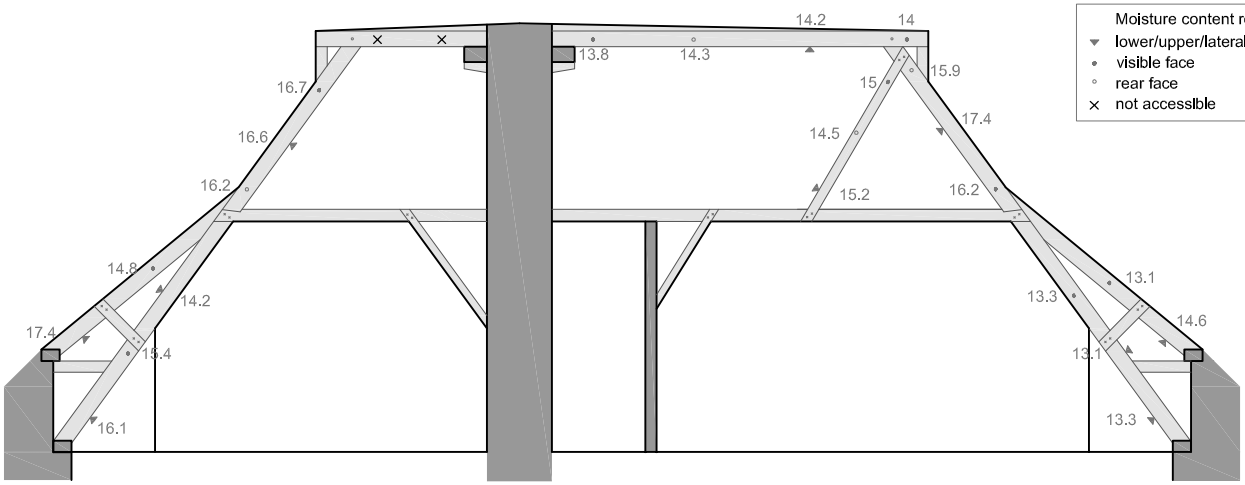
Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (Injury to living tree)
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

Frame X



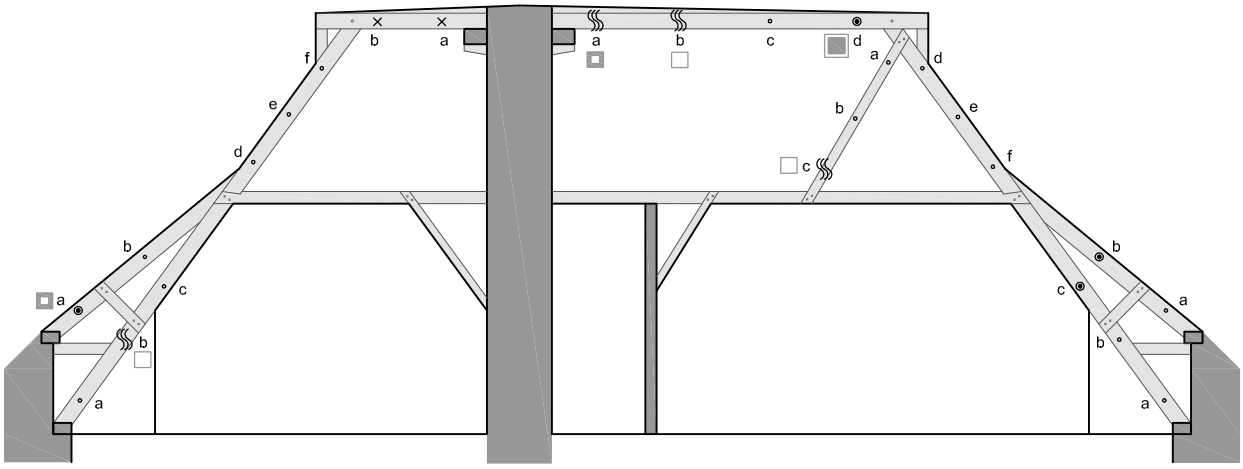
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20



Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & Int. decay
- extensive decay

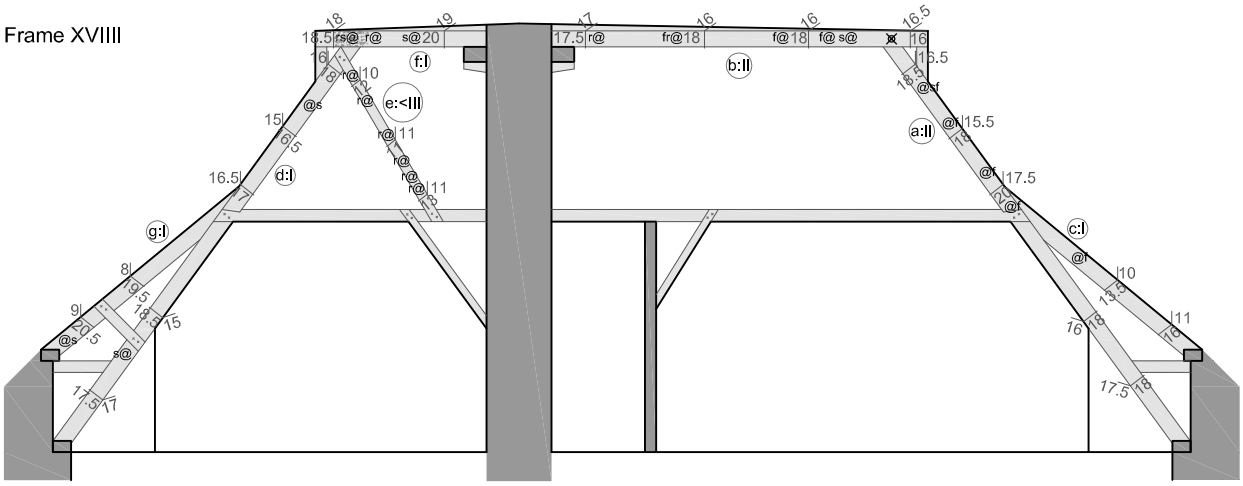


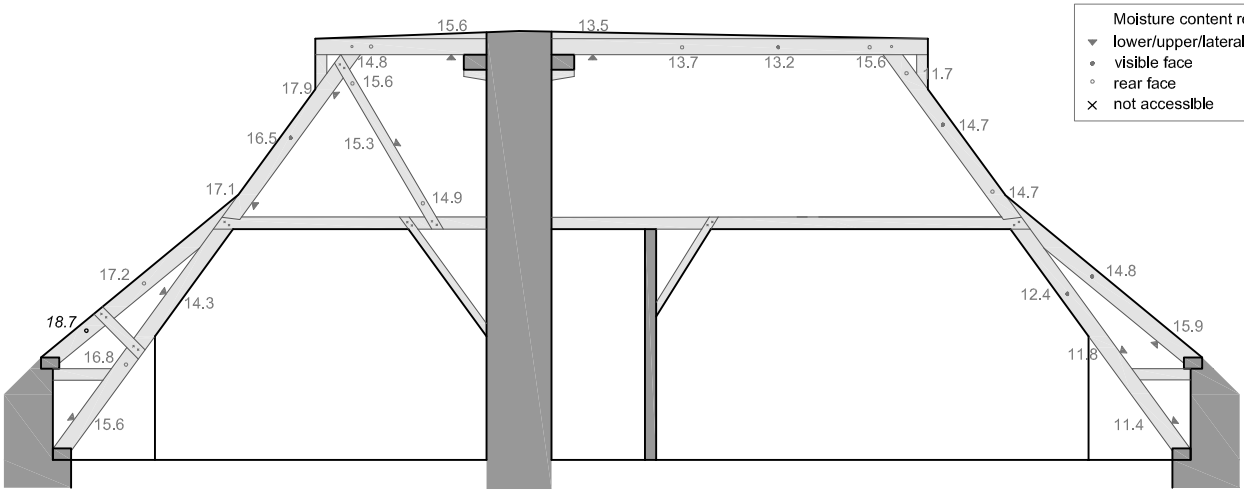
0 1 5

Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (Injury to living tree)
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

Frame XVIIII



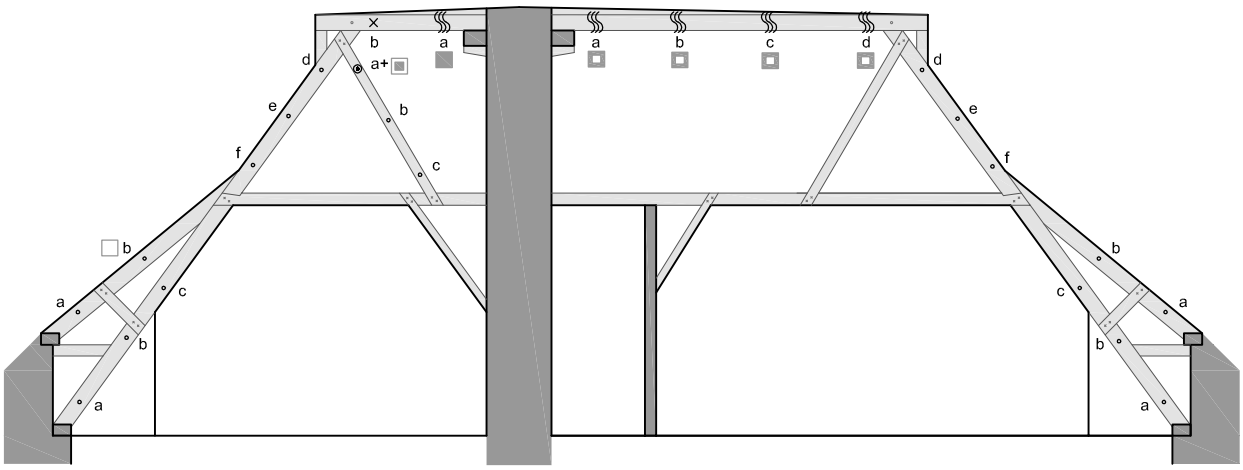


Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20

Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & Int. decay
- extensive decay

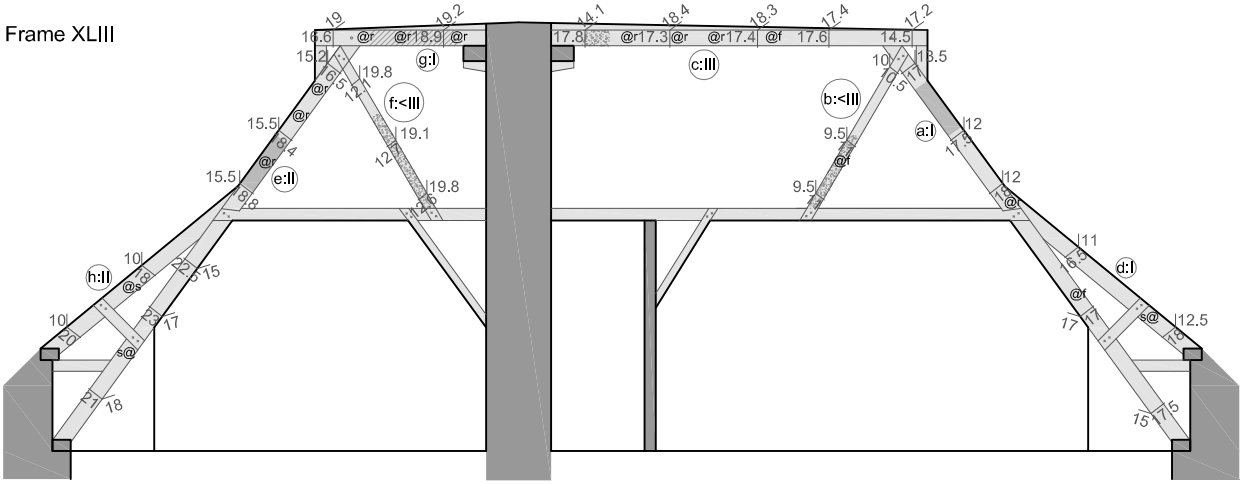


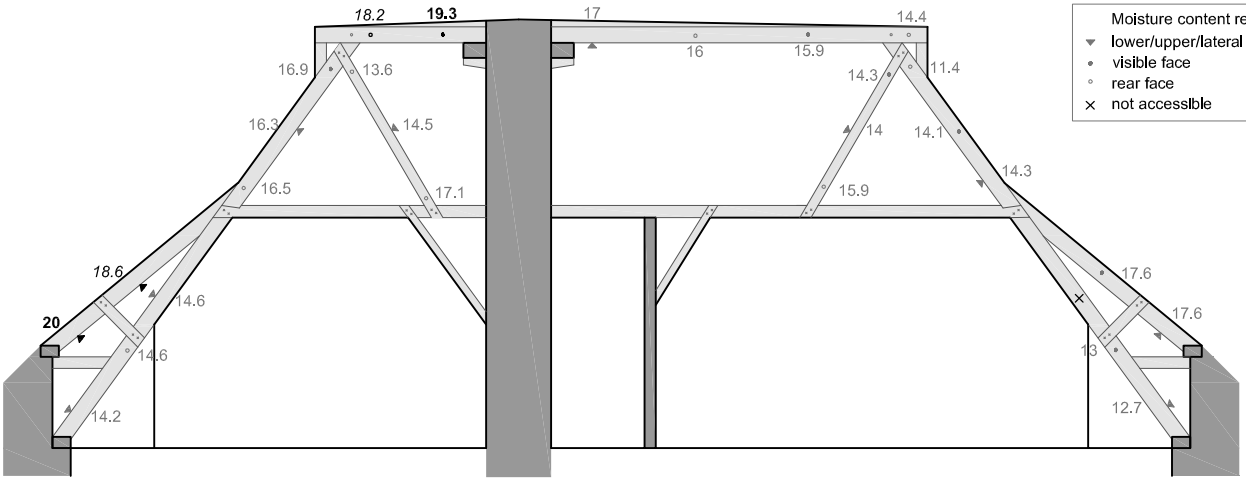
0 1 5

Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (Injury to living tree)
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

Frame XLIII



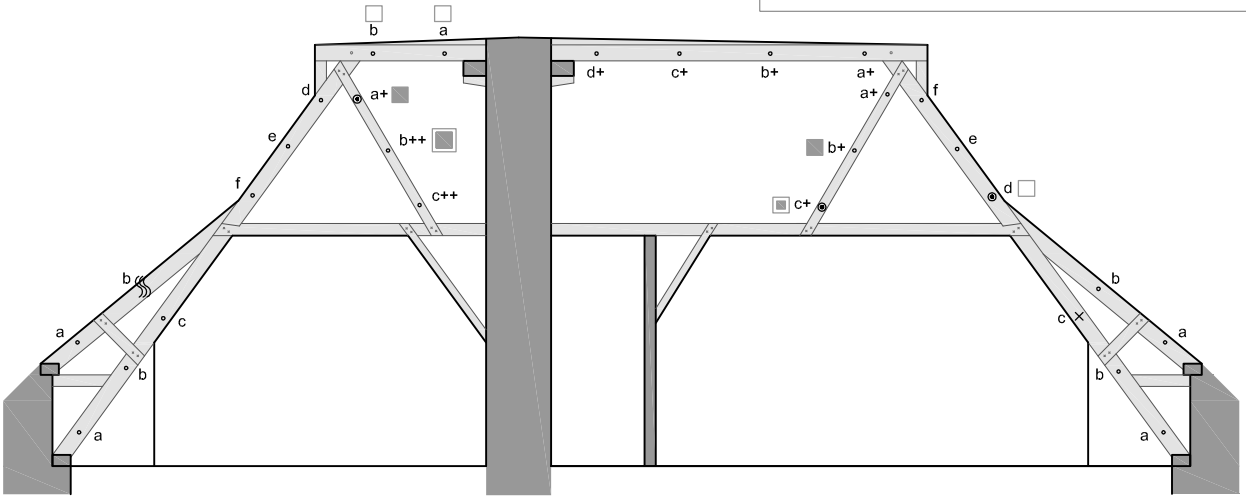


Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20

Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & Int. decay
- extensive decay



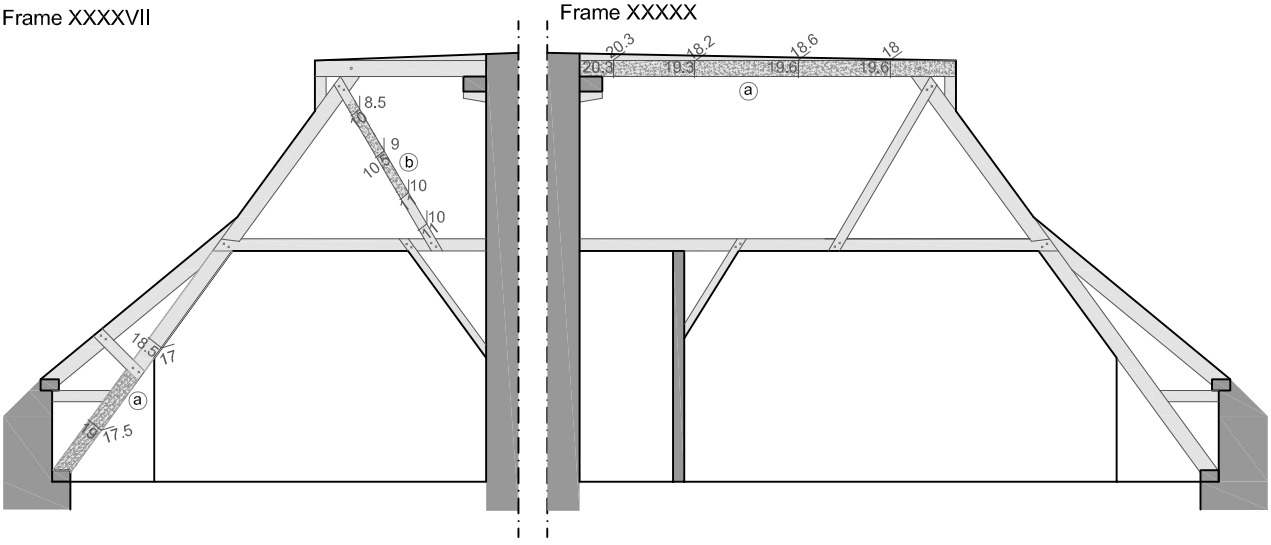
0 1 5

Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (Injury to living tree)
- crack
- element rotation
- open joint
- (x) element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

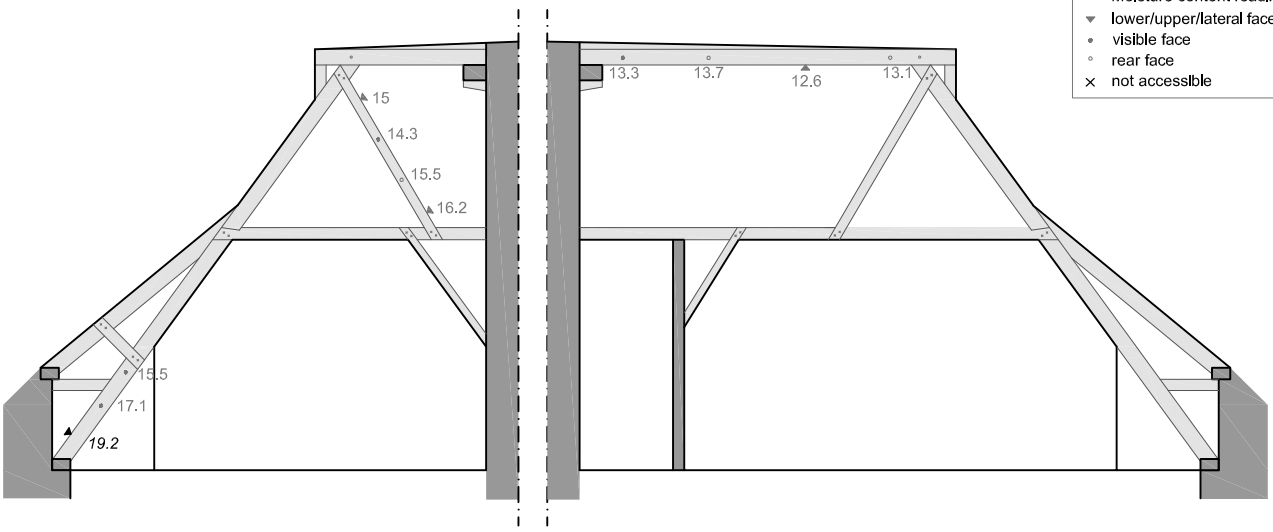
Frame XXXXVII

Frame XXXXX



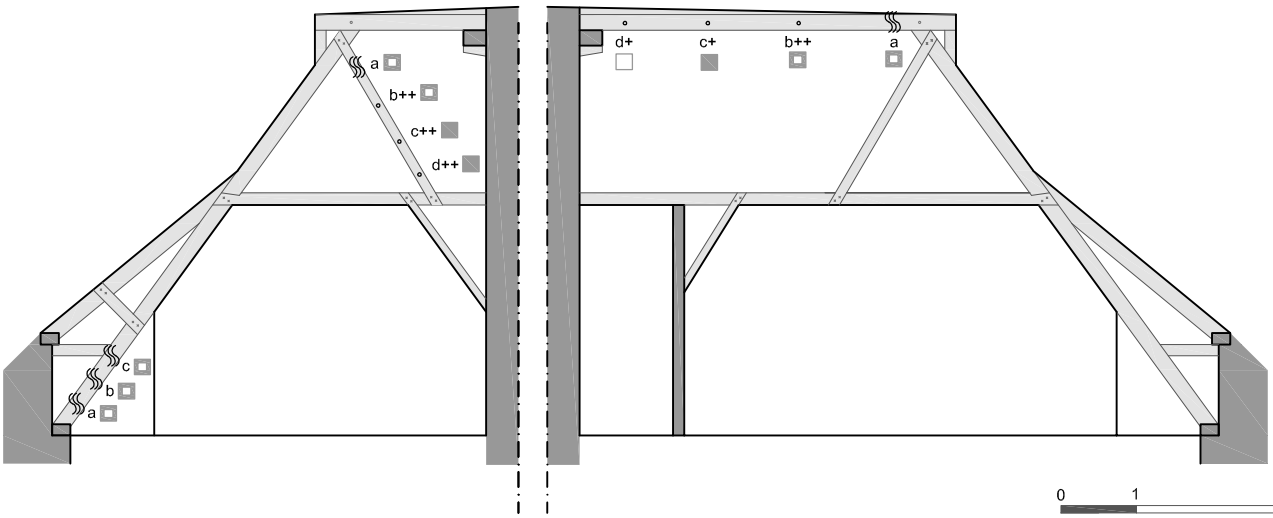
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20



Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & Int. decay
- extensive decay

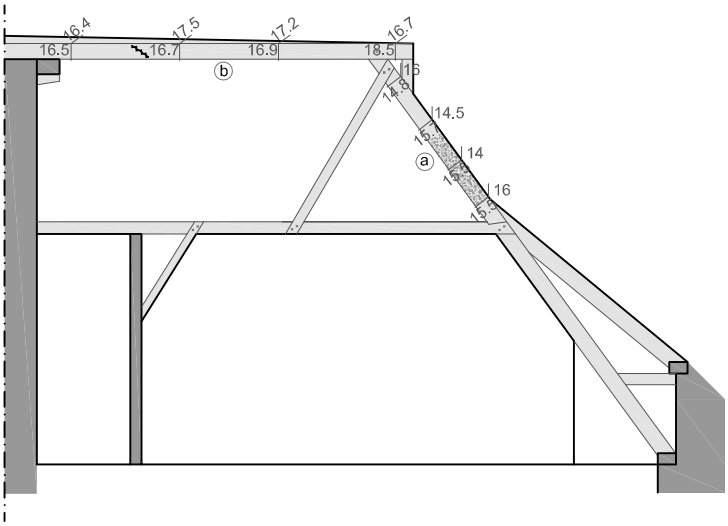


0 1 5

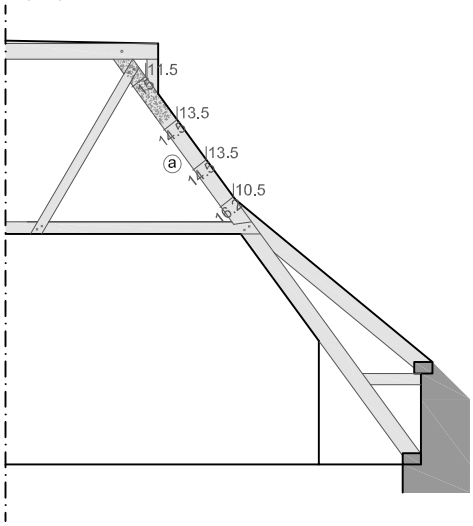
Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (Injury to living tree)
- crack
- element rotation
- open joint
- (x) element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

Frame XXII

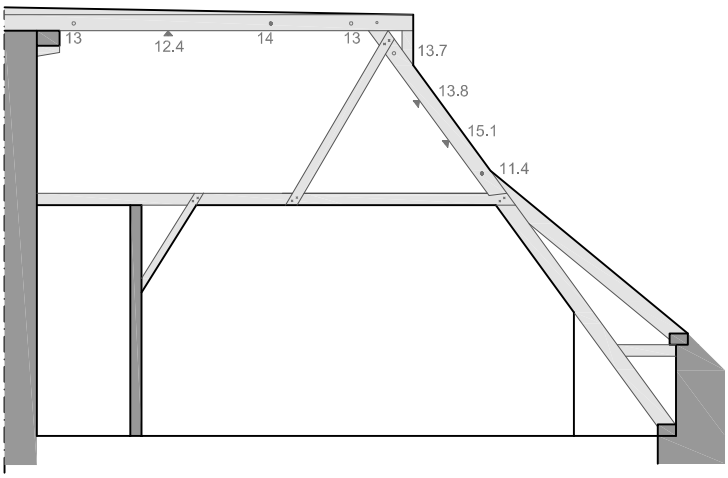


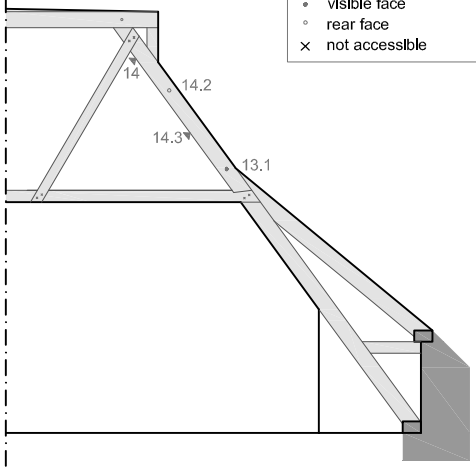
Frame XXXXIX



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

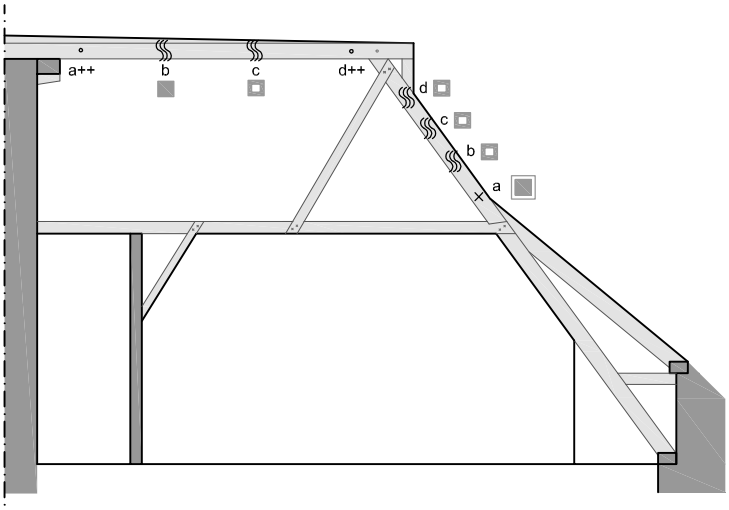
readings <18
readings >18
readings >20

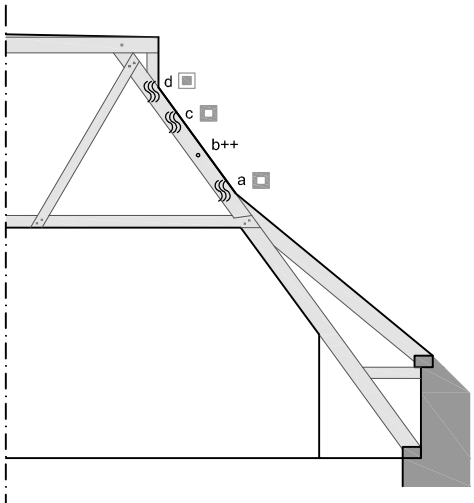




Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & Int. decay
- extensive decay





0 1 5

Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- element name
- wet surface
- efflorescence
- decayed peg
- Insect attack
- fungi attack

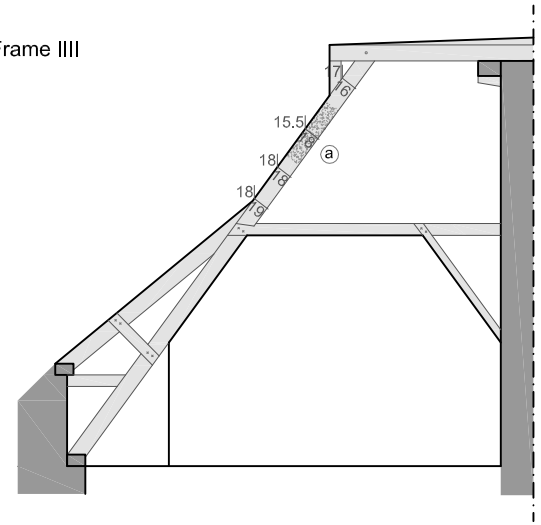
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

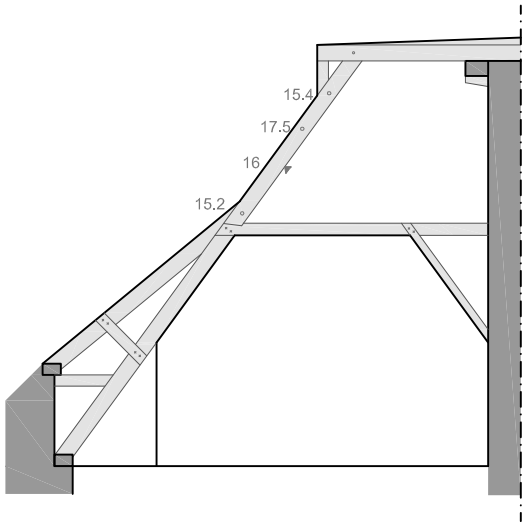
readings <18
readings >18
readings >20

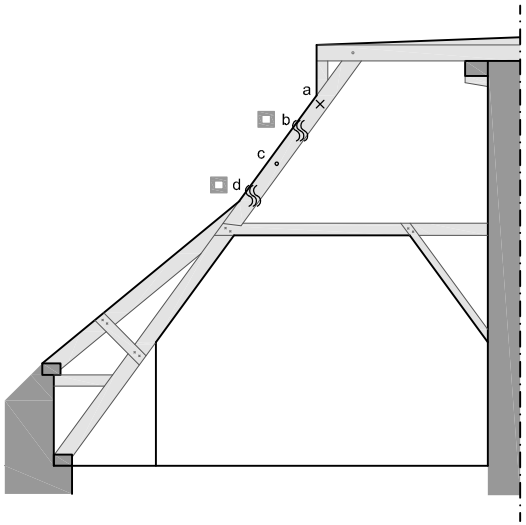
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- Internal decay
- ext. & int. decay
- extensive decay

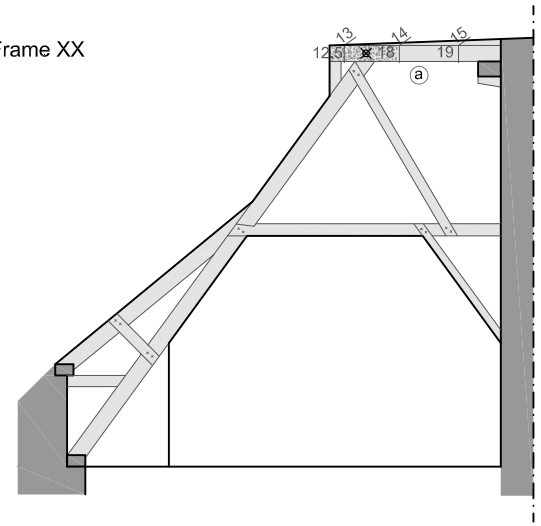
Frame IIII

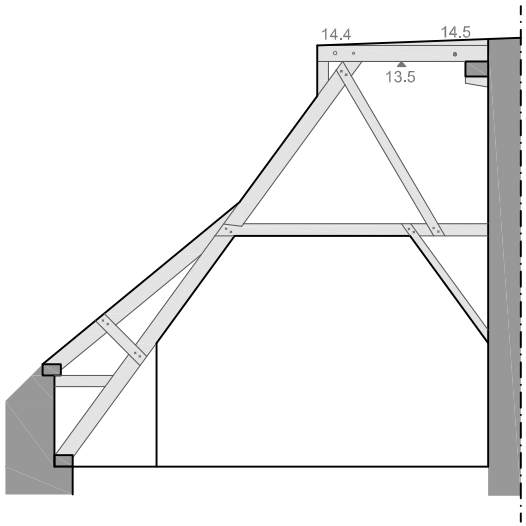


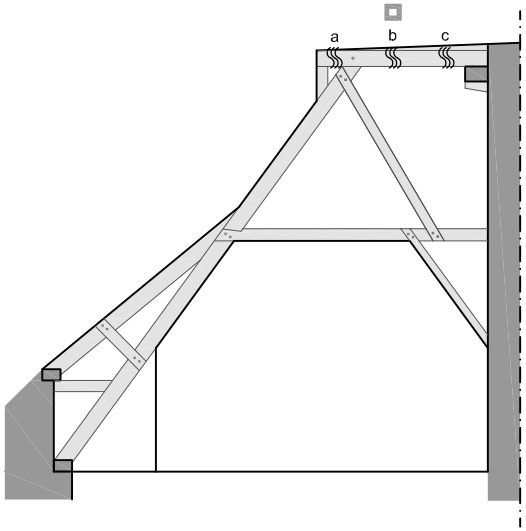




Frame XX







0 1 5

Sections 1:100 (looking East)

Visual inspection:
- highly inclined slope of grain
- big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

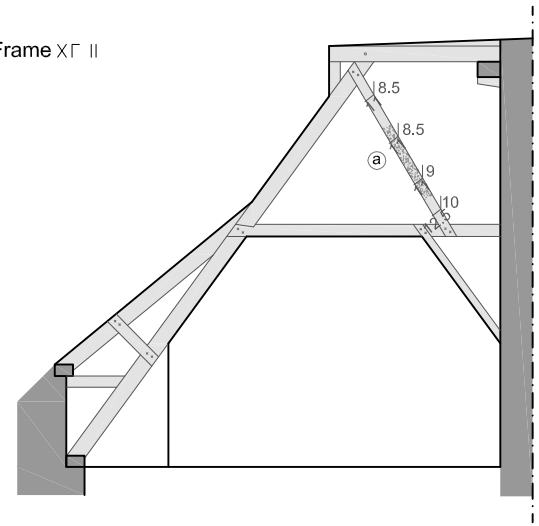
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

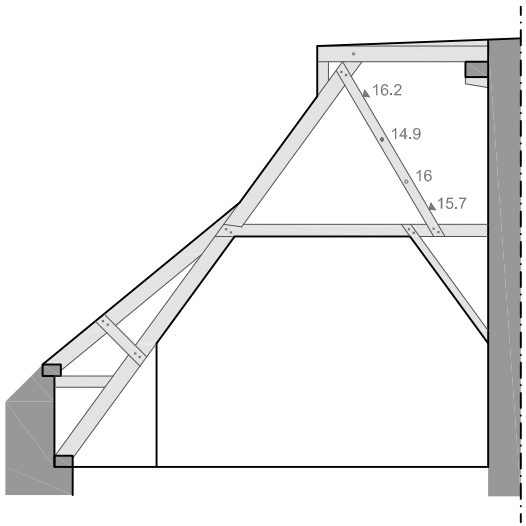
readings <18
readings >18
readings >20

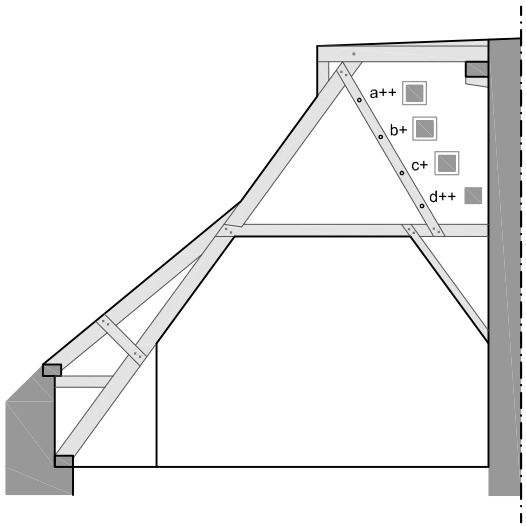
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & int. decay
- extensive decay

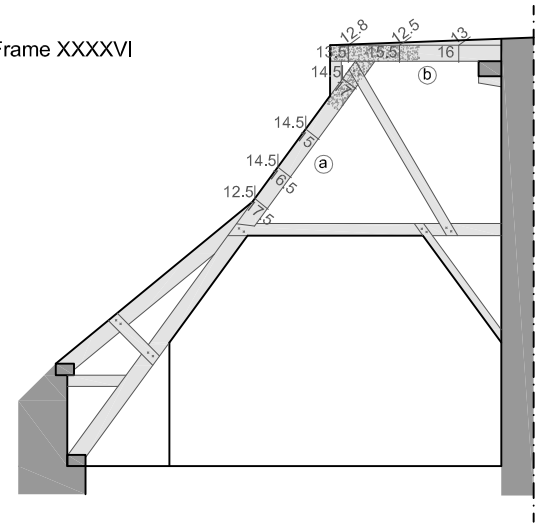
Frame XΓ II

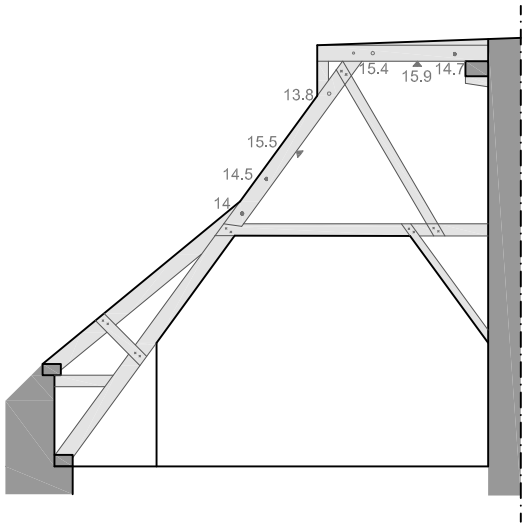


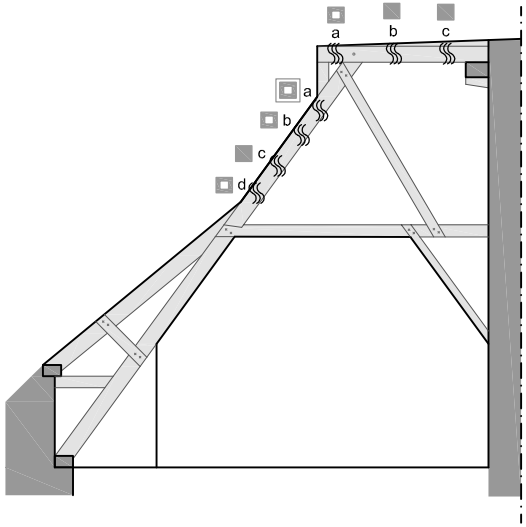




Frame XXXXVI







0 1 5

NEWHAILES HOUSE

Location: EAST LOTHIAN | INVERESK (EAST LOTHIAN)

X coordinate: 332781 Y coordinate: 672626

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PUBLIC

Rcahms ID: 53819

HS Listing: A

Original Use: Residential

Current Use: Museum

Freestanding: ☑ N. of floors above ground level: 4 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1686	1719	CENTRE BLOCK, CALLED WHITEHILL - JOE ROCK THINKS THERE WAS A RUIN TO THE NORTH WEST OF WHITEHILL (ABOUT 8 FEET FROM THE HOUSE), WHICH WAS LATER INCORPORATED IN THE HOUSE WHEN THE WEST WING WAS ADDED - ACCORDING TO JOE ROCK THE CONSTRUCTION OF WHITEHILL WA	BUILDINGS OF SCOTLAND COLLECTION & JOE ROCK WEBSITE

People involved:

Last Name	First Name	Role	Attributed
SMITH 1	JAMES 1	ARCHITECT, COMMISSIONERPATRON	☐
ANTONIUS	HENRY	WRIGHT	☐
MCLELLAN	JAMES	WRIGHT	☑
CAMPBELL	ROBERT	SMITH	☑
RAMSAY	ALEXANDER	GLAZIER	☑
HART	EDWARD NED	WRIGHT	☐
DAVIDSON	JAMES	MASON	☐
ISAAC	EDWARD	WRIGHT	☐
YOUNG	JOHN	MATERIAL SUPPLIER, WRIGHT	☐
CLARK	JOHN	PAINTER	☐
SUTHERLAND	JAMES	MERCHANT	☐
STEWART	PATRICK	MERCHANT	☐
CRIGHTON	JAMES	MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1717	1723	SOUTHEAST WING (LIBRARY) ADDED - INTERIORS: NEW STAIRCASE (NOW DEMOLISHED) AND HALL - HOUSE CALLED NEWHAILES FROM 1709	JOE ROCK WEBSITE & BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
GIBBS	JAMES	ARCHITECT	☑
ADAM	WILLIAM	ARCHITECT	☑
YOUNG	JOHN	WRIGHT	☐
BUCHANAN	JAMES	PLASTERER	☐
MACKENZIE	GEORGE	MERCHANT	☐
SIMPSON	GEORGE	GLAZIER	☐
SMITH 1	JAMES 1	ARCHITECT	☑
CRIGHTON	JAMES	MASON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1733	1751	NORTHWEST WING (STATE APARTMENT) ADDED, INCORPORATING THE RUIN - REVERSED THE ORIENTATION OF THE HOUSE WITH A DRIVEWAY FROM THE SOUTH ENTERING	JOE ROCK WEBSITE

THROUGH NEW STONE GATE PIERS - LIBRARY FINISHED - INTERIOR DECORATIONS

People involved:

Last Name	First Name	Role	Attributed
KENT	WILLIAM	ARCHITECT	☑
CRIGHTON	JAMES	MASON	☐
CLAYTON	THOMAS	PLASTERER	☐
NORIE	JAMES	PAINTER	☐
STRACHAN	WILLIAM	CARVER	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1907		NOT SPECIFIED	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2000		NOT SPECIFIED	JOE ROCK PERSONAL COMMENT

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	85
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	86
JOE ROCK WEBSITE		☐	HTTPS://SITES.GOOGLE.COM/SITE/NEWHAILESNEWRESEARCH/HOM	
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	

ARCHIVAL REFERENCES

Archive	Doc.Num.	Folios	Title
National Library of Scotland	MS 25818	42	Newhailes Estate Papers: account of John Young wright 1720
National Library of Scotland	MS 25818	50	Newhailes Estate Papers: account of John Young wright 1718
National Library of Scotland	MS 25818	49	Newhailes Estate Papers: account of Andrew Cuthbertson slater 1721
National Library of Scotland	MS 25837	157	Newhailes Estate Papers: account of timber 1723-4
National Library of Scotland	MS 25837	109	Newhailes Estate Papers: account of timber John Young wright 1722
National Library of Scotland	MS 25837	88	Newhailes Estate Papers: account of John Young wright 1721-2
National Library of Scotland	MS 25837	15	Newhailes Estate Papers: account of John Young wright 1722
National Library of Scotland	MS 25837	78	Newhailes Estate Papers: account of John Young wright 1722
National Library of Scotland	MS 25837	75	Newhailes Estate Papers: account of John Young wright 1722
National Library of Scotland	MS 25837	53	Newhailes Estate Papers: account of Jon Wilson 1722
National Library of Scotland	MS 25837	55	Newhailes Estate Papers: account of Jon Wilson 1722
National Library of Scotland	MS 25837	35	

Title	Newhailes Estate Papers: account of John Young wright 1722				
Archive	National Library of Scotland	Doc.Num.	MS 25837	Folios	81
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25833	Folios	222
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25834	Folios	9
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25783	Folios	77
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25834	Folios	36
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25834	Folios	139
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25834	Folios	113
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25834	Folios	117
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25834	Folios	110
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25835	Folios	82
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25783	Folios	144
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	43
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	87
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	206
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	224
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25791	Folios	95
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	208
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	236
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25836	Folios	237
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25837	Folios	43
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25837	Folios	101
Title	Transcription of Joe Rock				
Archive	National Library of Scotland	Doc.Num.	MS 25837	Folios	131
Title	Transcription of Joe Rock				

Archive	National Library of Scotland	Doc.Num.	MS 25837	Folios	140
Title	Transcription of Joe Rock				

Suggestions for further research	

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive	National Library of Scotland	Doc. Num.	MS 25833	Folios	222
Title	Transcription of Joe Rock	Date: from	1709	to	
Contents	3 September: 'I Edward Isaate [Isaac], wright in Preston pans grants me to have received from John Adams, in name for his magisties Advocate the soume of thirtie three pund Scots monie which with ane hundred and seavon pund Scots formerlie received by me from my Ladie Hailles makes in hoall tuell [twelve] pund sterling to accompt for work wrought by me at the house of New Haills belong to my Lord Advocate written and subscribed be me at Edr. [Edinburgh] the 3 day of September 1709 be me Edward Isaate.				
Summary and comments	1709 Edward Isaac wright: account of non-specified work at Newhailes house.				
Archive	National Library of Scotland	Doc. Num.	MS 25834	Folios	36
Title	Transcription of Joe Rock	Date: from	1710	to	
Contents	31 May: Receipt from Edward Isaac, wright for £40 Scots and take his [-?-] therefore to account of lining my Lord's closet and other two rooms				
Summary and comments	1710 Edward Isaac wright: account of interiors work.				
Archive	National Library of Scotland	Doc. Num.	MS 25834	Folios	9
Title	Transcription of Joe Rock	Date: from	1710	to	
Contents	18 January: Payment to Patrick Sheills of Easter Dudingston, conform to My Ladys instructions £40 5s 8d [Scots]				
Summary and comments	1710 John Young wright: account of furnished stones.				
Archive	National Library of Scotland	Doc. Num.	MS 25783	Folios	77
Title	Transcription of Joe Rock	Date: from	1710	to	
Contents	17 April: Receipt by Edward [Ned] Hart, wright for £99 Scots to buy sixtie Sueds [Swedish?] deals and seven of them [67 in total?] and nails for lining the laigh [lower] dining room and Mr. James bed chamber at New Hailes [NLS MS 25834 f. 29] [Factor's accounts note payment to Edward Isaat, wright for buying timber and nails for lining the laigh dining room, £99 31 May: Payment to James Ramsay, wright for his gates £9 12s [Scots]				
Summary and comments	1710 Edward Hart wright and Edward Isaat wright: accounts of timber. No details of works. James Ramsay wright for gates.				
Archive	National Library of Scotland	Doc. Num.	MS 25834	Folios	113
Title	Transcription of Joe Rock	Date: from	1711	to	
Contents	8 May: Lady Hailes due to James Sutherland, To 40 deals £22 [Scots]				
Summary and comments	1711 James Sutherland merchant: account of deals.				
Archive	National Library of Scotland	Doc. Num.	MS 25834	Folios	117
Title	Transcription of Joe Rock	Date: from	1711	to	
Contents	10 May: Leith, £32 Scots for 40 deals to Lady Dalrymple, James Sutherland				
Summary and comments	1711 James Sutherland merchant: account of deals.				
Archive	National Library of Scotland	Doc. Num.	MS 25834	Folios	110
Title	Transcription of Joe Rock	Date: from	1711	to	
Contents	18 September: Receipt by Edward Isaat, wright for £20 Scots, in part payment for wright work at Newhailes				
Summary and comments	1711 Edward Isaac wright: account of non specified work.				
Archive	National Library of Scotland	Doc. Num.	MS 25834	Folios	139
Title	Transcription of Joe Rock	Date: from	1711	to	
Contents	20 [January?]: Receipt by Edward Isaat, wright in Dalkeith for £12 Scots in part payment of plaster work done by him.				
Summary and comments	1711 Edward Isaac wright: plaster work.				
Archive	National Library of Scotland	Doc. Num.	MS 25835	Folios	82
Title	Transcription of Joe Rock	Date: from	1715	to	
Contents	27 July: Pay to John Young wright, £41 12s Scots for 26 ells [97.5 ft.] lining presently done to the upper dining room by My Ladies				

order

Summary and comments: 1715 John Young wright: accounts of interior works.

Archive: National Library of Scotland | Doc. Num.: MS 25783 | Folios: 144

Title: Transcription of Joe Rock | Date: from 1717 to

Contents: 14 November: Payment to John Young, wright for work wrought at Newhailes per acct. My Ladys order £3 6s 8d.

Summary and comments: 1717 John Young wright: account of unspecified work.

Archive: National Library of Scotland | Doc. Num.: MS 25818 | Folios: 50

Title: Newhailes Estate Papers: account of John Young wright 1718 | Date: from 1718 to

Contents: John Young, 1718, wright work in office houses and parks of Newhailes

Summary and comments: 1718 wright John Young: office houses and parks

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 206

Title: Transcription of Joe Rock | Date: from 1719 to

Contents: 30 November: Account from Joseph Forester, plumber for 515 stone lead £8 4s 5½d stg. Discharged 3 June 1721

Summary and comments: 1719 Joseph Forester plumber: account of lead.

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 87

Title: Transcription of Joe Rock | Date: from 1719 to

Contents: 8 August: 'Articles of agreement between Patrick Stewart, merchant in Edinburgh and William Rig writer there; The said Patrick Stewart obliges himself to deliver betwixt [now] and Michaelmas next the number of twenty thousand bleu sclaits or scailzie of the dimensions following. Viz. The shortest to be ten inches long and six inches broad at the lower end with four easing sclaits to each hundred, the foresaid easings not to be under eight inches broad & fifteen inches long and to be delivered free of all charges at Fisherrow port to the Leige or James Geddeses for the which charges the said William Big obliges himself by [?] &c To pay the said Patrick Stewart or order at the said term of Michaelmas the sum of forty pounds sterling money being at the rate of forty shill: sterl for each thousand...' Noted verso: 'Edinburgh 3 September 1719, Receipt from Patrick Stewart for £25 stg. from W Rigg'

Summary and comments: 1719 Patrick Stewart merchant: account of slates. Joe Rock thinks it's a big amount that could cover all the house, including the wings.

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 43

Title: Transcription of Joe Rock | Date: from 1719 to

Contents: 1 April: Receipt from John Young for 4 guineas for wright work of the new building at Newhailes

Summary and comments: 1719 John Young wright: accounts of non-specified works.

Archive: National Library of Scotland | Doc. Num.: MS 25791 | Folios: 95

Title: Transcription of Joe Rock | Date: from 1720 to 1721

Contents:
Nsd. Series of unitemised payments made by James Dalrymple, 1720-21:
Forrester, plumber, £8 14s 5d.
James Craig, timber, £28.
George Simson, glazier for the library windows, £5 2s 2d.
John Young, wright in full of account, £27 17s.
William Craig, smith, Potterrow, £5.
William Miller in part for garden seeds, 1719, 1720, 1721, £10.
James Henry, coppersmith, £1 1s 6d.
John Steell acct. £7 2s 7d. [brewer]
Andrew Cuthbertson for the office houses at Newhailes, £4 15s 10d

Summary and comments: 1720-1 various accounts including timber and non-specified work by John Young wright.

Archive: National Library of Scotland | Doc. Num.: MS 25818 | Folios: 42

Title: Newhailes Estate Papers: account of John Young wright 1720 | Date: from 1720 to

Contents:
Mr Dalrymple of Hailes Esquire's Accompt of wright work wrought be John Young at the New Building of New Hailes Aprile 1720
barrows, tresses for masons, doors, *bearers to the stair*, *boxes to the windows*, closets, scaffolding for masons/slaters/, *safe lintels to the windows*, lodge for masons,
[...] *Item for sawing the trees and making the wallpletts £10*
[...] *Item making the roof to the Library £296 12s.*
[...] *Item for sawing 200 dailles to lath the roof of the Library and the four closets £20*
Item for putting up the inside of the roof of the library with the roofs of the four closets £40
Item for cutting the roof of the main house to gett out the stone conness? 12s.
Item for necessarie charges in going to buy timber £12
tot £286 10s.

Summary and comments: 1720 wright John Young: materials and works related to the roof above the library

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 224

Title: Transcription of Joe Rock | Date: from 1720 to

Contents: 30 November: Account from Joseph Forester, plumber for 515 stone lead £8 4s 5½d stg. Discharged 3 June 1721

Summary and comments: 1720 George Mackenzie merchant: account of 144 trees.

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 236

Title: Transcription of Joe Rock | Date: from 1721 to

Contents: 22 July: Receipt from Thomas Curie for 16 double trees at £1 8s per piece.
40 deals at 15s per piece.
1 spar at 8s.
Total £52 16s, discharged 8 November 1721.
Countersigned by John Young, wright.

Summary and comments: 1721 Thomas Curie merchant: account of 16 double trees, deals and a spar.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 43

Title: Transcription of Joe Rock | Date: from 1721 to

Contents: 5 October: Receipt from John Young, wright for £15.

Summary and comments: 1721 John Young wright: non-specified.

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 208

Title: Transcription of Joe Rock | Date: from 1721 to

Contents: 14 April: Receipt from John Young, wright, part payment for wright work at the library... Discharged by Henry Fletcher witnessed by James Geddes and William Rig writer in Edinburgh 'at the park end of New Hailes'.

Summary and comments: 1721 John Young wright: account of work at the library.

Archive: National Library of Scotland | Doc. Num.: MS 25818 | Folios: 49

Title: Newhailes Estate Papers: account of Andrew Cuthbertson slater 1721 | Date: from 1721 to

Contents: Andrew Cuthbertson slater, 1721, for slating the main roof of Newhailes

Summary and comments: 1721 main block of Newhailes slated

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 88

Title: Newhailes Estate Papers: account of John Young wright 1721-2 | Date: from 1721 to 1722

Contents: *Sr James Dalrymple of haills Account of wright work ??? John Young since the first Jullay 1721 to the ffirst of May 1722 of seavirill pisis of work about the Newhous and officesis housis*
[...] *Item for putting up the roofs of the offishousis £2*
[...] *Item for mending the roof of the Mainhows £1 10s.*
tot £18

Summary and comments: 1721-2 wright John Young: works on roofs of office houses and main house, but very limited expenses thus limited works.

Archive: National Library of Scotland | Doc. Num.: MS 25836 | Folios: 237

Title: Transcription of Joe Rock | Date: from 1721 to

Contents: 25 July: Receipt from Mr. James Craig for 140 double trees, £28 stg. The trees are for Sir David Dalrymple's new building. Discharged by Henry Fletcher of Saltoun 5 August.

Summary and comments: 1721 James Craig merchant: account of 140 double trees.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 101

Title: Transcription of Joe Rock | Date: from 1722 to

Contents: 5 October: Receipt from John Young, wright for £15.

Summary and comments: 1722 wright John Young: non-specified.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 78

Title: Newhailes Estate Papers: account of John Young wright 1722 | Date: from 1722 to

Contents: Mrs Butt, 1722,
80 choice clean deals, wainscot, planks
tot £11
John Young bought them from her

Summary and comments: 1722 wright John Young: deals and planks bought from Mrs Butt. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 109

Title: Newhailes Estate Papers: account of timber John Young wright 1722 | Date: from 1722 to

Contents: *1722 The Honnrd Sir James Dalrymple of Hails ??? To Jon Wilson for timber funrnished to the new building att Newhails*
June 5th To 300 Choice long dealls att £26
to workmen to help of the timber transportance? to Leith the 5 of June 1722
I John Young wright in ??? Grant me to have recaived the above number of dealls for the use of Sir James Dalrymple of haills as writis my hand ..... John Young

Summary and comments: 1722 wright John Young: account of timber deals purchase and transport. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 15

Title: Newhailes Estate Papers: account of John Young wright 1722 | Date: from 1722 to

Contents: John Young 31 August 1722
22 planks 13 feet long 4 1/4 inches thick
3 planks 9 feet long 4 1/2 inches thick
tot £4

Summary and comments: 1722 wright John Young: planks of different sizes. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 75

Title: Newhailes Estate Papers: account of John Young wright 1722 | Date: from 1722 to

Contents: John Young 31 August 1722
22 planks 13 feet long 4 1/4 inches thick
3 planks 9 feet long 4 1/2 inches thick
tot £4

Summary and comments: 1722 wright John Young: planks of different sizes. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 53

Title: Newhailes Estate Papers: account of Jon Wilson 1722 | Date: from 1722 to

Contents: Jon Wilson, 3rd August 1722
100 choice clean deals 12 feet long
200 long deals
tot £26

Summary and comments: 1722 account of deals. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 55

Title: Newhailes Estate Papers: account of Jon Wilson 1722 | Date: from 1722 to

Contents: John Young for Jon Wilson, 12th July 1722
60 clean choiced fine deals

Summary and comments: 1722 account of deals. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 35

Title: Newhailes Estate Papers: account of John Young wright 1722 | Date: from 1722 to

Contents: John Young for Jon Wilson, 12th July 1722
60 clean choiced fine deals

Summary and comments: 1722 John Young wright: account of deals and tar. No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 131

Title: Transcription of Joe Rock | Date: from 1722 to

Contents: 13 July: Account from John Wilson, merchant in Edinburgh. 60 choice clean flooring deals £5. Noted Leith, 12 July 1722, received from John Wilson, merchant in Edinburgh, signed John Young. Discharged 18 January 1723

Summary and comments: 1722 John Wilson merchant: account of timber deals.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 81

Title: Transcription of Joe Rock | Date: from 1722 to

Contents: 2 February: Received from capt. Matthew Campbell: 86 fine flooring deals 17ft long £8 12s. sent to the library at Newhailes. To William Mitchell received.

Summary and comments: 1722 account of timber deals for the library.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 157

Title: Newhailes Estate Papers: account of timber 1723-4 | Date: from 1723 to 1724

Contents: [one side] *Accompt of timber ??? ???*

[other side] *1723 Mr James Winram? Bot of Sam Stanton*
Octr 4th To 16 cuphars a 15d. 12s. 6d.
To 6 half deals a 6d. 3s.
To 1 ps Oake 6d. 16s.
For the Wester butess? Wilson
6 Nov 1724 Contents ??? by Sam Stanton

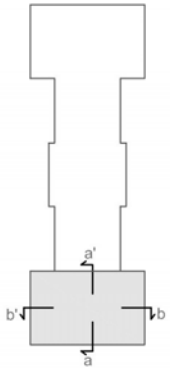
Summary and comments: 1723-4 account of timber (few deals and others). No details of works.

Archive: National Library of Scotland | Doc. Num.: MS 25837 | Folios: 140

Title: Transcription of Joe Rock | Date: from 1723 to

Contents: 1 February: Receipt by John Young, wright for £10

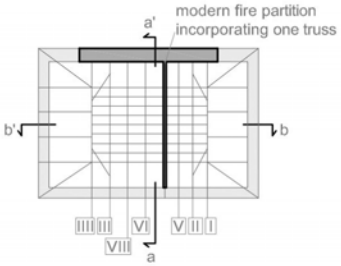
Summary and comments: 1723 John Young wright: non specified.



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

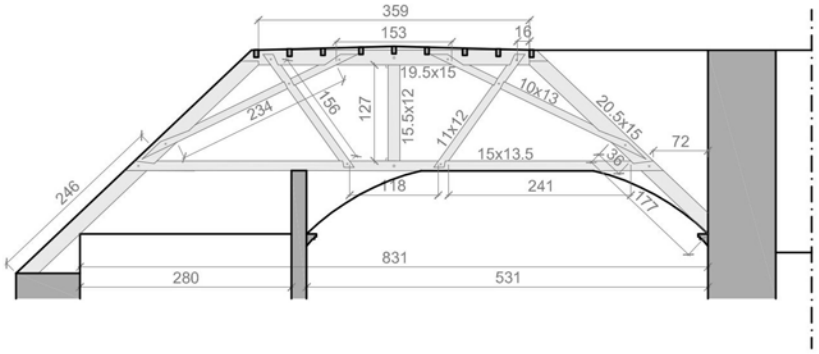
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

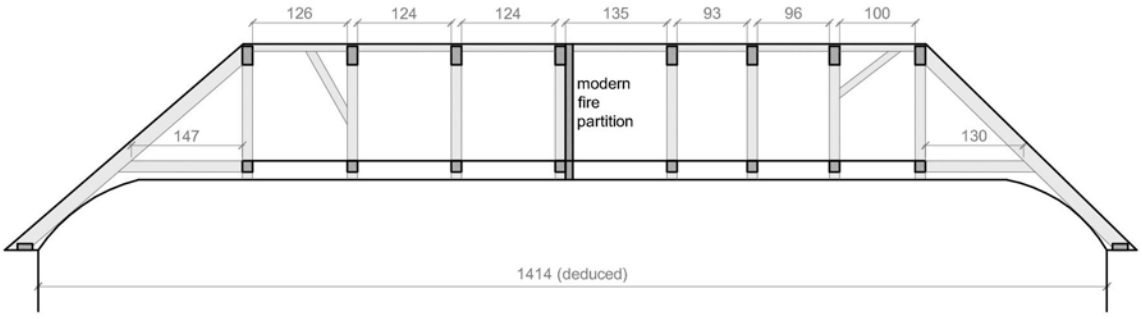
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

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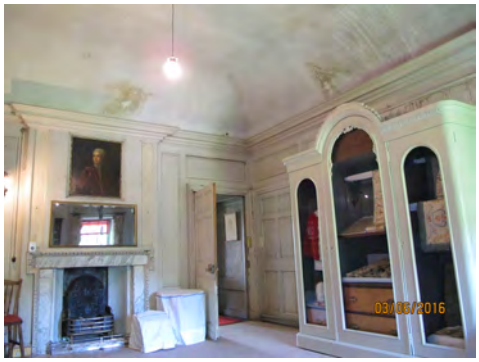


one of the attic spaces underneath I:\Arch\A

INITIAL SURVEY | **Building name** NEWHAILES HOUSE | **Roof location** N wing

Survey date(s) 18/09/2014 | See drawing: NH-N-1

Roof Geometry: Flat, Hipped

Roof Max Span [m]: 8.3 | Roof Height [m]: 3

Roof Pitch/es [°]: 43 | Roof Length [m]: 13.2

Type of Primary Structure: 2D framing

Truss ☑ OTHER

Frame ☐ Other

Average Distance in between Primary Structure [m]: 1.3

Type of Secondary Structure: common rafters, purlins, sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1733 To 1751 Identified by: Estimated

Roof General Description:

Only the N wing of the house could be surveyed. It's a flat hipped roof with 8 trusses. Each truss has an upper beam and a collar, a central post and 2 diagonal struts, one connecting the rafter to the upper beam and the other connecting the upper beam to the collar. The collar is raised to leave space for the partially vaulted ceiling underneath. The upper beam has a varying scantling, bigger in the middle, so to provide a slope for the rain water. The trusses support a series of small purlins and common rafters.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 20.5 B: 15 Or Purlin - H: B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: dovetail, lapped, mortice and tenon, notch

Fasteners Types: Metal nail, Timber dowel

Joints description:

All lapped dovetail chamfered with metal nails, except for the post which has mortice and tenon with timber pegs and wedges, and for the joint between the rafters and the upper tie-beam which is a notched mortice and tenon. Cross notched lapped joint between 2 struts.

Wood Species: all pinus sylvestris except for the post which is picea abies and the dowels which are quercus sp.

Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description:

Numbered from I to VIII (even though number VII is not visible), but not in sequence.

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology



Roof structure link I:\Arch\A



Roof structure link I:\Arch\A



Timber elements' dressing link I:\Arch\A



Joint: post and lower tiebeam link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation

Accessibility limitations

Past interventions: Recent work include a fire partition, addition of floor boards, and replacement of most of the sarking and of some purlins. The sarking has been replaced with floor boards which don't allow for ventilation.



Past interentions | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐

Diffuse insect exit holes ☑

Most timbers have diffuse insect exit holes on the axed faces only, which means that the insect attack is confined to the sapwood.

	Damage Type:	Damage Status:	Damage Role:		
Roof Damage				link	
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes: The roof space was probably in use in the past since there is plastering inside. Most of the joints of the struts connecting the collars to the upper beams are partly open (1 cm max) which seems to indicate that they are working in tension. The posts and upper beams are slightly twisted, probably because all of the joints are on one side.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

DETAILED SURVEY **Building name** NEWHAILES HOUSE **Roof location** N wing

Survey date(s) 03/06/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings NH-N-1, NH-N-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
North-west rafters	430	rectangular	bending, compression		the visible face is hand axed
South-east rafters	312	rectangular	bending, compression	pinus sylvestris	the visible face is hand axed
Upper beams	408	rectangular	bending	pinus sylvestris	3 faces hand axed and 1 face hand sawn
Lower beams	714	rectangular	bending, tension		the visible face is hand axed
Struts: collar & upper beam	184	rectangular	tension		2 hand axed faces and 2 hand sawn faces
Struts: rafter & upper beam	317	rectangular	compression	pinus sylvestris	2 hand axed faces and 2 hand sawn faces
Posts	127	rectangular	compression	picea abies	2 faces hand axed and 2 faces hand sawn
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

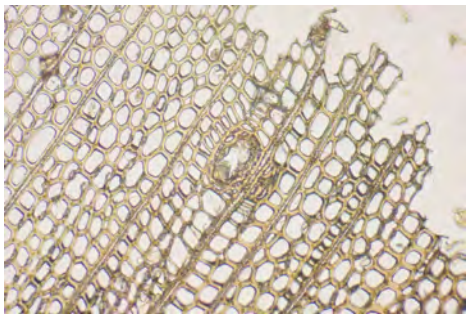
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings NH-N-1, NH-N-2

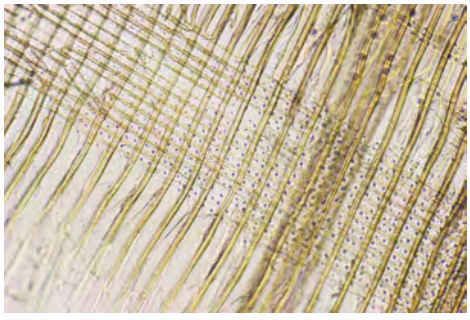
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & upper beam	Corner mortice & tenon	compression, shear	none	
rafter & collar	Encounter dovetail	tension	nails	
strut & strut	Crossing halved notched	tension	nails	
strut & other	Encounter dovetail	compression, tension	nails	
post & other	Encounter mortice & tenon	compression	wooden dowels, wooden keys	quercus sp.

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

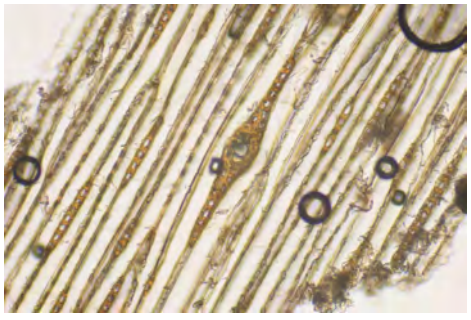
Microscopic identification of the timber species See drawing NH-N-2



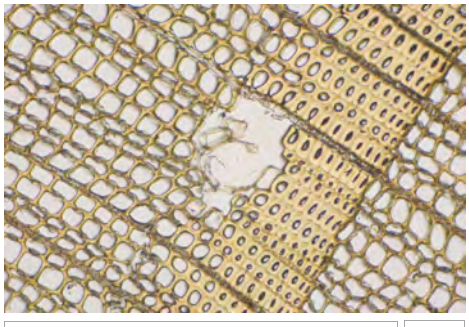
Post: transv. Section x100 I:\Arc



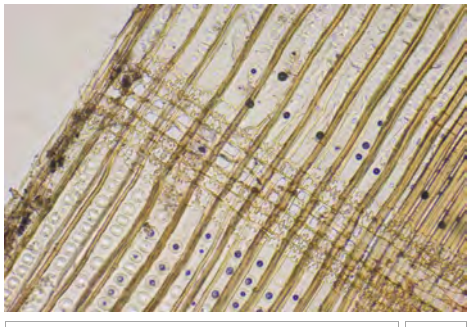
Post: radial section x100 I:\Arc



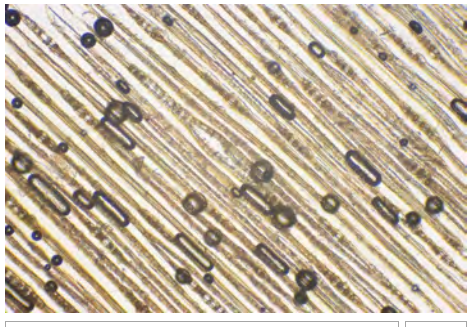
Post: tang. Section x100 I:\Arc



Rafter: transv. Section x100 I:\Arc



Rafter: radial section x100 I:\Arc



Rafter: tang. Section x50 I:\Arc

Air Temperature and Relative Humidity measurements See drawing NH-N-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
attic space	NW corner	03/06/2016	10:30 am	17.7	57
attic space	SE corner	03/06/2016	10 am	18	55.8
attic space	NE corner	03/06/2016	10:15 am	17.6	57
roof space	Close to frame I	03/06/2016	11:15 am	19	54.3
roof space	Close to frame III	03/06/2016	11 am	18.7	55.1

Frame/Truss name II See drawing NH-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other

Element name A strut upper beam & collar

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.3x12.5 | min. size (hxb) [cm] 10.2x12.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%] 9 tangential

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other insect exit holes on axed faces

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a

Moisture Content [%] 14.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.3 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name B strut upper beam & rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 9.1x13.9 | min. size (hxb) [cm] 9.8x13.3 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%] 16 tangential

Knots [min d/section h] 1.5/14 single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other insect exit holes on axed faces

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	14.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	13.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	15.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name C northwest rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues only one face (and the two side ones partially) visible because of plaster

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 14.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D upper beam

Dating original construction Signs of reuse redundant lap joint on corner top - probably removed element

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 20.2x15.4 min. size (hxb) [cm] 19.5x15 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 3.5/15.2 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



redundant lap joint on top corner I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 15.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 13.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name E post

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 16x11.7 min. size (hxb) [cm] 16x11.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 3.5/16 group Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name F strut upper beam & collar

Dating original construction Signs of reuse

Timber treated ☐

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.2x11.7 min. size (hxb) [cm] 10x11.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential

Knots [min d/section h] 1.5/11.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a

Moisture Content [%] 14.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name G strut upper beam & rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.1x14 min. size (hxb) [cm] 9.7x13.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 1.3/8.3 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a

Moisture Content [%] 13.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 13.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name I south east rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues: only one face (and the two side ones partially) visible because of plaster

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☐ Jointed element ☐

Strength affecting defects

Pith location Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Estimated level of damage Emergency interv. needed ☐

Past interv. ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 14.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 14.2	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name H lower beam

Dating: original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues: only one face visible due to inspection floor boards

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☐ Jointed element ☐

Strength affecting defects

Pith location Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Estimated level of damage Emergency interv. needed ☐

Past interv. ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 13.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		

Moisture Content [%] 16.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Measurement Point d

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Measurement Point e

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Frame/Truss name III See drawing NH-N-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other

Element name A strut upper beam & collar

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.2x11.9 | min. size (hxb) [cm] 11x11.9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%] 12 tangential

Knots [min d/section h] 2.3/11 single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other: insect exit holes on axed faces

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a

Moisture Content [%] 13.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name B strut upper beam & rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 4 | tangential

Knots [min d/section h]: 1.5/10 | single | Knotty element ☑ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I



knots on the strut | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other: insect exit holes on axed faces

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a			
Moisture Content [%]	15.2	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	14.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	14.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name C north west rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: not visible because of plaster

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119:



plaster partly hiding the section | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point	Moisture Content [%]	Visible Material Degradation	Not Accessible for: hygrometer
a	16.9	☐	☐
b	14.8	☐	☐

Element name D upper beam

Dating: original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 17.7x14.4 min. size (hxb) [cm]: 15.8x14.3 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 5 tangential
Knots [min d/section h]: 2.5/14 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects: 4cm deep check on one side all along the element
Estimated Strength Class according to UNI 11119: I



old humidity stains I:\Arc

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other: insect exit holes on axed faces. Old humidity stains.

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point	Moisture Content [%]	Visible Material Degradation	Not Accessible for: hygrometer
a	14.6	☐	☐
b	15.2	☐	☐
c	15	☐	☐
d	16	☐	☐

Element name E post

Dating: original construction
Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.9x11.7 min. size (hxb) [cm] 15.4x11.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 1.7/11.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



the dressing I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other insect exit holes on axed faces

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name F strut upper beam & collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.4x10.9 min. size (hxb) [cm] 10x10.8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 9 tangential

Knots [min d/section h] 5.5/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other insect exit holes on axed faces

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 13.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 14.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name G strut upper beam & rafter

Dating: original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 9.7x13.4 min. size (hxb) [cm] 9.5x13.4 Single piece ☑ Jointed element ☐

Strength affecting defects
Pith location: side Slope of grain [%]: 2 tangential
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119: I

Material degradation
Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other: insect exit holes on axed faces

Mechanical Damage
Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 13.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 13.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 14.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name H lower beam

Dating: original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues: only one face visible due to inspection floor boards
Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location | Slope of grain [%] | Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a			
Moisture Content [%]	15.2	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	14.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]		Visible Material Degradation ☐	Not Accessible for: hygrometer ☑
Measurement Point d			
Moisture Content [%]		Visible Material Degradation ☐	Not Accessible for: hygrometer ☑
Measurement Point e			
Moisture Content [%]		Visible Material Degradation ☐	Not Accessible for: hygrometer ☑

Element name I south east rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Past interventions

Accessibilityissues: only one face (and the two side ones partially) visible because of plaster

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location | Slope of grain [%] | Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage

Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

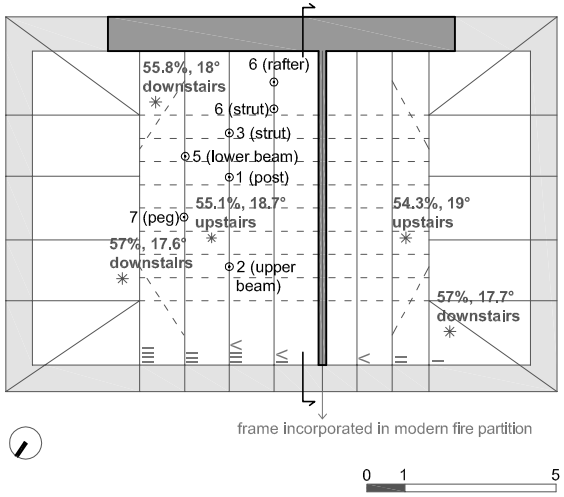
External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%]	Visible Material Degradation ☐	Not Accessible for: hygrometer ☑
Measurement Point b		
Moisture Content [%]	Visible Material Degradation ☐	Not Accessible for: hygrometer ☑

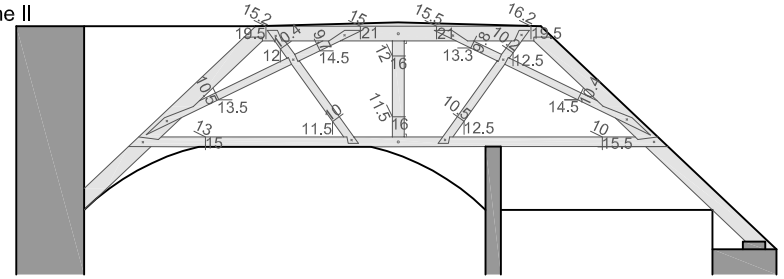
Plan 1:200

- ✳ air humidity and temperature
- ⊙ timber samples for species identification

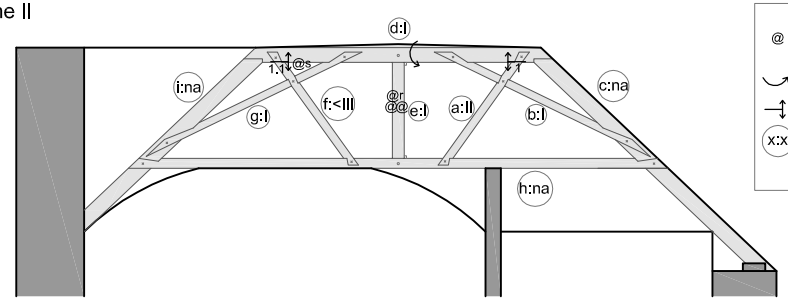


Sections 1: 100 (looking South)

Frame II



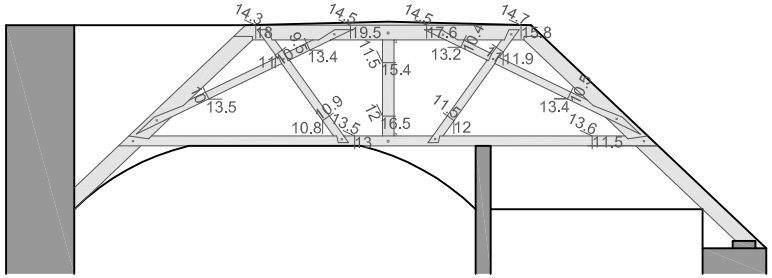
Frame II



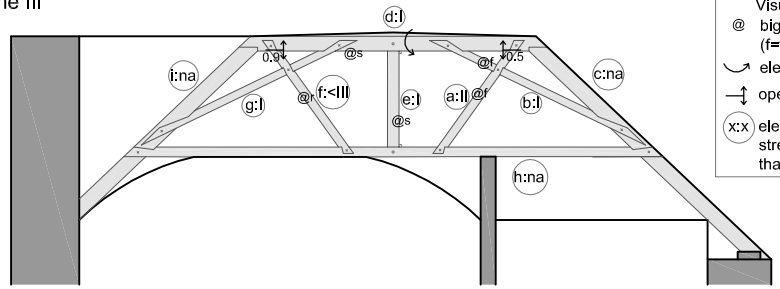
Visual inspection:
- @ big knots (f=front, r=rear, s=sides)
- element rotation
- open joint (measure in cm)
- x:x element name : estimated strength class (na=less than 2 faces visible)

Sections 1: 100 (looking South)

Frame III

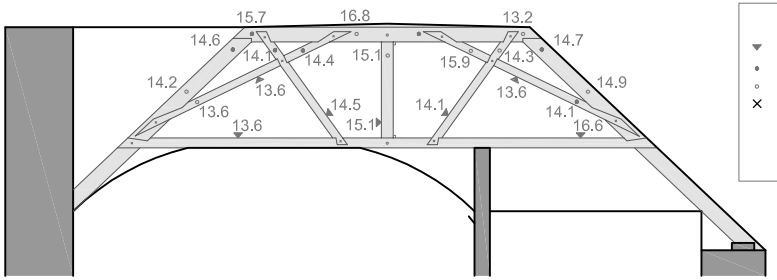


Frame III



Visual inspection:
- @ big knots (f=front, r=rear, s=sides)
- element rotation
- open joint (measure in cm)
- x:x element name : estimated strength class (na=less than 2 faces visible)

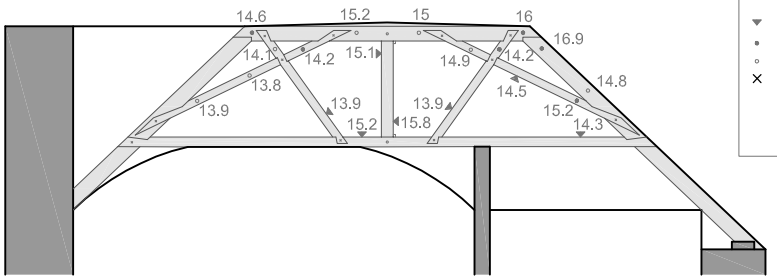
Frame II



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20

Frame III



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20

0 1 5

PINKIE HOUSE

Location: EAST LOTHIAN | INVERESK (EAST LOTHIAN)
X coordinate: 334880 Y coordinate: 672651
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Rcahms ID: 53873
HS Listing: A

Original Use: Residential
Current Use: School

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1575	1600	L SHAPED HOUSE INCORPORATING EARLIER FORTALICE	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1613		RETAINED THE TOWER ADDING A PAIR OF SQUARE PEPPERPOTS AT THE NORTH END - RAISED THE PROJECTING JAMB 2 STOREYS HIGHER - BUILT A NEW LONG WING TO SOUTH	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
SETON	SIR ALEXANDER 1ST	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1675	1705	WEST WING	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1768	1778	REPAIR WORKS TO ROOFS	NLS MS14716

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1795	1805	WEST SIDE	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1955		STRENGTHENING OF THE LONG HALL ROOF	HES REPORT

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
BATH M.	2013	☐	PHILOSTRATUS COMES TO SCOTLAND: A NEW SOURCE FOR THE PICT PINKIE	
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME II. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	392-398
DUNBAR J. G.	1978	☐	THE ARCHITECTURE OF SCOTLAND	70
HANKE T.	2004	☐	THE STABLE OF HALKERSTON LODGE AND MORAY HOUSE - ROOF ARCHITECTURE OF THE 1630S AROUND EDINBURGH	
HANKE T.	2006	☑	THE DEVELOPMENT OF ROOF CARPENTRY IN SOUTHEAST SCOTLAND	
MACDONALD A.	2016	☑	PRELIMINARY CONCLUSIONS ON STRESS CALCULATIONS FOR ROOF T PINKIE HOUSE, MUSSELBURGH (JUNE 2016)	

Author	Year	Unpubl.	Title	Pages
MCKEANE C.	2001	☐	THE SCOTTISH CHATEAU. THE COUNTRY HOUSE OF RENAISSANCE SC	183-188
MCWILLIAM C.	1928	☐	THE BUILDINGS OF SCOTLAND COLLECTION: LOTHIAN, EXCEPT EDINE	
SUMMERSON S. J. N.	1963	☐	THE CLASSICAL LANGUAGE OF ARCHITECTURE	507

ARCHIVAL REFERENCES

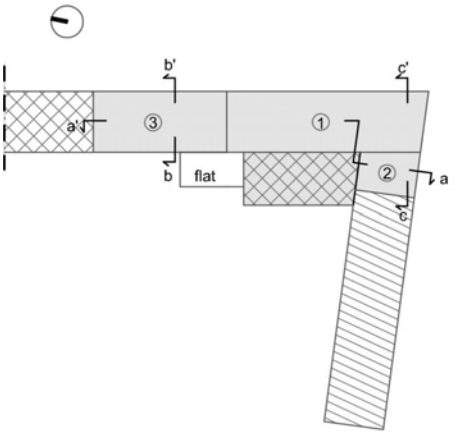
Archive	National Library of Scotland	Doc.Num.	MS 14716	Folios	
Title	Accounts of Hay family				
Archive	HES	Doc.Num.	uncatalogued	Folios	
Title	Report by HES technical officer WR Adams				
Archive	RCAHMS	Doc.Num.	LOR/M/17/5	Folios	
Title	Plans and elevations showing additions and alterations. Details showing new floor to painted gallery. Details showing roof over painted ceiling and catwalk.				
Archive	HES	Doc.Num.	uncatalgoued	Folios	
Title	Letter from Rentokil (Ratsouris Scotland Ltd) detailing proposed insecticidal treatment of main roofspace and provision of a thermal quilt (July 1973)				

Suggestions for further research	Hay papers in NLS

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

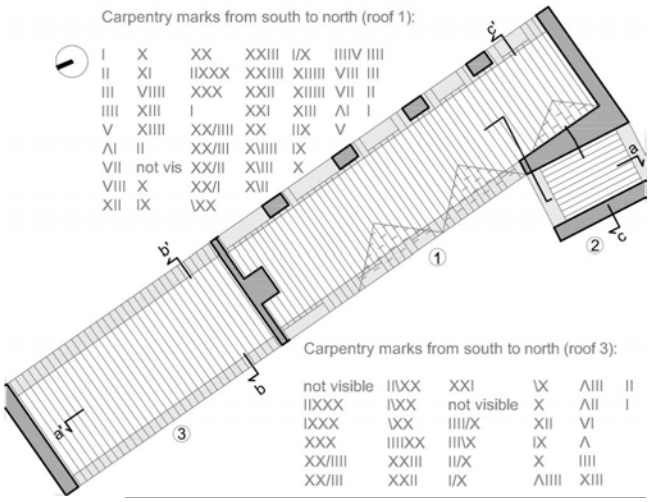
Archive	National Library of Scotland	Doc. Num.	MS 14716	Folios	
Title	Accounts of Hay family	Date: from	1768	to	1778
Contents	1768-78 repairs to the roof for a tot £16 86d. 48s.				
Summary and comments	1768-78 works to roof for £16. No details of works but they could be related to the addition of the struts to counteract the deflection of the lower collars and the cracking of the ceiling underneath.				
Archive	RCAHMS	Doc. Num.	LOR/M/17/5	Folios	
Title	Plans and elevations showing additions and alterations. Details showing new floor to painted gallery. Details showing roof over painted ceiling and catwalk.	Date: from	1954	to	
Contents					
Summary and comments	1955 roof strengthened with additional collars.				
Archive	HES	Doc. Num.	uncatalogued	Folios	
Title	Report by HES technical officer WR Adams	Date: from	1954	to	
Contents	[...] *A scheme to generally strengthen the main roof was submitted to the Private Architect in charge of the general alterations to the House for his consideration and comment. Briefly, this amounted to the introduction of new ties at a higher level than the existing ties and twice bolted to the main rafters at each end. On this new framework a catwalk was to be built to carry the load of foot traffic and assist in periodic inspection of the roof space. This meant that the original ceiling beams would only serve to carry the painted boards and that the main thrust of the roof would be transmitted to the wallheads and vibration on the painted boards reduced to minimum. This scheme was approved and carried out at a later date.* [....				
Summary and comments	1955 roof strengthened with additional collars.				
Archive	HES	Doc. Num.	uncatalgoued	Folios	
Title	Letter from Rentokil (Ratsouris Scotland Ltd) detailing proposed insecticidal treatment of main roofspace and provision of a thermal quilt (July 1973)	Date: from	1973	to	
Contents					
Summary and comments	Rentokil proposes insect treatment and insulation of roof in 1973				



Legend (plans):

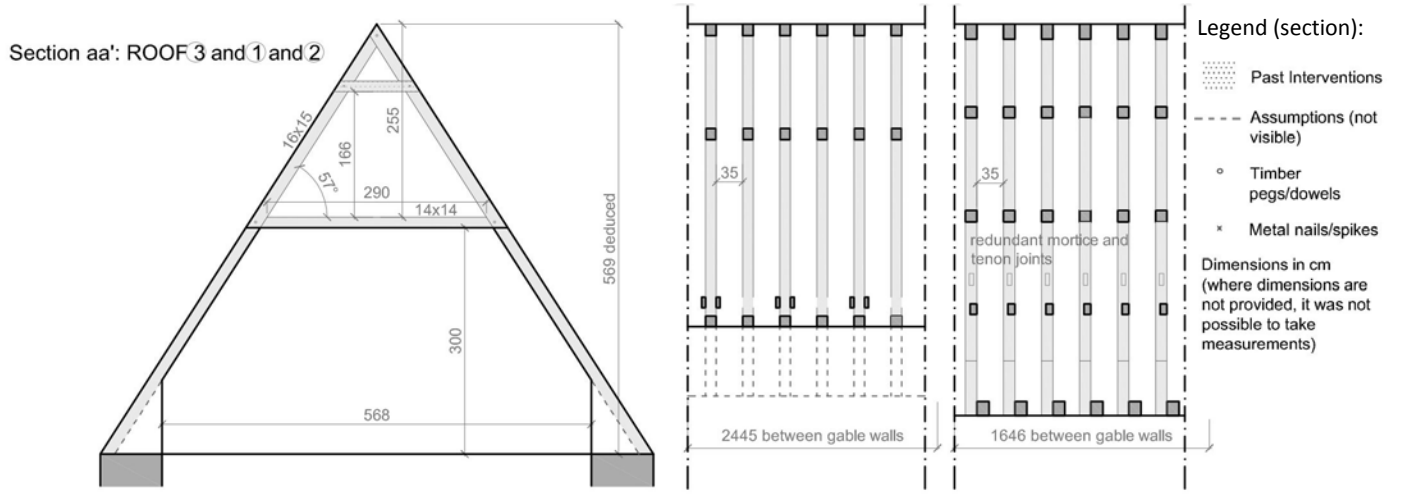
Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



Roof 1 and 2 from outside I:\Arch\A



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** PINKIE HOUSE | **Roof location** 1: long hall

Survey date(s) 09/10/2014 | See drawing: PKH-all-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 6.1 | Roof Height [m]: 4.6

Roof Pitch/es [°]: 52 | Roof Length [m]: 24.5

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.35

Type of Secondary Structure: sarking

Sarking boards: width [cm] 26 | thickness [cm] 3

Connection with lateral walls: None

Connection with gables: sarking interrupted (chimney), wall-plate

Roof Construction Period: From 1613 To | Identified by: Estimated

Roof General Description: Double pitch roof sandwiched between two gable walls, made of ashlar masonry, with other roofs intersecting on the West side. Composed of 50 frames with 3 collars each: 2 original and one added 1955. Some frames have vertical struts as well, connecting the rafters and the lower collars. The lower collars support the original early 17th century vaulted timber painted ceiling. As far as it's visible, the rafters simply sit on the wallhead and the space in-between them is infilled with rubble masonry up to the start of the painted ceiling.

Roofing Material: slate

Roofing Material Fixing: Metal nails, Timber Pegs

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 15 | B: 14 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description:

Wood Species: pinus sylvestris, except for, the pegs (both in joints and in sarking) which are quercus sp. | Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Partly in sequence, many double numbers

Signs of reused timbers:

Timber Treated ☑ for insects, in 1970s

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



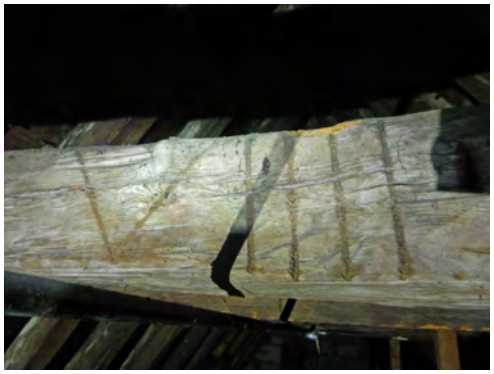
Connection with wall | link I:\Arch\A



Joints and slates' fixing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features: Original timber painted ceiling underneath

Unfavourable conditions:

Accessibility limitations: Connection with wall not well visible

Past interventions: Struts added sometime in 18th century, judging from the dressing. The ceiling probably had problems already back then, and the struts were inserted to counteract the deflection of the lower collars, supporting the ceiling. Additional collars were added to one frame every two in 1955 for the same reason and probably solved the problem.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains on sarking. Insect attack on all timbers, but has been treated and looks inactive.



Humidity stains | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage	transversal opening	Intervened on	Primary
Unit Damage			
Element Damage			
Connection Damage	Disconnection, Splitting	Intervened on	Collateral



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient joints
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: disconnection | link | I:\Arch\A

Description of visible damage: Some joints between rafters and collars partly opened. Probably overall transversal opening. That's why new collars have been added. The problem seems to have been solved since the ceiling hasn't shown new signs of damage.

Other Notes:

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** PINKIE HOUSE | **Roof location** 2: SE of long hall

Survey date(s) 09/10/2014 | See drawing: PKH-all-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 5.68 | Roof Height [m]: 5.69

Roof Pitch/es [°]: 57 | Roof Length [m]: 3.96

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.35

Type of Secondary Structure: sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1613 To | Identified by: Estimated

Roof General Description: Gabled roof intersecting long hall. Composed of 9 frames with one collar each and 7 frames in intersection. Connection with wall not visible.

Roofing Material: slate

Roofing Material Fixing: Metal nails, Timber Pegs

Timber elements' Section Shape: Square with wanes

Rafter Scantling [cm] H: 16 B: 15 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☑

Joint Types: lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Original timbers are all connected with mortice and tenon joints with timber pegs not flush. Collar added later has dovetail lapped joints with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types:

Carpentry Marks Description:

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roofing material fixing | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor ventilation, presence of pigeons/wasps/bats

Accessibility limitations

Past interventions: Some rafters doubles. Upper collar added.



Past interventions and wasps | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:		link
Roof Damage					
Unit Damage					
Element Damage					
Connection Damage					

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber link

INITIAL SURVEY | **Building name** PINKIE HOUSE | **Roof location** 3: old tower house

Survey date(s) 09/10/2014 | See drawing: PKH-all-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.44 | Roof Height [m]: 5.18

Roof Pitch/es [°]: 52 | Roof Length [m]: 16.46

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.42

Type of Secondary Structure: sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Rafter foot

Connection with gables:

Roof Construction Period: From 1575 To 1600 | Identified by: Estimated

Roof General Description: Gabled roof composed of 33 frames each with 3 collars and rafter feet (lower collar replaced in 19C?). Northern section of roof has ceiling attached under lower collar.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 20 | B: 15 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Original timbers are all connected with mortice and tenon joints with timber pegs not flush. Collar added later has dovetail lapped joints with metal nails.

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Partly in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof Structure | link I:\Arch\A



Roof Structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentery marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Some rafters reinforced with timber. New tie-beams next to rafter foot, not connected with rafters. Collar substituted with a lower one. Steel ties added in some frames to hang new tie-beams from rafters.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

Insect attack on some rafters, noit sure if active



Material degradation | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

DETAILED SURVEY **Building name** PINKIE HOUSE **Roof location** long hall

Survey date(s) 09/10/2016 09/03/2016 31/03/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings PKH-lh-1, PKH-lh-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
rafter	700	rectangular with wanes and bark	bending, compression	pinus sylvestris	hand axed
upper collar	200	rectangular with wanes and bark	bending, compression	pinus sylvestris	hand axed
lower collar	585	rectangular with wanes and bark	bending, tension		
intermediate collar	585	rectangular	bending, tension		machine sawn
strut	215	rectangular with wanes	tension		hand sawn
sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

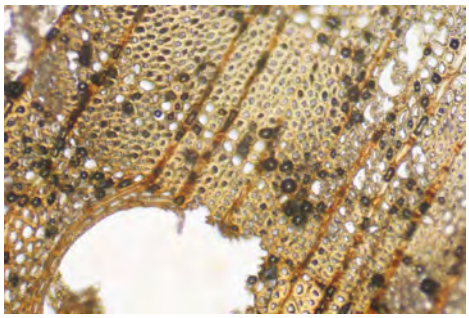
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings PKH-lh-1, PKH-lh-2

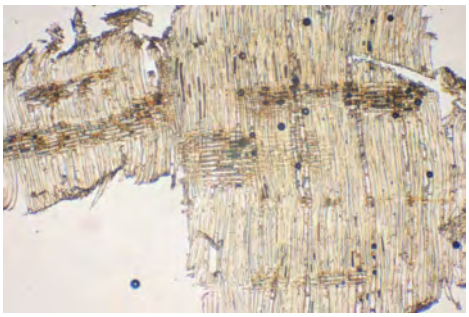
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner mortice & tenon	compression	wooden pegs	
rafter & upper/lower collars	Encounter mortice & tenon	compression, tension	wooden pegs	quercus sp.
rafter & intermediate collar	Encounter simple lap	tension	bolts	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

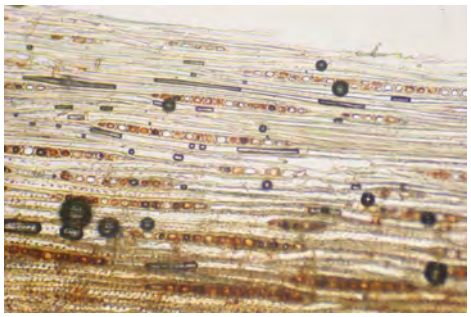
Microscopic identification of the timber species See drawing PKH-lh-2



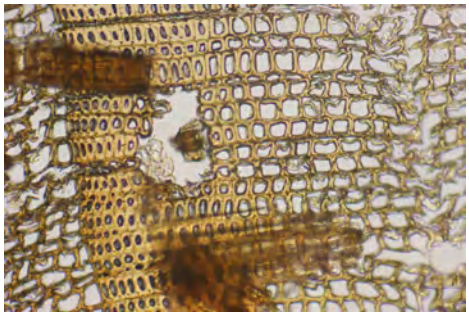
Peg rafter&collar: transv. section x100 I:\Arc



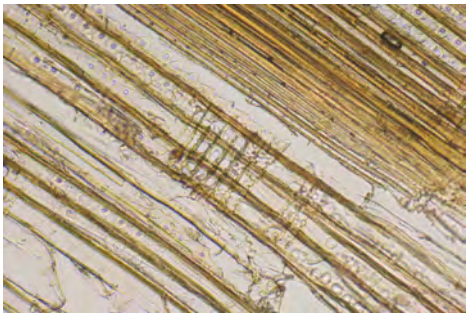
Peg rafter&collar: radial section x50 I:\Arc



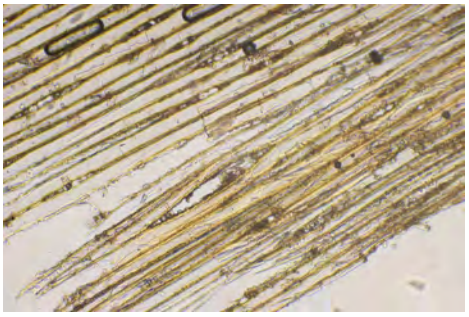
Peg rafter&collar: tang. section x100 I:\Arc



Rafter: transv. section x100 I:\Arc



Rafter: radial section x100 I:\Arc



Rafter: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing PKH-lh-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	N side	09/03/2016	11:20 am	14.8	48.7

roof space	N side	09/03/2016	11:20 am	14.8	48.7
roof space	S side	09/03/2016	11 am	14.9	48.8
attic space	N side	09/03/2016	10:20 am	19.5	36.5
attic space	S side	09/03/2016	10 am	17.8	39.5

Frame/Truss name north XI — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area
Joints with decayed peg: between upper collar & E rafter | Insect attack
Failed joints | Fungi attack
Other: E rafter twisted

Frame/Truss name XXVIII — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area
Joints with decayed peg: between upper collar & E rafter | Insect attack
Failed joints: between lower collar & W rafter | Fungi attack
Other

Frame/Truss name XXVIIII — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area
Joints with decayed peg: between upper collar & W rafter | Insect attack
Failed joints: between lower collar & W rafter | Fungi attack
Other: E rafter has reduced section due to old insect attack

Frame/Truss name north I — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area: E rafter
Joints with decayed peg: between upper collar & W rafter | Insect attack
Failed joints | Fungi attack
Other

Connection name between W rafter & lower collar — FrameTrussCode: PH-lh-nI

Mechanical Damage:	Type	Status	Role
Splitting: shear failure along grain	☑	unknown	primary
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☐		



rafter failed | I:\Ar

Estimated causes of primary damage:

Poor design ☑ fastener too close to borders
Poor maintenance ☐
External actions ☐
Material degrad. ☐
Poor construction ☐
Past interventions ☐
Other ☐

Description: part of rafter covering peg failed

Estimated damage level: rupture
Emergency intervention needed ☐

Frame/Truss name XXX — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints: between lower collar & W rafter | Fungi attack
Other

Frame/Truss name IIXXX — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area: W rafter

Joints with decayed peg: between upper collar & both rafters
Insect attack:
Failed joints:
Fungi attack:
Other:

Frame/Truss name IXXX — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area: both rafters
Joints with decayed peg:
Insect attack:
Failed joints: between lower collar & E rafter
Fungi attack:
Other:

Frame/Truss name north X — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area:
Joints with decayed peg:
Insect attack:
Failed joints: between lower collar & both rafters
Fungi attack:
Other:

Frame/Truss name non visible 1 — See drawing PKH-LH-4

Missing elements:
Elements with defects in critical area: E rafter
Joints with decayed peg: between upper collar & both rafters
Insect attack:
Failed joints: between lower collar & W rafter
Fungi attack:
Other: checks on both sides of both rafters

Element name A west rafter

Dating: original construction
Signs of reuse:
Timber treated: ☑ for insects, in 1970s
Accessibilityissues:
Past interventions: additional collar connecting the rafters & supporting the ceiling
Differences compared to other elements of the same type:
Section: nominal size (hxb) [cm]: 15x13.7 min. size (hxb) [cm]: 15x13.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 3 tangential
Knots [min d/section h]: 2/16 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☑
Other defects:
Estimated Strength Class according to UNI 11119: lower than III

Material degradation

Insect attack ☐ Type: Status:
Way of identification:
Fungi attack ☐ Type: Status:
Way of identification:
Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type — Status — Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☑ 9cm out of plomb — unknown
Estimated level of damage: initial Emergency interv. needed ☐
Mater.Degr. and Damage Extent:
Way of identification:

Estimated causes of primary damage
Poor design ☑ inadequate arrangement
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 16 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B upper collar

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13.2x10.5 min. size (hxb) [cm] 12.5x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 1/15 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☑ 9cm out of plomb unknown

Estimated level of damage initial Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point d

Moisture Content [%] 13 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 11.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C east rafter

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues

Past interventions additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.5x14 min. size (hxb) [cm] 15x14 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 1/14 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119 lower than III



checks on both sides of rafter I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point f

Moisture Content [%] 14.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point g

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point h

Moisture Content [%] 16.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Connection name between E rafter & upper collar FrameTrussCode PH-lh-nv1

Mechanical Damage: Type Status Role

Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



decayed peg, nothing left I:\Ar

Estimated causes of primary damage:

Poor design ☐ Poor maintenance ☐

External actions ☐ Material degrad. ☑

Poor construction ☐

Past interventions ☐

Other ☐

Description: decayed peg, nothing left

Estimated damage level: medium

Emergency intervention needed ☐

Frame/Truss name south I See drawing PKH-LH-3

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar and both rafters Insect attack

Failed joints between lower collar & W rafter Fungi attack

Other upper collar has reduced section due to old insect attack

Element name A west rafter

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues lower end not visible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15x14 min. size (hxb) [cm] 15x13 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point i

Moisture Content [%] 18.1

Ultrasonic velocity [m/s] 2118

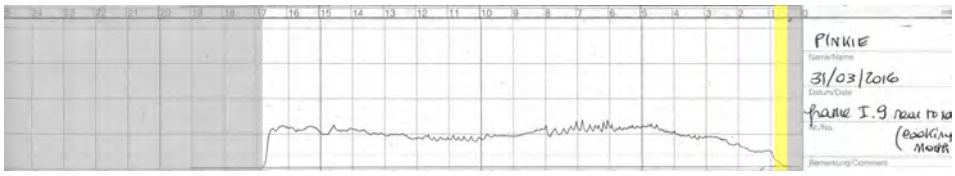
Density loss based on ultrasonic test [%] -30.6

Material Degradation based on Micro-drill [%] 2.3

Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point l

Moisture Content [%] 17.4

Ultrasonic velocity [m/s] 2116

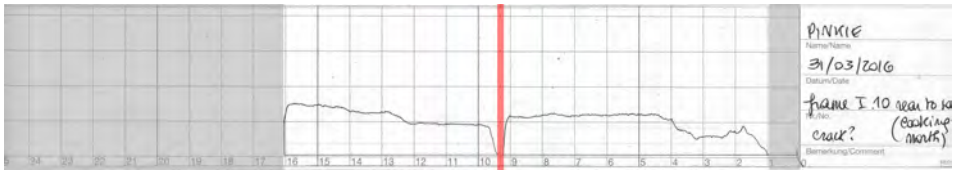
Density loss based on ultrasonic test [%] -30.5

Material Degradation based on Micro-drill [%] 1.7

Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point m

Moisture Content [%] 17.9

Ultrasonic velocity [m/s] 2003

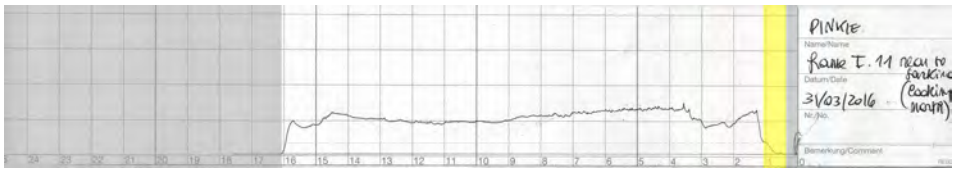
Density loss based on ultrasonic test [%] -26

Material Degradation based on Micro-drill [%] 3.8

Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point n

Moisture Content [%] 17.7

Ultrasonic velocity [m/s] 2267

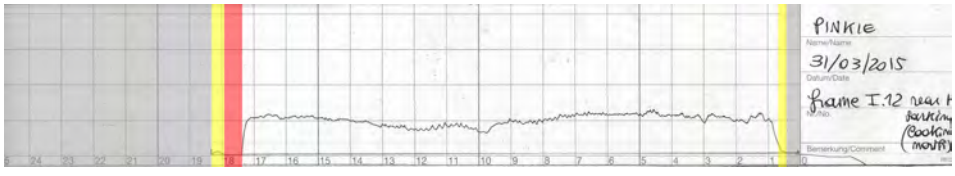
Density loss based on ultrasonic test [%] -36.5

Material Degradation based on Micro-drill [%] 6.2

Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point o

Moisture Content [%] 18.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B upper collar

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s - section reduced Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15x14 min. size (hxb) [cm] 14x13 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 3/14 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

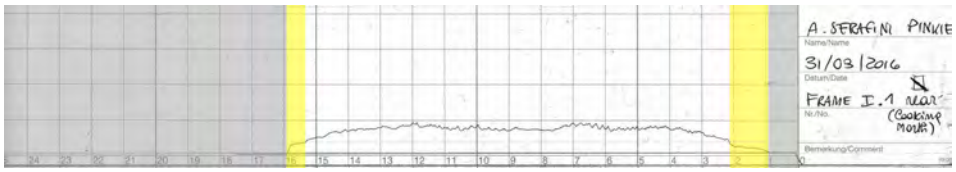
Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2226 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -34.9

Material Degradation based on Micro-drill [%] 9.3

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

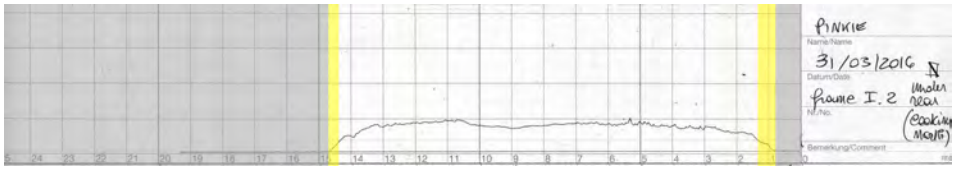
Moisture Content [%] 15.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2118 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -30.6

Material Degradation based on Micro-drill [%] 5.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

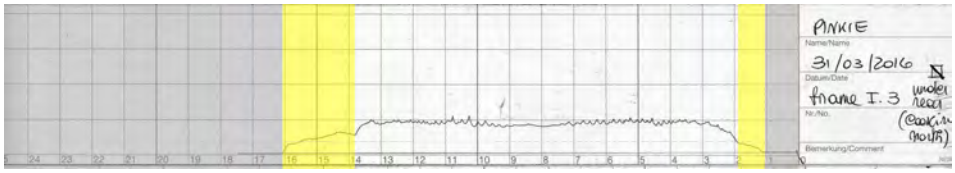
Moisture Content [%] 16 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2184 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -33.2

Material Degradation based on Micro-drill [%] 12.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name C east rafter

Dating original construction | Signs of reuse

Timber treated ☑ for insects, in 1970s

Accessibilityissues lower end not visible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.5x13.5 | min. size (hxb) [cm] 14x13 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 5 tangential

Knots [min d/section h] 4/13 single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status

Way of identification

Fungi attack ☐ Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point d

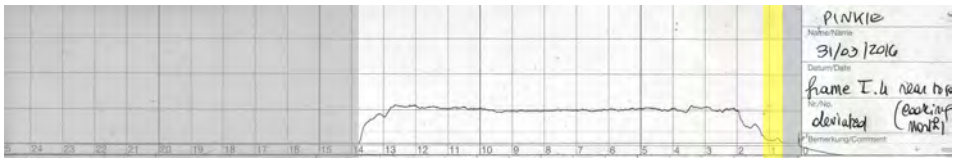
Moisture Content [%] 17.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2058 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -28.2

Material Degradation based on Micro-drill [%] 4.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point e

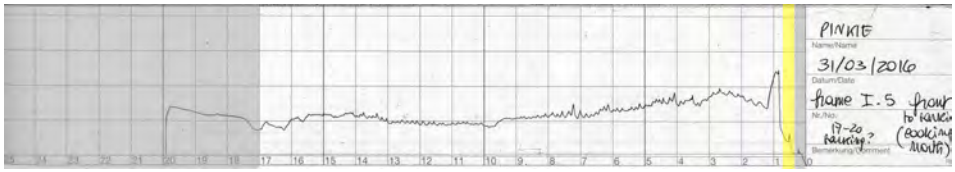
Moisture Content [%] 17.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2153 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -32

Material Degradation based on Micro-drill [%] 1.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point f

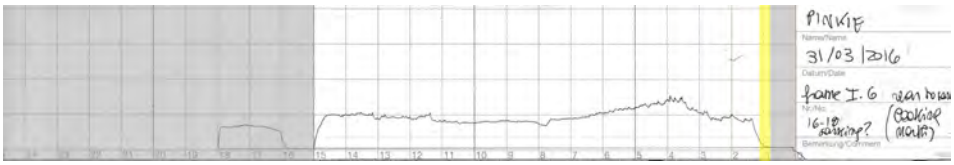
Moisture Content [%] 17 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2312 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -38.3

Material Degradation based on Micro-drill [%] 2.2

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point g

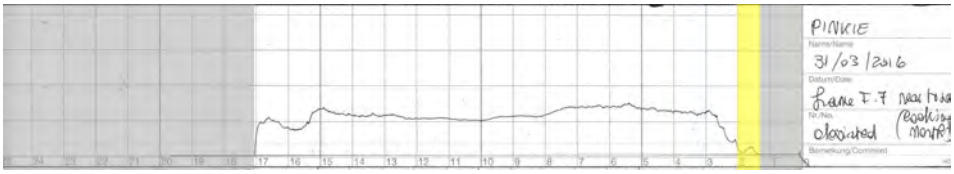
Moisture Content [%] 19.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2163 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -32.4

Material Degradation based on Micro-drill [%] 4

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point h

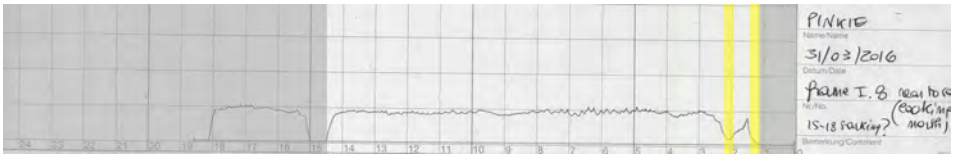
Moisture Content [%] 18.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2054 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -28.1

Material Degradation based on Micro-drill [%] 3.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Connection name between E rafter & lower collar | FrameTrussCode PH-lh-sl

Mechanical Damage: Type | Status | Role

Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



failed peg | I:\Ar

Estimated causes of primary damage:

Poor design ☑ wrong geometry | Poor maintenance ☐

External actions ☐ | Material degrad. ☐

Poor construction ☐ | Description

Past interventions ☐ | peg failed because joint charged in tension. 8cm open

Other ☐ | Estimated damage level rupture

Emergency intervention needed ☐

Frame/Truss name south XIIII | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area

Joints with decayed peg between upper collar & E rafter | Insect attack

Failed joints between lower collar & both rafters | Fungi attack

Other E rafter twisted

Frame/Truss name VXX | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area E rafter

Joints with decayed peg between upper collar & W rafter | Insect attack

Failed joints between lower collar & E rafter | Fungi attack

Other E rafter has reduced section due to old insect attack

Frame/Truss name south X | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: E rafter has reduced section due to old insect attack

Frame/Truss name south XII — See drawing PKH-LH-2
Missing elements | Elements with defects in critical area
Joints with decayed peg: between upper collar & E rafter | Insect attack
Failed joints: between lower collar & E rafter | Fungi attack
Other: W rafter has been cut to put entrance

Frame/Truss name north VIII — See drawing PKH-LH-3
Missing elements | Elements with defects in critical area: W rafter
Joints with decayed peg: between upper collar & E rafter | Insect attack
Failed joints: between lower collar & W rafter | Fungi attack
Other

Frame/Truss name north VII — See drawing PKH-LH-2
Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints: between lower collar & E rafter | Fungi attack
Other: upper collar & W rafter have reduced section due to old insect attack

Frame/Truss name VI — See drawing PKH-LH-2
Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other: upper collar & W rafter have reduced section due to old insect attack

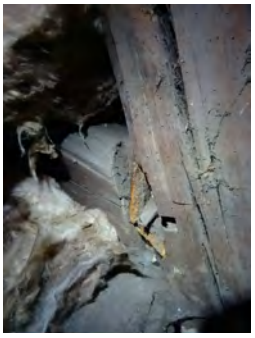
Frame/Truss name south V — See drawing PKH-LH-2
Missing elements | Elements with defects in critical area
Joints with decayed peg: between upper collar and both rafters | Insect attack
Failed joints: between lower collar & W rafter | Fungi attack
Other: upper collar has reduced section due to old insect attack; E rafter has been cut to put window

Frame/Truss name south IIII — See drawing PKH-LH-2
Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints: between lower collar & W rafter | Fungi attack
Other: upper collar & W rafter have reduced section due to old insect attack

Connection name between W rafter & lower collar — FrameTrussCode: PH-lh-sIIII

Mechanical Damage:

Type	Status	Role
Splitting: shear failure along grain ☑	unknown	primary
Crushing: compr. failure across grain ☐		
Disconnection due to shrinkage ☐		
Cracking ☐		
Fixing failure ☐		



Estimated causes of primary damage:

Poor design ☑ fastener too close to borders
Poor maintenance ☐
External actions ☐
Material degrad. ☐
Poor construction ☐
Description: part of rafter covering peg failed. 4cm open
Past interventions ☐
Other ☐

rafter failed I:\Ar
Estimated damage level: rupture
Emergency intervention needed ☐

Frame/Truss name south III — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area:
Joints with decayed peg: between upper collar and both rafters
Insect attack:
Failed joints: between lower collar & both rafters
Fungi attack:
Other: upper collar & W rafter have reduced section due to old insect attack

Frame/Truss name south II — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area: W rafter
Joints with decayed peg: between upper collar and both rafters
Insect attack:
Failed joints: between lower collar & both rafters
Fungi attack:
Other: upper collar has reduced section due to old insect attack

Frame/Truss name centre II — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area: E rafter
Joints with decayed peg: between upper collar & W rafter
Insect attack:
Failed joints: between lower collar & W rafter
Fungi attack:
Other:

Frame/Truss name XIIIII — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area: both rafters
Joints with decayed peg: between upper collar & E rafter
Insect attack:
Failed joints:
Fungi attack:
Other:

Frame/Truss name north II — See drawing PKH-LH-2

Missing elements:
Elements with defects in critical area: both rafters
Joints with decayed peg: between upper collar & E rafter
Insect attack:
Failed joints: between lower collar & W rafter
Fungi attack:
Other:

Frame/Truss name north III — See drawing PKH-LH-6

Missing elements:
Elements with defects in critical area: both rafters
Joints with decayed peg: between upper collar & both rafters
Insect attack:
Failed joints:
Fungi attack:
Other:

Element name A west rafter

Dating: original construction | Signs of reuse:

Timber treated: ☑ for insects, in 1970s | Accessibilityissues: lower end not visible

Past interventions: additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 16x13.5 | min. size (hxb) [cm]: 14x12 | Single piece: ☑ | Jointed element: ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 4 | tangential

Knots [min d/section h]: 4/11 | single | Knotty element: ☐ | Defects in critical area: ☑ | Deep checks on both sides of element: ☐

Other defects: shakes all along element

Estimated Strength Class according to UNI 11119: lower than III

Material degradation

Insect attack: ☐ | Type: | Status: | Way of identification:

Fungi attack: ☐ | Type: | Status: | Way of identification:

Corrosion: ☐ | Wet surface: ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Estimated level of damage: | Emergency interv. needed: ☐

Mater.Degr. and Damage Extent: | Way of identification:

Element name B upper collar

Dating: original construction | Signs of reuse:

Timber treated: ☑ for insects, in 1970s | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 13x11.7 | min. size (hxb) [cm]: 13x11.5 | Single piece: ☑ | Jointed element: ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 9 | tangential

Knots [min d/section h]: 3/13 | single | Knotty element: ☐ | Defects in critical area: ☐ | Deep checks on both sides of element: ☐

Other defects:

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack: ☐ | Type: | Status: | Way of identification:

Fungi attack: ☐ | Type: | Status: | Way of identification:

Corrosion: ☐ | Wet surface: ☐ | Other:



insects treatment | I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

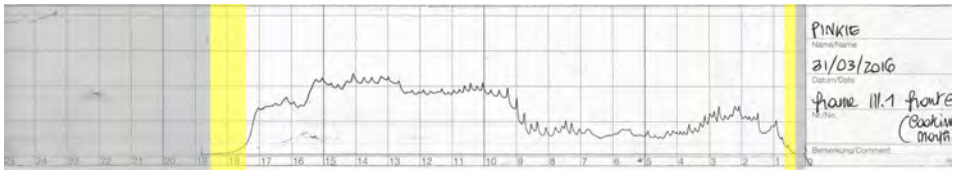
Estimated level of damage: | Emergency interv. needed: ☐

Mater.Degr. and Damage Extent: | Way of identification:

Measurement Point a

Moisture Content [%] 19.4
Ultrasonic velocity [m/s] 2185
Density loss based on ultrasonic test [%] -33.3
Material Degradation based on Micro-drill [%] 7.3
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

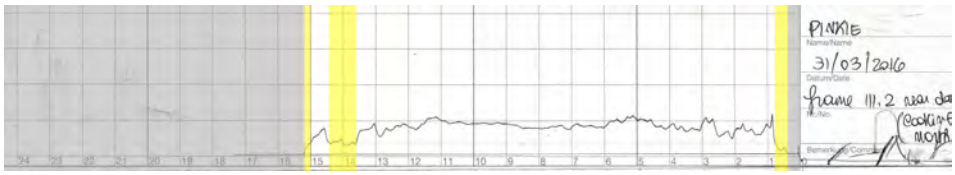


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 19.1
Ultrasonic velocity [m/s] 2051
Density loss based on ultrasonic test [%] -28
Material Degradation based on Micro-drill [%] 6.7
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C east rafter

Dating original construction
Signs of reuse
Timber treated ☑ for insects, in 1970s
Accessibilityissues lower end not visible
Past interventions additional collar connecting the rafters & supporting the ceiling
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 15.5x14.5 min. size (hxb) [cm] 15x14 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] 4/15.5 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

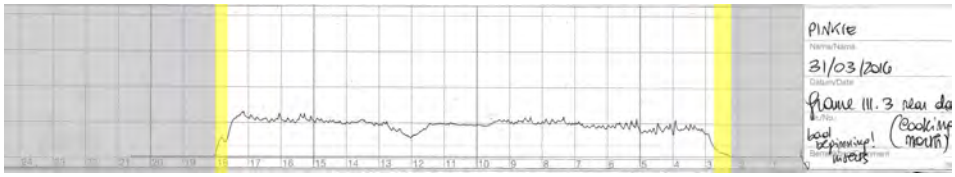
Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point c

Moisture Content [%] 18.1
Ultrasonic velocity [m/s] 1769
Density loss based on ultrasonic test [%] -16.8
Material Degradation based on Micro-drill [%] 4.4
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

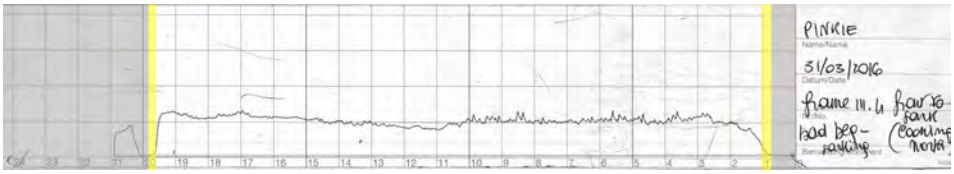
Moisture Content [%] 19.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2353 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -39.9

Material Degradation based on Micro-drill [%] 2.8

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point e

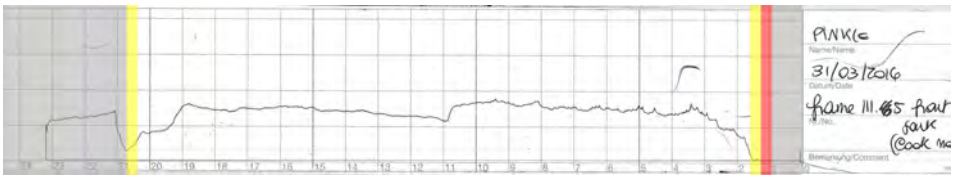
Moisture Content [%] 20.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2216 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -34.5

Material Degradation based on Micro-drill [%] 4.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point f

Moisture Content [%] 14.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point g

Moisture Content [%] 15.3 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point h

Moisture Content [%] 15.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name north IIII | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area

Joints with decayed peg between upper collar & both rafters | Insect attack

Failed joints between lower collar & W rafter | Fungi attack

Other

Frame/Truss name north V | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area E rafter

Joints with decayed peg: between upper collar & E rafter | Insect attack:
Failed joints: between lower collar & both rafters | Fungi attack:
Other:

Frame/Truss name south VII — See drawing PKH-LH-2

Missing elements: | Elements with defects in critical area: E rafter
Joints with decayed peg: between upper collar & W rafter | Insect attack:
Failed joints: between lower collar & W rafter | Fungi attack:
Other:

Frame/Truss name south VIII — See drawing PKH-LH-2

Missing elements: | Elements with defects in critical area: W rafter
Joints with decayed peg: between upper collar & E rafter | Insect attack:
Failed joints: between lower collar & W rafter | Fungi attack:
Other:

Element name A west rafter

Dating: original construction | Signs of reuse:
Timber treated: ☑ for insects, in 1970s | Accessibilityissues: lower end not visible
Past interventions: additional collar connecting the rafters & supporting the ceiling
Differences compared to other elements of the same type:
Section: nominal size (hxb) [cm]: 18x14 | min. size (hxb) [cm]: 18x14 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 2 | tangential
Knots [min d/section h]: 8/18 | single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐
Other defects:
Estimated Strength Class according to UNI 11119: III

Material degradation

Insect attack ☐ | Type: | Status:
Way of identification:
Fungi attack ☐ | Type: | Status:
Way of identification:
Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: | Emergency interv. needed ☐
Mater.Degr. and Damage Extent: | Way of identification:

Estimated causes of primary damage
Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 16.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s]: | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 15.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B upper collar

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.5x11 min. size (hxb) [cm] 15x11 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 3/15 Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point d

Moisture Content [%] 16.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 16.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C east rafter

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues lower end not visible

Past interventions additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19.5x15.5 min. size (hxb) [cm] 19x15 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 8 tangential

Knots [min d/section h] 1/16 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point f

Moisture Content [%] 16.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point g

Moisture Content [%] 16.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point h

Moisture Content [%] 17.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Connection name between E rafter & upper collar | FrameTrussCode PH-lh-sVIII

Mechanical Damage:	Type	Status	Role
Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



decayed peg | I:\Ar

Estimated damage level initial

Emergency intervention needed ☐

Estimated causes of primary damage:

Poor design ☐ | Poor maintenance ☐

External actions ☐ | Material degrad. ☑

Poor construction ☐

Past interventions ☐

Other ☐

Description: decayed peg

Frame/Truss name IIIIV | See drawing PKH-LH-5

Missing elements | Elements with defects in critical area both rafters

Joints with decayed peg | Insect attack

Failed joints between lower collar & W rafter | Fungi attack

Other wound on E rafter

Element name A west rafter

Dating original construction | Signs of reuse

Timber treated ☑ for insects, in 1970s

Accessibilityissues lower end not visible

Past interventions additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 14.5x13.2 | min. size (hxb) [cm] 14x12.5 | Single piece ☑ | Jointed element ☐

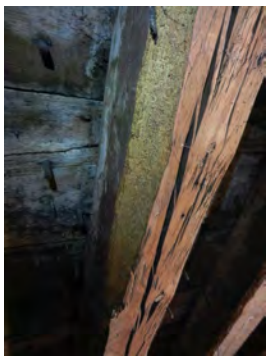
Strength affecting defects

Pith location centre | Slope of grain [%] 6 tangential

Knots [min d/section h] 4/15 single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



treatment for insects | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point c

Moisture Content [%] 15.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 16.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 16.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B upper collar

Dating original construction Signs of reuse
Timber treated ☑ for insects, in 1970s
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 12x12 min. size (hxb) [cm] 12x11.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

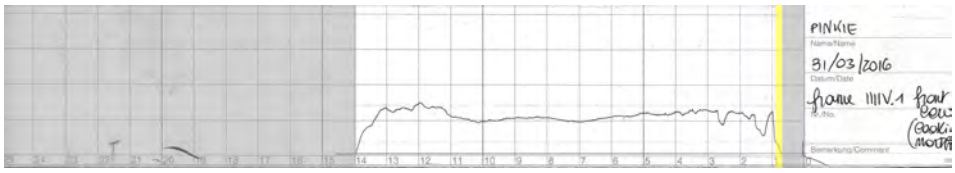
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 18.3
Ultrasonic velocity [m/s] 1950
Density loss based on ultrasonic test [%] -24
Material Degradation based on Micro-drill [%] 1.8
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 17.8
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C east rafter

Dating original construction
Signs of reuse
Timber treated ☑ for insects, in 1970s
Accessibilityissues lower end not visible
Past interventions additional collar connecting the rafters & supporting the ceiling
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 15x14 min. size (hxb) [cm] 14x13 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential
Knots [min d/section h] 4/14 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐
Other defects wound in central section
Estimated Strength Class according to UNI 11119 II



Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type wound (injury to living tree) I:\Arc
Status
Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point f

Moisture Content [%] 16.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point g

Moisture Content [%] 15.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point h

Moisture Content [%] 16.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name south XI See drawing PKH-LH-2

Missing elements Elements with defects in critical area E rafter

Joints with decayed peg between upper collar & E rafter Insect attack

Failed joints Fungi attack

Other

Frame/Truss name north XII See drawing PKH-LH-2

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar & E rafter Insect attack

Failed joints between lower collar & W rafter Fungi attack

Other

Frame/Truss name XXVII See drawing PKH-LH-4

Missing elements Elements with defects in critical area W rafter

Joints with decayed peg between upper collar & W rafter Insect attack

Failed joints Fungi attack

Other

Element name A west rafter

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues lower end not visible

Past interventions additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 16x14.5 min. size (hxb) [cm] 16x14 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 3 | tangential

Knots [min d/section h]: 5/14 | single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☑ 7cm out of plomb	unknown	

Estimated level of damage: initial | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point e

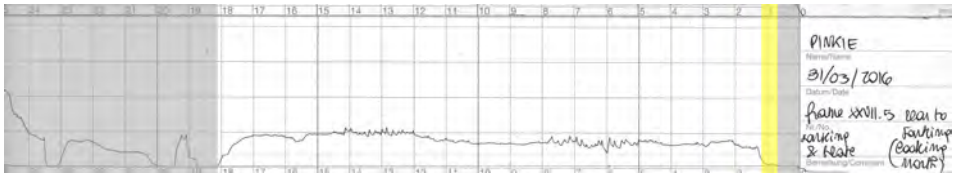
Moisture Content [%]: 18 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 2171 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -32.7

Material Degradation based on Micro-drill [%]: 2.7

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point f

Moisture Content [%]: 15 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]:

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point f

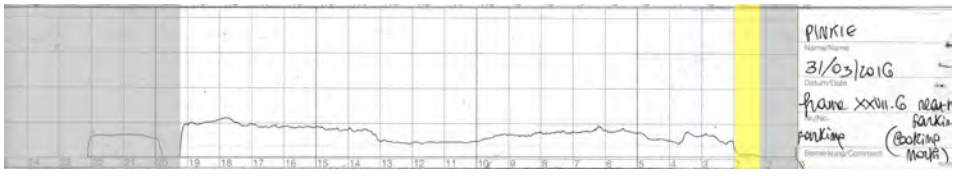
Moisture Content [%]: 18.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 2345 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -39.6

Material Degradation based on Micro-drill [%]: 4

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point g

Moisture Content [%]: 15.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]:

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point g

Moisture Content [%] 17.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point h

Moisture Content [%] 16 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B upper collar

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.5x13.5 min. size (hxb) [cm] 15x13 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 8 tangential

Knots [min d/section h] 3/14 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☑ 7cm out of plomb	unknown	

Estimated level of damage initial Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

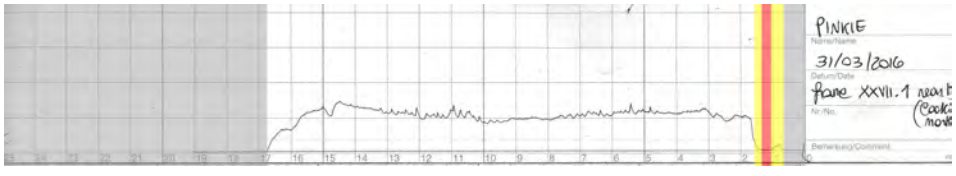
Moisture Content [%] 18 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1941 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -23.6

Material Degradation based on Micro-drill [%] 5.5

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 17 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point h

Moisture Content [%] 14.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C east rafter

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s Accessibilityissues lower end not visible

Past interventions additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 16.7x13.7 min. size (hxb) [cm] 16.5x13.5 Single piece ☑ Jointed element ☐

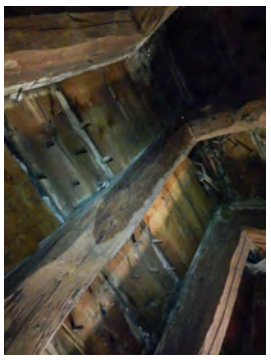
Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 4/14 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



wet surface close to upper end I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☑ 9cm out of plomb	unknown	

Estimated level of damage initial Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point b

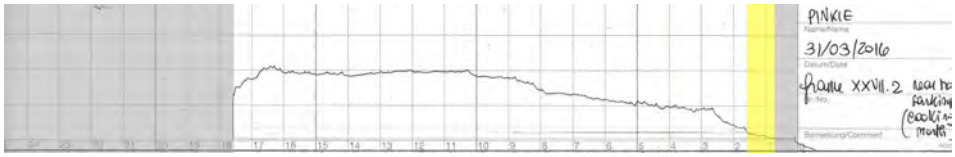
Moisture Content [%] 18.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2032 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -27.2

Material Degradation based on Micro-drill [%] 4.8

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

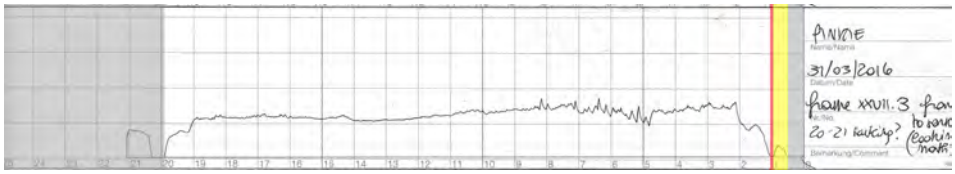
Moisture Content [%] 18.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2153 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -32

Material Degradation based on Micro-drill [%] 2.6

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

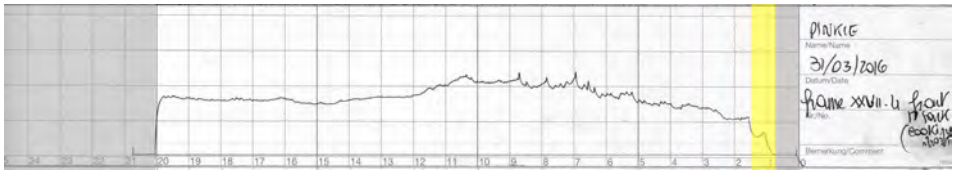
Moisture Content [%] 18.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2055 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -28.1

Material Degradation based on Micro-drill [%] 2.8

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Connection name between W rafter & lower collar | FrameTrussCode PH-lh-XXVII

Mechanical Damage: Type		Status	Role
Splitting: shear failure along grain	☐		
Crushing: compr. failure across grain	☐		
Disconnection due to shrinkage	☐		
Cracking	☐		
Fixing failure	☑	unknown	primary



decayed peg, nothing left | I:\Ar

Estimated causes of primary damage:

Poor design ☐ | Poor maintenance ☐

External actions ☐ | Material degrad. ☑

Poor construction ☐

Past interventions ☐

Other ☐

Description: decayed peg, nothing left

Estimated damage level: medium

Emergency intervention needed ☐

Frame/Truss name north XIIII | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area: E rafter

Joints with decayed peg: between upper collar & E rafter | Insect attack

Failed joints | Fungi attack

Other

Frame/Truss name XXVI | See drawing PKH-LH-2

Missing elements | Elements with defects in critical area

Joints with decayed peg: between upper collar & both rafters | Insect attack

Failed joints: between lower collar & E rafter | Fungi attack

Other

Frame/Truss name IVX — See drawing PKH-LH-2

Missing elements | Elements with defects in critical area: E rafter

Joints with decayed peg: between upper collar & both rafters | Insect attack

Failed joints | Fungi attack

Other

Frame/Truss name XVII — See drawing PKH-LH-5

Missing elements | Elements with defects in critical area

Joints with decayed peg: between upper collar & W rafter | Insect attack

Failed joints: between lower collar & W rafter | Fungi attack

Other

Element name A west rafter

Dating: original construction | Signs of reuse

Timber treated ☑ for insects, in 1970s | Accessibilityissues: lower end not visible

Past interventions: additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 16.5x13 | min. size (hxb) [cm]: 16x12.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 2 | tangential

Knots [min d/section h]: 5/16 | single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☑ 19cm out of plomb | unknown

Estimated level of damage: medium | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name B upper collar

Dating: original construction | Signs of reuse

Timber treated ☑ for insects, in 1970s | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 12.5x11.7 | min. size (hxb) [cm]: 12x11.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 2 | tangential

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☑ 19cm out of plomb	unknown	

Estimated level of damage medium Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name C east rafter

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1970s

Accessibilityissues lower end not visible

Past interventions additional collar connecting the rafters & supporting the ceiling

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x13 min. size (hxb) [cm] 13x13 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 3/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☑ 19cm out of plomb	unknown	

Estimated level of damage medium Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☑ inadequate arrangement

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

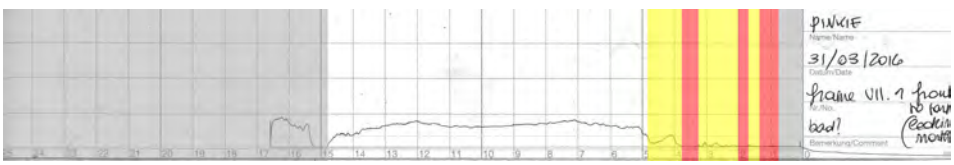
Moisture Content [%] 18.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 2165 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -32.5

Material Degradation based on Micro-drill [%] 26.3

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 15.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XVIII See drawing PKH-LH-2

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar & both rafters Insect attack

Failed joints between lower collar & E rafter Fungi attack

Other

Frame/Truss name XVIIII See drawing PKH-LH-2

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar & W rafter Insect attack

Failed joints Fungi attack

Other

Frame/Truss name XX See drawing PKH-LH-2

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar & E rafter Insect attack

Failed joints Fungi attack

Other

Frame/Truss name XXII See drawing PKH-LH-2

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar & W rafter Insect attack

Failed joints between lower collar & E rafter Fungi attack

Other

Frame/Truss name XXIIII See drawing PKH-LH-2

Missing elements Elements with defects in critical area

Joints with decayed peg between upper collar & W rafter Insect attack

Failed joints Fungi attack

Other

Frame/Truss name	**XXIII**	See drawing PKH-LH-2	
Missing elements		Elements with defects in critical area	E rafter
Joints with decayed peg	between upper collar & W rafter	Insect attack	
Failed joints		Fungi attack	
Other	E rafter twisted and has reduced section due to old insect attack		

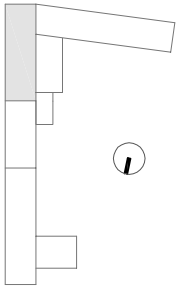
Frame/Truss name	**non visible 2**	See drawing PKH-LH-2	
Missing elements		Elements with defects in critical area	
Joints with decayed peg	between upper collar & both rafters	Insect attack	
Failed joints	between lower collar & both rafters	Fungi attack	
Other			

Frame/Truss name	**XIII**	See drawing PKH-LH-2	
Missing elements		Elements with defects in critical area	
Joints with decayed peg	between upper collar & E rafter	Insect attack	
Failed joints	between lower collar & E rafter	Fungi attack	
Other			

Plan 1:200

- ✳ **air humidity and temperature**
- ⊙ timber samples for species identification

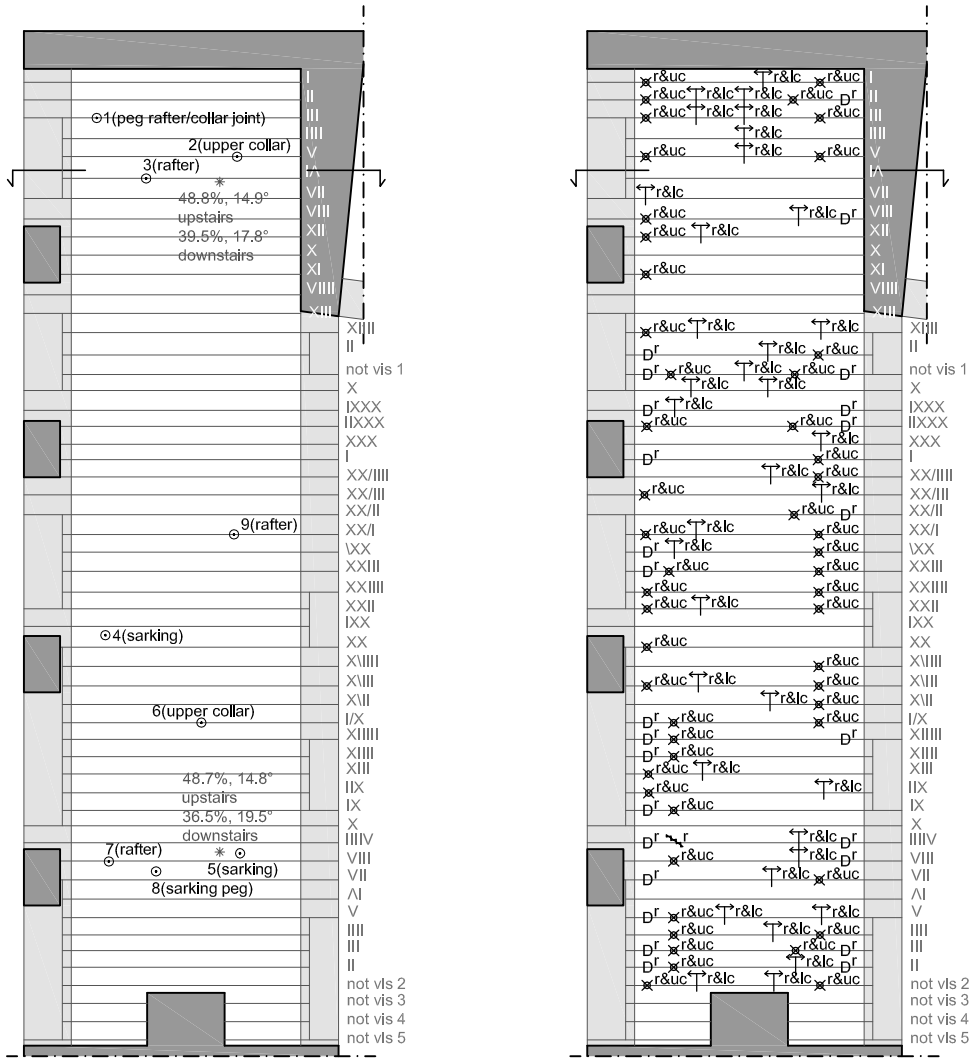
0 1 5



Visual Inspection:

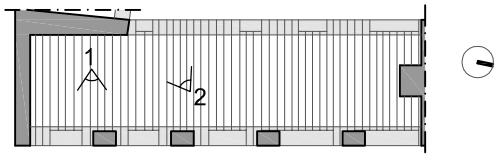
r=rafter
uc=upper collar
lc=lower collar
sk=sarking

- D element with defects in critical area
- wound (injury to living tree)
- failed joint
- decayed peg in joint

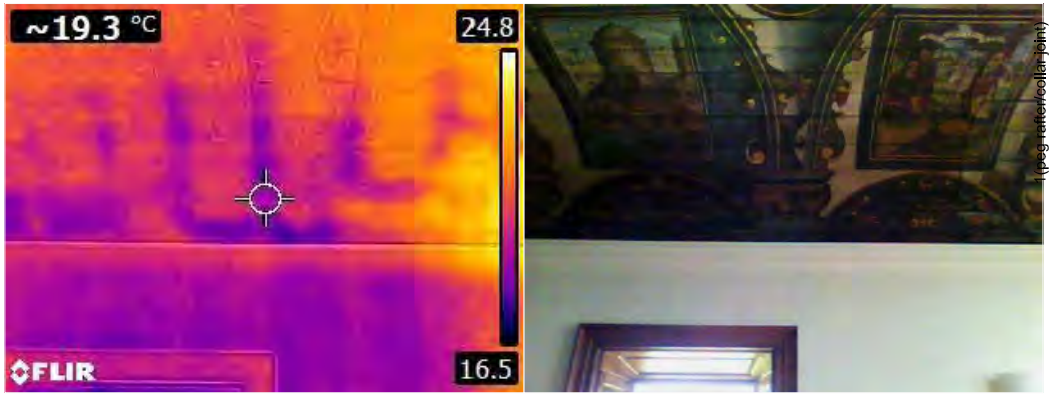


Themographic images

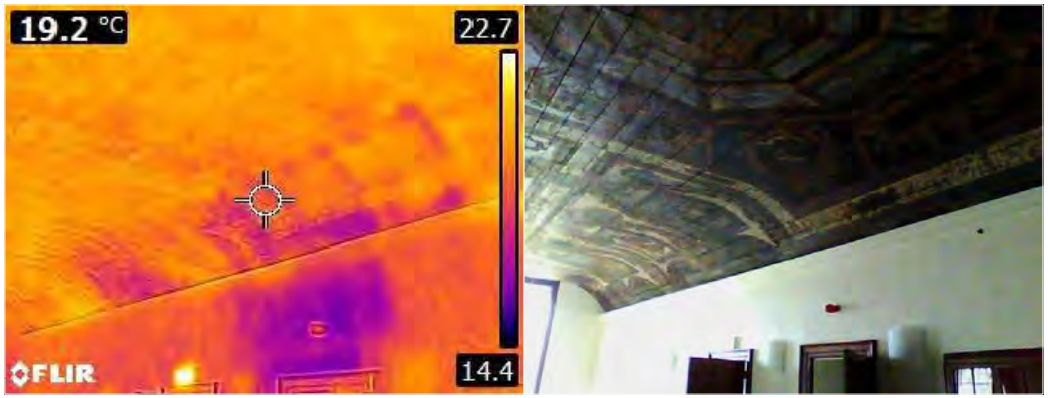
Plan 1:500



1: areas with lower temperature identify the position of the structure behind the painted timber panels



2: areas with lower temperature identify patches of humidity on the East wall



0 1 5

Sections 1:100 (looking North)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- decayed peg in joint
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

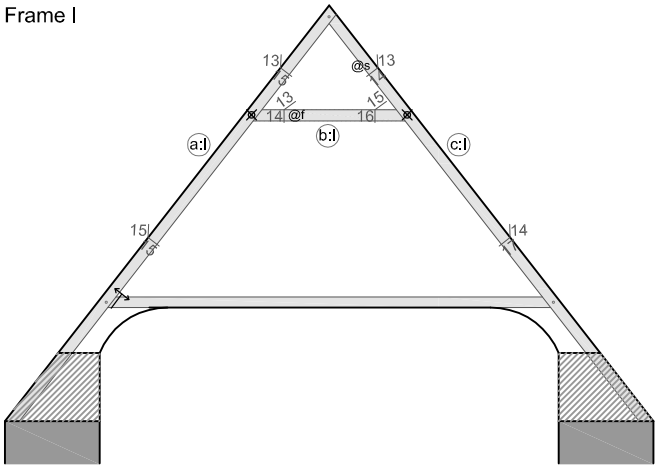
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

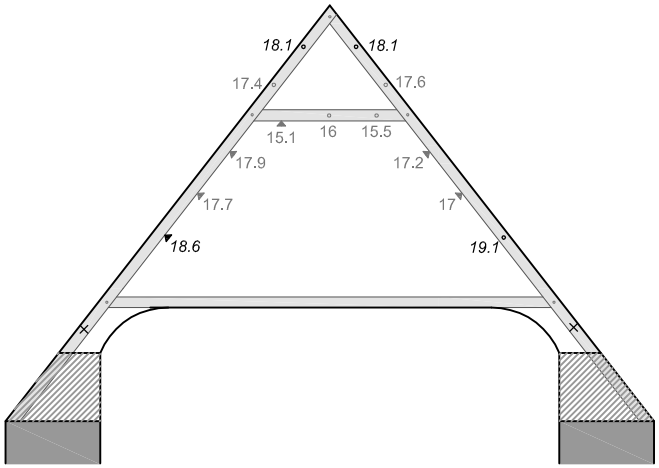
readings <18
readings >18
readings >20

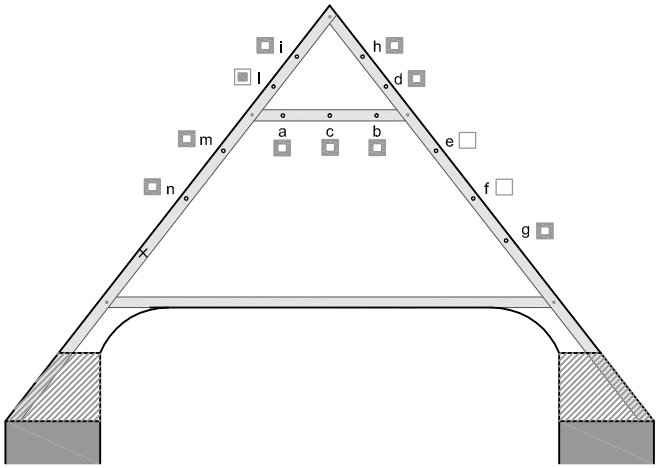
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & int. decay
- extensive decay

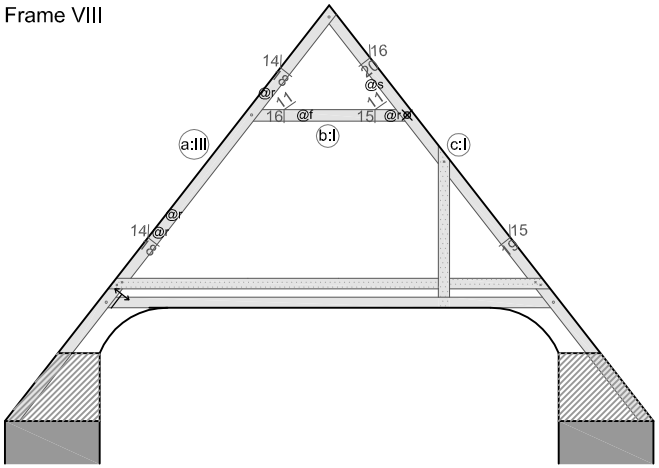
Frame I

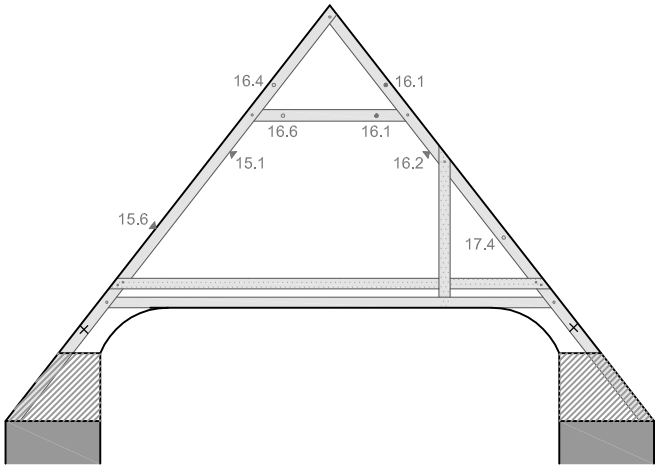






Frame VIII





0 1 5

Sections 1:100 (looking North)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- decayed peg in joint
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

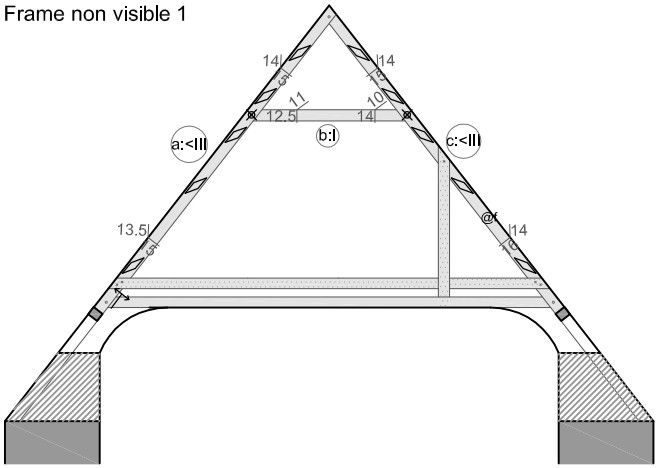
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

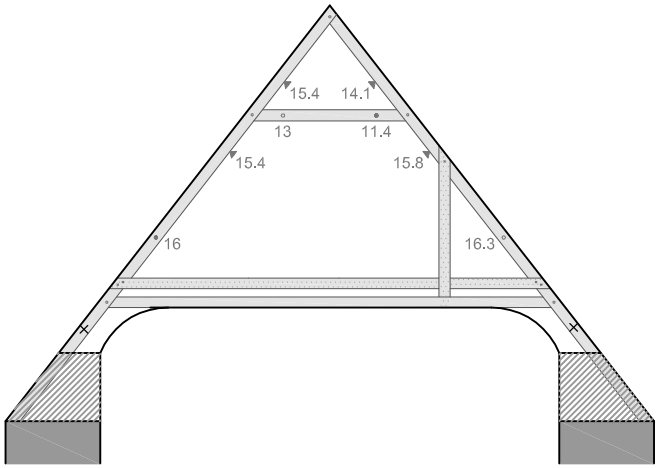
readings <18
readings >18
readings >20

Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

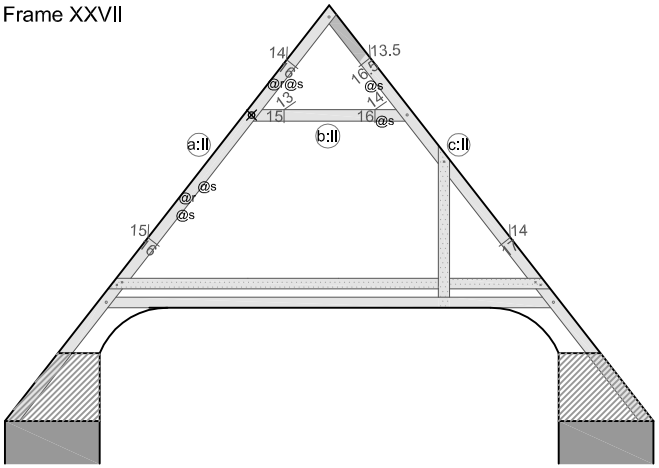
Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & int. decay
- extensive decay

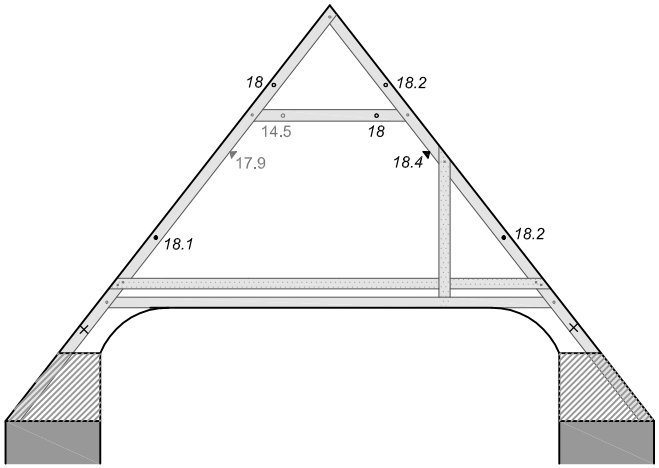
Frame non visible 1

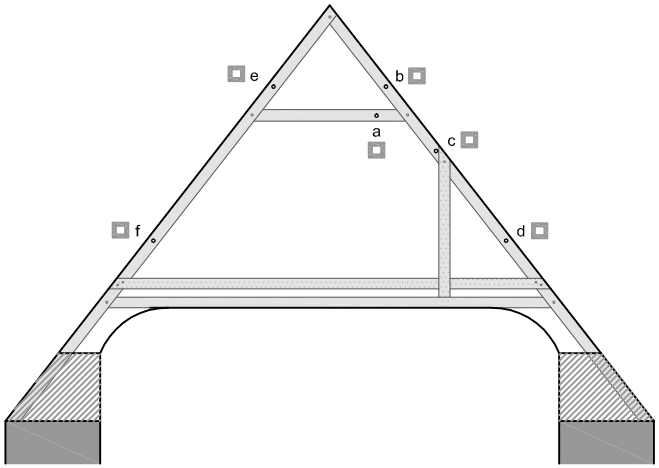




Frame XXVII







0 1 5

Sections 1:100 (looking North)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
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Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
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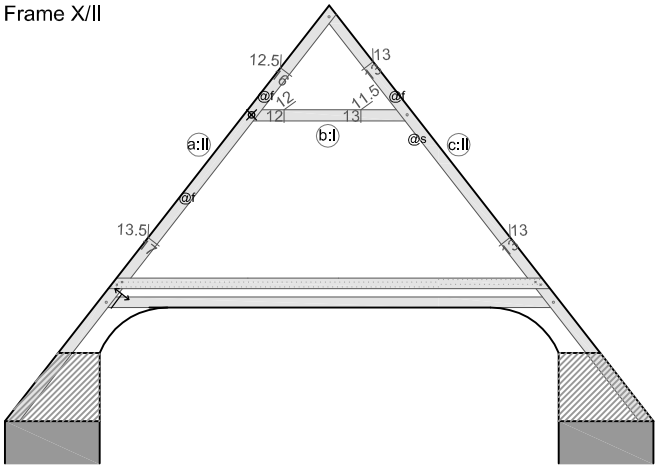
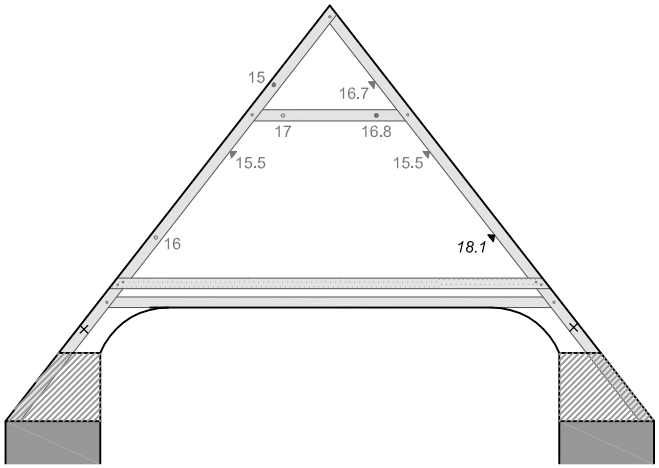
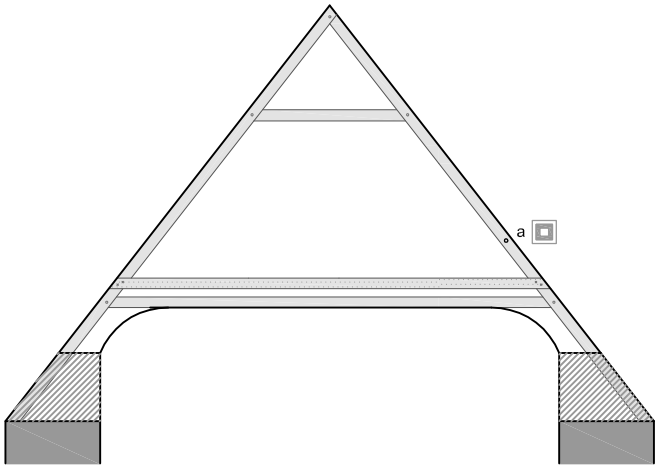
Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & int. decay
- extensive decay

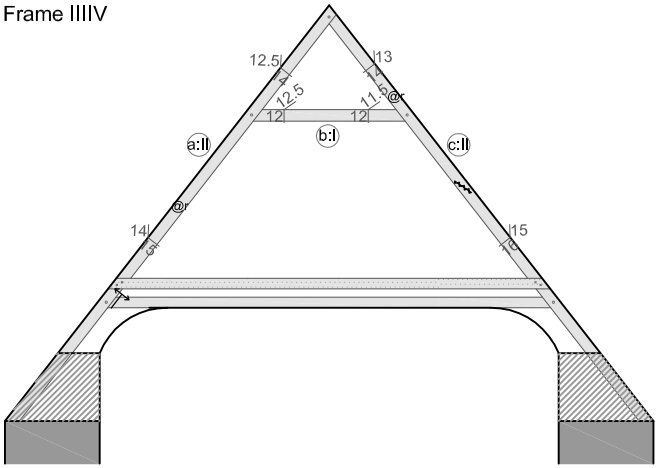
Frame X/II

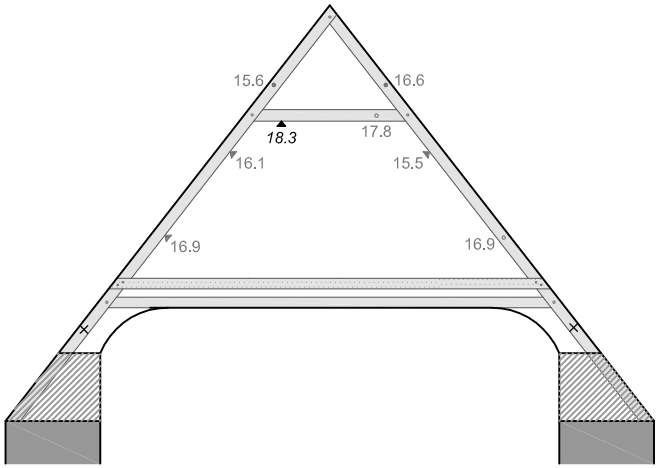


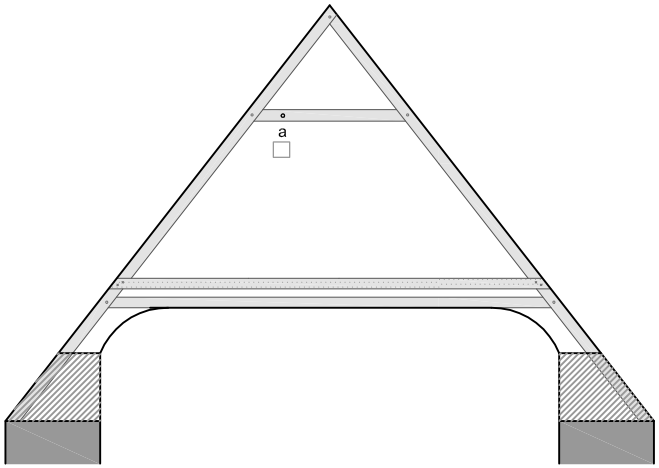




Frame IIIIV







0 1 5

Sections 1:100 (looking North)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
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Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
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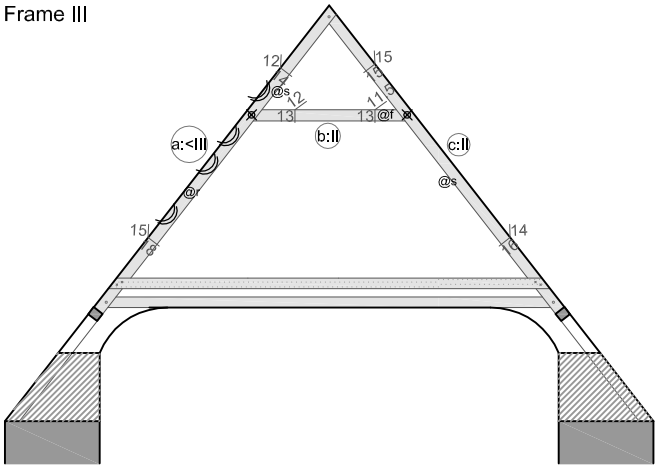
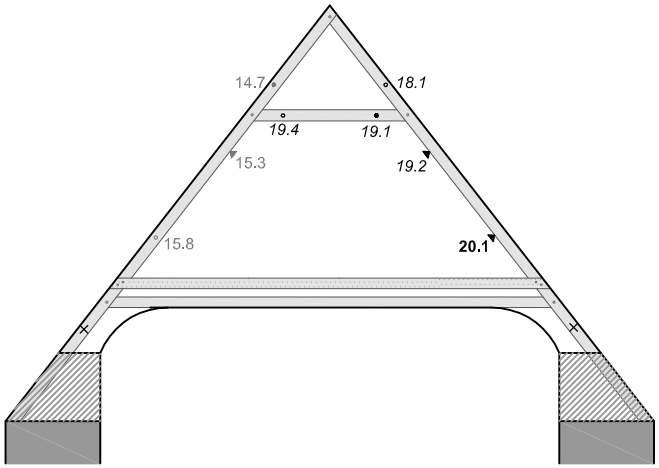
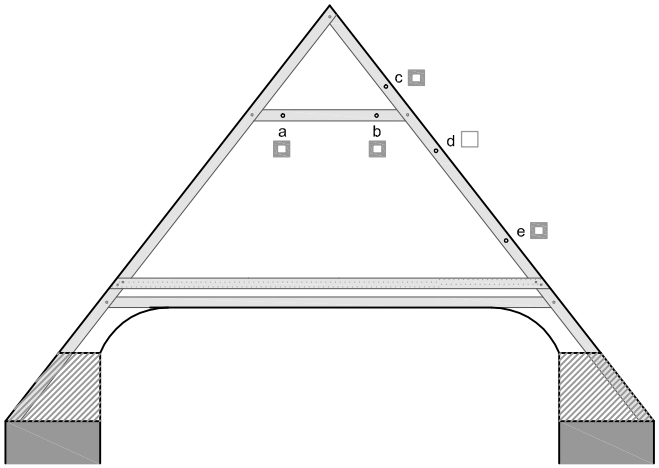
- internal decay
- ext. & int. decay
- extensive decay

Frame III







0 1 5

Preliminary conclusions on stress calculations for roof timbers at Pinkie House, Musselburgh

1 Introduction

A structural analysis was carried out for the semi-trussed rafters which form the principal structural elements of the roof.

The analysis was based on survey drawings and member dimensions provided by Anna Serafini. Dimensional checks on the overall shape of the roof using trigonometry indicated that the survey was very accurate.

It was noted that there was considerable variation in the cross-sectional dimensions of both rafters and collars. Stress calculations were carried out for the complete range of sizes.

The analysis was carried out for a combination of dead load (due to the self weight of the structure and the weights of slates, sarking and painted ceiling), gravitational imposed load (due to snow) and imposed wind load. The values of snow and wind load were appropriate for the latitude and location of the building but it was noted that, in view of the pitch of the roof, the likelihood of significant snow load was small.

The analysis was based on the following assumptions:

- that the rafters were continuous from apex to wallhead
- that the joints between the collars and the rafters behaved as hinges
- that no significant internal force passed through the apex joint

Due to lack of access it was not possible to make a precise assessment of the support conditions at the junctions between the wallhead and the lower ends of the rafters. Two separate analyses were therefore carried out, one based on the assumption that no horizontal reaction occurred at the wallhead and one on the assumption that sufficient horizontal reaction could be developed to eliminate bending moment in the lowest sections of the rafters. It is likely that the actual behaviour of the roof lies somewhere between these two extremes.

For each of the analyses a full set of internal forces was evaluated and bending moment and shear force diagrams were drawn. Maximum combined bending and axial stresses were evaluated from these. The likely levels of shear stress in the oak pegs at the junctions between the lower collars and the rafters were also assessed.

A visual inspection was carried out from within the interior of the roof-space and the following noted:

- that the overall geometry of the roof had been preserved, indicating that the structure was fulfilling its support function adequately. There was no

evidence of sagging or other movement which would indicate that the structure was failing to provide the necessary support for the roof covering.

- that, relatively recently, the lower collars had been augmented by the insertion of additional timber elements. These appeared to be relieving the original lower collars of all structural functions other than that of providing support for the underlying painted ceiling.
  For the purposes of the structural analysis (i.e. calculation of internal forces) it was assumed that the functions of both sets of lower collars were combined. For the stress calculations, it was assumed that the internal forces were carried by the original collars only.
- that the tendons of some of the original collars had pulled out from the mortices in the rafters but that this did not appear to have caused significant distortion of the roof surface.

2 Results of the calculations

2.1 Assuming no horizontal reactions at the wallhead

It was found that:

- the highest stresses occurred in the rafter elements at the location of the junction with the lower collars. These stresses were local and diminished rapidly with distance from the collar joint.
- the highest stresses (both combined bending and axial stress in the rafters and shear stress in the oak pins) were within the failure strengths of the timber but were close to the failure strengths. In other words, that the factor of safety against strength failure was minimal.
- the tie force in the lower collars was high (around 10 kN).
- failure of the joint between the lower collar and the rafter would cause that particular frame to collapse. It would, of course, derive support from adjacent frames through connection by the sarking, but only if the adjacent frames had an adequate margin of strength.

2.2 Assuming sufficient horizontal reaction at the wallhead to minimise bending in the lower section of the rafters

It was found that for this support condition the combined stresses in the rafters were significantly lower than the probable failure strength of the timber (around 10% of the failure strength).

3 Conclusions

1 The analysis showed that the roof geometry and timber sizes are adequate for all conditions of support but marginal in the absence of a connection at the wallhead which is capable of producing a significant horizontal reaction.

2 In view of the good overall condition of the roof it seems probable that significant horizontal reaction is in fact being developed at the junctions between the wallheads and the rafters.

3 It was found that the integrity of the joint between the lower collar and the rafter was critical to the structural functioning of the roof if no horizontal reaction was present at the wallhead. The fact that some of the connections appeared to have failed without causing significant distress to the overall shape of the roof is a further indication that the rafter/wallhead joint is providing a significant horizontal reaction.

4 It is reasonable to conclude that if, in future, there is any indication of structural failure (e.g. by the development of sagging in the roof surface) it is likely that the cause of this will be movement in the rafter/wallhaead junction producing a reduction in the horizontal reaction.

5 The most critical structural aspect of the roof is the junction of the rafters and the wallhead.

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9 June 2016

EDINBURGH ST ANDREW'S AND ST GEORGE'S CHURCH

Location: EDINBURGH, CITY OF | EDINBURGH (EDINBURGH, CITY OF)

X coordinate: 325425 Y coordinate: 674098

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: CHURCH

Rcahms ID: 52433

HS Listing: A

Original Use: Church

Current Use: Church

Freestanding: ☑ N. of floors above ground level: 1 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1782	1784		HS

People involved:

Last Name	First Name	Role
FRAZER	MAJOR ANDREW	ARCHITECT
KAY	DAVID	ARCHITECT

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1787		STEEPLE	HS

People involved:

Last Name	First Name	Role
STEVENS	ALEXANDER THE ELD	ARCHITECT

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1953		INTERIORS	HS

People involved:

Last Name	First Name	Role
ESME	GORDON	ARCHITECT

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1976	1979	INTERIORS	HS

People involved:

Last Name	First Name	Role
HURD & PARTNERS	ROBERT	ARCHITECT

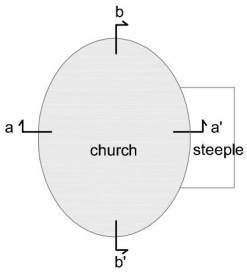
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2003	2004	INTERIORS AND VODAPHONE PLANT INSTALLED IN ROOF SPACE	CHURCH ARCHITECT

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
GIFFORD J. & CHRISTOPHER WILSON	1984	☐	THE BUILDINGS OF SCOTLAND COLLECTION: EDINBURGH	

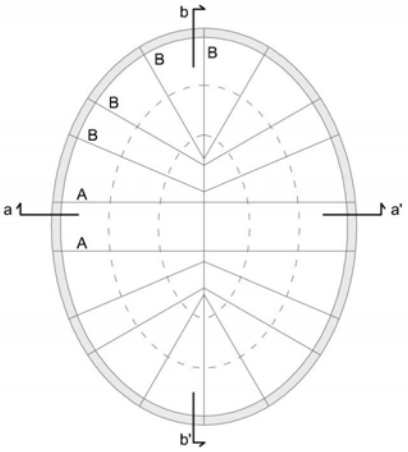
Suggestions for further research:



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

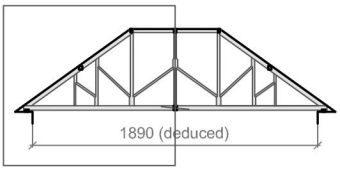
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

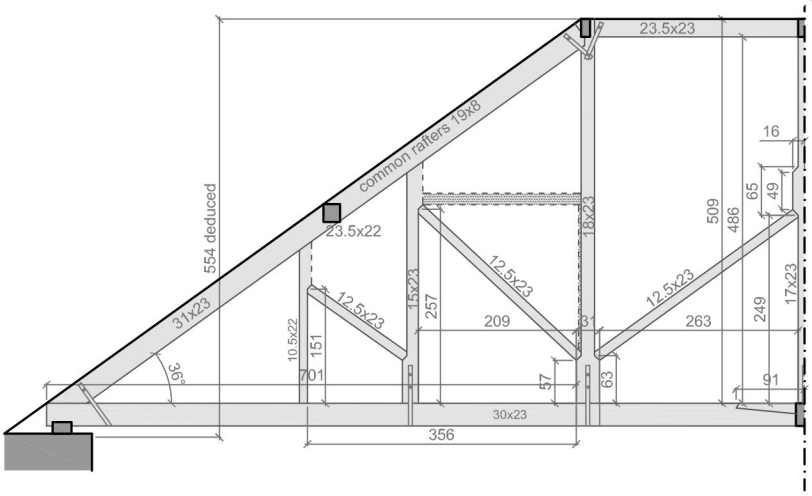


Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa': Truss A

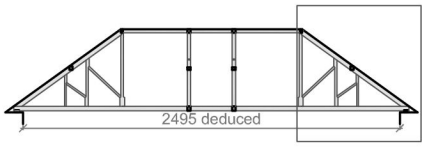


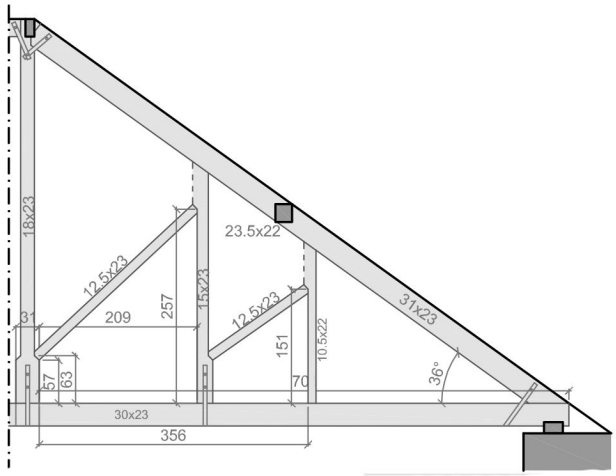


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb': Truss B





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Roof from outside I:\Arch\A



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** EDINBURGH ST ANDREW'S AND ST GEORGE'S | **Roof location** Church main hall

Survey date(s) 03/07/2015 | See drawing: SASGC-MH-1

Roof Geometry: Conical, Flat

Roof Max Span [m]: 18.9 | Roof Height [m]: 5.5

Roof Pitch/es [°]: 36 | Roof Length [m]: 25

Type of Primary Structure: 3D framing

Truss ☑ OTHER

Frame ☐

Average Distance in between Primary Structure [m]: 2.75

Type of Secondary Structure: common rafters, purlins, sarking

Sarking boards: width [cm] | thickness [cm]: 2.3

Connection with lateral walls: Wall-plate

Connection with gables: no gables

Roof Construction Period: From 1782 To 1784 Identified by: Estimated

Roof General Description:

It's an elliptical space, with two main 'queen' trusses and radial trusses on the sides. The queen trusses have two additional lateral posts and a central one. The structure is quite homogeneous, it doesn't look like it has been much altered.

Roofing Material: lead, slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 31 B: 23 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-sawn) Bark ☐

Joint Types: joggle, mortice and tenon, scarf

Fasteners Types: Metal bolt, Metal strap, Timber dowel

Joints description:

All mortice and tenon, with timber dowels and metal straps. Tie-beams have simple scarf joints.

Wood Species: pinus sylvestris

Way of identification: direct micro

Carpentry Marks Types: small chiseled roman numerals

Carpentry Marks Description:

only a few visible

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Metals straps and bolts in some joints - some look original some are more recent. Some metal brackets around tie-beams (later interventions)

Dendrochronology:



Roof structure link I:\Arch\A



Connection with wall link I:\Arch\A



Joints link I:\Arch\A



Timber elements' dressing link I:\Arch\A



Carpentry marks link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: Few metal straps have been added to reinforce the joints between posts and upper beams (in 2003/4), whilst metal straps have been added around the tie-beams, probably earlier (50s or 70s?). The sarking on the slopes looks original, the one on the platform has been replaced.



Past interventions | link | I:\Arch\A

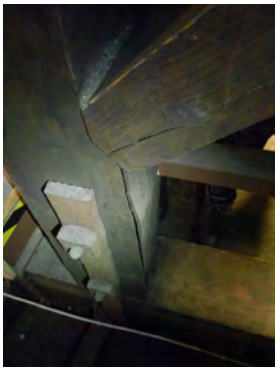
Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☐

Some humidity stains on sarking



Humidity stains on sarking | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks	Unknown	
Connection Damage			



Cracks in post and strut | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: Cracks in a few elements: a strut, a post and a rafter. A thorough visual inspection of all the roof structure should be carried out to make hypotheses on the causes.

link

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

DETAILED SURVEY **Building name** EDINBURGH ST ANDREW'S AND ST GEORGE'S CHURCH **Roof location** Church main hall

Survey date(s) 03/02/2016 14/03/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SASGC-MH-1, SASGC-MH-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafters	860	rectangular	bending, compression	pinus sylvestris	hand sawn
Tie-beam	2010	rectangular	bending, tension	pinus sylvestris	hand sawn
Upper beam	590	rectangular	bending, compression		hand sawn
Big posts	510	rectangular	tension	pinus sylvestris	hand sawn
Medium posts	320	rectangular	shear, tension		hand sawn
Small posts	215	rectangular	compression, shear		hand sawn
Big strut	325	rectangular	bending, compression		hand sawn
Medium strut	285	rectangular	bending, compression		hand sawn
Small strut	155	rectangular	bending, compression	pinus sylvestris	hand sawn
Purlin		rectangular	bending, compression	pinus sylvestris	hand sawn
Common rafter	860	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

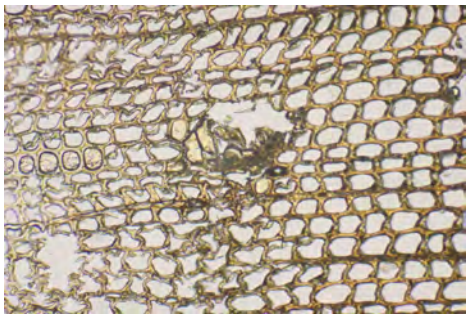
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SASGC-MH-1, SASGC-MH-2

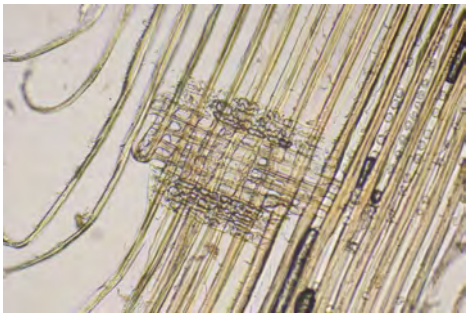
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & tie-beam	Corner mortice & tenon	compression, shear	none	
rafter & big post	Corner double step	compression, shear	metal straps	
posts & struts	Encounter mortice & tenon with joggles	compression, shear		
big/medium posts & tie-beam	Encounter mortice & tenon	tension	metal straps	
big posts & upper beam	Corner mortice & tenon	shear	metal straps	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

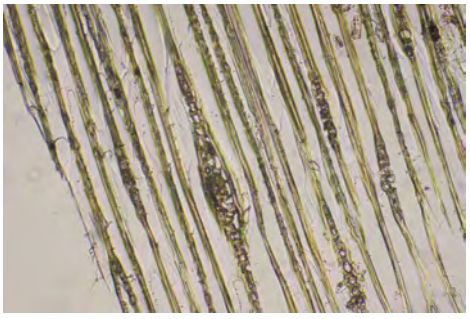
Microscopic identification of the timber species See drawing SASGC-MH-2



Post: transv. section x100 I:\Arc



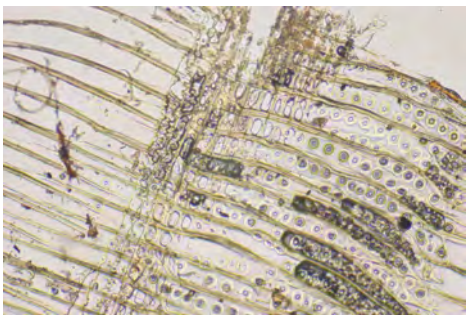
Post: radial section x100 I:\Arc



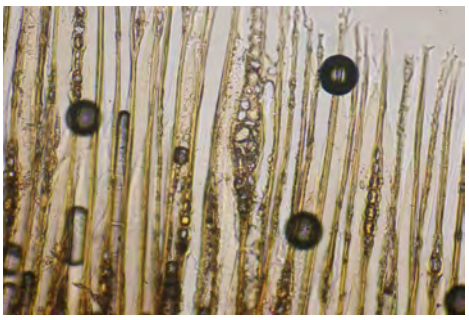
Post: tang. section x100 I:\Arc



Rafter: transv. section x100 I:\Arc



Rafter: radial section x100 I:\Arc



Rafter: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SASGC-MH-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	W side	03/02/2016	3 pm	13.3	55.3

roof space	centre	03/02/2016	2:20 pm	13.8	51.6
roof space	E side	03/02/2016	2:40 pm	12.5	56.4

Frame/Truss name central west — See drawing SASGC-MH-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints: between S small post & small strut | Fungi attack

Other: cracks in lateral post e, strut d, rafter r

Element name A tie-beam

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: lower face not visible because of ceiling

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 30.5x22 | min. size (hxb) [cm]: 30x22 | Single piece ☐ | Jointed element ☑

Strength affecting defects

Pith location: centre | Slope of grain [%]: 6 | tangential

Knots [min d/section h]: 10/30 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II



scarf joint at centre of tie-beam | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point	Moisture Content [%]	Visible Material Degradation	Not Accessible for: hygrometer
a	14.3	☐	☐
b	14.2	☐	☐
c	11.7	☐	☐
d	14.3	☐	☐
e	13.8	☐	☐
f	14.1	☐	☐

Element name B south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: upper part only visible from tie-beam level

Past interventions: metal straps around side and lower faces

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 30.7x22.7 | min. size (hxb) [cm]: 30x22.5 | Single piece ☑ | Jointed element ☐

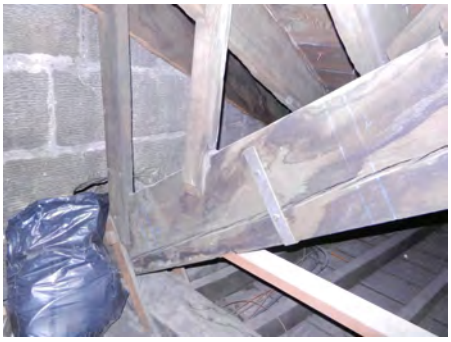
Strength affecting defects

Pith location: centre | Slope of grain [%]: 4 | tangential

Knots [min d/section h]: 3.5/22 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I



lower part of rafter | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 13.9 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 13.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name C south small post

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 12.5x22.5 | min. size (hxb) [cm]: 10x22.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 5 | tangential

Knots [min d/section h]: | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I



joont with rafter | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 8.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 10.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D south small strut

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 10x22.5 min. size (hxb) [cm] 10x22.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential
Knots [min d/section h] 6/10 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 lower than III


big knot on side I:\Arc

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑ compression	unknown	unknown
Crushing ☐		
Other ☐		

Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☑ bell tower pushing?

Measurement Point a
Moisture Content [%] 12.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 15.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name E south medium post

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 18.7x22 min. size (hxb) [cm] 15x22 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 2 | tangential

Knots [min d/section h]: 0.5/22 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: lower than III



crack close to bottom end | I:\Arc

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☑	shear, tension	unknown	unknown
Crushing ☐			
Other ☐			

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☑ bell-tower pushing?

Measurement Point a

Moisture Content [%]: 12.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 13.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name F south medium strut

Dating: original construction | Signs of reuse

Timber treated ☐ | Past interventions | Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 11.2x22.5 | min. size (hxb) [cm]: 11x22.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 6 | tangential

Knots [min d/section h]: 4.5/22.5 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%] 12.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 12.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name G south big post

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues upper part only visible from tie-beam level

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19.8x22.7 min. size (hxb) [cm] 17x22 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 7 tangential

Knots [min d/section h] 5/23 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects shakes all along upper part

Estimated Strength Class according to UNI 11119 lower than III



shakes in upper part I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 13.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name H south big strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x22.7 min. size (hxb) [cm] 13x22.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 4/13 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 13.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 14.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 13.8	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name I central post

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues upper part only visible from tie-beam level

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 21x22 min. size (hxb) [cm] 16x22 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential

Knots [min d/section h] 3.5/18.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 13.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 14.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name L north big strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12x22 min. size (hxb) [cm] 12x22 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 2/12 Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 13.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 14.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name M north big post

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues upper part only visible from tie-beam level

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 21.1x21.5 min. size (hxb) [cm] 18x21 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 4 tangential

Knots [min d/section h] 3/18 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



joints with struts I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 14.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name N north medium strut

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12x22.5 min. size (hxb) [cm] 12x22.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 5.5/15 group Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 14 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 13.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name O north medium post

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 16.4x22.5 min. size (hxb) [cm] 15x22.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 5.5/15 group Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role	
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 13.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 14.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name P north small strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10x22.5 min. size (hxb) [cm] 10x22 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 5 tangential

Knots [min d/section h] 3/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 17 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name Q north small post

Dating original construction Signs of reuse

Timber treated ☐

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.6x20.9 min. size (hxb) [cm] 10x20.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 4 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name R north rafter

Dating original construction Signs of reuse

Timber treated ☐

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 30.5x23 min. size (hxb) [cm] 30x23 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 6/23 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II



crack close to bottom end I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑	unknown	unknown
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☑ unknown

Measurement Point a

Moisture Content [%] 14.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

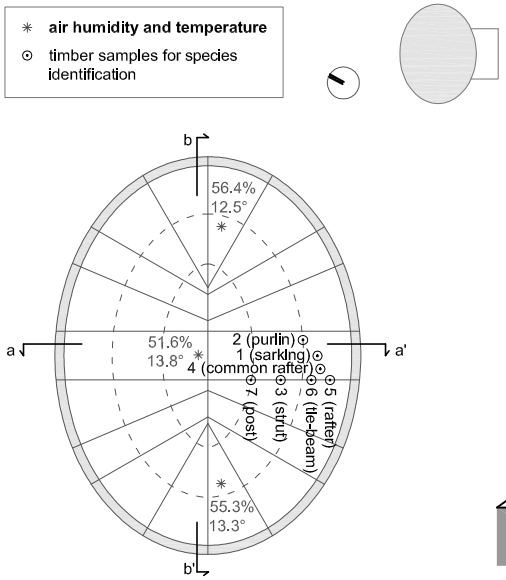
Measurement Point b

Moisture Content [%] 15 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

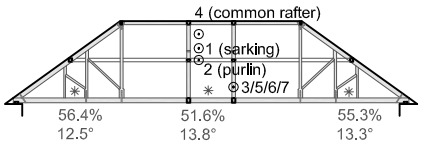
Measurement Point c

Moisture Content [%] 14.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Plan 1:500

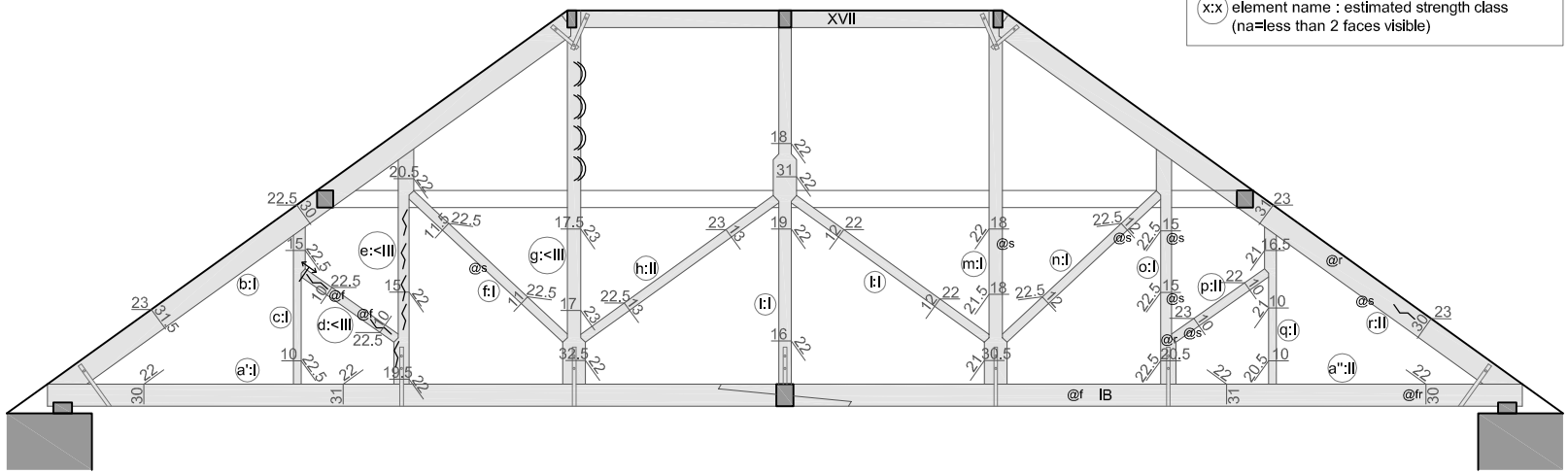


Section aa' 1:500 (looking South)

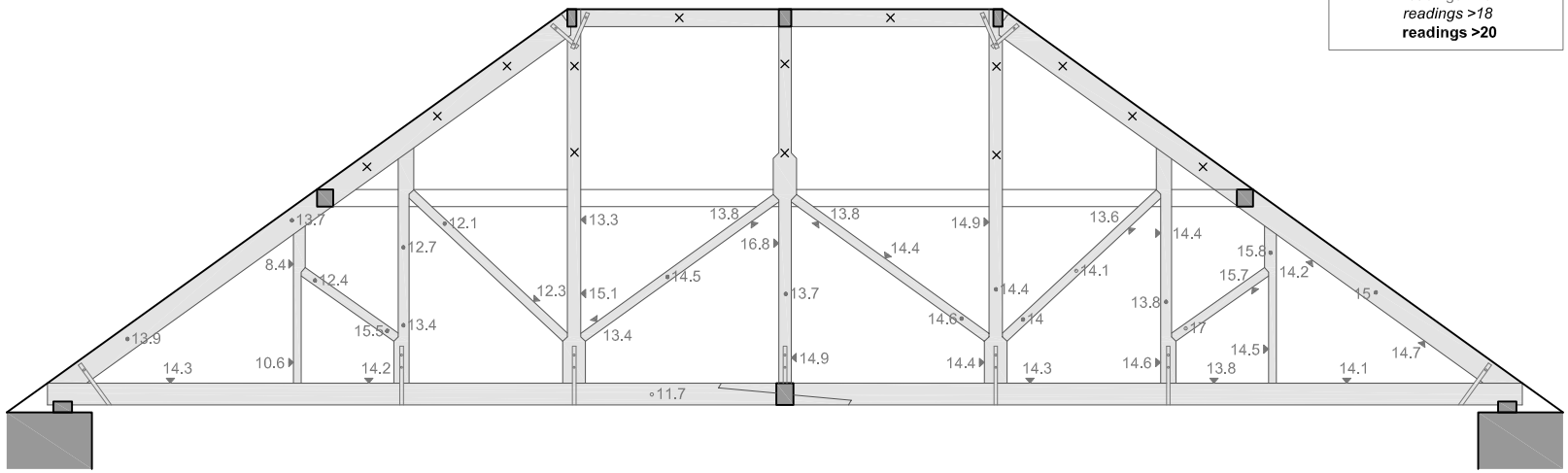


0 5 10

Section aa' 1: 100 (looking West)



Section aa' 1: 100 (looking West)



0 1 5

GLASGOW ST ANDREW'S IN THE SQUARE CHURCH

Location: GLASGOW, CITY OF | GLASGOW (GLASGOW, CITY OF)

X coordinate: 259698 Y coordinate: 664681

Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: CHURCH

Rcahms ID: 44237

HS Listing: A

Original Use: Religious

Current Use: Religious

Freestanding: ☑ N. of floors above ground level: 1 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1740	1757	ROOF STRUCTURE BUILT BETWEEN 1751 AND 1753	RENWICK 1911

People involved:

Last Name	First Name	Role	Attributed
DREGHORN	ALLAN	DESIGNER	☐
NAISMITH	MUNGO	MASON	☐
CLAYTON	THOMAS	PLASTERER	☐
ROBERTSON	JOHN	WRIGHT	☐
CROSS	JAMES	MASON	☐
LAWSON	GAVIN	MASON	☐
CATION	DAVID	MASON	☐
WILSON	JOHN	WRIGHT	☐
FLEMING	WILLIAM	WRIGHT	☐

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1874		INTERIORS	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1906			RCHAMS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1921		INTERIORS	HS

People involved:

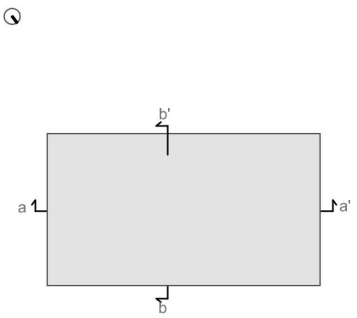
Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1980	1989	NO RECORDS - CHURCH ARCHITECT THINKS IT INVOLVED CARBON FIBRE RODS AND RESIN INJECTION BY RBR SCOTLAND LTD	CHURCH ACHITECT

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
GLENDINNING M. & MACKECHNIE A.	2004	☐	SCOTTISH ARCHITECTURE	118
RENWICK R. (ED.)	1911	☐	EXTRACTS FROM THE RECORDS OF THE BURGH OF GLASGOW WITH AND OTHER DOCUMENTS VOL. VI A.D. 1739-59	
WILLIAMSON E. & RICHES A.	1990	☐	THE BUILDINGS OF SCOTLAND COLLECTION: GLASGOW	

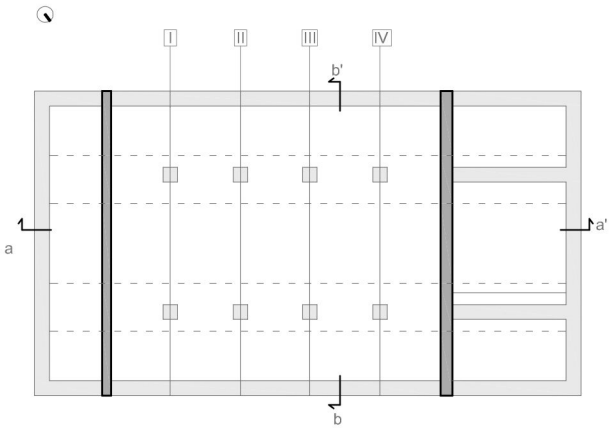
Suggestions for further research:



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

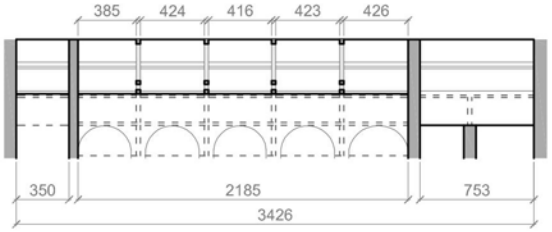
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

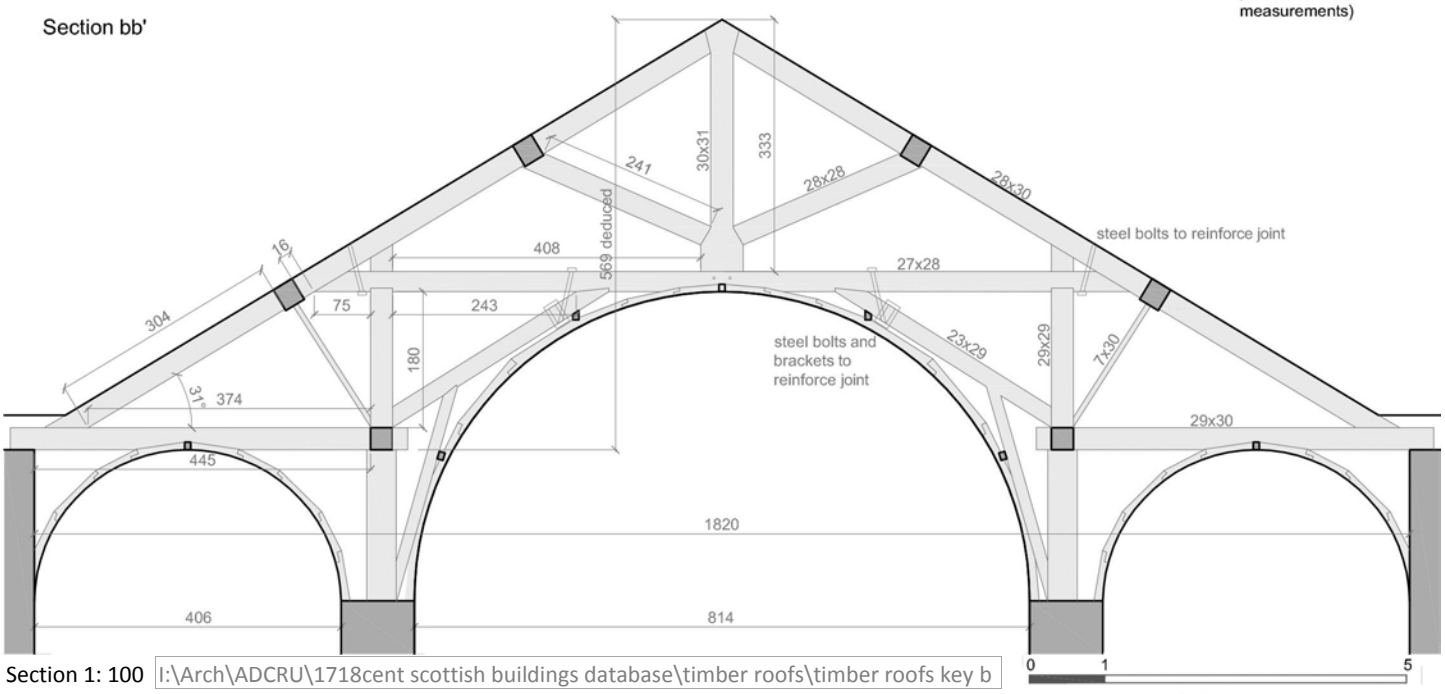
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

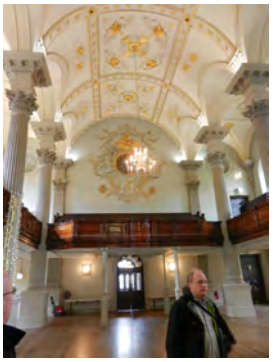
Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b



Roof from outside I:\Arch\A



Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** GLASGOW ST ANDREW'S IN THE SQUARE CHU | **Roof location** Church main hall

Survey date(s) 31/08/2015 | See drawing: SASC-MH-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 8.4 - 4 | Roof Height [m]: 7.7

Roof Pitch/es [°]: 31 | Roof Length [m]: 34.3

Type of Primary Structure: 2D framing

Truss ☑ PRINCESS-POST

Frame ☐

Average Distance in between Primary Structure [m]: 4.5

Type of Secondary Structure: common rafters, purlins, sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables: purlins

Roof Construction Period: From 1739 To 1756 Identified by: Estimated

Roof General Description: Gabled roof with steeple on northwest side. Steeple structure wasn't surveyed. Main roof supported by two transversal walls and 4 princess post trusses in the central part. All three posts have slanted struts on both sides. Trusses span reduced by intermediate columns, one on each side. Original plaster ceiling underneath.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular, Square

Rafter Scantling [cm] H: 30 B: 28 Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) Bark ☐

Joint Types: joggle, mortice and tenon, notch

Fasteners Types: Timber dowel

Joints description: All mortice and tenon, timber dowels only between central post and collar. Central post has joggles. Lateral post and slanted strut between lateral post and collar have notches. Fasteners not visible.

Wood Species: pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: small chiseled roman numerals, strange marks (from scandinavia?)

Carpentry Marks Description: In sequence from I to IIII (east to west)

Signs of reused timbers:

Timber Treated ☐

Other Materials: Resin and steel bolts/brackets

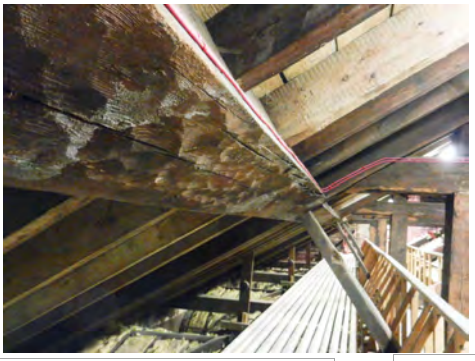
Dendrochronology:



Roof structure link I:\Arch\A



Connection with wall link I:\Arch\A



Timber dressing link I:\Arch\A



Joints and carpentry marks link I:\Arch\A



carpentry marks on sarking link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features: Original plaster vaulted ceiling underneath

Unfavourable conditions: poor ventilation

Accessibility limitations: lower part of lateral posts not visible

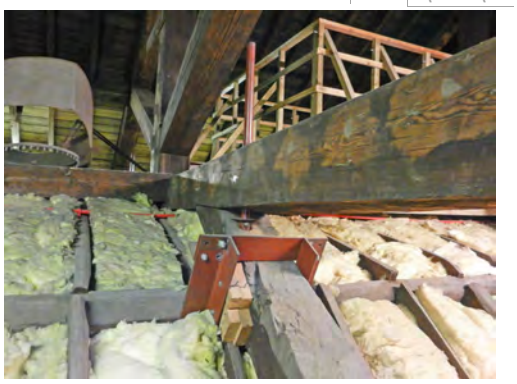
Past interventions: Some sarking and common rafters replaced. Steel bolts added to reinforce joint between rafter and collar. Steel brackets and bolts added to reinforce joint between slanted strut and collar. Checks filled with resin. Insect treatment in 1990s.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☑ Humidity stains ☑ Diffuse insect exit holes ☐

Fungi attack close to west gable wall. It's active, they are trying to treat it. Some insect attack on rafters and collar, only in corners.



Past interventions | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks	Active	
Connection Damage	Disconnection	Unknown	



Material degradation | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: purlin cracking | link | I:\Arch\A

Description of visible damage: Some elements are cracking: purlins, rafters... Some joints between posts and struts are opening. Not sure what the cause might be.



Damage: rafter cracking | link | I:\Arch\A

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber

DETAILED SURVEY **Building name** GLASGOW ST ANDREW'S IN THE SQUARE CHURCH **Roof location** Church main hall

Survey date(s) 20/01/2016 16/02/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SASC-MH-1, SASC-MH-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafter	1045	square	bending, compression	pinus sylvestris	hand axed and hand sawn
Centrtal post	330	square	compression	pinus sylvestris	hand axed and hand sawn
Upper strut	260	square	bending, compression		hand axed and hand sawn
Collar	1080	square	bending, compression	pinus sylvestris	hand axed and hand sawn
Lateral post	470	square	compression		hand axed and hand sawn
Strut post&collar	335	square	bending, compression	pinus sylvestris	hand axed and hand sawn
Strut post&rafter	190	rectangular	compression	pinus sylvestris	hand axed and hand sawn
Strut post&strut	295	rectangular	compression		
Interrupted tie-beam	525	square	bending, tension		hand axed and hand sawn
Purlin	450	square	bending, compression	pinus sylvestris	hand axed and hand sawn
Common rafter		rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
Sarking		sheet	bending, tension	pinus sylvestris	hand axed and hand sawn

* estimated based on drawings because not fully accessible

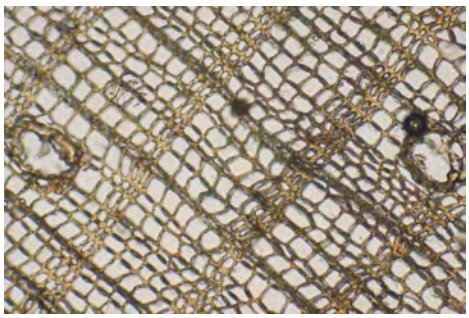
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SASC-MH-1, SASC-MH-2

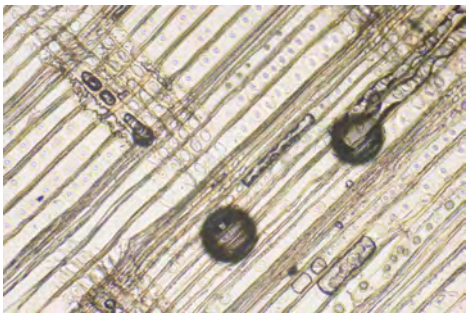
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
central post & struts/rafters	Encounter mortice & tenon with joggles	compression	none	
central post & collar	Encounter mortice & tenon	compression	wooden dowels	
strut & collar, strut & strut	Encounter birdsmouth	compression, shear	none	
all others	Encounter mortice & tenon	compression	none	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

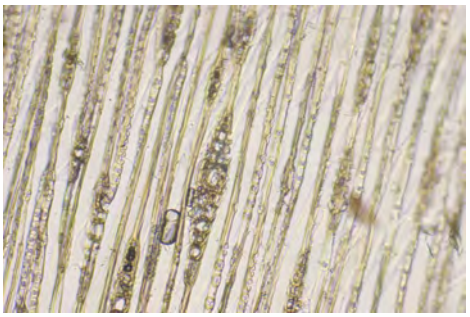
Microscopic identification of the timber species See drawing SASC-MH-2



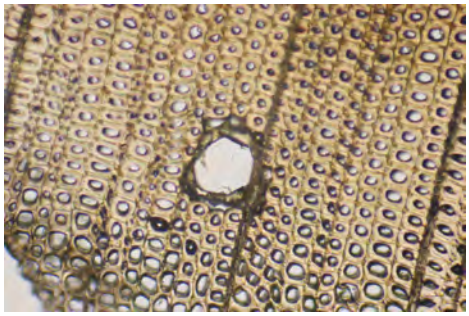
Strut: transv. section x100 I:\Arc



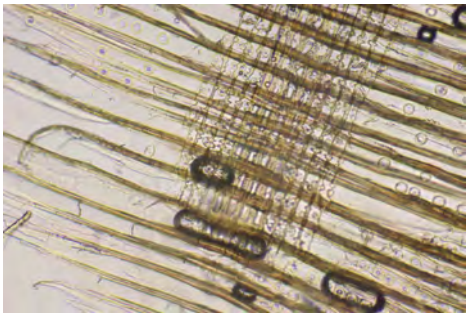
Strut: radial section x100 I:\Arc



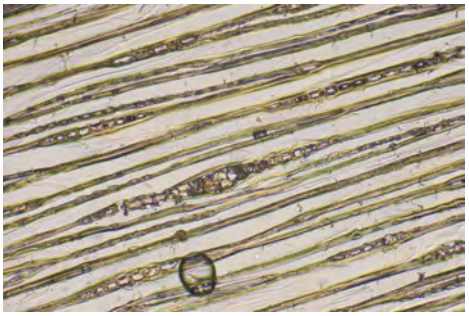
Strut: tang. section x100 I:\Arc



Purlin: transv. section x100 I:\Arc



Purlin: radial section x100 I:\Arc



Purlin: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SASC-MH-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
attic space	E side	16/02/2016	1:20 pm	18.3	36

attic space	W side	16/02/2016	1 pm	18.5	34.5
roof space	SW side	16/02/2016	10:10	13.4	55.8
roof space	centre	16/02/2016	10:30	13.2	56.6
roof space	NE side	16/02/2016	10:50 am	13.3	56.5

Frame/Truss name III — See drawing SASC-MH-2

Missing elements — Elements with defects in critical area: collar, N strut between post & collar

Joints with decayed peg — Insect attack: rafters & collar

Failed joints: between collar & N rafter, between S strut & post — Fungi attack: E gable

Other: shaked at top end of S rafter - N rafter & S upper strut partly rotated

Element name A south lateral post

Dating: original construction — Signs of reuse

Timber treated ☑ for insects, in 1990s — Accessibilityissues: lower part not well visible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 29x29.7 — min. size (hxb) [cm]: 29x29.5 — Single piece ☐ — Jointed element ☑

Strength affecting defects

Pith location: centre — Slope of grain [%]: 3 — tangential

Knots [min d/section h]: 9/30 — group — Knotty element ☑ — Defects in critical area ☐ — Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: I



lower end with treatment for insect — I:\Arc

Material degradation

Insect attack ☐ — Type — Status — Way of identification

Fungi attack ☐ — Type — Status — Way of identification

Corrosion ☐ — Wet surface ☐ — Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage — Emergency interv. needed ☐

Mater.Degr. and Damage Extent — Way of identification

Estimated causes of primary damage

Poor design ☐ — Poor construct. ☐ — Degradation ☐ — Poor maintenance ☐ — Past interv. ☐ — External actions ☐ — Other ☐

Measurement Point a

Moisture Content [%]: 15.4 — Visible Material Degradation ☐ — Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 15.7 — Visible Material Degradation ☐ — Not Accessible for: hygrometer ☐

Element name B south strut post & rafter

Dating: original construction — Signs of reuse

Timber treated ☐ — Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 8.5x30.2 — min. size (hxb) [cm]: 8x30 — Single piece ☑ — Jointed element ☐

Strength affecting defects

Pith location: side — Slope of grain [%]: 6 — tangential

Knots [min d/section h]: 8.5x30.5 — single — Knotty element ☑ — Defects in critical area ☐ — Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C south interrupted tie-beam

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues end close to wall not well visible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 29.1x30.6 min. size (hxb) [cm] 29x30.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] 2.5/31 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



joint with rafter and wall I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 15.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues bottom end close to wall not well visible

Past interventions steel reinforcement at joint with collar

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 29.3x29.7 min. size (hxb) [cm] 28x29.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 1 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects shake close to upper end

Estimated Strength Class according to UNI 11119 III



insect attack on lower corner I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum Status unknown

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent insect attack seems to be affecting only sapwood on corners of element

Way of identification visual inspection

Measurement Point a

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 15.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 15.3 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point e

Moisture Content [%] 13.2 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point f

Moisture Content [%] 13.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name E south strut post&collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions steel brackets reinforcing joint with collar

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 24x26 min. size (hxb) [cm] 24x26 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 7/21 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III



joint between struts I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	16.2	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	16.2	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	16.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name F collar

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1990s

Accessibilityissues

Past interventions steel reinforcement at joint with rafters

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 26.9x28.6 min. size (hxb) [cm] 25.5x27 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 13 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects highly inclined slope of grain close to joint with N rafter

Estimated Strength Class according to UNI 11119 II



reinforcement of joint with rafter I:\Arc

Material degradation

Insect attack ☑ Type Anobium Punctatum Status unknown

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a			
Moisture Content [%]	14.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	13.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	14.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	14.2	Visible Material Degradation ☑	Not Accessible for: hygrometer ☐
Measurement Point e			
Moisture Content [%]	14.1	Visible Material Degradation ☑	Not Accessible for: hygrometer ☐
Measurement Point f			
Moisture Content [%]	14.3	Visible Material Degradation ☑	Not Accessible for: hygrometer ☐

Element name G south upper strut

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 28.2x27.5 min. size (hxb) [cm] 28x27 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 9 tangential
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I



Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

wedge in joint with rafter I:\Arc

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a			
Moisture Content [%]	13.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			

Moisture Content [%] 13.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 13.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name H central post

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1990s Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 30x29.5 min. size (hxb) [cm] 30x29.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 4 tangential

Knots [min d/section h] 10/30 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other



treatment for insect at top end I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 14 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 13.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name I north upper strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 27.7x27.7 min. size (hxb) [cm] 27.5x27.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	13.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	13.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	15	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name L north rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions steel reinforcement at joint with collar

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 29.2x28.1 min. size (hxb) [cm] 29x28 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 1 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☑ Type Anobium Punctatum Status unknown

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other



rotation of north rafter I:\Arc

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 14.6 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 15 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 14.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name M north strut post&collar

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1990s Accessibilityissues

Past interventions steel brackets reinforcing joint with collar

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 22.5x27.2 min. size (hxb) [cm] 22x26.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 11 tangential

Knots [min d/section h] 3/21 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 16 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name N north lateral post

Dating original construction Signs of reuse

Timber treated ☑ for insects, in 1990s Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 30.2x29 min. size (hxb) [cm] 30x29 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] 4/29 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 13.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name O north strut post&rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 6.7x30.2 min. size (hxb) [cm] 6.5x30 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 5.5/30 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

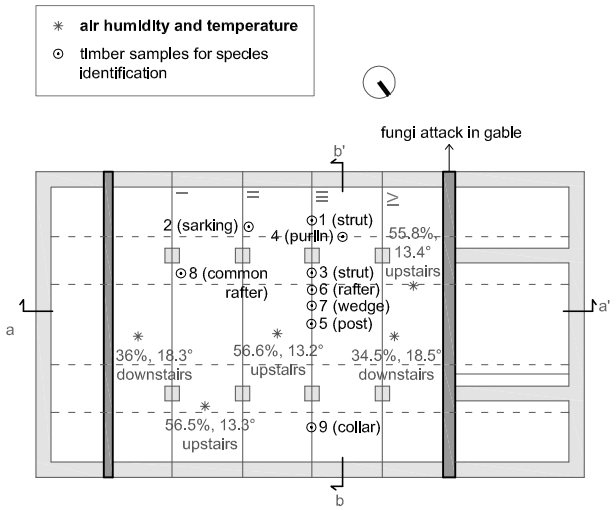
Measurement Point a

Moisture Content [%] 15.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

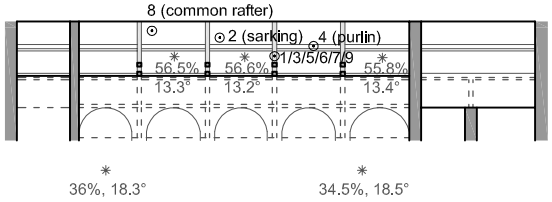
Measurement Point b

Moisture Content [%]	15.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Plan 1:500

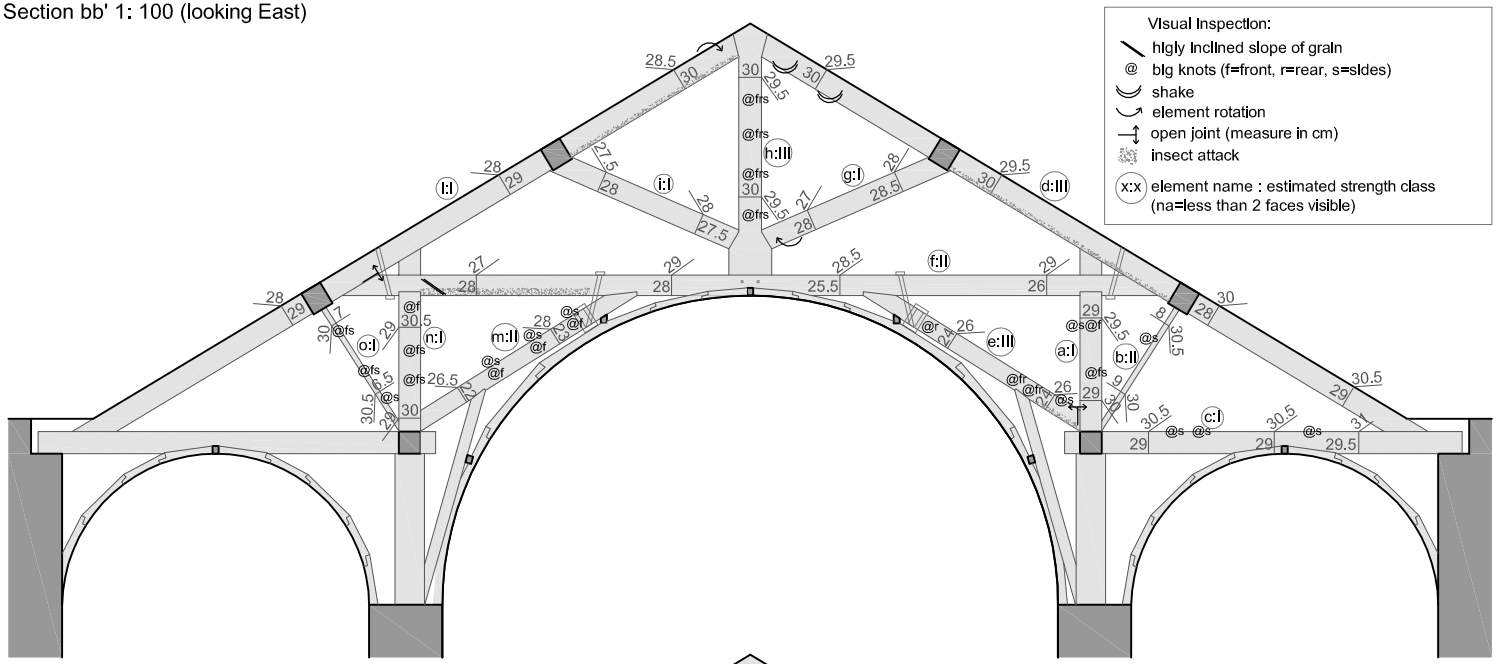


Section aa' 1:500 (looking South)

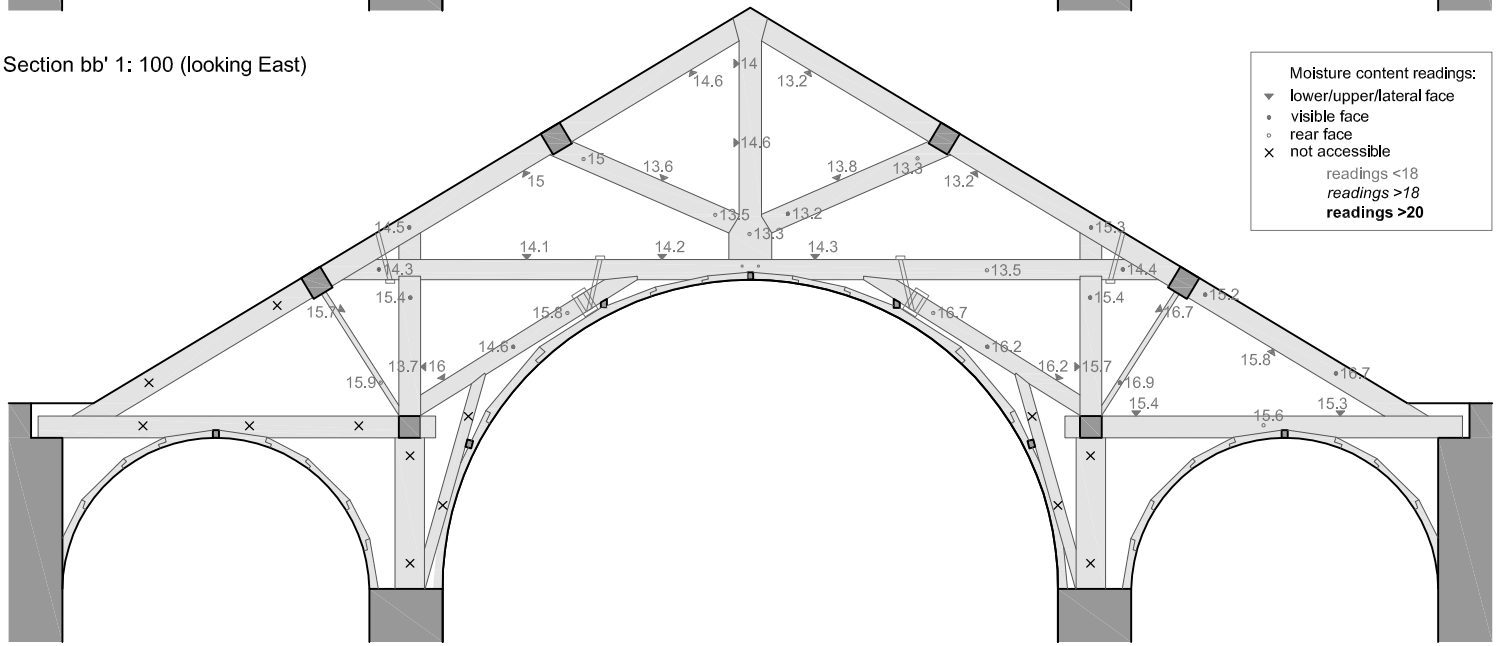


0 5 10

Section bb' 1: 100 (looking East)



Section bb' 1: 100 (looking East)



0 1 5

STIRLING CASTLE

Location	STIRLING		STIRLING
X coordinate	279000	Y coordinate	694000
Geogr. Referencing System	BRITISH NATIONAL GRID		





Property status	PUBLIC
Rcahms ID	46245
HS Listing	A
Original Use	Military, Residential
Current Use	Museum

Freestanding ☑ N. of floors above ground level 4 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1100	1199	AT LEAST, BUT COULD BE OLDER	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1370	1379	N GATE IS PROBABLY THE EARLIEST SURVIVING BUILDING	HS

People involved:

Last Name	First Name	Role
KING OF SCOTLAND	ROBERT II	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1495	1505	MAIN FRONTISPIECE OF THE CASTLE AND MAIN ROYAL ENCLAVE	HS

People involved:

Last Name	First Name	Role
KING OF SCOTLAND	JAMES IV	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1500	1799	DEFENCES OF THE NETHER BAILEY, ON A LOWER TERRACE N OF THE MAIN ENCLOSURE	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1530	1555	PALACE	HS

People involved:

Last Name	First Name	Role
KING OF SCOTLAND	JAMES V	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1550	1559	ARTILERY BASTION AND FLANKING WORKS	HS

People involved:

Last Name	First Name	Role
QUEEN OF SCOTLAND	MARY OF GUISE	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1557		KING'S OLD BUILDINGS, MAINLY 16TH CENTURY, PERHAPS 1557	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1585	1625	W RANGE OF PALACE REBUILT AND PARTS OF BOTH THE KITCHEN AND S RANGE CLEARED AWAY TO RATIONALISE THE PALACE PLAN AFTER SERIOUS STRUCTURAL COLLAPSE	RCAHMS

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1594		CHAPEL ROYAL ON THE N SIDE	HS

People involved:

Last Name	First Name	Role
KING	JAMES VI & I	COMMISSIONERPATRON

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1671	1687	REPAIRS - ROOFS AS WELL	EUL LA II 87 - NRS GD/29/92 - NRS GD124/11/37 - NRS E37/24 - NRS E36/30

People involved:

Last Name	First Name	Role
MCCLELAND		

MCCLELLAND	JAMES	WRIGHT
BRUCE	SIR WILLIAM	SURVEYOR GENERAL
BAINE	JAMES	MATERIAL SUPPLIER

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	1699	1703	WORKS TO THE ROOFS, INCLUDING RE-SARKING, CUTTING THE RAFTERS (COUPLES) TO INSERT WINDOWS, REINFORCING THE RAFTERS (COUPLES) WITH ADDITIONAL TIMBERS.	NRS E37/33

People involved:

Last Name	First Name	Role
SANDS	ANDREW	WRIGHT
MAN	JAMES	MATERIAL SUPPLIER, WRIGHT
ALLAN	JAMES	MATERIAL SUPPLIER, WRIGHT
LOU	JAMES	WRIGHT
WATSON	JAMES	MERCHANT

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1708	1714	OUTER DEFENCES	HS

People involved:

Last Name	First Name	Role
DURY	CAPTAIN THEODORE	DESIGNER
SMITH 1	JAMES 1	ENGINEER
BACHOP	THOMAS	MASON
WATSON	JAMES	MASON
MOWBRAY	ROBERT	WRIGHT
SMITH	GILBERT	MASON

Intervention type:	From:	To:	Description:	Reference:
RECONSTRUCTION	1855		NORTH AND EAST WINGS OF KING'S OLD BUILDINGS REBUILT AFTER FIRE	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1975	1976	RENOVATION OF INTERIORS OF KING'S OLD BUILDINGS	HS

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
CRONE A. & FAWCETT R.	1998	☐	DENDROCHRONOLOGY, DOCUMENTS AND THE TIMBER TRADE: NEW FOR THE BUILDING HISTORY OF STIRLING CASTLE, SCOTLAND	
FENWICH H.	1970	☐	ARCHITECT ROYAL. THE LIFE AND WORKS OF SIR WILLIAM BRUCE, 16	39, 73, 90
GIFFORD J.	2002	☐	THE BUILDINGS OF SCOTLAND COLLECTION: STIRLING AND CENTRAL	
GOMME A.	2002	☐	SCOTTISH HAMMERBEAM ROOFS AND ONE THAT ISN'T	
HANKE T.	2007	☑	ASPECTS OF TIMBER IN RENAISSANCE AND POST-RENAISSANCE SCO THE CASE OF STIRLING PALACE	
TABRAHAM C. & GROVE D.	1995	☐	FORTRESS SCOTLAND AND THE JACOBITES	25-32, 46-51

ARCHIVAL REFERENCES

Archive	Doc.Num.	Folios
National Records of Scotland	E36/30	

Title: Sir William Bruce of Balcoskie: Holyrood, Stirling, Edinburgh, the Bass, 4 Mar. 1671-18 Jan. 1674, rendered 9 July 1674

Archive	Doc.Num.	Folios
Edinburgh University Library	La II 87	1A

Title: Holyroodhouse, Stirling Castle, Dumbarton Castle, Edinburgh Castle Vouchers of expenditures on works (1684-86)

Archive	Doc.Num.	Folios
Edinburgh University Library	La II 87	6

Title: Wright work at Holyroodhouse and Stirling Castle (4 vouchers)

Archive	Doc.Num.	Folios
National Records of Scotland	GD124/15	471

Title: Letter to the Earl of Mar from Mr James Smith, surveyor of Her Majesty's works, in Edinburgh. He describes the dismal state of the

Palace of Holyroodhouse and the Castle of Stirling.

Archive	National Records of Scotland	Doc.Num.	GD124/11	Folios	37
Title	Letter to the Earl of Mar from the Privy Council, authorising him to repair roof etc of Stirling Castle				
Archive	National Records of Scotland	Doc.Num.	E37/24	Folios	
Title	Estimate of materials required for reparation of Holyroodhouse, with notes of unfinished rooms their work to be done by Robert Mill under contract and of buildings and repairs necessary at Stirling Castle				
Archive	National Records of Scotland	Doc.Num.	GD29/92	Folios	
Title	Warrant by the Lords Commissioners of the Treasury to Sir W. Bruce of Balcaskie as Surveyor General to repair the roof and alleyways at Sterling Castle, provide for wright and glass-work of the rooms there				
Archive	National Records of Scotland	Doc.Num.	E37/33	Folios	
Title	Duplicate account of work in Stirling Castle, bearing copy treasury warrant discharging Earl of Mar for sums required - Sep 1699-July 1703				
Archive	National Records of Scotland	Doc.Num.	GD124/15	Folios	207/3
Title	Letter to the Earl of Mar from the Earl of Seafield. Difficulty in obtaining money to repair Stirling Castle - 9 Apr 1700				
Archive	National Records of Scotland	Doc.Num.	GD124/15	Folios	216/2
Title	Letter to the Earl of Mar from the Marquis of Annandale. Annandale has urged the Lords of Treasury to do something for the Castle of Stirling - 11 Apr [1701])				
Archive	National Records of Scotland	Doc.Num.	GD124/15	Folios	506/23
Title	Letter to the Earl of Mar from the Earl of Glasgow. Sensible of Mar's diligence in the above matter. Payment made for repair of Stirling Castle - 19 Jun 1707				
Archive	National Records of Scotland	Doc.Num.	GD124/15	Folios	567
Title	Letter to the Earl of Mar from Col John Erskine, his step-father, at Alloa. Family matters. Negotiations with Balgowan. Repairs to Stirling Castle necessary - 16 May 1707				
Archive	National Library of Scotland	Doc.Num.	MS1646Z02	Folios	18a
Title	Plan of the 3d Stage at A in the Section, Andrews Jelfe (Architect), Thomas Moore (Engineer)				

Suggestions for further research	Maybe Stirling Town Archives

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: National Records of Scotland | Doc. Num.: GD29/92 | Folios:

Title: Warrant by the Lords Commissioners of the Treasury to Sir W. Bruce of Balcaskie as Surveyor General to repair the roof and alleyways at Sterling Castle, provide for wright and glass-work of the rooms there | Date: from 1671 to

Contents:
1671
remove iron gratings from the windows *in the front of the house* [holyrood]
[...] with all possible diligence he make effectuall and speedie? provision of stone, lime, timber, iron, glass & all other necessarie for that work in the most frugall way and to the best advantage he can: he observing in all his ma.ties directions and orders of worke [...] he is also appointed to repair the roofs and alleways of Stigling Castle, making them *wind-tight*
He needs to make the carriage for the cannon and the dyke in the park too. He shall provide materials and workmanship for all the works.

Summary and comments: 1671 Sir William Bruce, the King's Surveyor General, is appointed to repair the roofs of Stirling Castle and make them wind-tight. No details of the works.

Archive: National Records of Scotland | Doc. Num.: E36/30 | Folios:

Title: Sir William Bruce of Balcoskie: Holyrood, Stirling, Edinburgh, the Bass, 4 Mar. 1671-18 Jan. 1674, rendered 9 July 1674 | Date: from 1671 to

Contents:
Hollyrudehouse 7th Septr 1671
Discharge
Repayed to James Bayne £480 payd out by him for 1000 daill bought from Jon Neilson merd in Stirling for the use of the reparationes at Stirling Castle conforme to receit n.1 £480
Jon Anderson & William Patton skippers in Leith for transporting the timber in their boat up to the Castle
Jon Hamilton overseer of works
knappel, stones, lime, wainscot, hair, nails, sand, ...
Samuel Mckreef for knappel wainscot & other timber £621 15s.

Summary and comments: 1671 wright James Baine is paid for 1000 deals for the repair works at Stirling Castle. Another merchant is paid more than £600 for other timber.

Archive: National Records of Scotland | Doc. Num.: E37/24 | Folios:

Title: Estimate of materials required for reparation of Holyroodhouse, with notes of unfinished rooms their work to be done by Robert Mill under contract and of buildings and repairs necessary at Stirling Castle | Date: from 1682 to

Contents:
[outside] *Estimat of materialls to be provyded for the use and towards the reparation of his Ma.ties Palace of Holyroodhouse As also ane nott of such roumis as ar yet unfinished in the said Palace. Lykwayis A Particular nott of Buildings & Reparationis necessar at his Ma.tis Castle of Stirling*
18th July 1682
[inside] *Estimat of materialls to be provyded for the use, and towards the reparation of his Ma.ties Palace of Holyroodhouse, to be presently done, as follows viz*
lime for mason work & plaster in Duke of Hamilton and Treasurer and Lord Registers apartments
sand
rebats to make two arches in the Duke of Hamilton kitchen and a door in the Treasurer's apartment
stone plaster hair
door nails
[...] *whytning or spanish whyt?* [...] *for whytning of rooffs &syd? walls which stand in wood*
[...] *1000 dailla* [...] *towards these reparations for sarking below the leaid work within the ??? Palace 48£ per 100* £480
[...] *half hundred double treis for the rofe of the work 18p. peece* tot. 54£
[...] *100 single trees at 9s. peece* £45
[...] *20 great trees for sawing at 2£ 10s. peece* £30
[...] *knappill for making new casem.ts*
[...] *5000 double floorings* [...] *for the rofe of the work at 10£ 1000* £50
single flooring
blind flooring
planshers
windows
[...] *1000 stones of lead [...] for helping of the main rooff & the infys of the wallheads & outfys of the ??? Palace*
[...] *half hundred great trees needful for making of garrons to lay upon the wallheads of the lead* [...] *at 1£ 10s. peece* £90
[...] *30 oak planks needful for going along the fare of the cornice whereupon the lead is to be layid at 1£ 10s. peece* £45
[...] *6000 scailie naills needful for putting on the slaits, that must be taken off the easing? in the infys of the Palace to get the lead*
[...] *layid in bilowit? at 5£ 1000* £30

[...] *100 prick? batts for putting on of the oak planks which project above the fare of the cornice at 4£ p.* £20
[...] *hogsheads of trass or pan cratch for pointing the alloring upon the wallheads & round the old tower?*
window nails
A particular nott of such roumes in the Palace of Holyroodhouse & others that are not yet finished nor completed viz.
[...] the rooff and the walls of the Pratches? from the great stairs to the door of the entrie of the Duke of Hamiltons lodgings is not yet plaistered
mason work that Robert Mill didn't do yet
A particular nott of Buildings & Reparations necissar at his Ma.tis Castle of Stirling as followes
[...] *Item the gallery or Transe w.ch enters the great hall being ane hundred feet long & thirten feet wyde wants the rooff and must be sarked and slated.*
[...] *Item the slait rooff of this Palace must be pointed & helped in severall of the flankers, or run rooff, as lykways the Bartisan covered with lead, together with the slait rooff and Bartisan of the great hall.*
Item the one side of the slait rooff of the Chappill became ruinous this last winter, and must newly sarked with dailles and newly slaites on that side; wheter the rooff y.rof be faulty or not cannot be known till the slaits & old sarken be taken off.
[...] *the slait rooffs of the whole castle would be pointed and a bargan made with a slaiter to maintain ym. yearlie hereafter upon a rentan yearly pension or sallarie.*
[...] *It is necessar all this work above mentioned be presently gone about* [...] *and for this effort it is necessar that money be provided for buying of materialls & payment of workmen* [...]
As to the particular Estimat, what these buildings and Reparations will cost at Stirling Castle it cannot be exactly sett doune without measuring of the dimensions of the places & rooffs to be built and repaired, w.ch must be done upon the place. [....

Summary and comments: 1682 materials needed to repair Stirling Castle: the gallery or transe which enters the great hall needs all the roof done; the chapel needs to be resarked and reslated and maybe even structural repairs, based on what is found once the sarking is taken off; the rest of the roofs need pointing and a slater should be contracted for their maintenance.

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 6

Title: Wright work at Holyroodhouse and Stirling Castle (4 vouchers) | Date: from 1684 to 1686

Contents
1
[outside] *Accompt of wright work at the Palace of Holyroodhouse 1685 be James Mcleland £ Scots 1144 14s.*
[inside] [...] *December 1684 to Jully 1685*
Frames for paintings, windows, casements, new coach house, repairs to guard stables, tables, benches, beds, shelves, press, partitions, doors, ladders, ...
TOT £1144 15s. 8d.
2
[outside] *Accompt of wright work at Stirling Castle 1685 be James Mcland Scots £655 16s. 06d.*
[inside] *Accompt of wright work wroght at the Castle of Stirling Be James Mcleland frae 29 of May to 24 of September 1685 conforme to agreeement*
Lining floors and windows and walls, making shelves, barrowes, ladders, tresses, boxes, casements, garrones, partitions, doors, ...
For making & ane putting ane new roof on the maine gaird ??? of 27 couple & sarking of the??? £48 12s.
TOT £655 16s. 06d.
3
[outside] *Accompt of wright work BeJames Mcleland at the Palace of Holyroodhouse fra Jyllu 1685 to March 1686*
Scots £1031 2s.
[inside] lining, flooring, casements, tables, presses, doors, shelves, windows, stairs, partitions, beds, replacing roof of stables and other repairs, ...
4
[outside] *Receipt Jon Hamiltone wright to Mr Jas Smith £6 7s, 5d. for reparatione in the foot guard. Hollyrudhous Scots £76 9s.*
6
[outside] *Instructions for the 8 article by the Abbreviat Acct.*
James McClealand and accompt for wright worke done at stirling and the abay
£2879 10s. 6d.
[outside] *Abbreviat accompt of wright worke by James McCleland wright for worke done at the palace of Holyroodhouse and Castle of Stirling from december 1684 to march 1686*
Frames for paintings, High Commissioner accommodation, girnels, platforms, repairs at stables, benches, ...
TOT £2908 10s. 6d.

Summary and comments: nothing related to roof structures

Archive: Edinburgh University Library | Doc. Num.: La II 87 | Folios: 1A

Title: Holyroodhouse, Stirling Castle, Dumbarton Castle, Edinburgh Castle Vouchers of expenditures on works (1684-86) | Date: from 1684 to 1686

Contents
[outside] Missing part
Mr James Smith
By
An accompt of money payed to severall persons for work & materialls furnished for the use of his Maj Palace & Castles from 14 Aprile 1684 to 1 of March 1686
[inside] *By an accompt of money payed to Mr James Smith overseer to his Mties works, and to his orders by Hugh Wallace of Inglistoun his Majesties cashkeeper from 14 Aprile 1684 to 1 March 1686*
1. Clearing casway-layers and others in Edinburgh Castle £360

2. Not specified £7704 4s.
3. To pay workers £4093 11s. 10d.
4. Not specified £657 15s.

TOT £12814 10s. 10d.

Received by J. Smith

By an accompt of money debursed by Mr James Smith overseer to his Mties works to the particular persons after mentioned for work don and wrought by them at his Maties Palace and Castles conform to the particular instructions afterspecified from 14 Aprile 1684 to March 1 1686

1. Casway men, levellers, sandmen, workmen and others to carry sand and stones and levelling the ground at Edinburgh Castle £1481 9s.
2. *It. to several persons for workmanship and furniture in repairing the Palace of Holyroodhouse for the reception of his royal highnes* […] *and afterwards continued for his Grace the Duke of Queensbury* […] *his accommodation anno 1685* […] £1002 18s.
3. Other people for works at Holyrood £1060
4. James Alexander and Mr Kikeus for painting at Holyrood and Edinburgh Castle £705
5. *To Robert Marshall wright in Dumbarton and others at Stirling* for defenses £720 18s.
6. *To James Mccleland & John Hamilton wrights for work don at the Palace of Holyroodhous & Castle of Stirling as the accompts & recepts from Dec. 1684 to March 1686* […] £ 2908 10s.
7. To James Dunbar merchant for deals and trees and two carvers brought from London to carve his Majestys statue in marble to be set up in the middle of the court of Holyrood £ 2321 16s.
8. To James Baine wright and John Callander smith for work at the Councill Chamber and windows of the privy chamber & oratory at Holyrood £629
9. Alexander Chambers for clensing walls at Edinburgh Castle £97

James Smith for visits to Blacknes, Dumbarton, Stirling Castles and the Bass £120

10. *To severall persons who were active in smothering & suppressing the fire in his Ma. Palace of Holyrood hous Feb. 1686* […] £173 4s. 4d.
11. John Mastertoun glass work at Holyrood and Edinburgh Castle 1683-4-5-6 £1130 14s.
12. *To severall persons for reparations don at his Ma. Palace of Holyroodhous in the latter end of 1685 and beginning of 1686 about the stables and other office houses* […] £463

TOT £12814 10s. 10d.

Summary and comments: Abstract of specific accounts of James Smith surveyor general between 1684 and 1686 at Edinburgh Castle, Dumbarton Castle, Stirling Castle, Holyrood Palace. Non specified works are carried out at Stirling Castle by wrights James Mccleland and John Hamilton.

Archive: National Records of Scotland | Doc. Num.: GD124/11 | Folios: 37

Title: Letter to the Earl of Mar from the Privy Council, authorising him to repair roof etc of Stirling Castle | Date: from 1687 to

Contents:

Lettir from Lords ??? Tweeddale Hamilton Atholl & Tarbats to Earl of Mar anent reparation of roof of stirling castle
12 August 1687
My Lord
having receaved information, that the ??? & ??? rooffe of his Ma.tie Castle of Stirling, was in a very bad condition, wee gave order for visiting thereof, and report being made to us of the same, wee find the condition of it is such, that if not tymengly helped, it will become altogither ruinous, and that the espense of the advance of 700 merks will prevent it; wee have therefore thought fitting, to give you Lord the trouble to cause? agree with workmen, for going presently, about the separation thereof, and that you Lord may advance the 700 merks or materialls & workmanship which shall be allowed in what you are to the King, an accompt of the by gone few dueties of the Lord or otherways. This is recommended to you […]

Summary and comments: 1687 the Earl of Mar is recommended to carry out £700 worth works to repair the roofs of Stirling Castle –this money wouldn't have been sufficient to replace all of the roofs, including the structures, but one or two yes, or the sarking for all of them.

Archive: National Records of Scotland | Doc. Num.: E37/33 | Folios:

Title: Duplicate account of work in Stirling Castle, bearing copy treasury warrant discharging Earl of Mar for sums required - Sep 1699-July 1703 | Date: from 1699 to 1703

Contents:

[outside] *Accompt of work in Stirling Castle from September 1699*
[inside] *Accompt of work by Andrew Sands wright in September 1699*
10 days and a half work with his son - brehouse, guns carriage, interiors, ...
Accompt of work wrought in the Castle of Stirling by James Man wright since the 30 October 1699 to the 28 March 1701
partition walls, doors, windows, scaffolding, floors, stairs, beds, stuff for masons/plasterers/slaters/plumbers/glaziers, ladders, models for cornices, 'happer' to feed the pigeons!...
[...] *Item for taking down the runrooff and flankers and timbering of it new over again with new sarking £9*
[...] *Item for bridleing? of the couples and cutting of safe lintles above the entry £3*
[...] *Item for cutting and bridleing? of the couples above the window that looks out in the southside of the dining room £3*
[...] *Item for cutting the rooff above the door in the Traunce? next the dining room propeing it and cutting safe lintels ??? 13d. 4s.*
Item for cutting the sarking and rooff for the limb? in the Traunce? 12s.
[...] *Item for timbering of the rooff in the long Traunce? about the chimneys and sarking it £1 1d.*
Item for cutting and takeing down of a great dormerun? in the Traunce? & cutting the couples and pulling up of another one £2
[...] *Item for cutting of the coupled and sarking for the meassons to put up the limb? in the gable behind the bed chamber and dining room £1 6s. 8d.*

Item for timbering of the limb again & sarking of it £1 4s.
[...] *Item for turning? coupleing, cutting of the couples and sarking of the windows, ther ebeing seven of them £30*
Item to ditto Mans for for mending the work £12
Item for work in the northside of the place £20
deals used also as soles of windows and doors, as 'washing boards', as floor boards
tot £704 1s. 6d. !

Accompt of work wrought in the Castle of Stirling by Tho. Bachop meason
tot £1104 2s. 8d. !

Accompt of iron work wrought to the Castle of Stirling by John Bell Smith
tot £200 6s. 8d.

Accompt of work wrought in The Castle of Stirling by Adam Jack slatter
tot £341 3s.

Accompt of glasswork wrought in the Castle of Stirling by John Don glazier
tot £367 14s. 6d.

Accompt of plaster work wrought in the Castle of Stirling by Rob. Whyt plaisterer
tot £235 16s.

Accompt of timber & other materialls furnished to the ??? work in the Castle of Stirling by James Watsons merch in Stirling from the 30th of October 1699 to the 28th March 1701
deals
deals broad
deals broad and long
single trees
double trees
great trees
great dormonds?
oak spars
wainscot planks
knaple
greta oak tree for the ???
tot £1499 3s. 10d.

Accompt of materialls furnished by James Man wright
glew = glue?
nails
garrow nails
coal and candle for him during the work
carriage of timber to the castle
windows
tot £257 9s.

Accompt of materialls to Thomas Bachop
tot £14 4s.

Accompt of materialls to Robert Whyt
tot £269 18s.

Accompt of materialls to Adam Jack
tot £108 8s.

Accompt payd to James Dick gunner
tot £2

Accompt of mony payed for the necessares under??? to the Castle by James Walsone
tot £100 1s. 6d.

TOT £5252 15s. 8d.

Accompt of work wrought in the castle of Sterling since the clearing of accompts the 26th Aptile 1701
Accompt James Allan wright
door, floor, window, ...
tot £23 7s. 6d.

Thomas Bachop mason £20 11s. 8d.
John Bekll smith £14 2s.
Adam Jack slater £61 2s.

John Don glazier £27 3s.
James Tuccoll? painter £130
Andrew Millar coupar £3 7s.
James Lou wright £4 10s.
James Watsone £624 2s. 8d.

TOT £908 5s. 10d.

Accompt of work wrought in the Castle of Stelring be James Allan wright begun in Decer 1702 and ended in July 1703
doors, stuff for masons, scaffolding, cutting 'couples' and putting 'safe lintels' for windows', floors, 'timbering the rooff'?, partition walls, shelves, seats, chimneys, cases, ...
[...] *Item for fixing trees to the cupples above the bed chamber and closet for strengthening yrof where the chamb was £6*
[...] *Item for taking off the old sarking above that part betwyxt the bed chamber & wester roum & helping the cupples and sarking of new £5*
[...] *Item for taking off the old sarking of the part* [wester chamber] *& sarking it again £2 8s.*
[...] *Item for fixing of trees for strengthening the cupples above the middle chamber & closet next the wester chamber £2*
[...] *Item for working and fixing up trees to the cupples & blaks? above these rommes £2 8s.*
[...] *Item for taking the old rotten sarking off all that part of the house* [south side] *timbering about the new limb and the plankers thereof and serving the slaters with scaffolding, planker boards and fillets £8 13s. 4d.*
tot £722 9s. 4d.

Thomas and Tobias Bachop masons £725 18s.
John Bell smith £73 14s. 10d.
Dunca Ker smith £14 13s. 8d.
Adam Jack slater £167 13s.
John Don glazier £362 13s.
Robert Whyte plasterer £90 18s.

Accompt of timber and other materialls furnished to the forsd works in the castle of Stelring By James Watsone merchand in Sterling From December 1702 to the sepoth of July 1703
deals
snades? deals
single trees
double trees
balks
long trees
short trees
wainscot
knaple
tot £1406 10s.

Accompt of materialls furnished to James Allan wright
gleu
nails
garron nails
coal and candle
carriage of timber
flooring nails
tot £300 3s. 6d.

materials to Adam Jack slater £158 2s.

TOT £10531 15s. 10d.

Charge of money got by the Earle of Mar from the Treasury? for reparations in the castle of Sterling
tot £5652 2s. 8d.

The treasury gives £10771 15s. 7d. to the Earl of Mar for these works

Summary and comments: 1699-1703 wrights Andrew Sands, James Man, James Allan, James Lou for work and merchant James Watson and wrights James Man and James Allan for materials. Works to the roofs, including re-sarking, cutting the rafters (couples) to insert windows, reinforcing the rafters (couples) with additional timbers. No roof replaced fully though.

Archive: National Records of Scotland | Doc. Num.: GD124/15 | Folios: 207/3

Title: Letter to the Earl of Mar from the Earl of Seafield. Difficulty in obtaining money to repair Stirling Castle - 9 Apr 1700 | Date: from 1700 to

Contents:
[outside] *E. Seafield 9th ap. 1700*
[inside] *Whitehall Qprile 9th 1700*
My Lord

I have obtained that letter which you desired for repairing of Stirling Castle, I have not mentioned in it the Master of the work, but however I believe it is his Office to manadge all money that is laid out upon the Kings houses & Castles, and he would take it very ill, if I should mcroach? upon him in the end of dayes, ther was much more difficulty in obtaining this letter now then there would have been at another time, because ther are so maney things to do wt the little money that we have in Scotland.
We hope now shortly to be with Yor Lord, however we have as yet sett no day for parting from this, so if you please you may ??? continue to writ what you hear, and think necessary to be known & if in any thing I can be further serviceable you may acquaint me for ther is non wishes Yor Lord better then the who am yor Lord most faithful & most humble servant Seafield

Summary and comments: No details of works.

Archive: National Records of Scotland | Doc. Num.: GD124/15 | Folios: 216/2

Title: Letter to the Earl of Mar from the Marquis of Annandale. Annandale has urged the Lords of Treasury to do something for the Castle of Stirling - 11 Apr [1701])

Date: from 1701 to

Contents:
[outside] *Marqs of Annandale 1st Aprile*
[inside] *The first of Aprile*
My dear lord I have urged the lords off Thresaurie as much as was possible for me to doe something in presence? of the Kings Letter for the Castle off Stirline the ??? Deputt after his ordinarie manner ??? ??? and ??? doe nothing at this tyme ??? who thinks he cannot doe ??? ??? he follow his leader was ??? willfull ??? ??? ??? we cleare yett there was nothing to be done nott being a quorum. I hope my dear lord you trust me I did my best as I shall ever in all your ???. ….

Summary and comments: No details of works.

Archive: National Records of Scotland | Doc. Num.: GD124/15 | Folios: 567

Title: Letter to the Earl of Mar from Col John Erskine, his step-father, at Alloa. Family matters. Negotiations with Balgowan. Repairs to Stirling Castle necessary - 16 May 1707

Date: from 1707 to

Contents:
[outside] *Coll. Erskine May 18th 1707*
Balgones affair
The north to be quitted on ???
hopes of getting payd of 300£ precept for reparation of the Castle
danger of the rooff of the great Hall & Chappel
coal sells fast at 7£ 6d. Chalder
?????????????
[inside] [...] *I request to get payment of your preceptfor the 3 hundred pound for the reparation of the Castle from time this month to be pelased to let me take your orders about it. I have ??? provyd dealls, the rooff of the great hall and the chaple will be ruined this winter if they be not mended this summer, they are good roofes and I grant pity they should fall, I wish ther wer som thing don about them. as for what furder about the garrison I doubt not but your lord will be myndfull of it and as for my own particular concern I like it wholy to you and shall truble your lord no furder now ...*

Summary and comments: 1707 Colonel John Erskine says that the roofs of the Chapel and Great Hall are in bad condition and need to be repaired soon.

Archive: National Records of Scotland | Doc. Num.: GD124/15 | Folios: 506/23

Title: Letter to the Earl of Mar from the Earl of Glasgow. Sensible of Mar's diligence in the above matter. Payment made for repair of Stirling Castle - 19 Jun 1707

Date: from 1707 to

Contents:
[outside] *E. of Glasgow Jun 19th 1707*
[inside] *My Dear Lord*
I received your last?, with a verry full & distinct accompt of your ??? dilligence, and the paine you have taken in that affair off Wightmans and Mathies; not only these two? lot? all our merchants in their part of Britain are most sensible of your ??? care of them; I shall be glad to have your ??? return as to the subsistance off our troupes; I ever am in great truth and with the greatest respect, ...
[After signature] *My Dear Lord, I took care last week to see that the 300£ for repairing Stirling Castle was payed; my mistake of our sufficient? clerks, the precet was drawen on the fonds of the civill? list, but I altered it on the army fonds, & saw payment made. aAdieu*

Summary and comments: No details of works.

Archive: National Records of Scotland | Doc. Num.: GD124/15 | Folios: 471

Title: Letter to the Earl of Mar from Mr James Smith, surveyor of Her Majesty's works, in Edinburgh. He describes the dismal state of the Palace of Holyroodhouse and the Castle of Stirling.

Date: from 1707 to

Contents:
Mr Ja. Smith concerning the Abie of Halarudhouse & Stirling Castle
Novemb. 6 1707
My Lord
since I have been preferred to be surveyor of Her Ma.tis works, I ame bound in duty to informe that unless some serious settled measure be laide doune for keeping her Ma.tis palace castles and forts in repaire they'l infallibly go all to ruine.
My lord the palace of holyroodhouse is in so dismail a conditione both in the roof & windowes that I ame ashamed to write of it, but ther is ane absolute necessitie of keeping it in repaire otherways it will inevitably perish if 500£ be bestoned by the housekeeper as I shall advise and the bond? made sune? it may be? more than a thousand pounds laide out in the ordinaire maner. What I say of the palace of holyrodhouse I may say meane? the same of the castle of stirling with the additione that the platforms and embrasures are all ruined the half being all ??? doune with the flashes of ??? and the other rotten having been made only of firr wals many years agoe but I ??? not head farr. I ought to medle? in this affaire, it being properly I being properly

the Mr of Ordonance his post to judge of and ordar these things and if any thing ??? a ??? of artiglarie be kept in thy place (of which I doubt) the master of the ordnance may order me or ??? of ane under him to represent the thing for there is ane absolute necessitie of looking after ??? in all the branches both in ??? Castle ??? Stirling as for ??? ??? not but Major Grall Maitland has given informatione since his affairs ??? ane but in a maner a doing wants greate support.
My lord wherin I am short or out of the ??? I hope will be pardoned when it is considered of preceeeding from My Lo
your most obliged dutifull most humble servt Smith

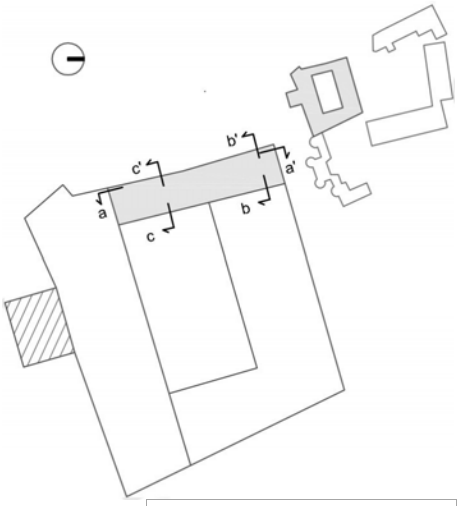
Summary and comments: 1707 James Smith, the King's Surveyor General, says that the roof of Holyrood Palace and Stirling Castle are in bad conditions – it is not sure if his evaluation is limited to the slates and sarking or includes the structure as well.

Archive: National Library of Scotland | Doc. Num.: MS1646Z02 | Folios: 18a

Title: Plan of the 3d Stage at A in the Section, Andrews Jelfe (Architect), Thomas Moore (Engineer) | Date: from 1719 to

Contents:

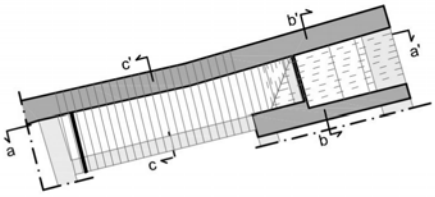
Summary and comments:



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

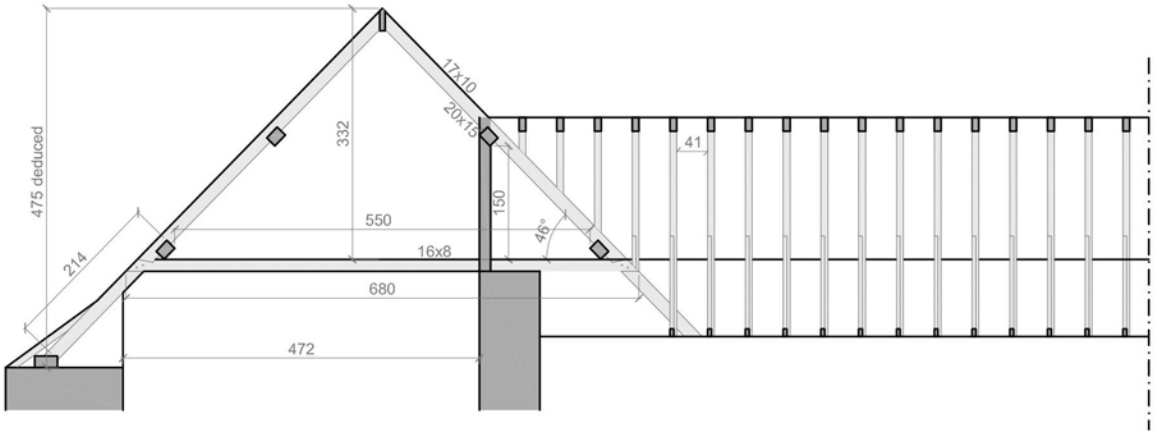
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

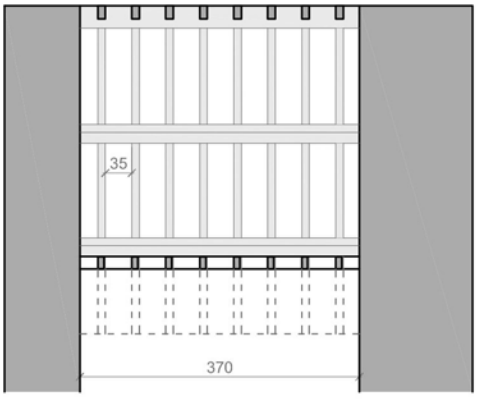
Section aa'



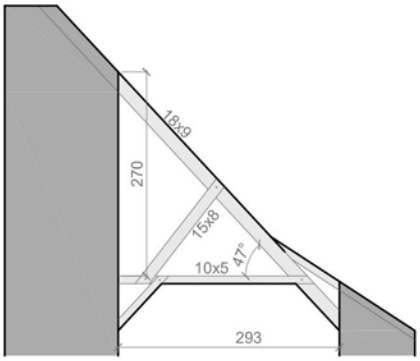
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section cc'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** STIRLING CASTLE_PALACE | **Roof location** 1: NW corner

Survey date(s) 01/10/2014 | See drawing: SCP-W-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 3.7 | Roof Height [m]: 4.75

Roof Pitch/es [°]: 46 | Roof Length [m]: 7

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]: 2

Type of Secondary Structure: common rafters, sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables: purlins

Roof Construction Period: From 1700 To 1725 Identified by: Estimated

Roof General Description: Western section of north range is gabled roof supported by 4 purlins, 2 on each side, and common rafters, connected by collars. There is a closed up window on the Eastern gable, suggesting it was originally an external gable. It seems reasonable to think this roof is part of a later construction phase. The purlins are oak, and they have redundant mortice and tenon joints, suggesting they are of earlier date and were reused.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: 20 B 15

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description: Rafters' apex: simple contact on a thin ridge purlin; between rafters and collars: dovetail lap secured by metal nails; between purlins and rafters: simple contact, rafters notched.

Wood Species: all pinus sylvestris except for the purlins which are oak

Way of identification: direct micro

Carpentry Marks Types

Carpentry Marks Description

Signs of reused timbers: Redundant mortice and tenon joints on purlins

Timber Treated ☐

Other Materials

Dendrochronology: carried out on samples from ceiling oak timbers and dated to 15th and 16th century - probably both Scottish and Baltic source (Crone & Fawcett 1998)



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: ridge support | link I:\Arch\A



Redundant joints in purlins | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not visible

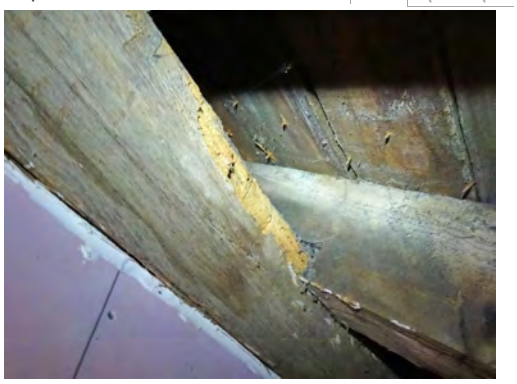
Past interventions: fire partition inserted between this roof and the west range. Some sarking replaced.



Fire partition | link I:\Arch\A

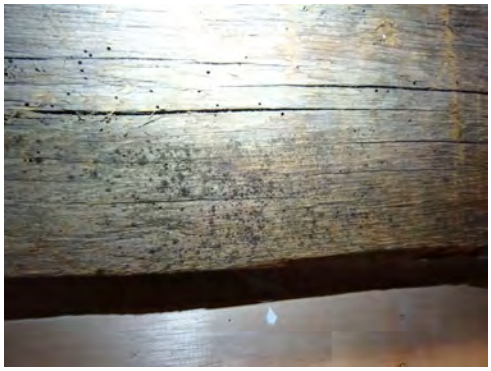
Material Degradation: Fungi attack ☑ Insect attack ☑ Humidity stains ☐ Diffuse insect exit holes ☑

Some insect and possibly fungi attack on the upper South purlin.



insect attack on purlin | link I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			



possible fungi attack on purlin | link I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage

link

Other Notes: The palace was built in 1539-42 but Hanke suggests that the roofs were replaced later. According to him, they belong to 3 different construction phases. Diversities only in structural composition, not in details of joining or materials. The Palace saw extensive building operations in late 16C, 17C and early 18C.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

INITIAL SURVEY | **Building name** STIRLING CASTLE_PALACE | **Roof location** 3: W range

Survey date(s) 01/10/2014 | See drawing: SCP-W-1

Roof Geometry: Shed

Roof Max Span [m]: 2.9 | Roof Height [m]: 3.4

Roof Pitch/es [°]: 47 | Roof Length [m]: 13.5

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Other

Average Distance in between Primary Structure [m]

Type of Secondary Structure: sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: None

Connection with gables

Roof Construction Period: From 1700 To 1725 | Identified by: Estimated

Roof General Description: Shed roof supported by common rafters with sprocket rafters. Slanted struts link the rafters to collars that support the ceiling. Rafters and collars are all half logs (roughly squared with a hand axe and then sawn in two). The struts are of later date, maybe early 19C. The roof was probably a two-pitch gabled roof like the others, but half of the building has collapsed.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 18 | B: 9 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: lapped

Fasteners Types: Metal nail

Joints description: All lapped secured by metal nails

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: strange marks (from scandinavia?)

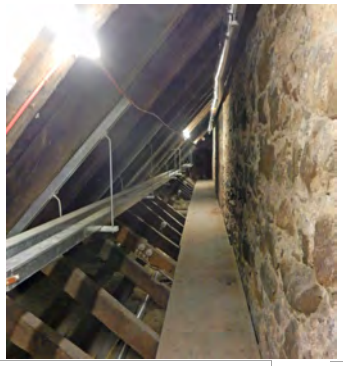
Carpentry Marks Description

Signs of reused timbers

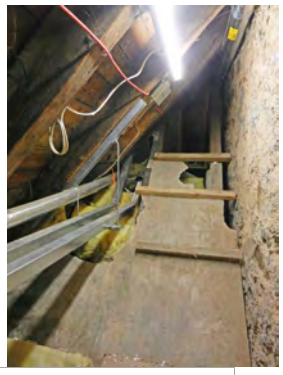
Timber Treated ☐

Other Materials

Dendrochronology: carried out on samples from ceiling oak timbers and dated to 15th and 16th century - probably both Scottish and Baltic source (Crone & Fawcett 1998)



Roof structure | link | I:\Arch\A



Intersection with south range | link | I:\Arch\A



Joints: rafter and strut | link | I:\Arch\A



Carpentry marks | link | I:\Arch\A



Carpentry marks | link | I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐



Decorative features

Unfavourable conditions

Accessibility limitations

Past interventions: The struts have probably been added in 19C. The sarking is more recent.

link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☑ Humidity stains ☐

Diffuse insect exit holes ☑

Some insect attack in rafters

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

link I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes: The palace was built in 1539-42 but Hanke suggests that the roofs were replaced later. According to him, they belong to 3 different construction phases. Diversities only in structural composition, not in details of joining or materials. The Palace saw extensive building operations in late 16C, 17C and early 18C.

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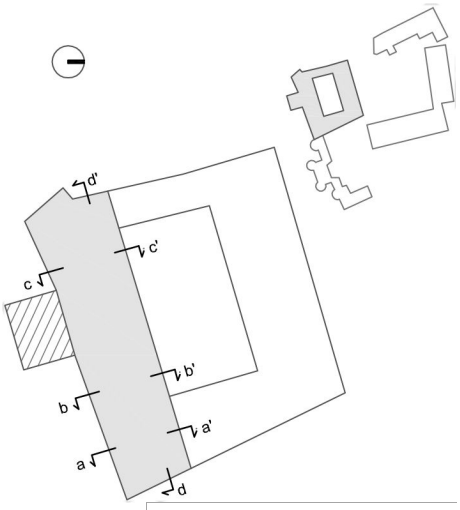


Plan 1:1000 I:\Arch\ADCRU\1718cent scott

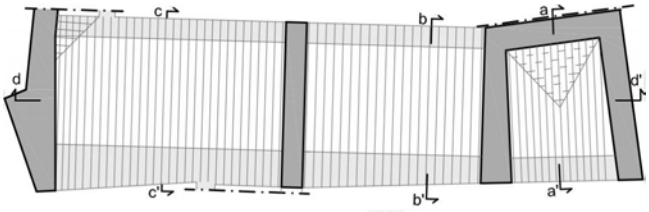
Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks

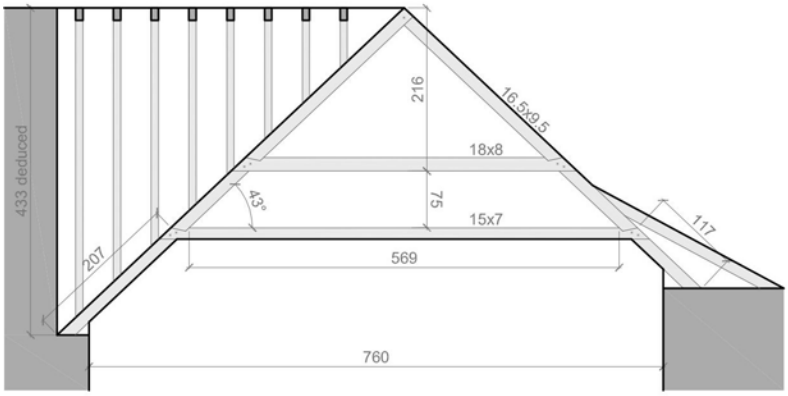
Carpentry marks from east to west

XXVII	I	not visible	XIX	XXI	VIIII
II	not visible	XIII	VI	XX	not visible
III	*WALL	not visible	not visible	XIII	not visible
IIII	not visible	not visible	*WALL	XVIII	not visible
V	not visible	XVI	not visible	XVII	not visible
not visible	III	XVII	not visible	XVI	IV
VI	V	XVIII	not visible	XV	III
not visible	IIII	VII	XXVI	XIV	II
X	VI	not visible	ΛXX	not visible	not visible
XVI	VII	V	not visible	XII	not visible
II	VIII	XII	XXIII	X\	
III	IX	XXIII	XXII	XI	

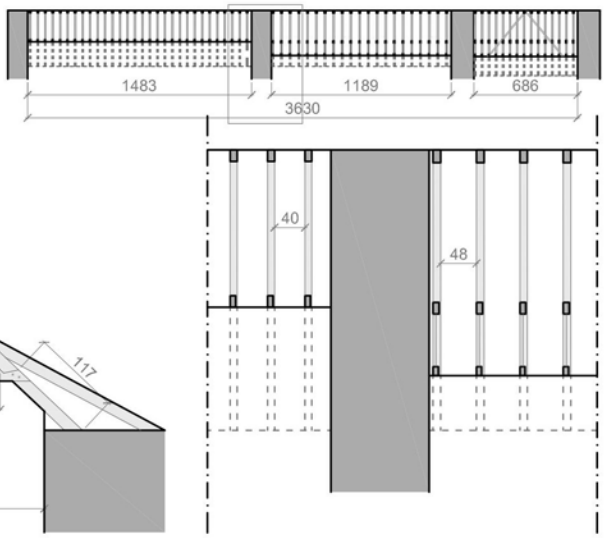


Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa'



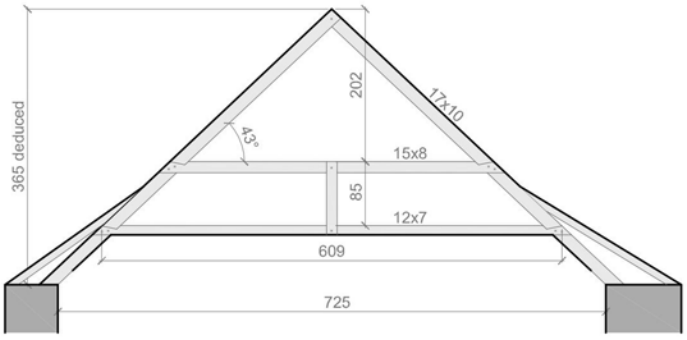
Section dd'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



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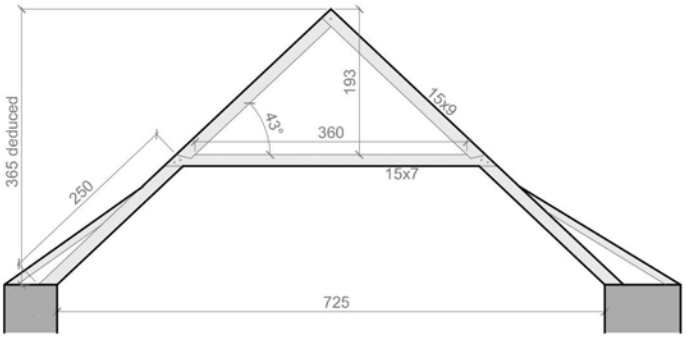

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Ceiling supported by roof structure I:\Arch\A

INITIAL SURVEY | **Building name** STIRLING CASTLE_PALACE | **Roof location** 4: S range

Survey date(s) 01/10/2014 | See drawing: SCP-S-1

Roof Geometry: Two-pitch gabled with intersections

Roof Max Span [m]: 7.25 | Roof Height [m]: 4.33

Roof Pitch/es [°]: 43 | Roof Length [m]: 36.2

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking

Sarking boards: width [cm] 27 | thickness [cm] 3

Connection with lateral walls: Unknown

Connection with gables: sarking interrupted (chimney), wall-plate

Roof Construction Period: From 1700 To 1725 | Identified by: Estimated

Roof General Description: Gabled roof supported by 2 intermediate gable walls and 14 frames in the East section, 21 frames in the middle section and 30 frames in the West section. Frames have 2 collars in East and middle section, 1 collar in the West section (but redundant joints on all rafters suggest that there was a lower collar in the West section as well). Middle section frames have vertical struts too. The lower collars support the ceiling. Rafters and collars are all half logs (roughly squared with a hand axe and then sawn in two).

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 16 | B: 9.5 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description: Rafters' apex: half lap joint secured by 1 or 2 metal nails: between rafters and collars: dovetail lap joints secured by 2 metal nails.

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals, strange marks (from scandinavia?)

Carpentry Marks Description: Not all numbers are visible, but the visible ones are mostly in sequence.

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology: carried out on samples from ceiling oak timbers and dated to 15th and 16th century - probably both Scottish and Baltic source (Crone & Fawcett 1998)



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not visible. Lower collars 'packed' in plastic sheets and therefore inaccessible for inspection.

Past interventions: Some collars doubled. Some sarking replaced.



Past interventions | link | I:\Arch\A



localized insect attack on rafter | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

Most timbers show diffuse insect exit holes on all faces, which probably correspond to past insect attack confined to the sapwood. Some timbers also show signs of active localized insect attack. Efflorescence on sarking on South side.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

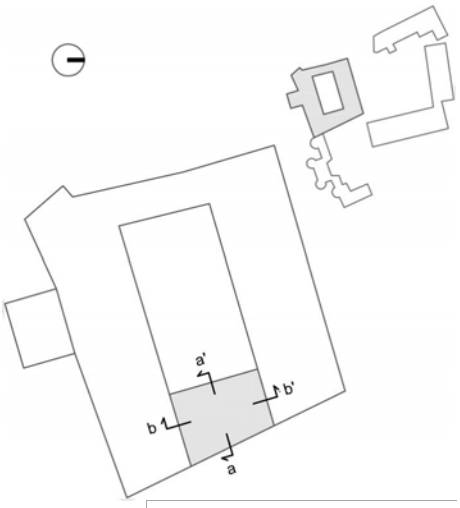
Estimated cause(s) of the primary damage: | link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage | link

Other Notes: The palace was built in 1539-42 but Hanke suggests that the roofs were replaced later. According to him, they belong to 3 different construction phases. Diversities only in structural composition, not in details of joining or materials. The Palace saw extensive building operations in late 16C, 17C and early 18C.

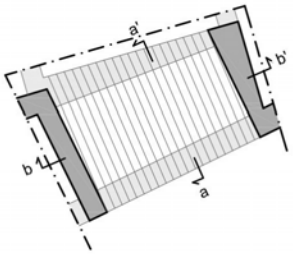
Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



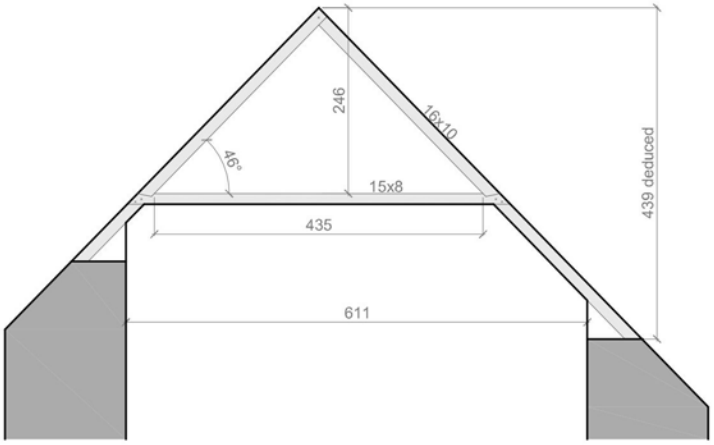
Carpentry marks from north to south

II
III
IIII
V
VI
VII
VIII
not visible
XIV
IX/X
XII
XIII
XIV
XV
not visible
XVIII
not visible
not visible
XXI
not visible

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

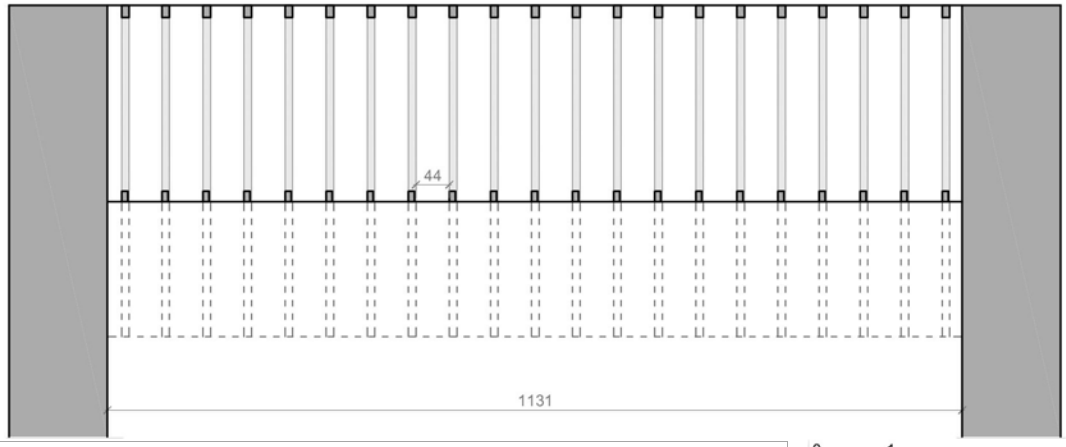
Section aa'



Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5



Roof from outside I:\Arch\A

INITIAL SURVEY | **Building name** STIRLING CASTLE_PALACE | **Roof location** 5: E range

Survey date(s) 01/10/2014 | See drawing: SCP-E-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 6.1 | Roof Height [m]: 4.39

Roof Pitch/es [°]: 46 | Roof Length [m]: 11.3

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables

Roof Construction Period: From 1700 To 1725 | Identified by: Estimated

Roof General Description: Gabled roof supported by 21 frames with one collar.



Roof structure | link I:\Arch\A

link I:\Arch\A

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 16 B: 10 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description

link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Mostly in sequence

Signs of reused timbers



Carpentry marks | link I:\Arch\A

Timber Treated ☐

Other Materials

Dendrochronology: carried out on samples from ceiling oak timbers and dated to 15th and 16th century - probably both Scottish and Baltic source (Crone & Fawcett 1998)

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall not visible

Past interventions

link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☑

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

link I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link I:\Arch\A

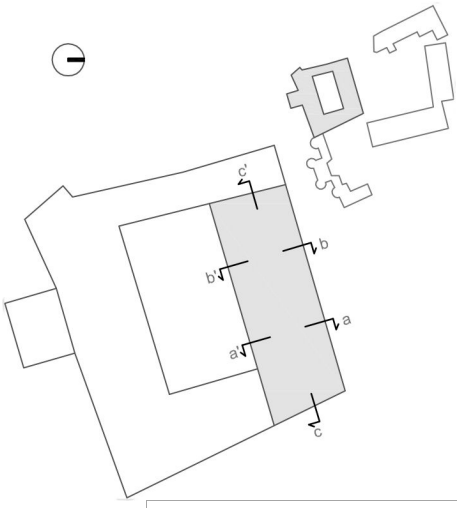
Description of visible damage

link

Other Notes: The palace was built in 1539-42 but Hanke suggests that the roofs were replaced later. According to him, they belong to 3 different construction phases. Diversities only in structural composition, not in details of joining or materials. The Palace saw extensive building operations in late 16C, 17C and early 18C.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui

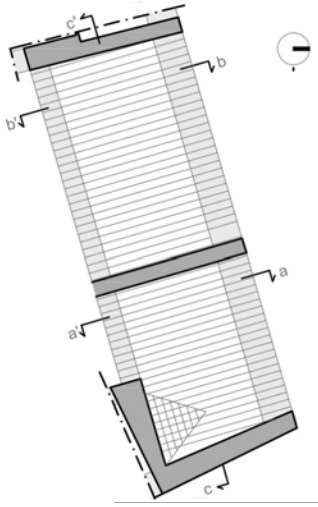
link



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



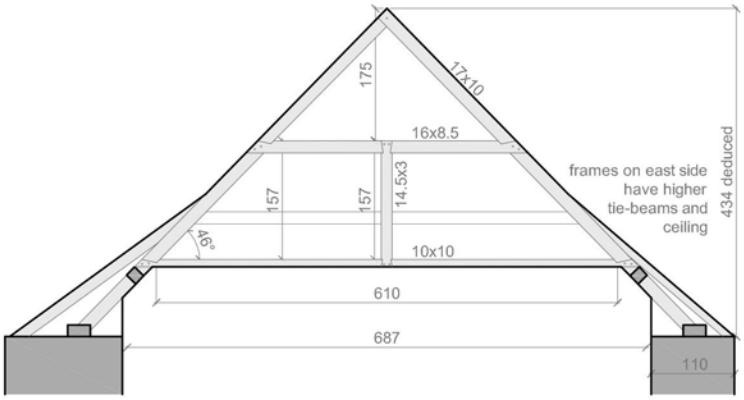
Carpentry marks from west to east:

XVIII	XVII	IIII
XVI	not visible	Λ
XI	VII	not visible
XX	XV	not visible
IX	VI	IV
V	XXIII	III
VIX	IIII	II
III	not visible	I
XIII	not visible	not visible
ΛIII	* WALL	not visible
XXII	not visible	not visible
XXI	II	not visible
XX	not visible	
XIX	not visible	
X	V	
XXIV	VI	
XII	VII	
XI	VIII	
XXVI	not visible	
XVIII	not visible	
III	XI	

Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

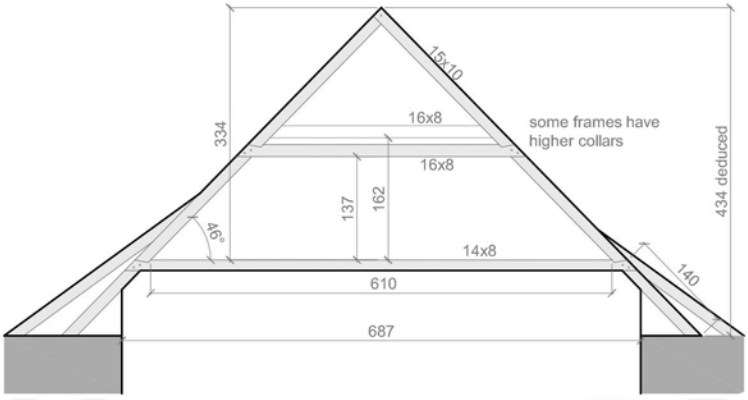
Section aa'



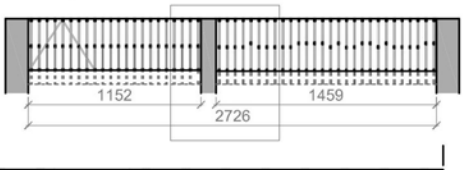
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

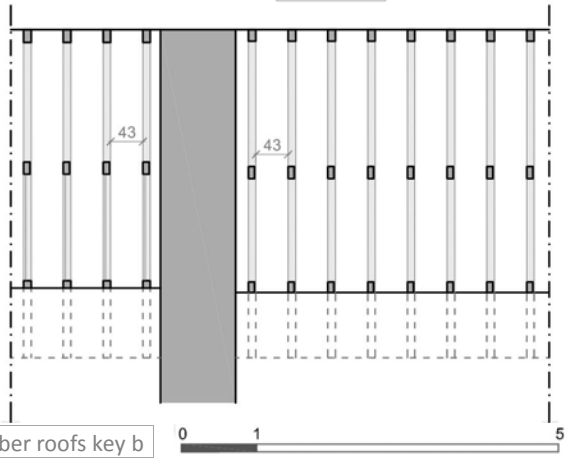
Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section bb'



Section cc'





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

INITIAL SURVEY | **Building name** STIRLING CASTLE_PALACE | **Roof location** 2: N range

Survey date(s) 01/10/2014 | See drawing: SCP-N-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 7 | Roof Height [m]: 4.34

Roof Pitch/es [°]: 46 | Roof Length [m]: 27.26

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s, Struts

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: purlins, sarking

Sarking boards: width [cm] 27 | thickness [cm] 2.5

Connection with lateral walls: None, Wall-plate

Connection with gables: sarking interrupted (chimney), wall-plate

Roof Construction Period: From 1700 To 1725 | Identified by: Estimated

Roof General Description: Gabled roof with an intermidiate gable wall: 22 frames on East side and 30 frames on West side. The external gable walls are made of rubble masonry, the intermediate one is in ashlar masonry. Frames have 2 collars each and sprockets on both sides. The lower collars support the ceiling. In the East section are vertical struts too, connecting the two collars. There is a small cross roof to the North-East with timbers of later date (probably 19C). Rafters and collars are all half logs (roughly squared with a hand axe and then sawn in two).

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: 16 | B: 10 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: dovetail, lapped

Fasteners Types: Metal nail

Joints description: Rafters' apex: simple lap joints, secured with one or two nails; between rafters and collars and collars and struts: dovetail lap joints secured with 2 nails

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Not all of the numbers are visible, but the visible ones are not in sequence

Signs of reused timbers

Timber Treated ☐

Other Materials

Dendrochronology: carried out on samples from ceiling oak timbers and dated to 15th and 16th century - probably both Scottish and Baltic source (Crone & Fawcett 1998)



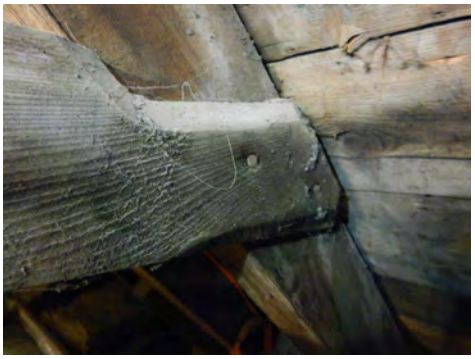
Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joint: rafter and collar | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: The lower collars are all 'packed' in plastic sheets and are therefore inaccessible for inspection.

Past interventions: Works finished in 2009: some sarking amd sprocket rafters replaced, insulation added on the ceiling. In the West part some collars have been lowered and new collars and vertical hangers added. In the East part some vertical struts have been removed, some replaced.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Intermediate gable wet on the East side: the masonry is disintegrating and falling on the timbers and the ceiling. Humidity stains on sarking and rafters look old. Most timbers show diffuse insect exit holes on all faces, which probably correspond to past insect attack confined to the sapwood. Some timbers also show signs of localized active insect attack.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage			

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

link

Description of visible damage

link

Other Notes: The palace was built in 1539-42 but Hanke suggests that the roofs were replaced later. According to him, they belong to 3 different construction phases. Diversities only in structural composition, not in details of joining or materials. The Palace saw extensive building operations in late 16C, 17C and early 18C.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui | link

DETAILED SURVEY **Building name** STIRLING CASTLE_PALACE **Roof location** 3: W range

Survey date(s) 10/02/2016 07/04/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SCP-W-1, SCP-W-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafter	465	rectangular	bending, compression	pinus sylvestris	3 hand axed faces and 1 hand sawn
Collar	260	rectangular	bending, compression		3 hand axed faces and 1 hand sawn
Upper strut	175	rectangular	compression	pinus sylvestris	3 hand axed faces and 1 hand sawn, but some seem to be machine sawn
Sprocket Rafter		rectangular	bending, compression		
Lower strut					
Sarking		sheet	bending, tension	pinus sylvestris	some hand sawn, some machine sawn

* estimated based on drawings because not fully accessible

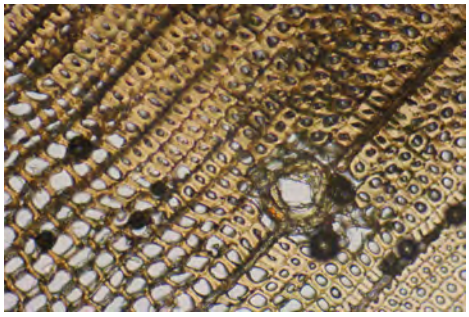
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SCP-W-1, SCP-W-2

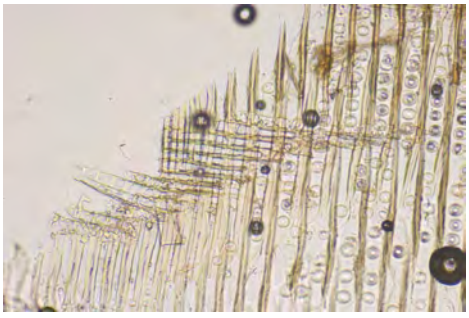
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & collar	Encounter simple lap	compression	nails	
upper strut & other	Encounter simple lap	compression	nails	
lower strut & collar	Encounter simple lap	compression	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

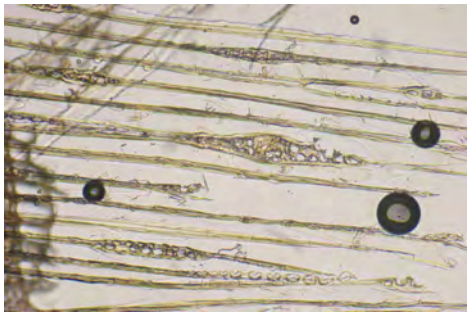
Microscopic identification of the timber species See drawing SCP-W-2



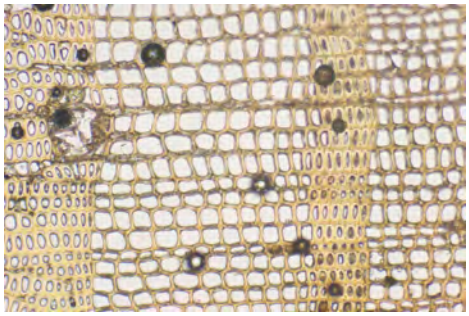
Rafter: transv. Section x100 I:\Arc



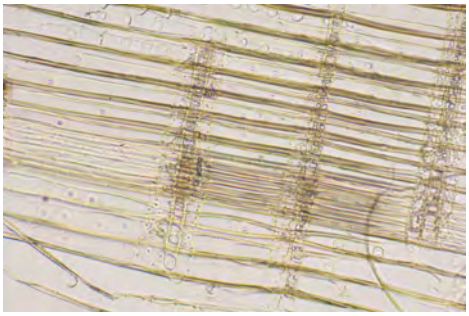
Rafter: radial section x100 I:\Arc



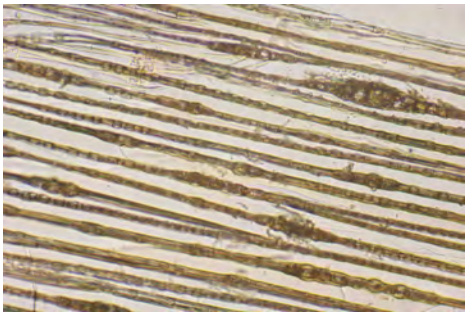
Rafter: tang. section x 100 I:\Arc



Upper strut: transv. Section x100 I:\Arc



Upper strut: radial section x100 I:\Arc



Upper strut: tang. Section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SCP-W-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	S side	10/02/2016	11:15 am	10	72
roof space	N side	10/02/2016	11:30 am	10.3	73.4

Frame/Truss name non visible 25 See drawing SCP-W-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other

Frame/Truss name non visible 15 See drawing SCP-W-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other

Element name A rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type: section not well squared, rounded on one side

Section: nominal size (hxb) [cm]: 16.3x8.8 | min. size (hxb) [cm]: 16x8.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 4 tangential

Knots [min d/section h]: 1/15.5 single | Knotty element ☑ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name B strut

Dating later | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 15x8 | min. size (hxb) [cm]: 15x8 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 3 | tangential

Knots [min d/section h]: | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ Type: | Status: | Way of identification:

Fungi attack ☐ Type: | Status: | Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: | Way of identification:

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Frame/Truss name non visible 4 | See drawing SCP-W-2

Missing elements: | Elements with defects in critical area: rafter

Joints with decayed peg: | Insect attack:

Failed joints: | Fungi attack:

Other:

Element name A rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues: upper end not visible because incorporated in wall

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 15.3x9 | min. size (hxb) [cm]: 15x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 8 | tangential

Knots [min d/section h]: 3/9 | single | Knotty element ☑ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects: shake near centre

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type: | Status: | Way of identification:

Fungi attack ☐ Type: | Status: | Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name B strut

Dating later
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 14.5x7 min. size (hxb) [cm] 14x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 7 tangential
Knots [min d/section h] 2/7 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Frame/Truss name non visible 25 See drawing SCP-W-2

Missing elements
Elements with defects in critical area
Joints with decayed peg
Insect attack rafter
Failed joints
Fungi attack
Other

Element name A rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 16x8.3 min. size (hxb) [cm] 15.5x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 9 tangential
Knots [min d/section h] 1/9 single Knotty element ☑ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification



insect attack I:\Arc

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Element name B strut

Dating later Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.7x7.2 min. size (hxb) [cm] 15x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 4/15 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Frame/Truss name non visible 20 See drawing SCP-W-2

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack strut

Failed joints Fungi attack

Other

Frame/Truss name	**non visible 12**	See drawing SCP-W-2	
Missing elements		Elements with defects in critical area	
Joints with decayed peg		Insect attack	rafter
Failed joints		Fungi attack	
Other			

Frame/Truss name	**non visible 6**	See drawing SCP-W-2	
Missing elements		Elements with defects in critical area	
Joints with decayed peg		Insect attack	rafter
Failed joints		Fungi attack	
Other			

Frame/Truss name	**non visible 6**	See drawing SCP-W-2	
Missing elements		Elements with defects in critical area	
Joints with decayed peg		Insect attack	rafter
Failed joints		Fungi attack	
Other			

DETAILED SURVEY **Building name** STIRLING CASTLE_PALACE **Roof location** 1: NW corner

Survey date(s) 10/02/2016 07/04/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SCP-NW-1, SCP-NW-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Purlins	370	rectangular	bending	quercus sp.	hand axed
Common rafters	640	rectangular	bending, compression	pinus sylvestris	3 hand axed faces and one hand sawn
Collars	680	rectangular	bending, compression, tension		
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

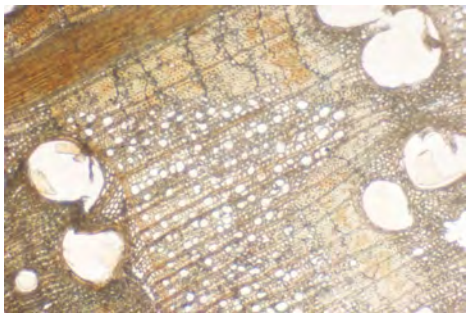
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SCP-NW-1, SCP-NW-2

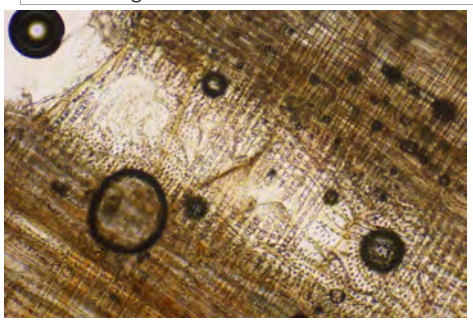
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafters & collars	Encounter dovetail	compression, tension	nails	
rafters & purlins	Encounter simple contact	compression	none	
rafter & rafter	Encounter simple contact	compression	none	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

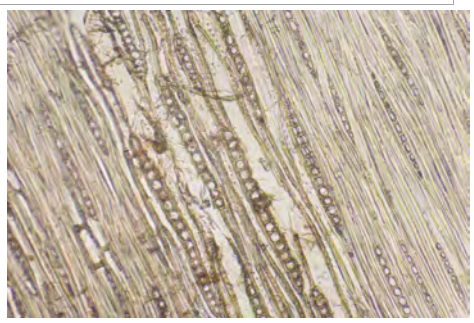
Microscopic identification of the timber species See drawing SCP-NW-2



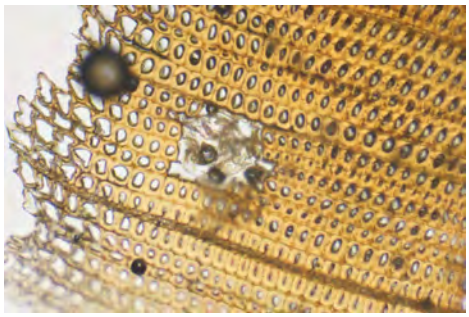
Purlin: transv. Section x40 I:\Arc



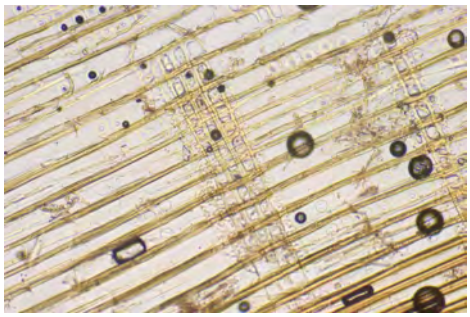
Purlin: radial section x 100 I:\Arc



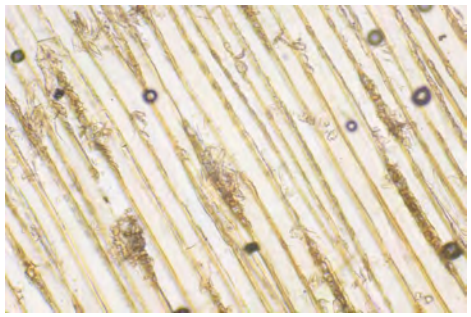
Purlin: tang. Section x100 I:\Arc



Sarking: transv. Section x100 I:\Arc



Sarking: radial section x100 I:\Arc



Sarking: tang. Section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SCP-NW-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	centre	10/02/2016	10:45 am	11.5	65

roof space	centre	16/06/2016	4 pm	19.6	62.2

Frame/Truss name all roof — See drawing SCP-NW-2

Missing elements | Elements with defects in critical area: purlin b

Joints with decayed peg | Insect attack: purlin b & c

Failed joints | Fungi attack: purlin b & c

Other

Element name A purlin

Dating: original construction | Signs of reuse: redundant mortice and tenon joint close to the West end

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 17.8x14.6 | min. size (hxb) [cm]: 17x14 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 5 | tangential

Knots [min d/section h]: 3/19 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: I



redundant joint on purlin | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐ | External actions ☐ | Other ☐

Element name B purlin

Dating: original construction | Signs of reuse: redundant mortice and tneon joint near the East end

Timber treated ☐ | Accessibilityissues

Past interventions: there are signs of coring

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 18x15.8 | min. size (hxb) [cm]: 17x15.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: centre | Slope of grain [%]: 5 | tangential

Knots [min d/section h]: 2.5/16 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☑

Other defects

Estimated Strength Class according to UNI 11119: lower than III

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: unknown
Way of identification: Estimated

Fungi attack ☑ Type: Unknown Status: unknown
Way of identification:

Corrosion ☐ Wet surface ☐ Other:



insect & possible fungi attack I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: the decay seems to be limited to the sapwood (3cm depth maximum)

Way of identification: visual inspection

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name C purlin

Dating: original construction Signs of reuse:

Timber treated ☐

Past interventions:

Accessibilityissues:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 18.8x14.8 min. size (hxb) [cm]: 18.5x14.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: centre Slope of grain [%]: 12 tangential

Knots [min d/section h]: 4/15 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

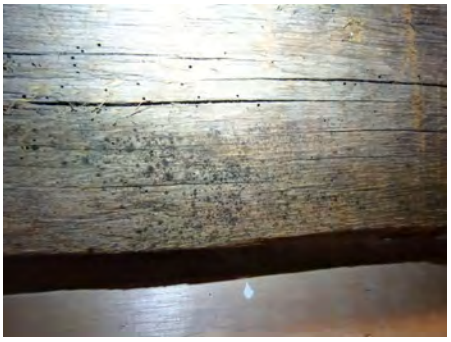
Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: unknown
Way of identification: Estimated

Fungi attack ☑ Type: Unknown Status: unknown
Way of identification:

Corrosion ☐ Wet surface ☐ Other:



possible fungi attack I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent:

Way of identification:

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Element name D purlin

Dating: original construction Signs of reuse:

Timber treated ☐

Past interventions: there are signs of coring

Accessibilityissues: the Eastern half of the purlin is not visible

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm] 19x16 min. size (hxb) [cm] 19x16 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 6 tangential

Knots [min d/section h] 5/15 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage

Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

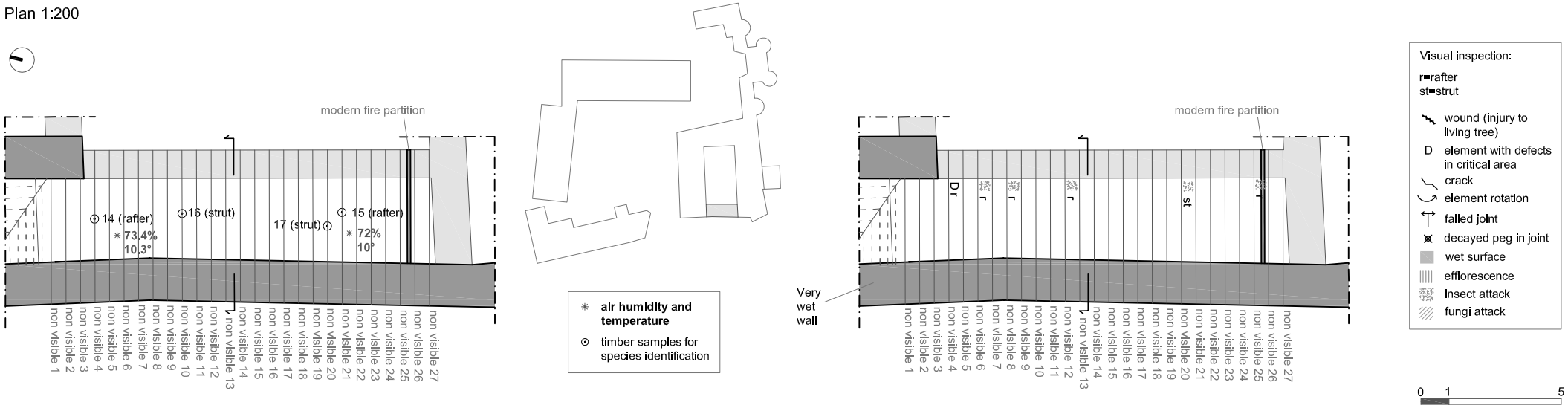
Degradation ☐ Poor maintenance ☐

Past interv. ☐

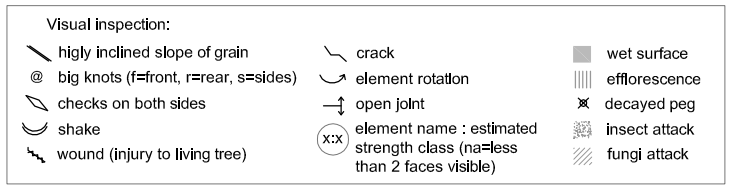
External actions ☐

Other ☐

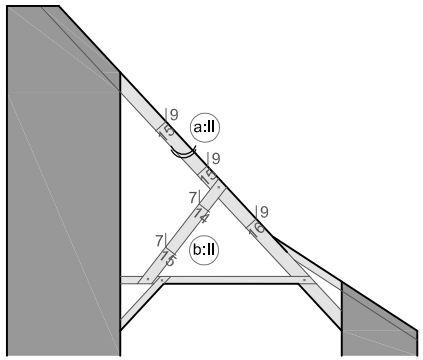
Plan 1:200



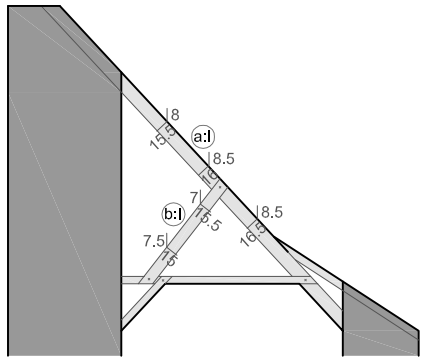
Sections 1:100 (looking North)



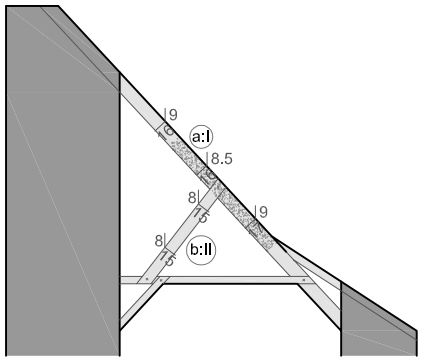
Frame nv4



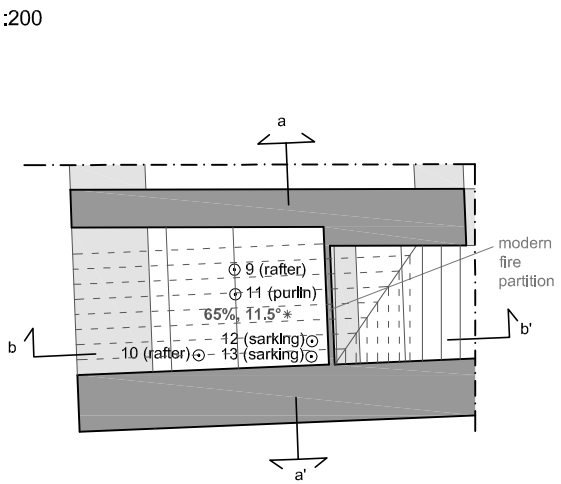
Frame nv15

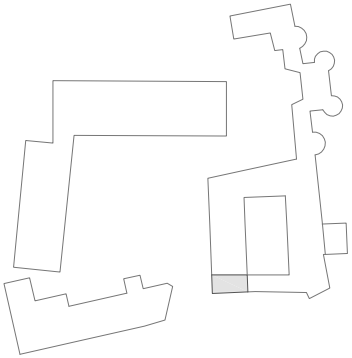


Frame nv25

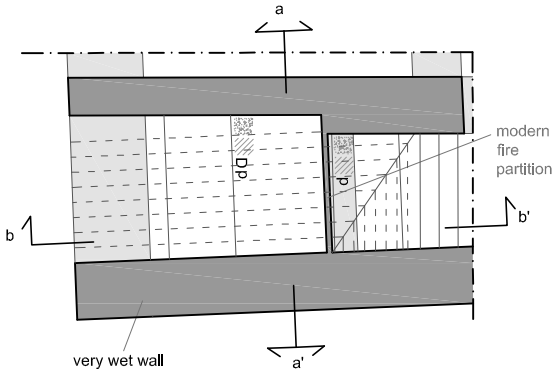


Plan 1:200





* **air humidity and temperature**
⊙ timber samples for species identification



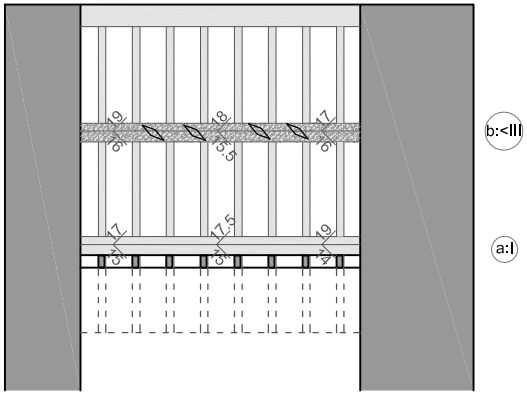
Visual inspection:
p=purlin
r=rafter
sk=sarking
wound (injury to living tree)
D element with defects in critical area
crack
element rotation
failed joint
decayed peg In joint
wet surface
efflorescence
insect attack
fungi attack

0 1 5

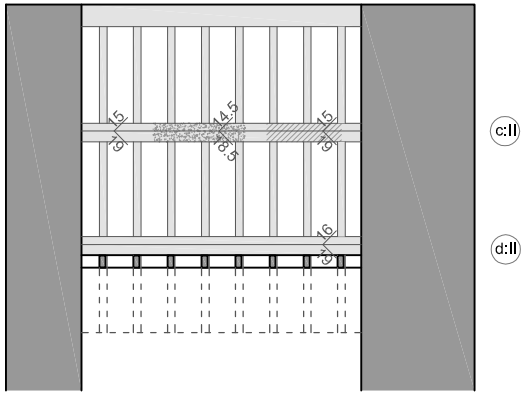
Sections 1:100 (looking North)

Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

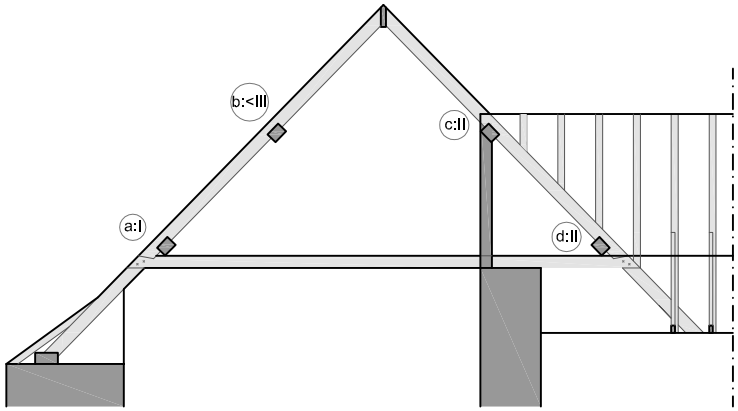
Section aa'1:100 (looking North)



Section aa' 1:100 (looking South)



Section bb' 1:100 (looking East)



DETAILED SURVEY **Building name** STIRLING CASTLE_PALACE **Roof location** 4: SW range

Survey date(s) 10/02/2016 07/04/2016 20/05/2016 16/06/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SCP-SW-1, SCP-SW-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafters	530	rectangular	bending, compression	pinus sylvestris	3 hand axed faces and 1 hand sawn
Collars	440	rectangular	bending, compression, tension	pinus sylvestris	the visible face is hand axed
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn
Sprocket rafters		rectangular	bending, compression		

* estimated based on drawings because not fully accessible

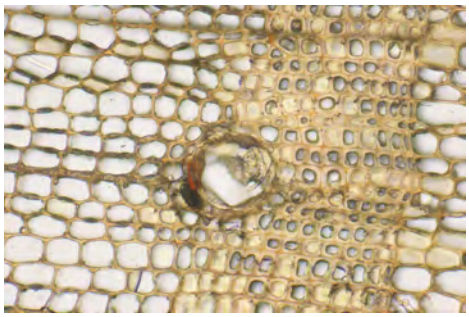
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SCP-SW-1, SCP-SW-2

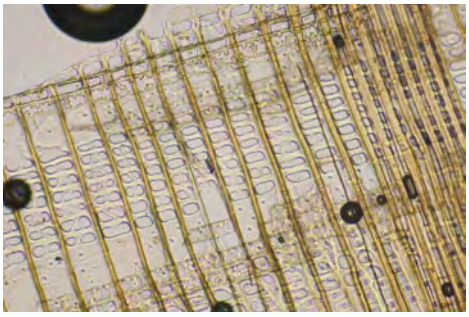
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner halved	compression	nails	
rafter & collar	Encounter dovetail	compression, tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

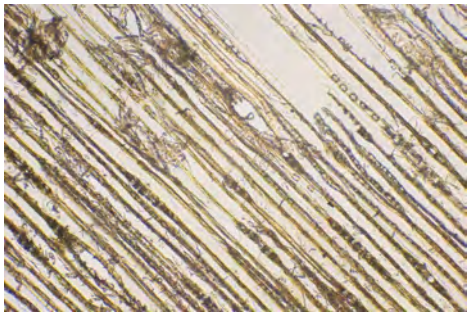
Microscopic identification of the timber species See drawing SCP-SW-2



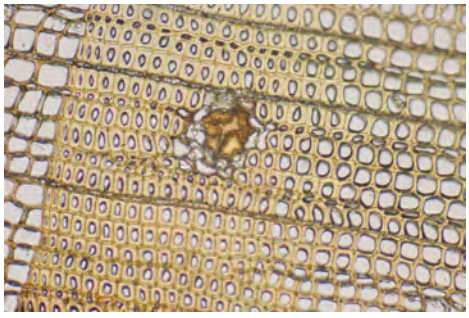
Rafter: transv. Section x100 I:\Arc



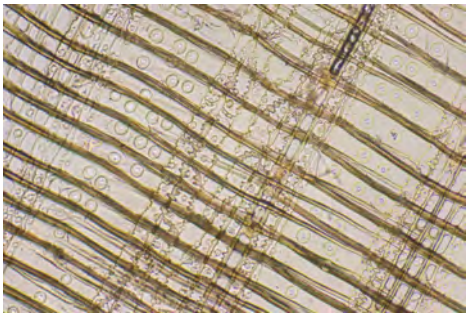
Rafter: radial section x100 I:\Arc



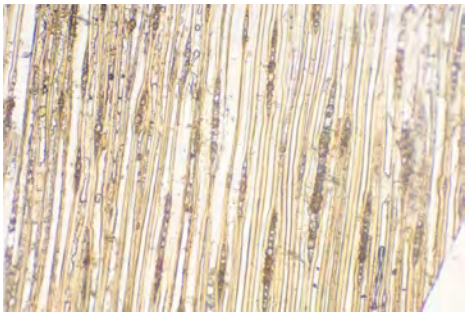
Rafter: tang. Section x50 I:\Arc



Sarking: transv. Section x100 I:\Arc



Sarking: radialection x100 I:\Arc



Sarking: tang. section x50 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SCP-SW-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	W side	10/02/2016	12 am	13	59

roof space	E side	10/02/2016	12 am	13.7	55.6
roof space	E side	20/05/2016	10 am	18.4	53
roof space	W side	20/05/2016	10:15 am	18.2	54.5
roof space	E side	16/06/2016	2:15 pm	22	54
roof space	W side	16/06/2016	2 pm	21.5	57

Frame/Truss name XII — See drawing SCP-NE-5

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack: S rafter

Failed joints | Fungi attack

Other

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type: upper part has a trapezoid section: depth reduced to 1.7cm

Section: nominal size (hxb) [cm]: 17.3x6.9 | min. size (hxb) [cm]: 17x1.7 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack, probably old | I:\Arc

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: non-active

Way of identification: Estimated

Fungi attack ☐ | Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: external section reduction up to 2cm and internal decay up to 2cm (points a-a')

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

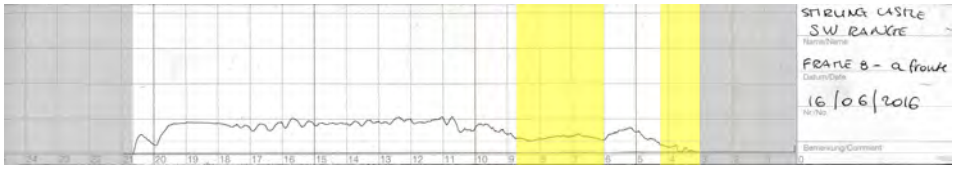
Moisture Content [%]: 11.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☑

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]: 12.8

Link to Micro-drill graph: I:\Arc



LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point a'

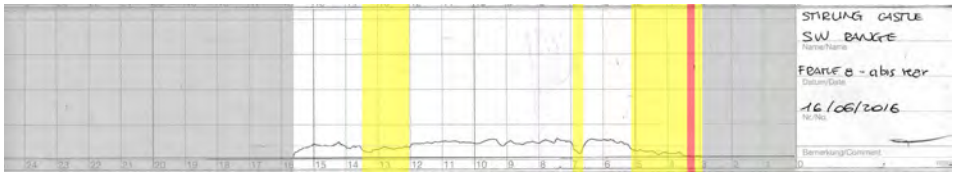
Moisture Content [%] | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]: 19.7

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

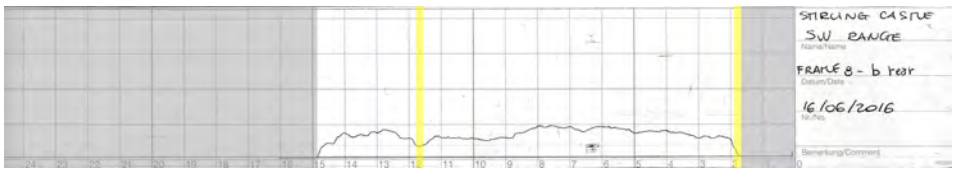
Moisture Content [%]: 11.1 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1145 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: 7.9

Material Degradation based on Micro-drill [%]: 2.5

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

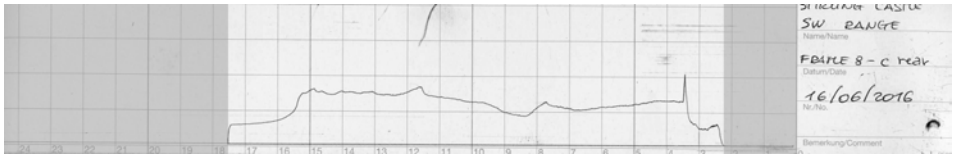
Moisture Content [%]: 9.7 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1501 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -6.2

Material Degradation based on Micro-drill [%]: 0

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name VIIII | See drawing SCP-SW-5

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack: S rafter

Failed joints | Fungi attack

Other

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 17.3x10.1 | min. size (hxb) [cm]: 17x10 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: active

Way of identification: Estimated

Fungi attack ☐ | Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role



insect attack on rafter | I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: external section reduction up to 3cm and internal decay up to 1.5cm

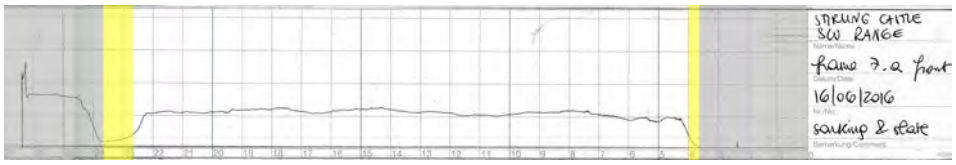
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]	11.8
Ultrasonic velocity [m/s]	1528
Density loss based on ultrasonic test [%]	-7.3
Material Degradation based on Micro-drill [%]	5.8
Link to Micro-drill graph	I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

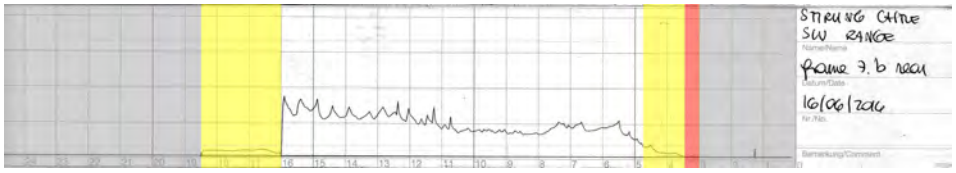


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]	16.2
Ultrasonic velocity [m/s]	1663
Density loss based on ultrasonic test [%]	-12.6
Material Degradation based on Micro-drill [%]	24
Link to Micro-drill graph	I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

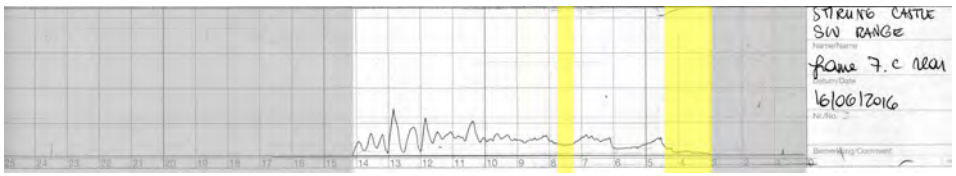


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]	12.3
Ultrasonic velocity [m/s]	1593
Density loss based on ultrasonic test [%]	-9.8
Material Degradation based on Micro-drill [%]	11.8
Link to Micro-drill graph	I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

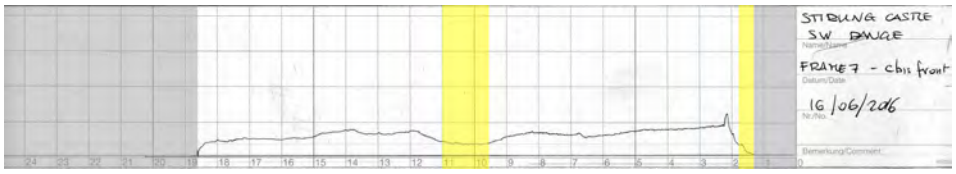


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c'

Moisture Content [%]	
Ultrasonic velocity [m/s]	
Density loss based on ultrasonic test [%]	
Material Degradation based on Micro-drill [%]	5.9
Link to Micro-drill graph	I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name not visible 5 — See drawing SCP-SW-4

Missing elements
Elements with defects in critical area
Joints with decayed peg
Insect attack
Failed joints
Fungi attack
Other efflorescence on upper face of S rafter

Element name A south rafter

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17x9 min. size (hxb) [cm] 16.5x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



efflorescence on upper face I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other efflorescence on upper face of the rafter

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 12.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1408 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -2.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 13.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1475 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -5.2

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 8.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1421 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name not visible 3 See drawing SCP-SW-4

Missing elements Elements with defects in critical area S rafter

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other: shakes all along S rafter

Element name A south rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 18.8x9 | min. size (hxb) [cm]: 18x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]:

Knots [min d/section h]: | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects: shakes all along the element

Estimated Strength Class according to UNI 11119:



shakes all along the element | I:\Arc

Material degradation

Insect attack ☐ | Type: | Status: | Way of identification:

Fungi attack ☐ | Type: | Status: | Way of identification:

Corrosion ☐ | Wet surface ☐ | Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: shakes up to 0.4cm wide | Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 8.9 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1365 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -0.8

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 12.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1519 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -6.9

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

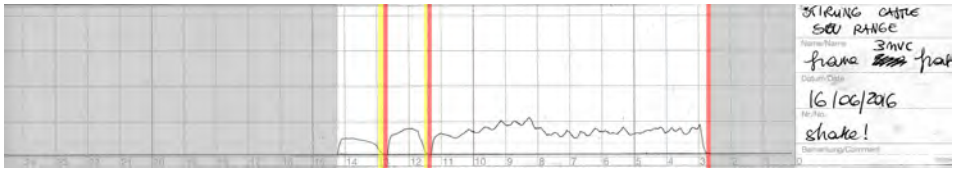
Moisture Content [%]: 13.7 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1236 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: 4.3

Material Degradation based on Micro-drill [%]: 6.5

Link to Micro-drill graph: I:\Arc



LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name II — See drawing SCP-SW-4

Missing elements | Elements with defects in critical area: N rafter

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other: wound on N rafter

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 15.3x8.5 | min. size (hxb) [cm]: 15x8 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects: shakes and a wound (injury to living tree)

Estimated Strength Class according to UNI 11119



wound (injury to living tree) | I:\Arc

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage | Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 12.4 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1666 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -12.7

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 12 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1680 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -13.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%] 13.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1534 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -7.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name not visible 10 See drawing SCP-SW-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13.8x7.9 min. size (hxb) [cm] 12.9x7.9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 2.7/8 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification NDT/SDT

Measurement Point a

Moisture Content [%] 11.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1469 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -4.9

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 12.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1547 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -8

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 11.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1655 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -12.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.8x9.3 min. size (hxb) [cm] 15.3x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential

Knots [min d/section h] 5.2/9 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other



big knot I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point d

Moisture Content [%] 11.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1732 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -15.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 11.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1455 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -4.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

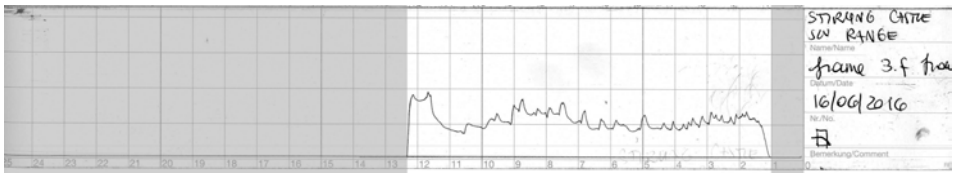
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 14.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1351 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -0.3



Material Degradation based on Micro-drill [%] 0

Link to Micro-drill graph I:\Arc

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name A collar

Dating Signs of reuse

Timber treated ☐ Accessibilityissues only one face partly visible because 'wrapped' in plastic

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] min. size (hxb) [cm] Single piece ☐ Jointed element ☐

Strength affecting defects

Pith location Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 12 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 13.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 14.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 13.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XV See drawing SCP-SW-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15.9x8.9 min. size (hxb) [cm] 15.5x8.8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 7.5/9 Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role



big knot I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point d

Moisture Content [%]	11.8	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐		
Ultrasonic velocity [m/s]	1527	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]	-7.2						
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%]	12.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐		
Ultrasonic velocity [m/s]	1511	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]	-6.6						
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%]	11.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐		
Ultrasonic velocity [m/s]	1445	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]	-4						
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north rafter

Dating: original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 16x8.7 min. size (hxb) [cm]: 15.5x8.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 9 tangential
Knots [min d/section h]: 2/14.9 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]	12	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐		
Ultrasonic velocity [m/s]	1533	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]	-7.4						
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]	11.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐		
Ultrasonic velocity [m/s]	1581	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]	-9.4						
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]	14.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐		
Ultrasonic velocity [m/s]	1576	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]	-9.2						
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C collar

Dating
Signs of reuse
Timber treated ☐
Accessibilityissues: only one face partly visible because 'wrapped' in plastic
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]
min. size (hxb) [cm]
Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location
Slope of grain [%]
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 12 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 10.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 10.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 11.9 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name not visible 2 | See drawing SCP-SW-3

Missing elements | Elements with defects in critical area
Joints with decayed peg | Insect attack
Failed joints | Fungi attack
Other

Element name A south rafter

Dating original construction | Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 18.3x9 min. size (hxb) [cm] 18x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 2.5/18.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: Very limited external decay

Way of identification: NDT/SDT

Measurement Point a

Moisture Content [%] 12.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1521 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -7

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 11.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1427 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -3.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

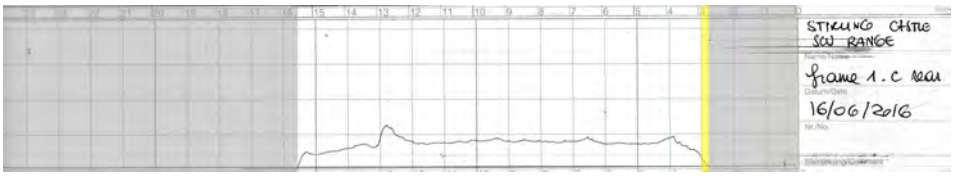
Moisture Content [%] 10.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1281 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] 2.5

Material Degradation based on Micro-drill [%] 1.7

Link to Micro-drill graph I:\Arc



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17x9 min. size (hxb) [cm] 16.5x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 8 tangential

Knots [min d/section h] 3.5/9 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Measurement Point d

Moisture Content [%] 12.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1700 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -14.1

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point e

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1517 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -6.8

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point f

Moisture Content [%] 13.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1387 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -1.7

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C collar

Dating original construction Signs of reuse

Timber treated ☐

Accessibilityissues: only one face partly visible because 'wrapped' in plastic

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] | min. size (hxb) [cm] | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location | Slope of grain [%] | Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]	15.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☑	micro-drill ☑		
Ultrasonic velocity [m/s]		Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]							
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]	13.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☑	micro-drill ☑		
Ultrasonic velocity [m/s]		Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]							
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%]	9.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☑	micro-drill ☑		
Ultrasonic velocity [m/s]		Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐			
Density loss based on ultrasonic test [%]							
Material Degradation based on Micro-drill [%]							
Link to Micro-drill graph							

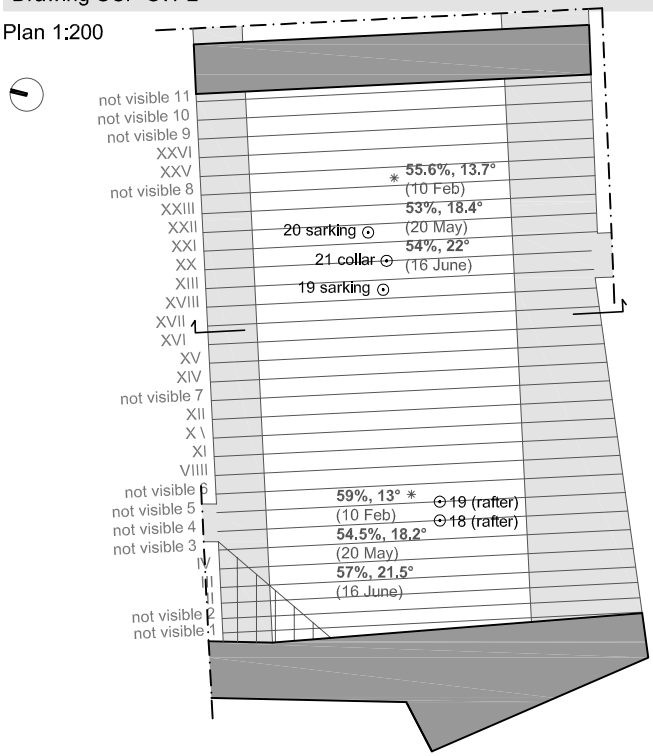
LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

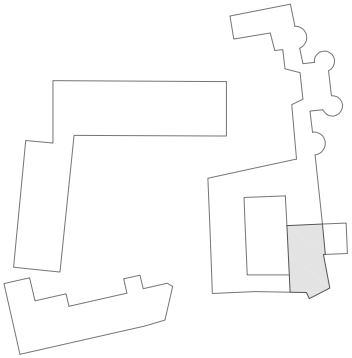
Building Name: Stirling Castle Palace | Roof Location: SW range | ANNA SERAFINI | Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou

Drawing SCP-SW-2 | PhD thesis | Architecture Department, University of Strathclyde

999

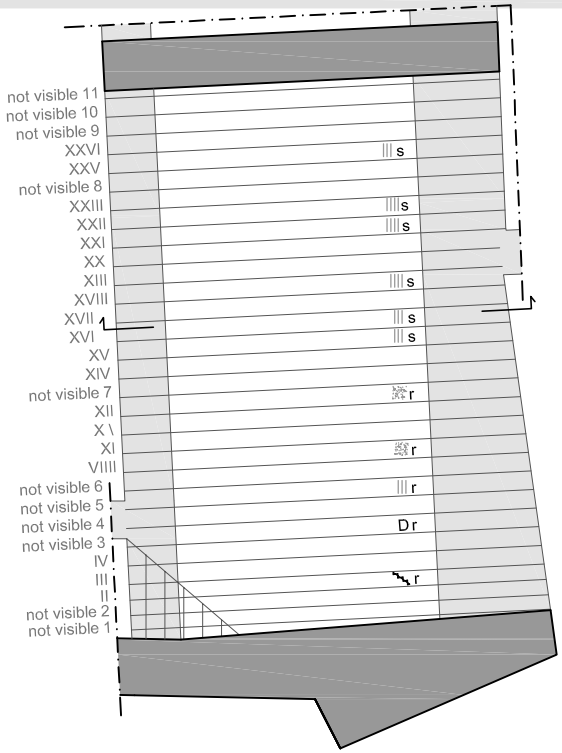
Plan 1:200





✳ air humidity and temperature

⊙ timber samples for species identification



Visual inspection:

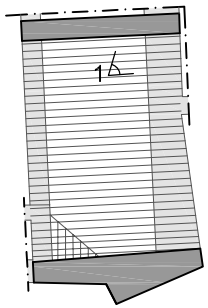
r=rafter
s=sarking

- wound (injury to living tree)
- D element with defects in critical area
- crack
- element rotation
- failed joint
- decayed peg in joint
- wet surface
- efflorescence
- insect attack
- fungi attack

0 1 5

Themographic images

Plan 1:500



1: areas with higher temperature show the position of the rafters behind the plaster in the attic spaces





Building Name: Stirling Castle Palace | Roof Location: SW range | ANNA SERAFINI | Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou

Drawing SCP-SW-3 | PhD thesis | Architecture Department, University of Strathclyde

1000

Sections 1:100 (looking East)

Visual inspection:

- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

Moisture content readings:

- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18

readings >18

readings >20

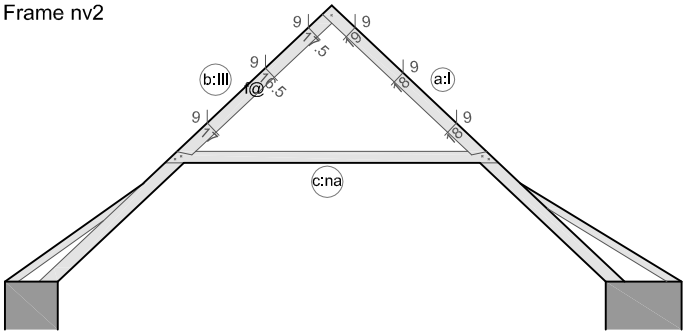
Ultrasound measurements:

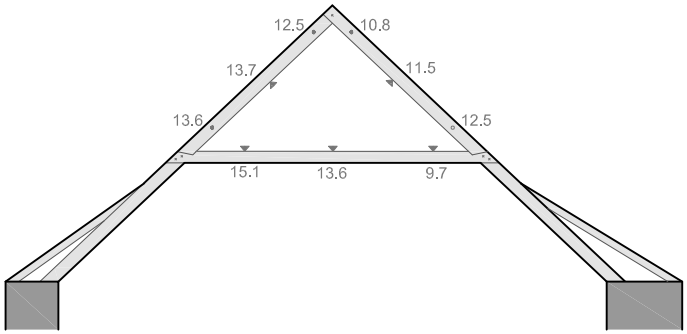
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

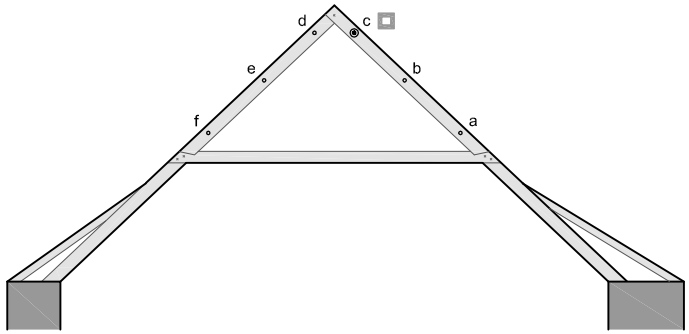
Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements

- good
- external decay
- Internal decay
- ext. & int. decay
- extensive decay

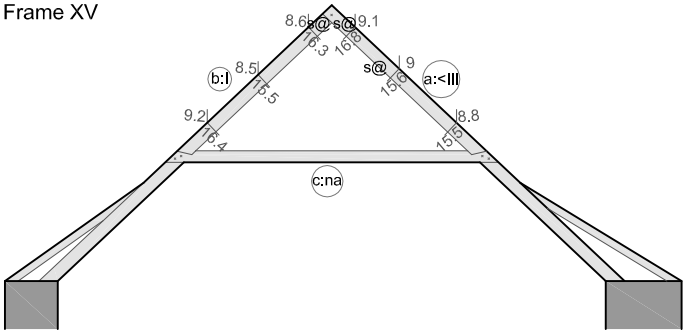
Frame nv2

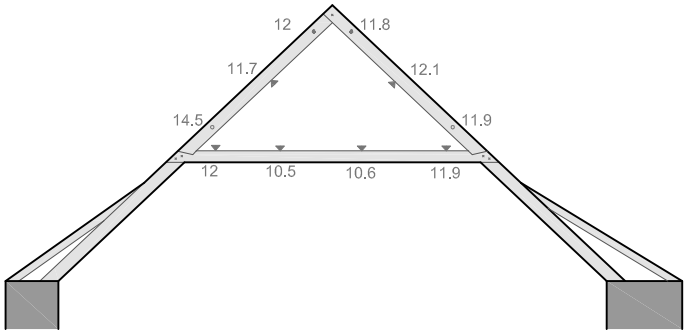


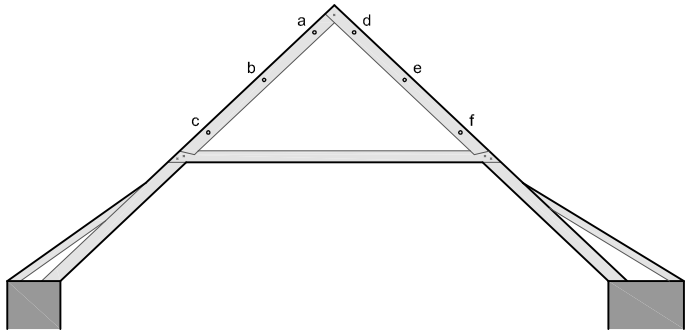




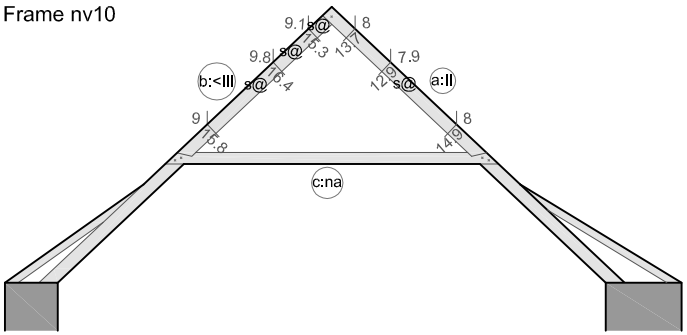
Frame XV

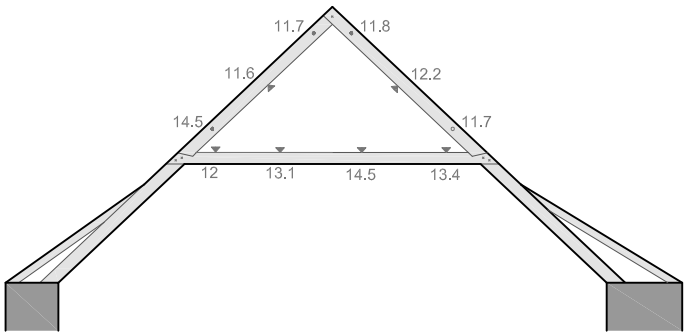


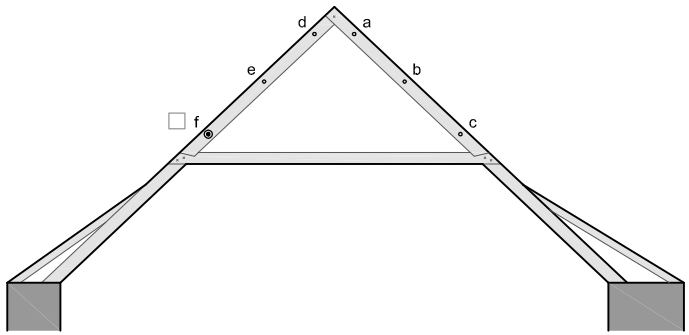




Frame nv10







Building Name: Stirling Castle Palace | Roof Location: SW range | ANNA SERAFINI | Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou

Drawing SCP-SW-4 | PhD thesis | Architecture Department, University of Strathclyde

1001

Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

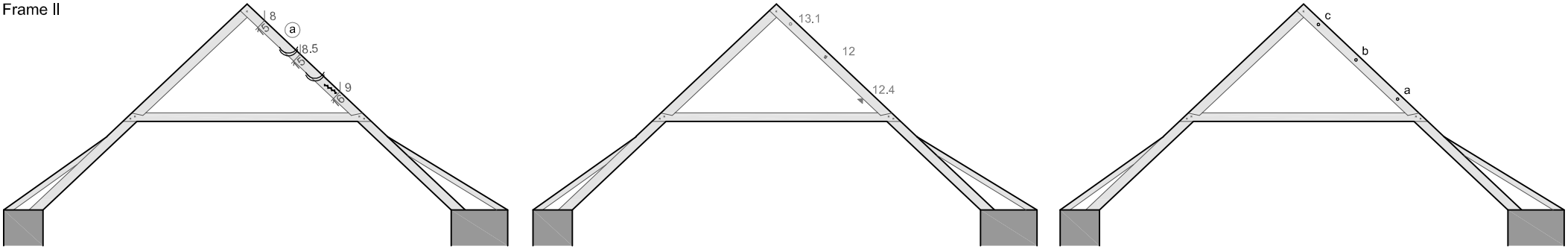
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20

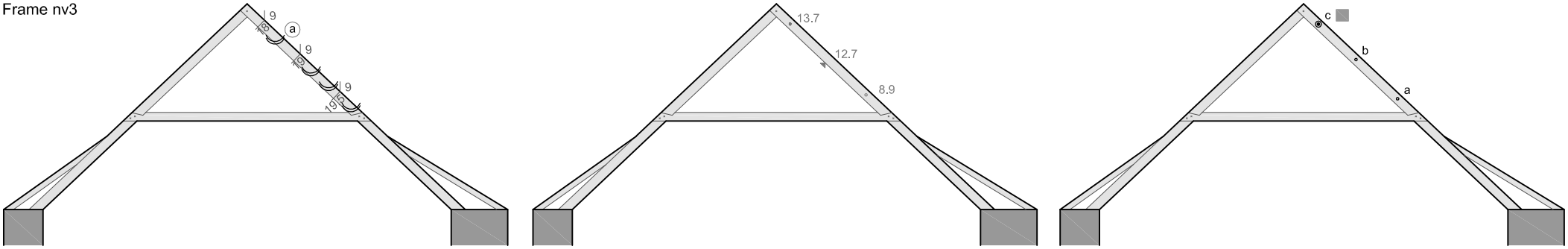
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- internal decay
- ext. & int. decay
- extensive decay

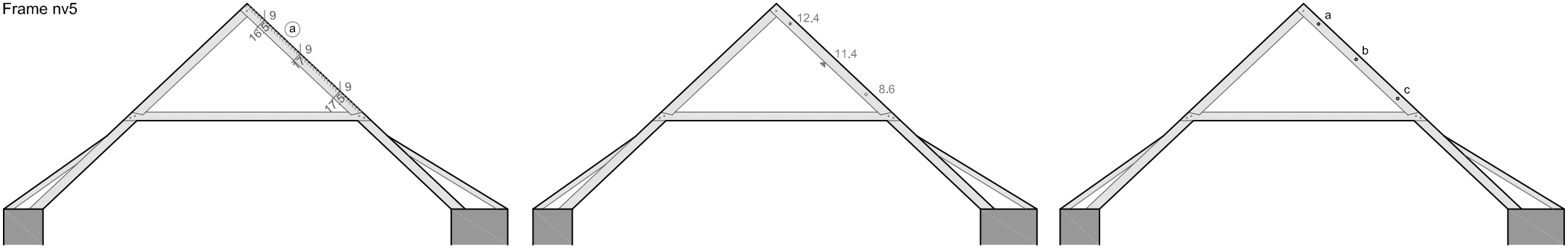
Frame II



Frame nv3



Frame nv5



Building Name: Stirling Castle Palace | Roof Location: SW range | ANNA SERAFINI | Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou
Drawing SCP-SW-5 | PhD thesis | Architecture Department, University of Strathclyde
1002

Sections 1:100 (looking East)

Visual inspection:
- higly inclined slope of grain
- big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

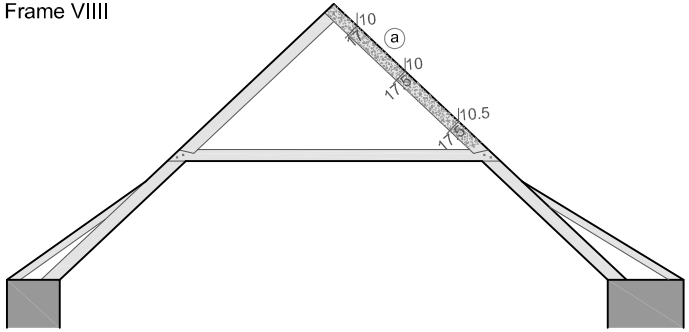
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

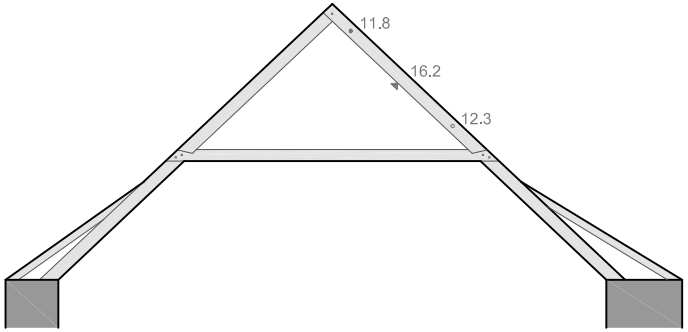
readings <18
readings >18
readings >20

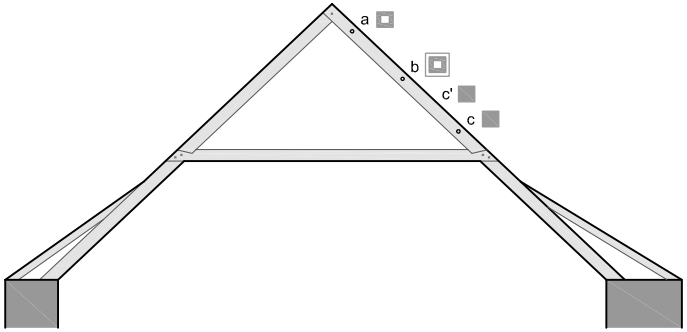
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- Internal decay
- ext. & int. decay
- extensive decay

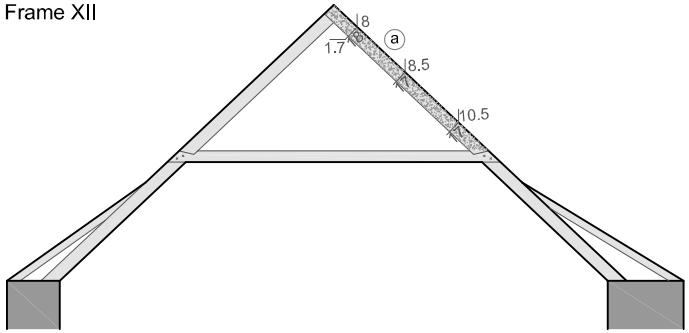
Frame VIIII

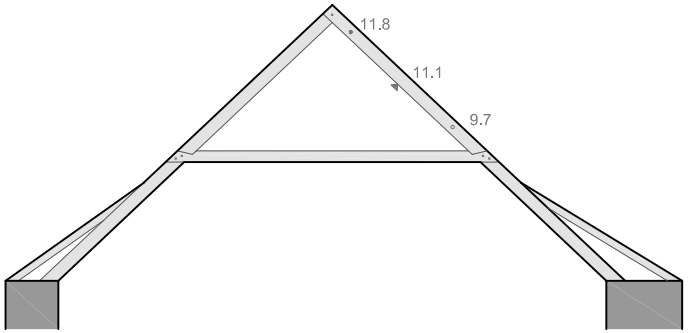


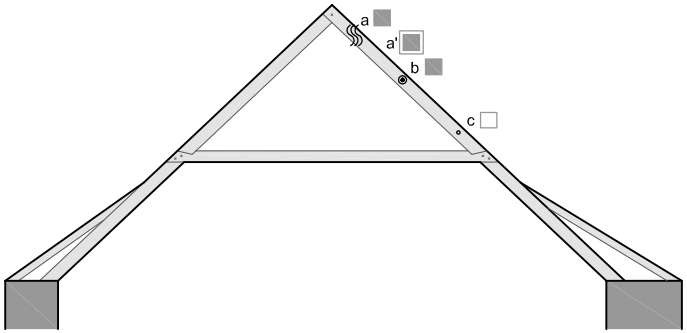




Frame XII







DETAILED SURVEY **Building name** STIRLING CASTLE_PALACE **Roof location** 2: NE range

Survey date(s) 10/02/2016 07/04/2016 29/04/2016 16/06/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SCP-NE-1, SCP-NE-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafters	580	rectangular	bending, compression	pinus sylvestris	3 hand axed faces and 1 hand sawn
Upper collars	370	rectangular	bending, compression	pinus sylvestris	3 hand axed faces and 1 hand sawn
Lower collars	670	rectangular	bending, tension		the visible face is hand axed
Struts	167	rectangular	compression, tension	pinus sylvestris	3 hand axed faces and 1 hand sawn
Sprocket rafters		rectangular	bending, compression		
Sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

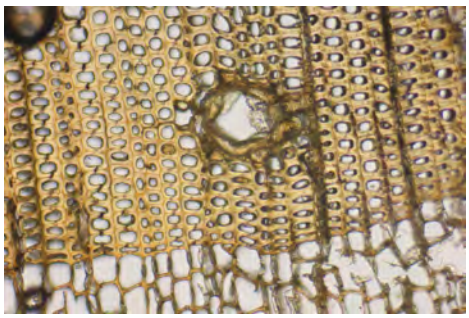
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SCP-NE-1, SCP-NE-2

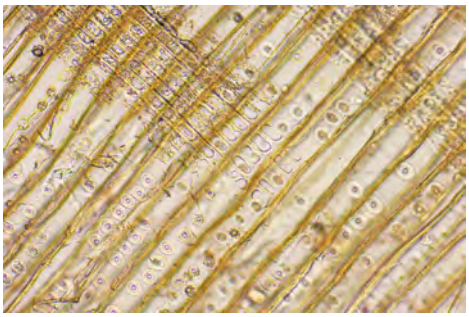
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner halved	compression	nails	
rafter & upper collar	Encounter dovetail	compression	nails	
rafter & lower collar	Encounter dovetail	compression, tension	nails	
strut & collar	Encounter dovetail	compression, tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

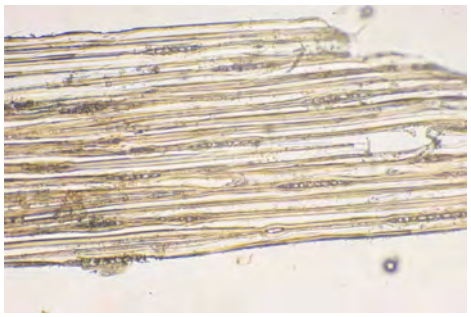
Microscopic identification of the timber species See drawing SCP-NE-2



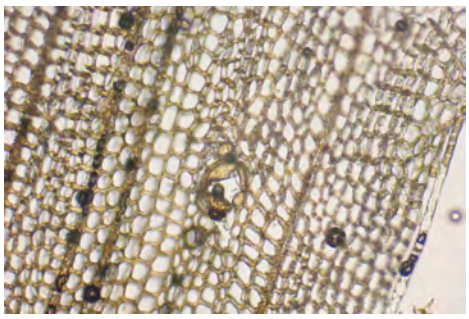
Rafter: transv. Section x100 I:\Arc



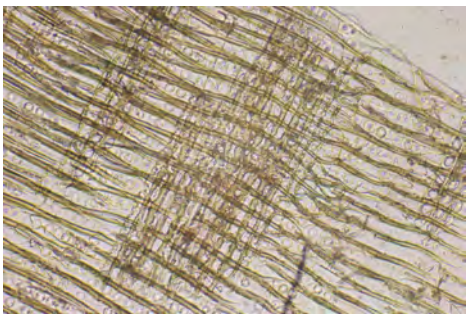
Rafter: radial section x100 I:\Arc



Rafter: trang. section x50 I:\Arc



Sarking: transv. Section x100 I:\Arc



Sarking: radial section x100 I:\Arc



Sarking: tang. Section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing SCP-NE-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]

roof space	centre	10/02/2016	10 am	12	67.2
roof space	centre	29/04/2016	10 am	17	61
roof space	centre	16/06/2016	10 am	18.6	63.8

Frame/Truss name not visible 9 — See drawing SCP-NE-2

Missing elements | Elements with defects in critical area: upper collar

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other: big shake in collar

Frame/Truss name III — See drawing SCP-NE-4

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack: south rafter

Failed joints | Fungi attack

Other

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 17.2x9.9 | min. size (hxb) [cm]: 16.9x9.7 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



I:\Arc

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: active | Way of identification: Estimated

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: external decay of 2.5cm maximum and internal decay of 0.5cm maximum

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

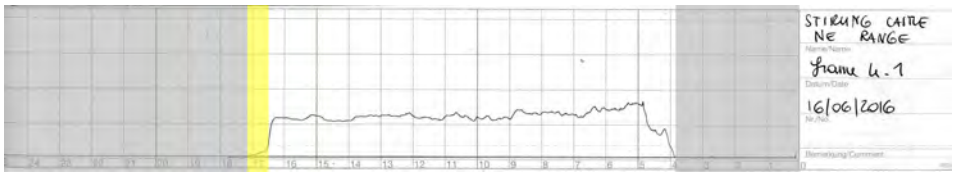
Moisture Content [%]: 15.8 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1089 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: 10.1

Material Degradation based on Micro-drill [%]: 4.6

Link to Micro-drill graph: I:\Arc

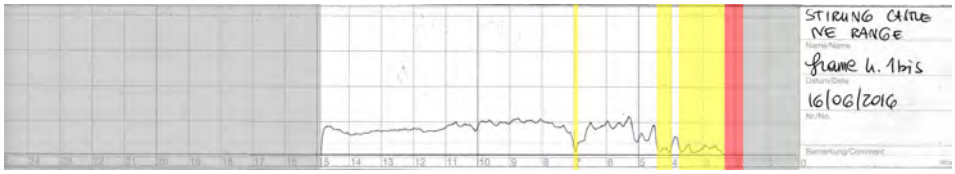


LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point a'

Moisture Content [%]
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 16.8
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

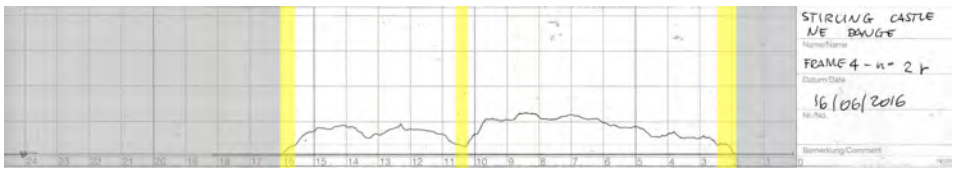


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 17
Ultrasonic velocity [m/s] 1231
Density loss based on ultrasonic test [%] 4.5
Material Degradation based on Micro-drill [%] 7.6
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

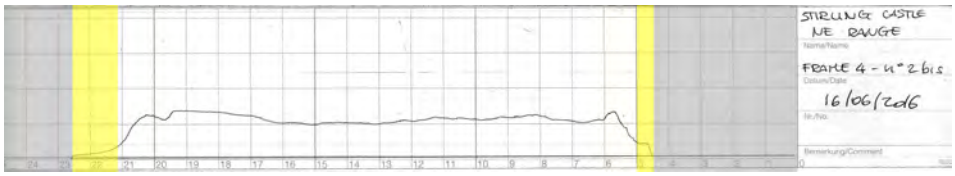


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b'

Moisture Content [%]
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 9
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☑

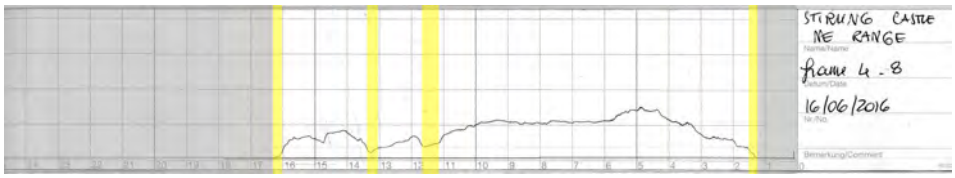


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 15.2
Ultrasonic velocity [m/s] 1069
Density loss based on ultrasonic test [%] 10.9
Material Degradation based on Micro-drill [%] 7.6
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☑ Higher gain ☑ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name non visible 7 See drawing SCP-NE-4

Missing elements
Elements with defects in critical area
Joints with decayed peg
Insect attack north rafter & south rafter
Failed joints
Fungi attack
Other

Element name A north rafter

Dating original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 16x9 min. size (hxb) [cm] 16x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side
Slope of grain [%]
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated

Fungi attack ☐ Type: Status:
Way of identification:

Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: very limited external decay

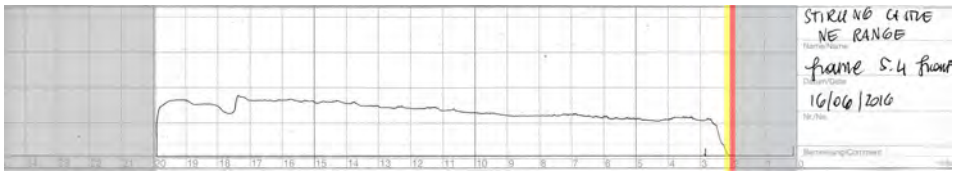
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 21.2
Ultrasonic velocity [m/s]: 2273
Density loss based on ultrasonic test [%]: -36.8
Material Degradation based on Micro-drill [%]: 1.9
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

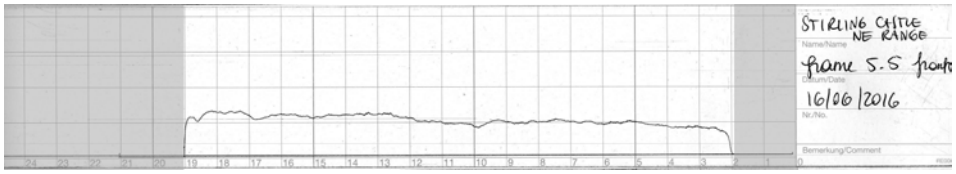


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 18.4
Ultrasonic velocity [m/s]: 2185
Density loss based on ultrasonic test [%]: -33.3
Material Degradation based on Micro-drill [%]: 0
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]:
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B south rafter

Dating: original construction Signs of reuse:

Timber treated ☐ Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 17.5x9 min. size (hxb) [cm]: 17x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]:

Knots [min d/section h]: Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack | I:\Arc

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated

Fungi attack ☐ Type: Status:
Way of identification:

Corrosion ☐ Wet surface ☐ Other:

Mechanical Damage

Type		Status	Role
Deformation	☐		
Cracks	☐		
Crushing	☐		
Other	☐		

Estimated level of damage: Emergency interv. needed ☐

Mater.Degr. and Damage Extent: very limited external decay

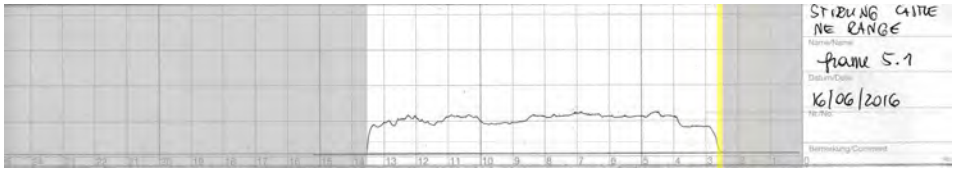
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐
Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%]: 15
Ultrasonic velocity [m/s]: 1989
Density loss based on ultrasonic test [%]: -25.5
Material Degradation based on Micro-drill [%]: 1.4
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

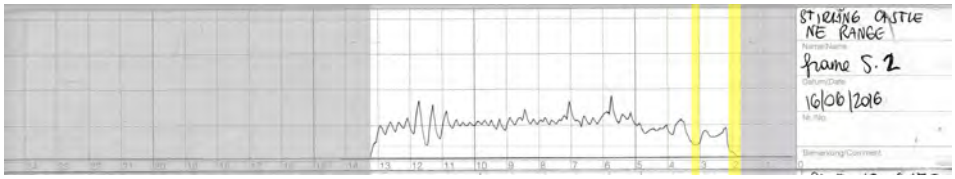


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 16.6
Ultrasonic velocity [m/s]: 2041
Density loss based on ultrasonic test [%]: -27.6
Material Degradation based on Micro-drill [%]: 4.4
Link to Micro-drill graph: I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 16.8
Ultrasonic velocity [m/s]: 1855
Density loss based on ultrasonic test [%]: -20.2
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name /\ See drawing SCP-NE-4

Missing elements: Elements with defects in critical area:
Joints with decayed peg: Insect attack: strut
Failed joints: Fungi attack:
Other:

Element name A strut

Dating: original construction Signs of reuse:

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.7x2.7 | min. size (hxb) [cm] 11.5x2.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack | I:\Arc

Material degradation

Insect attack ☑ | Type Anobium Punctatum | Status active | Way of identification Estimated

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: external decay up to 2cm | Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%] 18.1 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%] 18.3 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Frame/Truss name IIII | See drawing SCP-NE-2

Missing elements strut | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other

Frame/Truss name VI | See drawing SCP-NE-5

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack north rafter

Failed joints | Fungi attack

Other

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 17.1x10.2 | min. size (hxb) [cm]: 16.5x10 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



insect attack | I:\Arc

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: active

Way of identification: Estimated

Fungi attack ☐ | Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: max 1cm external decay

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

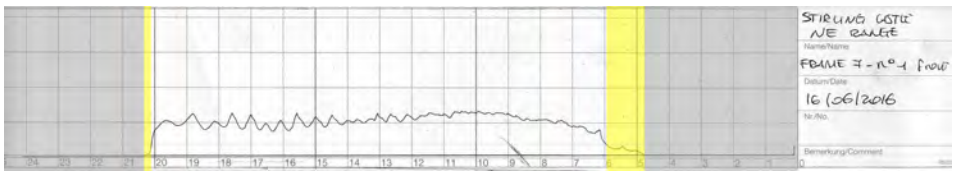
Moisture Content [%]: 15.5 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1542 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -7.8

Material Degradation based on Micro-drill [%]: 7.7

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

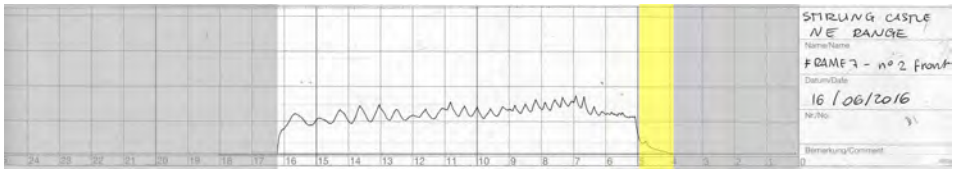
Moisture Content [%]: 16.5 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1958 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -24.3

Material Degradation based on Micro-drill [%]: 7.5

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%] 16.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1689 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -13.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 16.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1516 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -6.8

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name non visible 3 See drawing SCP-NE-5

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack north rafter

Failed joints | Fungi attack

Other

Element name A north rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 16.5x9.7 min. size (hxb) [cm] 16.1x9.3 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other



insect attack I:\Arc

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: maximum 1.5cm external decay

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

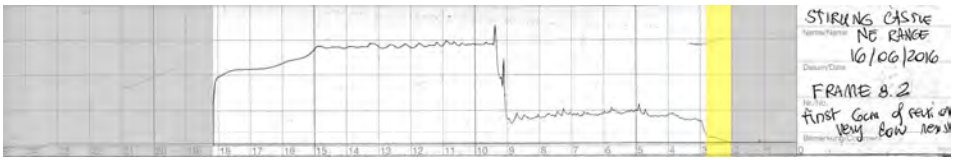
External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 16.9
Ultrasonic velocity [m/s] 1491
Density loss based on ultrasonic test [%] -5.8
Material Degradation based on Micro-drill [%] 4.8
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

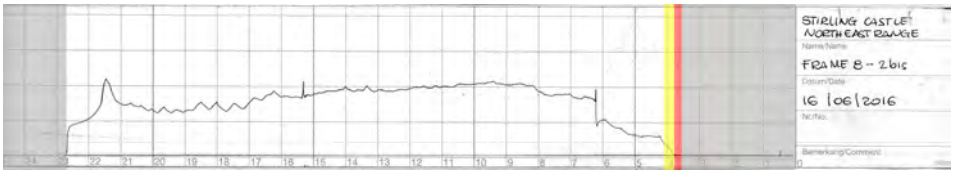


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point a'

Moisture Content [%]
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 2.6
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

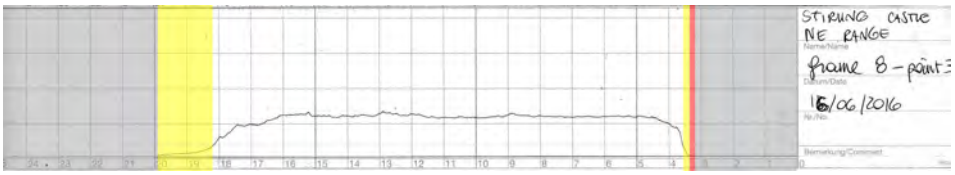


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 17.9
Ultrasonic velocity [m/s] 1548
Density loss based on ultrasonic test [%] -8
Material Degradation based on Micro-drill [%] 11.4
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

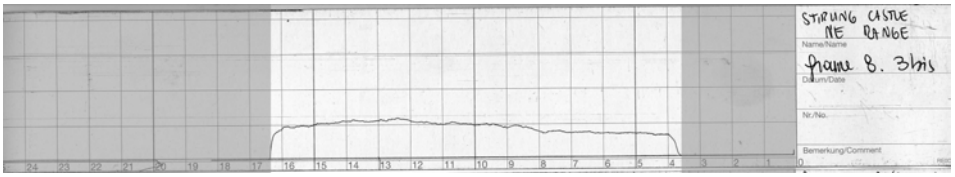


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b'

Moisture Content [%]
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 0
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

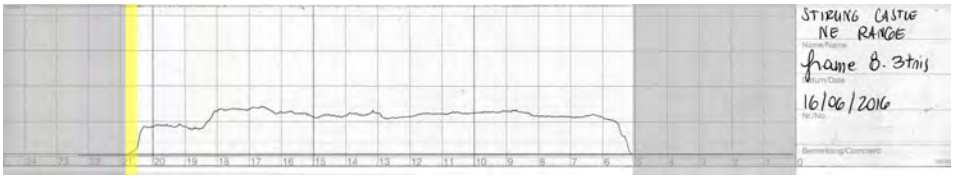


LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b''

Moisture Content [%]
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%] 2.4
Link to Micro-drill graph I:\Arc

Visible Material Degradation ☑ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]
Ultrasonic velocity [m/s]
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

Visible Material Degradation ☑ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1586 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -9.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name non visible 1 See drawing SCP-NE-5

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other next to wet gable

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.5x9.2 min. size (hxb) [cm] 17x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119



wet gable next to rafter I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other next to wet gable

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1889 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -21.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 16.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1506 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -6.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name non visible 10 See drawing SCP-NE-3

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack upper collar

Failed joints Fungi attack

Other

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17x10 min. size (hxb) [cm] 16x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 3/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]	15.8	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1652	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-12.2					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]	16.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1720	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-14.8					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]	15.8	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1632	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-11.4					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north rafter

Dating: original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 17.5x10 min. size (hxb) [cm]: 17x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 2 tangential
Knots [min d/section h]: 2/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects: shake near centre centre
Estimated Strength Class according to UNI 11119: III

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role



shake near centre I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]	17.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1509	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-6.5					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]	17	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1637	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-11.6					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]	16.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1417	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-2.9					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C upper collar

Dating: original construction
Signs of reuse
Timber treated ☐
Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm]: 16.5x7.5 min. size (hxb) [cm]: 16x7.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 2 tangential
Knots [min d/section h]: 3.5/7.5 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119: III

Material degradation

Insect attack ☑ Type: Anobium Punctatum Status: active
Way of identification: Estimated
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role



insect attack near centre I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: very limited external decay

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

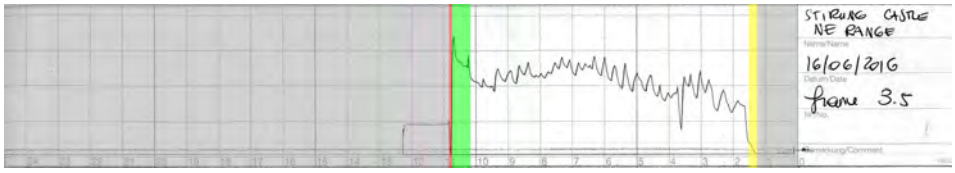
Measurement Point a

Moisture Content [%]	15.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	2326	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-38.9					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]	15.5	Visible Material Degradation ☑	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1760	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-16.4					
Material Degradation based on Micro-drill [%]	3.8					
Link to Micro-drill graph	I:\Arc					



LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]	15.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1687	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-13.6					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name D lower collar

Dating: original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues: only one face partly visible because wrapped in plastic sheet

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 10.8x9.8 min. size (hxb) [cm]: 10.5x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location
Slope of grain [%]
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 15.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 14.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 14.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name E strut

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 15x3.7 min. size (hxb) [cm] 15x3 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential
Knots [min d/section h] 3/15 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 17.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 21.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name XI See drawing SCP-NE-3

Missing elements Elements with defects in critical area upper collar, north rafter

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 18x9.8 min. size (hxb) [cm] 18x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]: 15
Ultrasonic velocity [m/s]: 1513
Density loss based on ultrasonic test [%]: -6.7
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 15.5
Ultrasonic velocity [m/s]: 1410
Density loss based on ultrasonic test [%]: -2.6
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%]: 14.7
Ultrasonic velocity [m/s]: 1431
Density loss based on ultrasonic test [%]: -3.4
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%]:
Ultrasonic velocity [m/s]:
Density loss based on ultrasonic test [%]:
Material Degradation based on Micro-drill [%]:
Link to Micro-drill graph:

Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑
Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north rafter

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues:

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm]: 17x9.8 | min. size (hxb) [cm]: 16x9.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 3 | tangential

Knots [min d/section h]: 3/9.5 | single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: II



knot near centre on tension side | I:\Arc

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: max 1.5cm external decay

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 17.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 2128 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -31

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

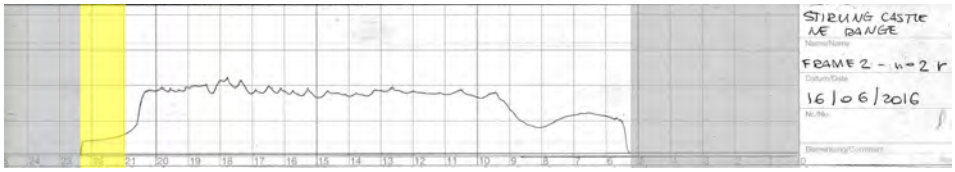
Moisture Content [%]: 18.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1884 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -21.3

Material Degradation based on Micro-drill [%]: 6

Link to Micro-drill graph: I:\Arc



LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%]: 16 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s]: 1775 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -17

Material Degradation based on Micro-drill [%]:

Link to Micro-drill graph:

LEGEND: Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point d

Moisture Content [%] | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☑ | ultrasonic ☑ | micro-drill ☑

Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name C upper collar

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 16x6.7 | min. size (hxb) [cm]: 16x6.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 16 | tangential

Knots [min d/section h]: 2.5/16.5 | single | Knotty element ☐ | Defects in critical area ☑ | Deep checks on both sides of element ☐

Other defects: shakes in central part

Estimated Strength Class according to UNI 11119: lower than III

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent: very limited external decay

Way of identification: NDT/SDT

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

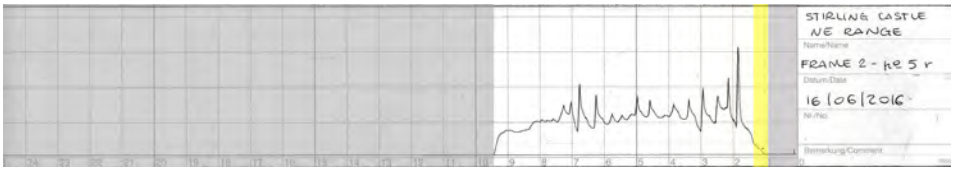
Moisture Content [%]: 17 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1334 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: 0.4

Material Degradation based on Micro-drill [%]: 4.6

Link to Micro-drill graph: I:\Arc



LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]: 14.3 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ | ultrasonic ☐ | micro-drill ☐

Ultrasonic velocity [m/s]: 1703 | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]: -14.2

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND | Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%] 16.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1580 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -9.3

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues only one face partly visible because wrapped in plastic sheet

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.1x9.6 min. size (hxb) [cm] 10x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location Slope of grain [%]

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 14.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 14.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 13.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 16.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name E strut

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 15x2.7 min. size (hxb) [cm] 15x2.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 9 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Measurement Point a

Moisture Content [%] 19.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 20.6 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Frame/Truss name II See drawing SCP-NE-3

Missing elements Elements with defects in critical area upper collar

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other cracks in upper collar and north rafter

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 17.5x9.8 min. size (hxb) [cm] 17x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: NDT/SDT

Measurement Point a

Moisture Content [%] 15.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1508 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -6.5

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 14.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1582 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -9.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 15.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1557 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -8.4

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 15.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1521 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -7

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 18x9.5 min. size (hxb) [cm] 18x9.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 5.5/9.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects shake close to top

Estimated Strength Class according to UNI 11119 lower than III



shakes and knot in upper part I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type		Status	Role
Deformation ☐			
Cracks ☑		unknown	unknown
Crushing ☐			
Other ☐			

Estimated level of damage initial Emergency interv. needed ☐

Mater.Degr. and Damage Extent No decay/damage

Way of identification NDT/SDT

Estimated causes of primary damage

Poor design ☐

Poor construct. ☑ poor material quality

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1663 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -12.6

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 15.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1539 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] -7.7

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑ ultrasonic ☑ micro-drill ☑

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

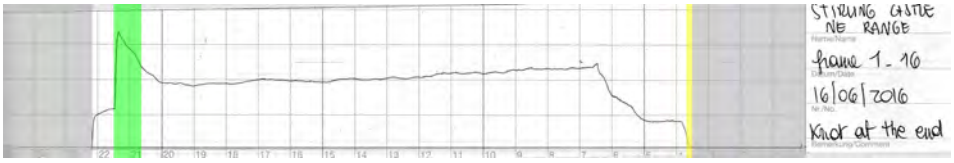
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] 1295 Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%] 1.9



Material Degradation based on Micro-drill [%] 1

Link to Micro-drill graph I:\Arc

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 18x7.5 min. size (hxb) [cm] 18x7.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 7 radial

Knots [min d/section h] 4/7.5 single Knotty element ☐ Defects in critical area ☑ Deep checks on both sides of element ☐

Other defects shakes near the centre

Estimated Strength Class according to UNI 11119 lower than III



Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

shakes near the centre I:\Arc

Deformation ☐
Cracks ☑ | unknown | unknown
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage
Way of identification: NDT/SDT

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%]	16.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1647	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-12					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point b

Moisture Content [%]	15.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1614	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-10.7					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Measurement Point c

Moisture Content [%]	14.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	ultrasonic ☐	micro-drill ☐	
Ultrasonic velocity [m/s]	1610	Higher voltage ☐	Higher gain ☐	Signal not stable enough to take ultrasonic measur. ☐		
Density loss based on ultrasonic test [%]	-10.5					
Material Degradation based on Micro-drill [%]						
Link to Micro-drill graph						

LEGEND Zero resistanc | Low resistance | High resistance (knot | Out of timber

Element name D lower collar

Dating: original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues: only one face partly visible because wrapped in plastic sheet

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 10.1x9.8 | min. size (hxb) [cm] 10x9.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location
Slope of grain [%]
Knots [min d/section h]
Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a

Moisture Content [%] 12.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%] 16.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point c

Moisture Content [%] 13.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point d

Moisture Content [%] 14 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐ ultrasonic ☑ micro-drill ☑
Ultrasonic velocity [m/s] | Higher voltage ☐ | Higher gain ☐ | Signal not stable enough to take ultrasonic measur. ☐
Density loss based on ultrasonic test [%]
Material Degradation based on Micro-drill [%]
Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Element name E strut

Dating original construction | Signs of reuse
Timber treated ☐ | Accessibilityissues
Past interventions
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 15x2.5 | min. size (hxb) [cm] 15x2.5 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%] 10 tangential
Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type		Status	Role
Deformation	☐		
Cracks	☐		
Crushing	☐		
Other	☐		

Estimated level of damage

Emergency interv. needed ☐

Mater.Degr. and Damage Extent: No decay/damage

Way of identification: visual inspection

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%]: 17.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

Link to Micro-drill graph

LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Measurement Point b

Moisture Content [%]: 17 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐ ultrasonic ☐ micro-drill ☐

Ultrasonic velocity [m/s] Higher voltage ☐ Higher gain ☐ Signal not stable enough to take ultrasonic measur. ☐

Density loss based on ultrasonic test [%]

Material Degradation based on Micro-drill [%]

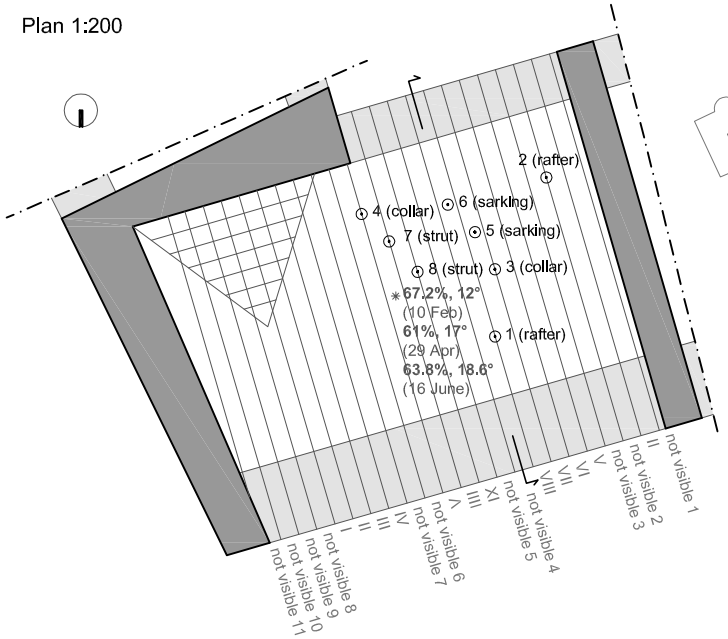
Link to Micro-drill graph

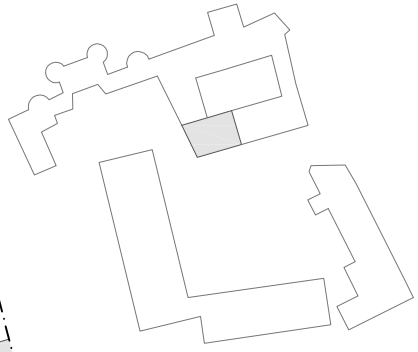
LEGEND Zero resistanc Low resistance High resistance (knot Out of timber

Building Name: Stirling Castle Palace | Roof Location: NE range | ANNA SERAFINI | Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou
Drawing SCP-NE-2 | PhD thesis | Architecture Department, University of Strathclyde

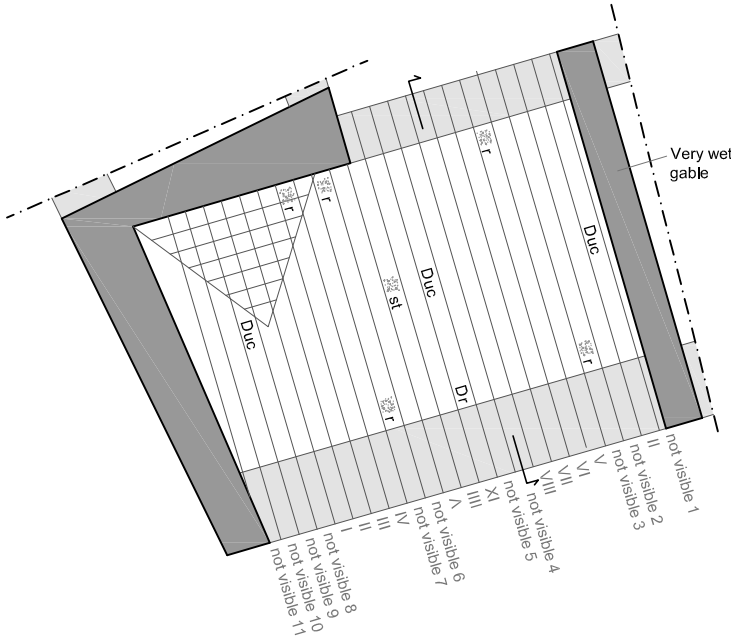
1030

Plan 1:200





* air humidity and temperature
⊙ timber samples for species identification



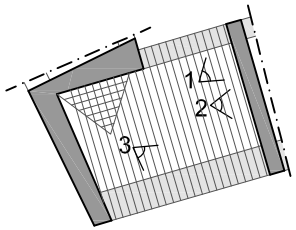
Visual Inspection:
r=rafter
uc=upper collar
st=strut

- wound (injury to living tree)
- D element with defects in critical area
- crack
- element rotation
- failed joint
- decayed peg in joint
- wet surface
- efflorescence
- insect attack
- fungi attack

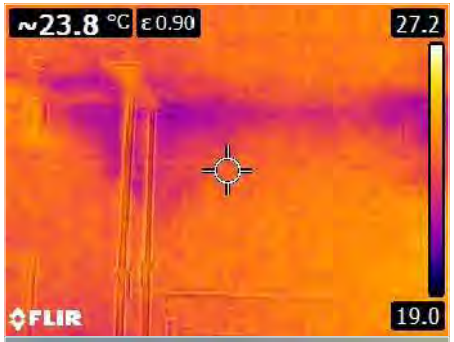
0 1 5

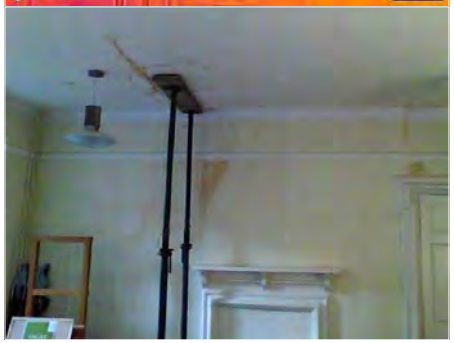
Themographic images

Plan 1:500

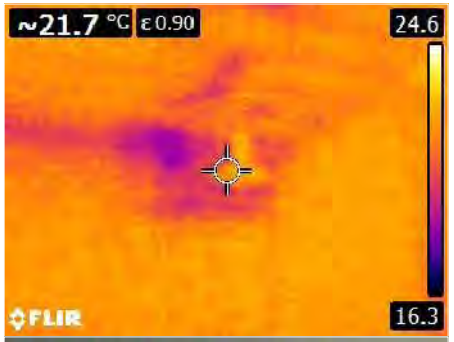


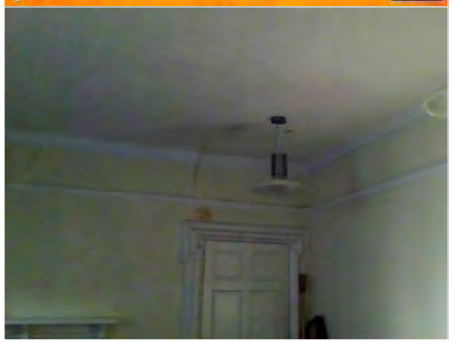
1: areas with lower temperature identify patches of humidity close to the West gable





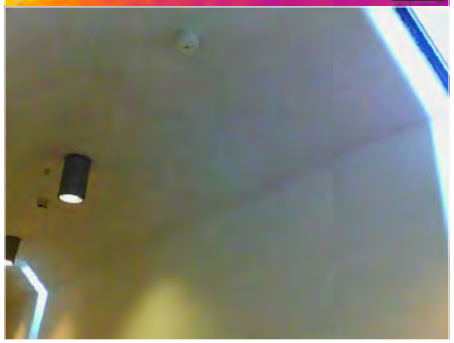
2: areas with lower temperature identify patches of humidity close to the West gable





3: areas with higher temperature show the position of the rafters behind the plaster in the attic spaces - the rafters are very well visible probably because insulation sheets are missing in between them





Sections 1:100 (looking West)

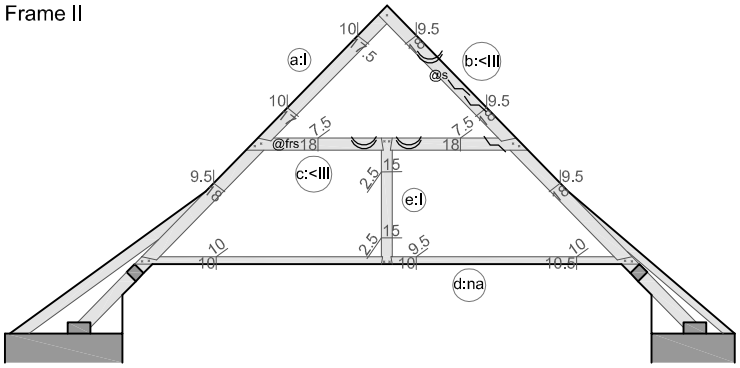
Visual inspection:
- higly inclined slope of grain
- @ big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

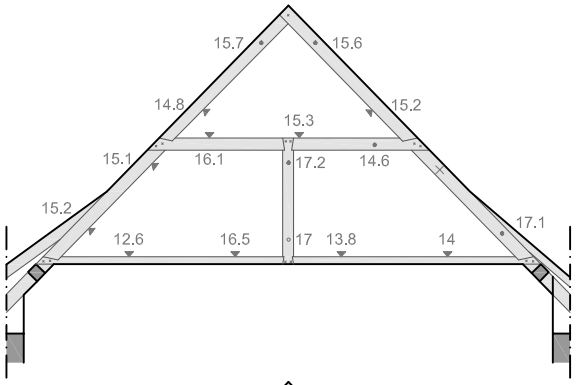
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible
- readings <18
- *readings >18*
- **readings >20**

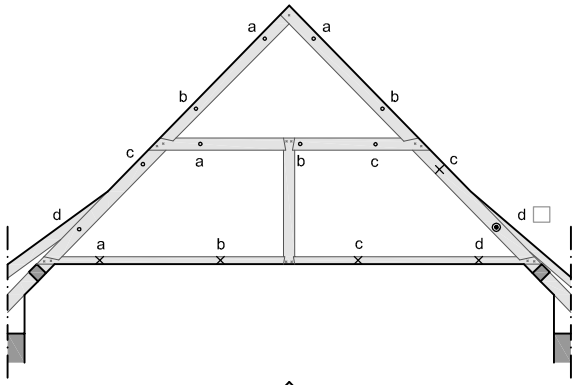
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- Internal decay
- ext. & int. decay
- extensive decay

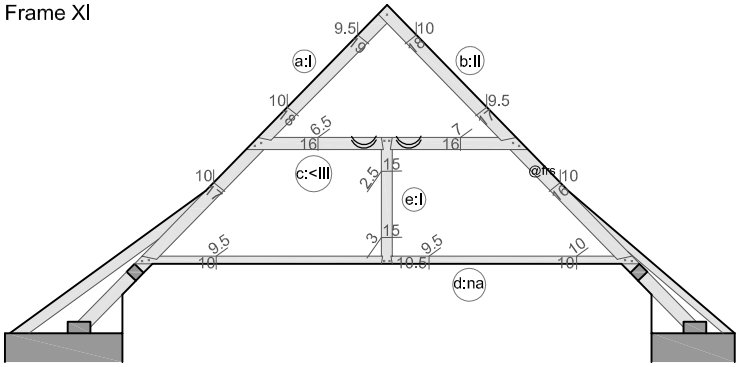
Frame II

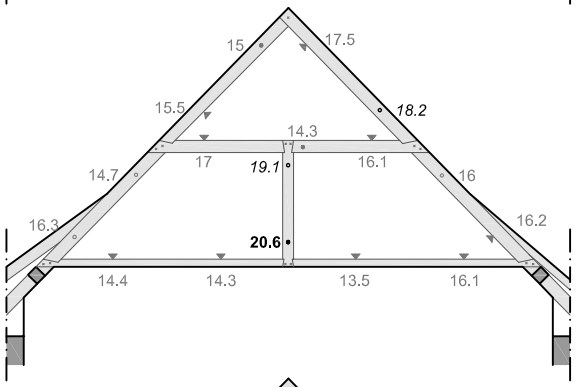


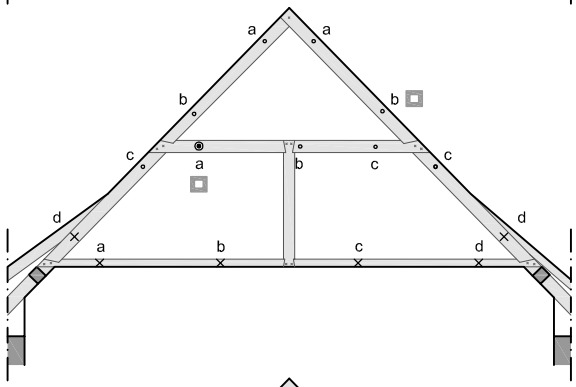




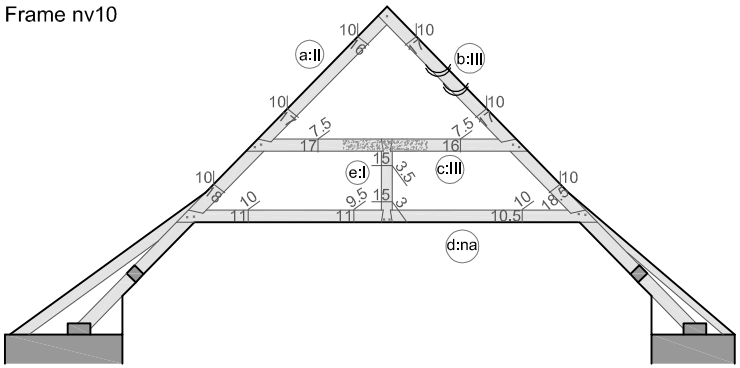
Frame XI

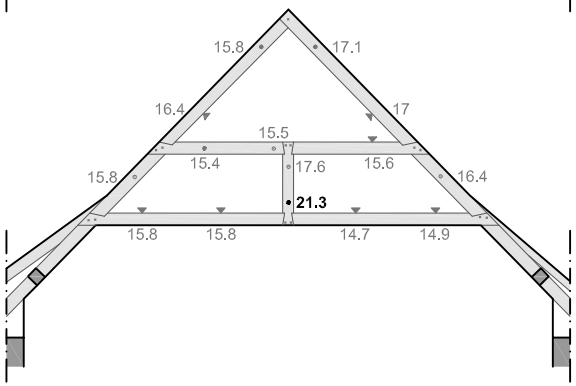


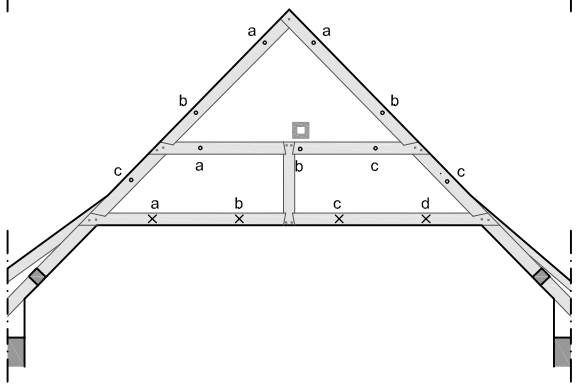




Frame nv10







Sections 1:100 (looking West)

Visual inspection:
- higly inclined slope of grain
- big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

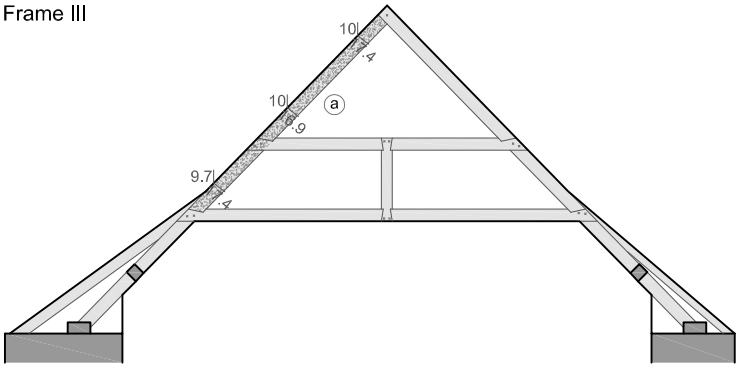
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

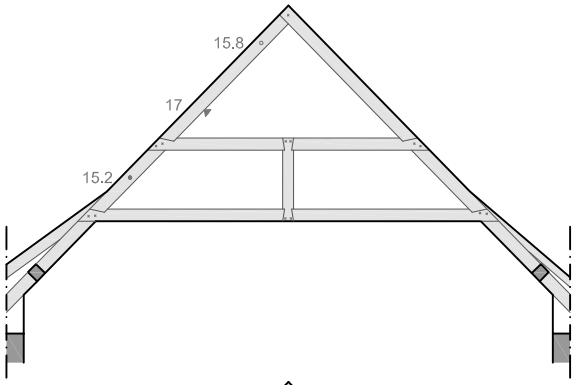
readings <18
readings >18
readings >20

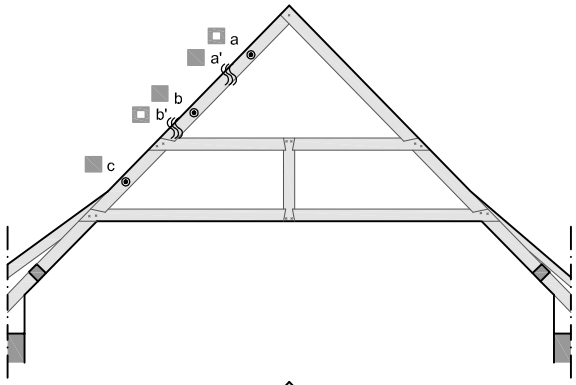
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- Internal decay
- ext. & int. decay
- extensive decay

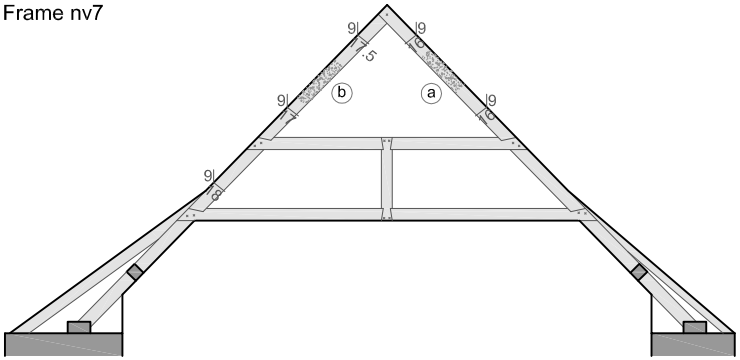
Frame III

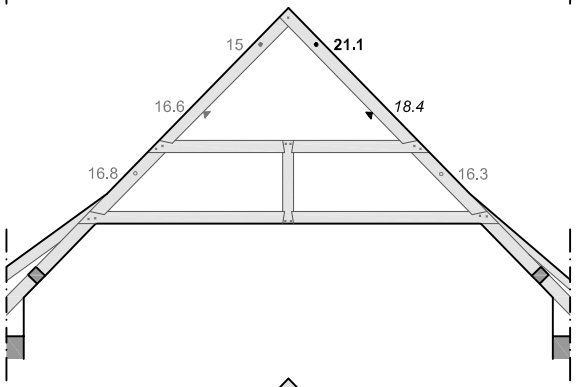


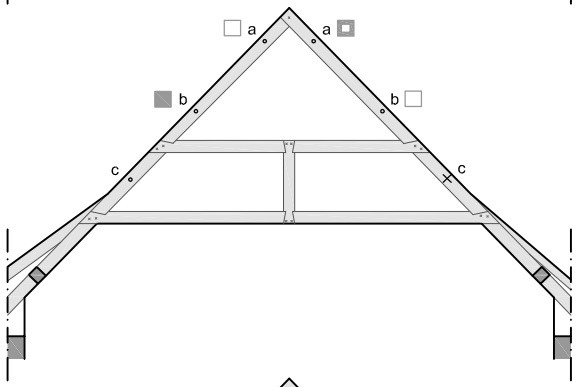




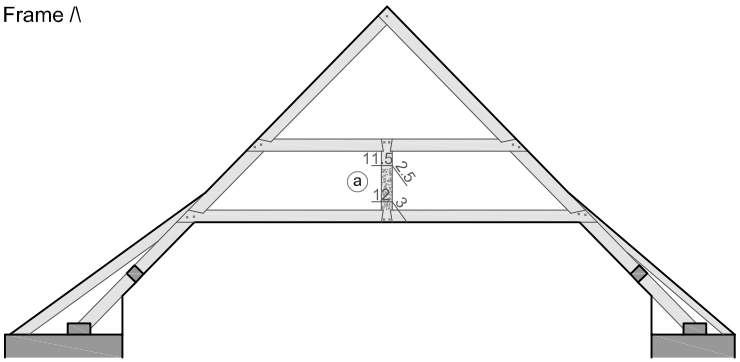
Frame nv7

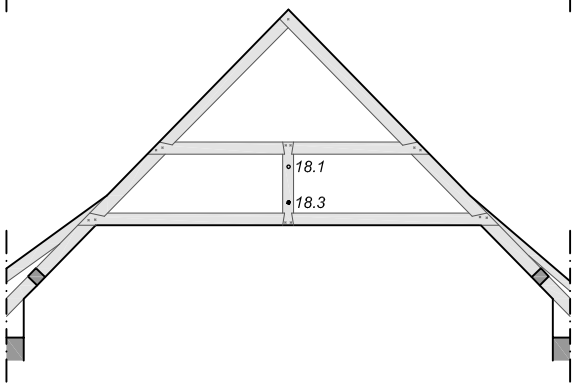


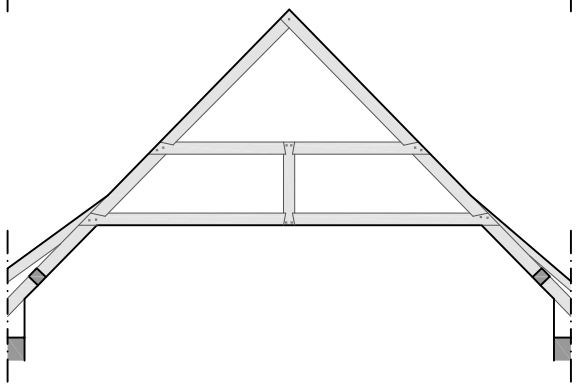




Frame /\







Building Name: Stirling Castle Palace | Roof Location: NE range | ANNA SERAFINI | Supervisors: Cristina Gonzalez Longo & Andrerw Agapiou
Drawing SCP-NE-5 | PhD thesis | Architecture Department, University of Strathclyde

1033

Sections 1:100 (looking West)

Visual inspection:
- higly inclined slope of grain
- big knots (f=front, r=rear, s=sides)
- checks on both sides
- shake
- wound (injury to living tree)
- crack
- element rotation
- open joint
- element name
- wet surface
- efflorescence
- decayed peg
- insect attack
- fungi attack

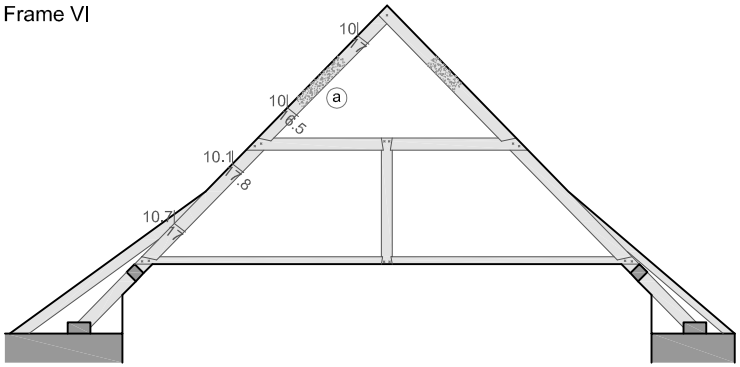
Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

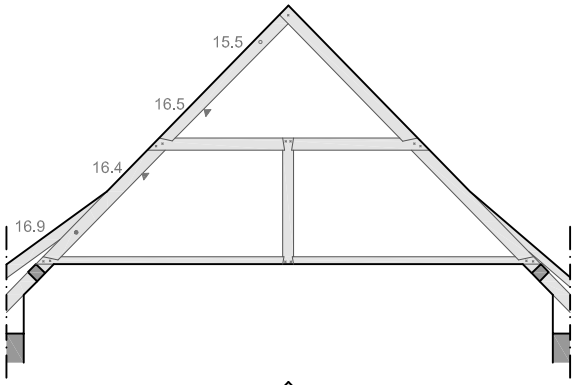
readings <18
readings >18
readings >20

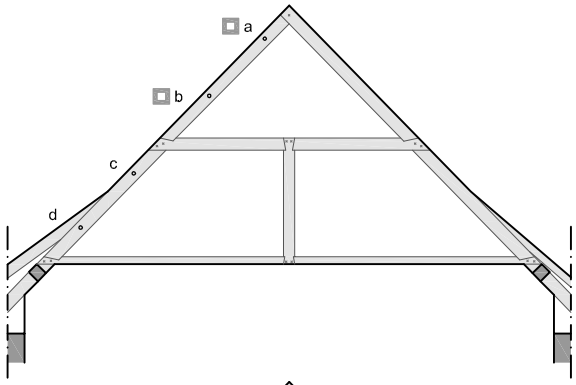
Ultrasound measurements:
- good velocity [+ higher voltage, ++higher voltage and gain]
- low velocity
- 2 faces not accessible
- signal not stable

Resistograph drills: where there is visible decay, high moisture content or low velocity/unstable signal in ultrasonic measurements
- good
- external decay
- Internal decay
- ext. & int. decay
- extensive decay

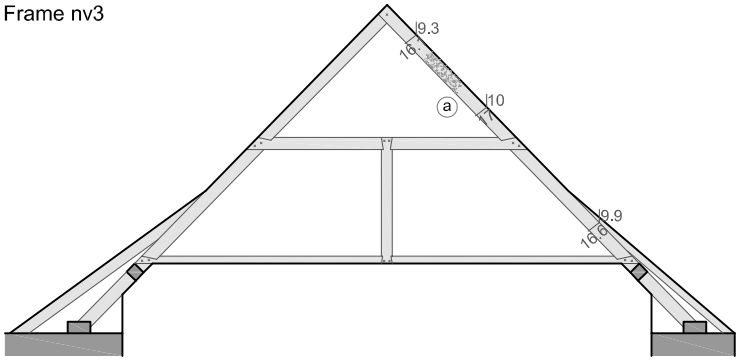
Frame VI

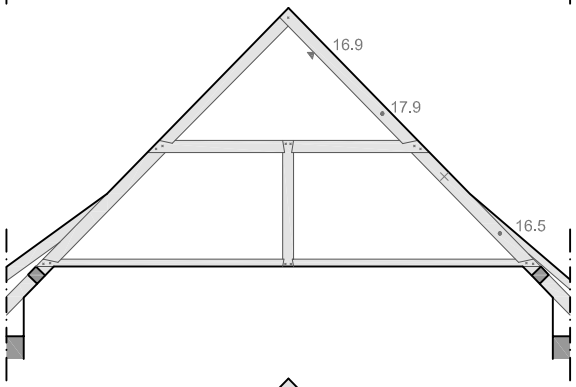


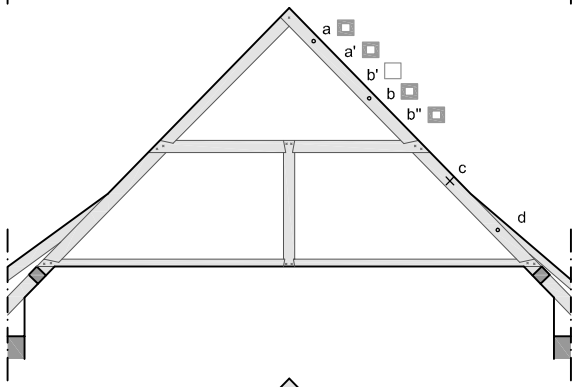




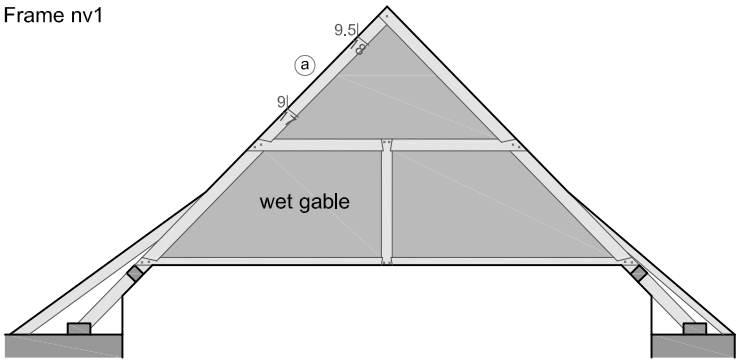
Frame nv3

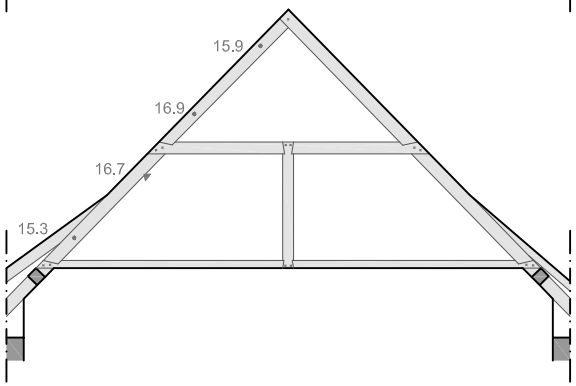


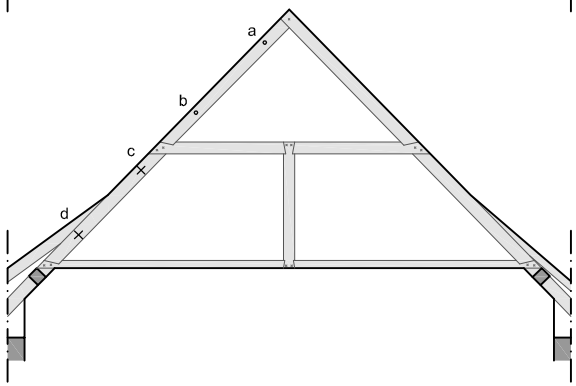


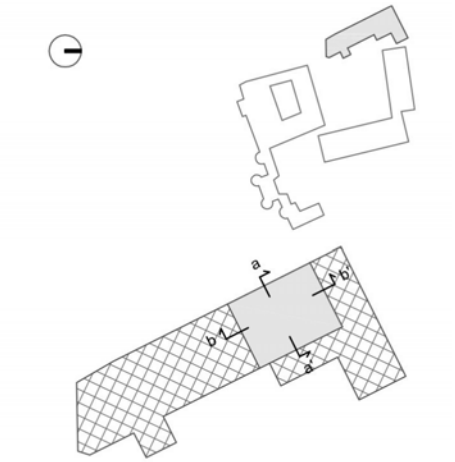


Frame nv1





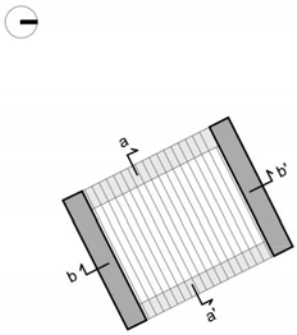




Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



Carpentry marks from south to north:

XX/I
XXXIIII
XXX/IIII
XXXII
XXIX
II
XXX
I/X
XXXI
X/II
X/IIII
XVII
XX
XXI
ΛIII
XXIII
not visible
not visible

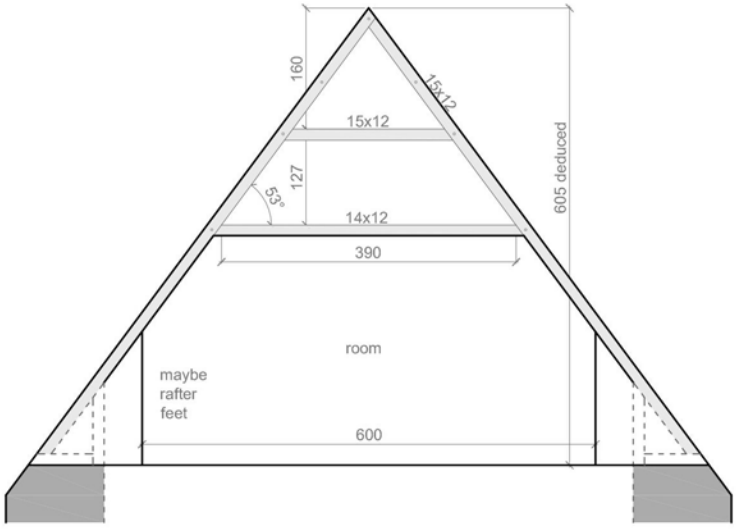
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

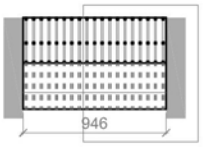
Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

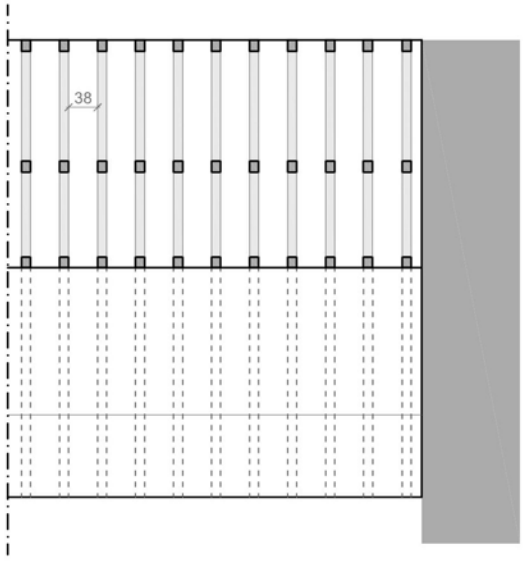
Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section aa'



Section bb'





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** STIRLING CASTLE_THE KING'S OLD BUILDINGS | **Roof location** N block next to NE wing

Survey date(s) 01/10/2014 | See drawing: SCKOB-N-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 7 | Roof Height [m]: 6.05

Roof Pitch/es [°]: 53 | Roof Length [m]: 9.46

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.4

Type of Secondary Structure: sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Unknown

Connection with gables:

Roof Construction Period: From 1557 To | Identified by: Estimated

Roof General Description: Gabled roof with 18 frames with 2 collars each. Connection with wall not visible. Rafters composed of 2 timbers with scarf joint.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 15 B: 12 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed) | Bark ☐

Joint Types: mortice and tenon, scarf

Fasteners Types: Metal nail, Timber peg not flush

Joints description: All mortice and tenon with timber pegs not flush. The rafters are made of 2 elements and have plain scarf joints with iron nails.

Wood Species: oak | Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals

Carpentry Marks Description: Not in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Joints: rafters | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☑ Insulation on ceiling ☑ Insulation on sarking ☑

Decorative features

Unfavourable conditions: presence of water tank

Accessibility limitations: Connection with wall not visible

Past interventions: Insulation and water tank added. Some rafters reinforced with timber.



Past interventions link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☐ Diffuse insect exit holes ☐

	Damage Type:	Damage Status:	Damage Role:	
Roof Damage				link
Unit Damage				
Element Damage				
Connection Damage				

Estimated cause(s) of the primary damage: link

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage link

Other Notes: Building presumably constructed in 1557. In 19C all roofs replaced after fire damage, besides this part that was surveyed. The roof typology, joints and numerals could point to the beginning of 17C, rather than mid 16C, but the scarf joints in the rafters are quite unique.

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs key bui link

DETAILED SURVEY **Building name** STIRLING CASTLE_THE KING'S OLD BUILDINGS **Roof location** N block next to NE win

Survey date(s) 10/02/2016 07/04/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings SCKOB-N-1, SCKOB-N-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
Rafters	750	square	bending, compression	quercus sp.	hand axed
Upper collars	200	square	bending, compression	quercus sp.	hand axed
Lower collars	390	square	bending, compression		hand axed
Sarking		sheet	bending, tension		

* estimated based on drawings because not fully accessible

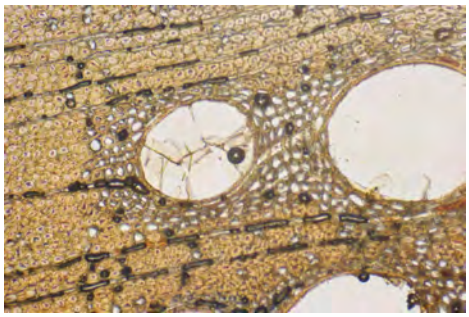
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings SCKOB-N-1, SCKOB-N-2

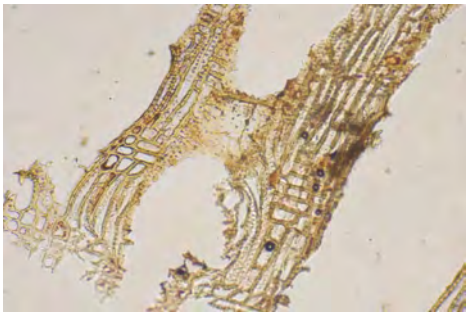
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter (same element)	Scarf halved	shear	nails	
rafter & rafter	Corner mortice & tenon	compression	wooden pegs	
rafter & collar	Encounter mortice & tenon	compression	wooden pegs	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

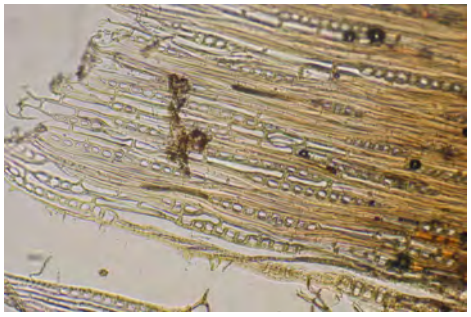
Microscopic identification of the timber species See drawing SCKOB-N-2



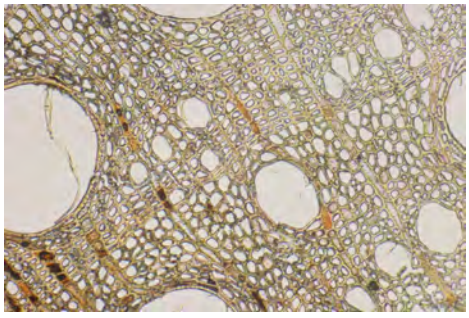
Rafter: transv. Section x100 I:\Arc



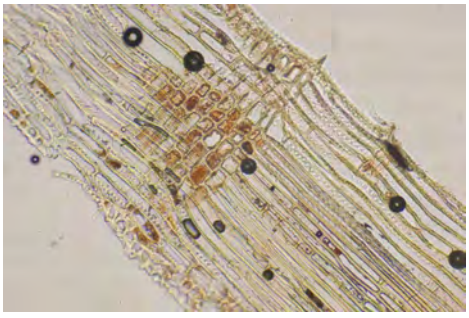
Rafter: radial section x100 I:\Arc



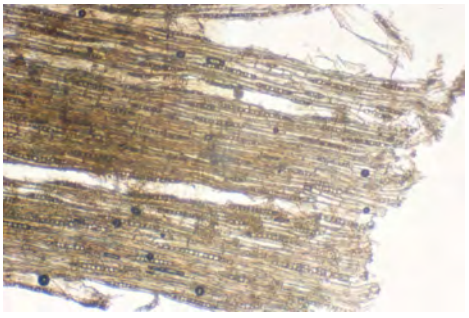
Rafter: trang. Section x100 I:\Arc



Upper collar: transv. Section x100 I:\Arc



Upper collar: radial section x100 I:\Arc

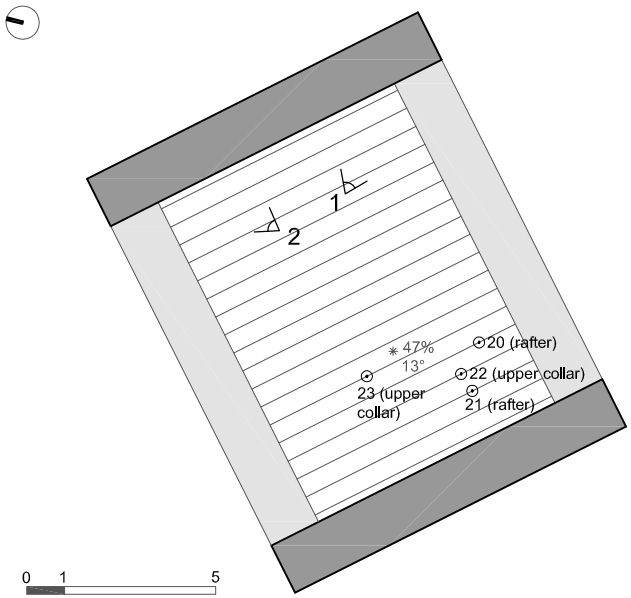


Upper collar: trang. Section x50 I:\Arc

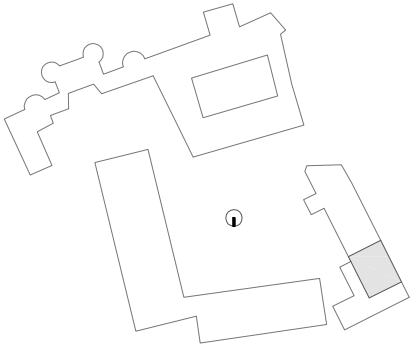
Air Temperature and Relative Humidity measurements See drawing SCKOB-N-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	N side	10/02/2016	12:45 am	16	47

Plan 1:200



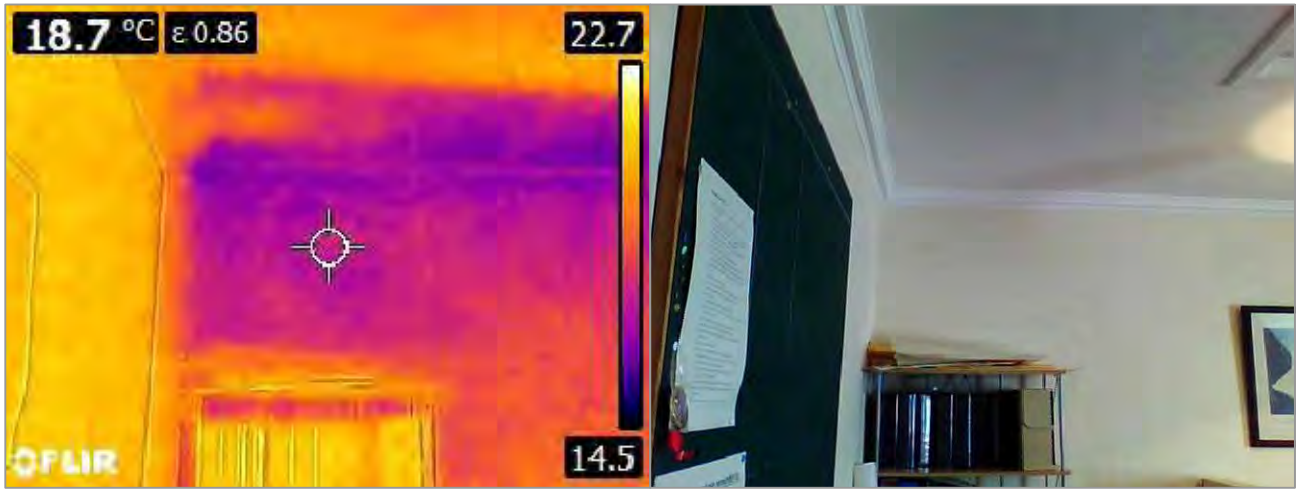
- air humidity and temperature
- timber samples for species identification
- thermographic images



1: areas with lower temperature on the left identify a patch of humidity close to the North-East gable



2: areas with lower temperature on the left identify a patch of humidity close to the North-East gable



TOUCH HOUSE

Location STIRLING | ST NINIANS

X coordinate 275328 Y coordinate 692755

Geogr. Referencing System BRITISH NATIONAL GRID





Property status PRIVATE

Rcahms ID 46238

HS Listing A

Original Use Residential

Current Use Residential

Freestanding ☑ N. of floors above ground level 3 Location link I:\Arch\AD Building picture link I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1500	1599	Z PLAN TOWER HOUSE - TODAY ONLY SE TOWER AND LOWER PORTION OF NW TOWER REMAIN	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1600	1699	NW TOWER REBUILT AND EXTENDED EAST (TODAY NORTH RANGE)	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1757	1762	MAIN BLOCK OF THE ORIGINAL BUILDING REPLACED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☑
STEINSON	JAMES	ARCHITECT	☑
GRAY	GIDEON	CONTRACTOR, MASON	☐
CLAYTON	THOMAS	PLASTERER	☐
PATERSON	GEORGE	WRIGHT	☐
GIBSON	HENRY	WRIGHT	☐
SETON	HUGH (SMITH)	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1800	1899	RANGE OF OFFICES AT THE NE ANGLE	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1810		ELLIPTICAL STAIRS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
GILLESPIE GRAHAM	JAMES	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1927	1930	RENOVATION OF INTERIORS, STRENGTHENING OF MAIN BLOCK ROOF AND REPLACEMENT OF NORTHEAST ROOF OF NORTH RANGE - POSSIBLY REPAIRS IN NORTHWEST ROOF OF NORTH RANGE AS WELL	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
LORIMER	SIR ROBERT	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR, DAMAGE	1968		CUPOLA FELL OFF DURING STORM - IT WAS REPLACED AND ROOF STRENGTHENED	OWNER

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2013		FOUND DRY ROT IN A CORNER OF THE ROOF - IT WAS REPAIRED WITH TIMBER AND STEEL	OWNER

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	405
GIFFORD J.	2002	☐	THE BUILDINGS OF SCOTLAND COLLECTION: STIRLING AND CENTRAL	

ARCHIVAL REFERENCES

Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	Account of materials				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	Letter from timber merchant to Mr Seton				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	transcription of account of timber				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	account of timber				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	Account for haulage from Stirling dock to Touch by James Danskin				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	account				
Archive	RCAHMS	Doc.Num.	LOR/T/1/5	Folios	
Title	Plans, sections and elevations of verandah, repairs to North wing roof and coal cellar. Plans and sections of new drive and forecourt				

Suggestions for further research

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: Account of materials | Date: from | to

Contents:
[…]
13 roods of scleatting @ 4£ 10sh per rood £58 – 10 – 0
468 yards of roofing and sarking @ 5sh a yard £117 – 0 – 0
592 feet of sheet lead for flanks & etc @ 18d £44 – 8 – 0
[…]

Summary and comments: Not dated but according to A. Mackechnie it could be late 17C. Not sure what 'roofing' implies, but this is not enough to be the construction of the roof on the old range. It's probably repairs and resarking only.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: Letter from timber merchant to Mr Seton | Date: from 1751 | to

Contents:
Dundee 27 September 1751
Mr. Setton,
Sir
I send you inclosed an Account of Wood bought from me by Mr. Geo. Paterson, Wright in Edinburgh, for your use and to your account which receive from the Bearer. I delivered the Wood here to Henry Gibson, one of Mr. Geo. Patersons foreman who ordered the logs to be cut out for your use as ordered by the by said Mr. Geo. Paterson his Master.
Please write me on Receipt of this, if it be convenient to pay the within account in Edinburgh, and where I shall call for it, or if it be more convenient for you, to pay the same at Alloa to James Kirk, Merchant thee, whose Receipt for the same shall be sufficiently good as my own, either of which is agreeable to,
Sir,
Your most obedient servant,
Ja. Key
[…]

Summary and comments: Letter from timber merchant to Mr Seton with account of timber bought by George Paterson, who must be the wright in charge of the timber works, and maybe more. The logs are brought on the construction site and cut there.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: account | Date: from 1757 | to

Contents:
Mr Robert Leckie for Hugh Seaton of Touch Esqr. To William Brown
1757
[…]
October 3 To livering 4 hundred 10 single sardish? Deals 110 ballons? and 30 sawn logs 3sh
To shoardues? As for 6 hundred deals @ 10p hund. 5sh
To waiting on timber altnight? one man 6d
[…]
To freight and port charges of timber ??? 2£ 11sh 4d
To man for waiting on timber all night 8d

Summary and comments:

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: account of timber | Date: from 1757 | to

Contents:
Hugh Seton Esqr. Of Touch
Bo't of Haig Deas & Co.
1757
Nov. 9 2 Copenhagen Logs measr. 59 ½ foot [18.7m] *@ 14d 3 – 9 – 5*
Cutting 6 Draught @ 8d 4
1758
April 4 26 Copenhagen Logs measr. 700 foot [219.8m] *@ 14d 40 – 16 – 8*
3 clean d.o for plank measr. 87 foot [27.3m] *@ d.o 5 – 1 – 6*
Cutting 96 draught @ 4 d 1 – 12 – 0
One barrel Stockholm Tar 1 – 5 – 0
April 18 11 Copenhagen Logs measr. 72 foot [22.6m] *@ 14 4 – 4 – 0*
Cutting 20 draught @ 4d 6 – 8
June 16 11 Copenhagen Logs measr. 362 ?? foot [113.6m] *@ 14 21 – 3 – 1*
One plank 3 inch thick [7.8cm] *12 foot* [3.8m] *long 2 – 6*

Cutting 24 Draught about 20 foot [6.28m] *long each @ 5d* *10 – 0*
Cutting 30 d.o @ 4d *10 – 0*
August 5 18 Riga Logs measr. 492 ?? foot [154.5m] *@ 14* *28 – 14 – 4*
August 19 Cutting 24 Draught each 23 foot [7.2m] *long @ 6d* *12 – 0*
Sept. 2 36 Riga Logs measured 1036 foot [325.3m] *@ 11* *60 – 8 – 8*
10 Norway 10&12 foot [3.2/3.8m] *Deals @ 11d and one hundred double flooring nails @ 12d for making affloat* *10 – 2*

£ 169 – 10 – 0
August 8 By your Draught on Charles Smith Esqr. *100 – 0 – 0*
Balance *69 – 10 – 0*

Alloa 21st November 1758 Received by the hands of Mr. Robert Leckie Payment of the above sum of Sixty nine Pounds Ten Shillings Sterling which is in full of all accounts. Haig Deas & Co.

Summary and comments: Account of wood bought for Mr Seton: Copenhagen (Norway) logs, Riga (Russia) logs, Norway deals and other small cuts. The Riga logs, being of higher quality, have probably been used for the purlins, whilst the Copenhagen logs have probably been used for the common rafters.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: transcription of account of timber | Date: from 1757 to

Contents:
Mr Setton of Touch by Mr Geo. Paterson
Bought off Jas Key, Dundee
1757
September 10th
To 30 Redwood scots pine Logs 9,209 Solid feet @ 9d. *10 – 2 - 4*
To 410 Best Superfine picked Gotenburg 1 ¼ Inch Deals @ 8£ p *32 – 13 – 4*
To Carriage paid to the Ship *5 – 0*
To Cash paid to Customhouse for a permit *2 – 0*
---
48 – 12 – 8

Summary and comments: Account of wood bought by George Paterson for Mr Seton: 30 scots pine logs and 410 high quality deals from Gotenburg (Sweden). This timber is probably for the roofs of the new house - the deals are sufficient to make the sarking of the central block, the logs could be for the common rafters.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: Account for haulage from Stirling dock to Touch by James Danskin | Date: from 1758 to

Contents:
James Danskin, Account for Haulage from Stirling dock to Touch
An account of money paid for Livering free Stones and Wood and Lead and Sclates for the use of Mr Seaton of Touch at the Shor of Stirling
1758
[…]
August 23 For taking out the float of wood paid 6sh
[…]
For taking care of wood lying at the Shor 2sh
[…]

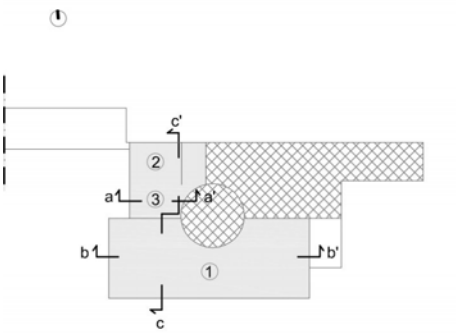
Summary and comments: Account of transport of materials to the house. No details on materials carried.

Archive: RCAHMS | Doc. Num.: LOR/T/1/5 | Folios:

Title: Plans, sections and elevations of verandah, repairs to North wing roof and coal cellar. Plans and sections of new drive and forecourt | Date: from 1928 to

Contents:

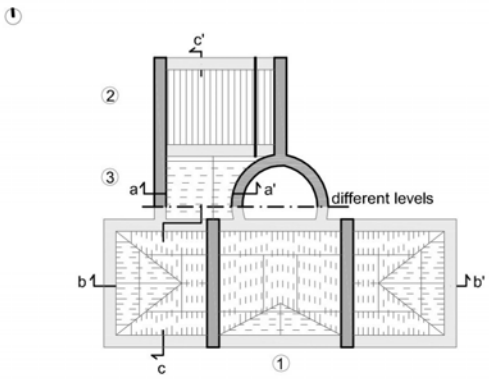
Summary and comments: Drawing by Lorimer showing replacement of the NorthEast roof of the North range in 1928



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

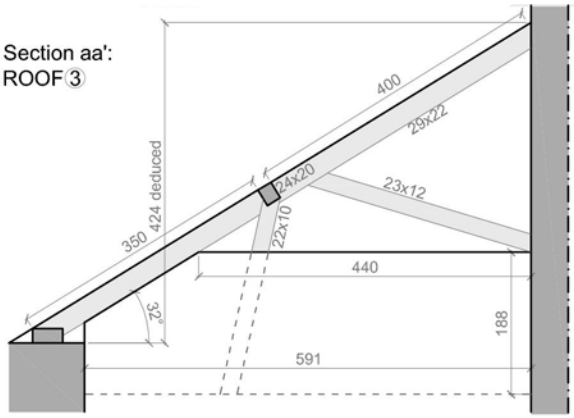
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



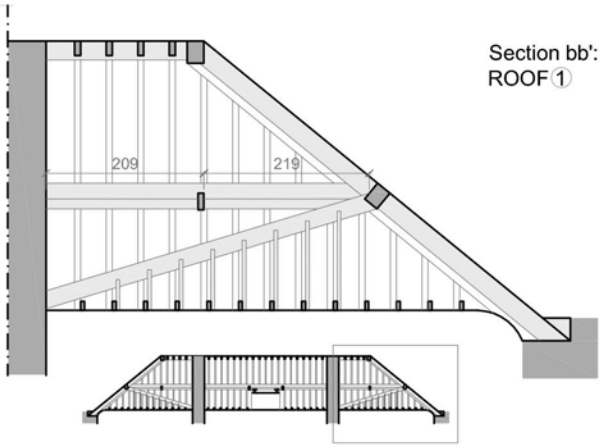
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa':
ROOF 3



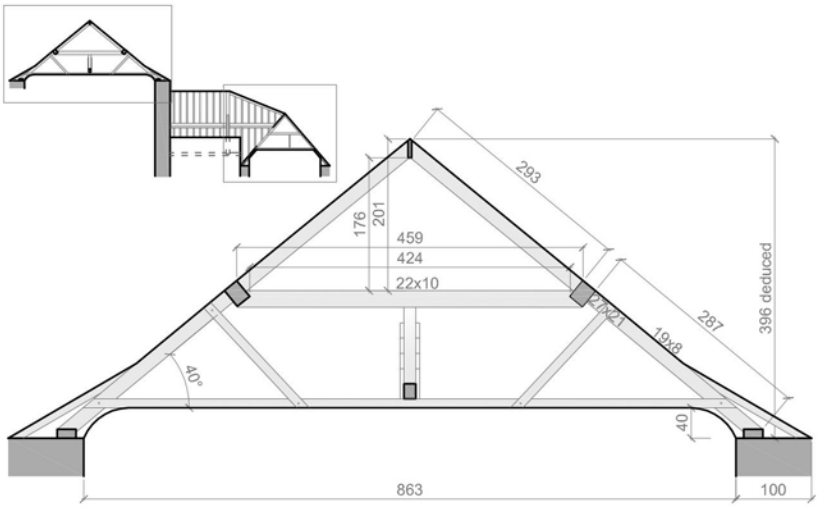
Section bb':
ROOF 1

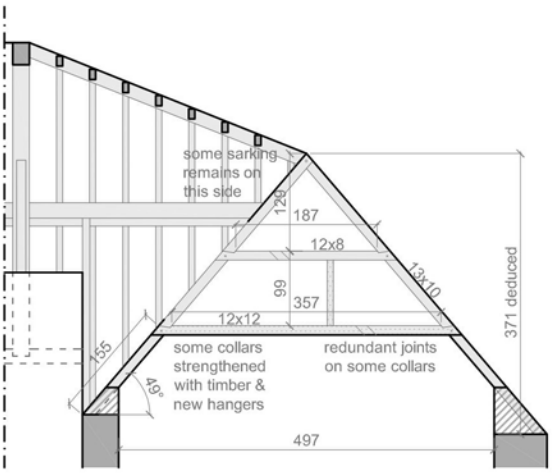


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section cc': ROOF 1-3-2





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** TOUCH HOUSE | **Roof location** 1: 18C block

Survey date(s) 12/08/2015 | See drawing: THH-MB-1

Roof Geometry: Hipped

Roof Max Span [m]: 8.6 | Roof Height [m]: 4

Roof Pitch/es [°]: 40 | Roof Length [m]: 23.4

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, sarking

Sarking boards: width [cm]: | thickness [cm]: 3

Connection with lateral walls: Wall-plate

Connection with gables: purlins

Roof Construction Period: From 1745 To 1755 | Identified by: Estimated

Roof General Description:

Hipped roof supported by two transversal walls and two longitudinal purlins, one on each side, and a slender ridge purlin. Horizontal struts, one on the sides and two at the centre, keep the purlins apart. The purlins support common rafters which in turn support the sarking. The ceiling is supported by collars that connect the common rafters. The pediment might be of later date, because there is sarking inside and the purlins have metal nails rather than timber pegs like the others.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: 27 | B 21

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description:

Between purlins and common rafters: double mortice and tenon with timber pegs not flush

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: strange marks (from scandinavia?)

Carpentry Marks Description:

only a few visible strange marks, not in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: purlin and common rafter | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

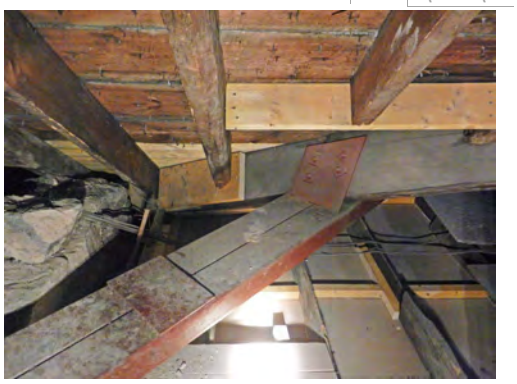
Unfavourable conditions: presence of pigeons/wasps/bats

Accessibility limitations: The west side of the roof is not accessible. There are bats everywhere.

Past interventions: The roof was strengthened in 1930s by Lorimer: he added two steel beams supporting the purlins in their central section. The steel beams sit on the external pediment and a wall extending from the rear wall. Dry rot was found in 2003 in the South East corner of the central part of the roof: a steel beam and new timber were added here to replace the rafter end.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains on purlins, sarking and common rafters. Possible fungi attack on South purlins near the gables.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks	Active	Primary
Connection Damage			



Humidity stains on purlin | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Possible fungi attack on purlin | link | I:\Arch\A

Description of visible damage: Cracks in horizontal struts due to purlins' deflection.

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** TOUCH HOUSE | **Roof location** 2: 17C block

Survey date(s) 12/08/2015 | See drawing: THH-MB-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 4.7 | Roof Height [m]: 3.46

Roof Pitch/es [°]: 49 | Roof Length [m]: 8.96

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: purlins, sarking

Sarking boards: width [cm] | thickness [cm]: 3

Connection with lateral walls: Unknown

Connection with gables: unknown

Roof Construction Period: From 1670 To 1700 | Identified by: Estimated

Roof General Description: Gabled roof composed of 15 frames with two collars each. Ceiling is supported by lower collar. Connection with lateral walls not visible. Still reatains some of the original sarking inside, on the South side. Some timbers have redundant lap joints, they might have been reused. Others are not full logs but half logs, sawn in two. These are probably replacements of the 18th century.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 13 | B: 10 | Or Purlin - H: | B

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: cleat, dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description: Rafters' apex: mortice and tenon with timber pegs not flush. Between rafters and collars: dovetail lapped with metal nails. Ther is a short purlin wityh cleats connecting some rafters on the north side.

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals, strange marks (from scandinavia?)

Carpentry Marks Description: Roman numerals not in sequence. Some strange marks.

Signs of reused timbers: Redundant lap joints on some collars

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Redundant joints in collar | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance, poor ventilation

Accessibility limitations: Connection with lateral walls not visible

Past interventions: Some lower collars reinforced in timber and hangers hadded, probably during repair works in 1930s. Sarking replaced on North side.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

East gable is visibly wet and the masonry is disintegrating to dust and falling on the timbers and ceiling underneath. There is probably a problem of water ingress. The sarking is broken in some areas. A few areas might be affected by biotic attack.



East gable wet and disintegrating | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage	Splitting	Unknown	Collateral



Sarking broken and biotic attack | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: splitting of connection | link | I:\Arch\A

Description of visible damage: Some collars seem to be splitting at the joint with the rafters. This doesn't seem to be affecting the overall performance of the roof.

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** TOUCH HOUSE | **Roof location** 3: between 17C & 18C blocks

Survey date(s) 12/08/2015 | See drawing: THH-MB-1

Roof Geometry: Mono-pitch

Roof Max Span [m]: 3.7 | Roof Height [m]: 4.24

Roof Pitch/es [°]: 32 | Roof Length [m]: 5.5

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: purlins

Roof Construction Period: From 1745 To 1755 | Identified by: Estimated

Roof General Description:

A mono-pitch roof linking the 17C roof with the 18C one. Composed of one purlin running between the wall which separates the main block and the North range and a hip rafter ending on the cupola wall. The purlin supports a principal rafter in the centre of its length and common rafters all along. One strut goes from the wall to the principal rafter to hang the ceiling underneath. Another strut, almost vertical, supports the purlin and sits on a wall running East-West on which the 17th roof sits as well.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: 24 | B 20

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: Between purlisn and common rafters: double mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: strange marks (from scandinavia?)

Carpentry Marks Description:

Signs of reused timbers: Redundant joints in purlin: probably a principal rafter was removed?

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Redundant joints in purlin | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall only partly visible

Past interventions



Humidity stains | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains in sarking and common rafters



Damage: purlin deflection | link I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks, Permanent Deformation	Active	Primary
Connection Damage			



Damage: strut cracking | link I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient overall arrangement, insufficient dimensions
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: Purlin is deflected and strut that supports it is cracked. Intervention needed urgently.

link I:\Arch\A

Other Notes: Owner very helpful and eager to look into the building's history and problems

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link I:\Arch\A

DETAILED SURVEY **Building name** TOUCH HOUSE **Roof location** 1: 18C block

Survey date(s) 17/02/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings THH-118C-1, THH-118C-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
hip rafter	685	rectangular	bending, compression		hand axed and hand sawn
principal rafter	625	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
upper collar	460	rectangular with wanes	bending, compression		hand axed and hand sawn
side purlin	405	rectangular	bending, compression		hand axed and hand sawn
end purlin	225	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
central purlin	810	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
common rafter	600	rectangular with wanes	bending, compression	pinus sylvestris	hand axed and hand sawn
sarking		sheet	bending, tension	pinus sylvestris	hand sawn
strut	460	rectangular	bending, compression		hand axed and hand sawn
lower collar	865		bending, tension		not visible
small strut	190	rectangular	tension		hand sawn

* estimated based on drawings because not fully accessible

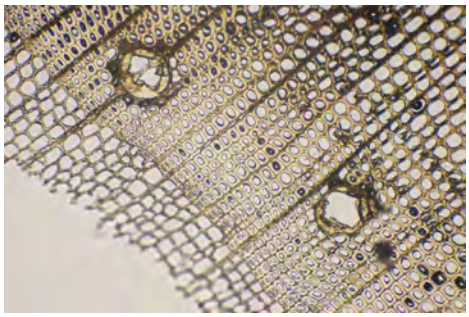
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings THH-118C-1, THH-118C-2

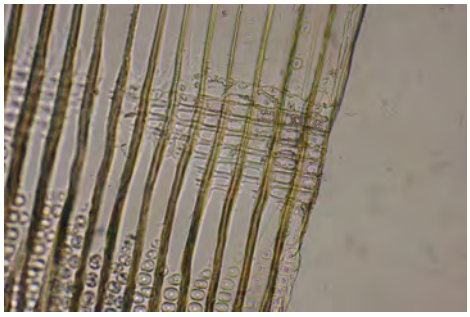
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
purlin & principal/hip rafter	Encounter mortice & tenon	compression	none	
common rafter & purlin	Encounter mortice & tenon	compression	wooden pegs	
rafter & lower collar	Encounter halved	tension	nails	
strut & rafter/collar	Encounter halved	tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

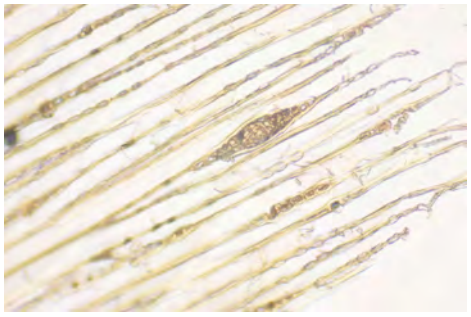
Microscopic identification of the timber species See drawing THH-118C-2



Principal rafter: transv. section x100 I:\Arc



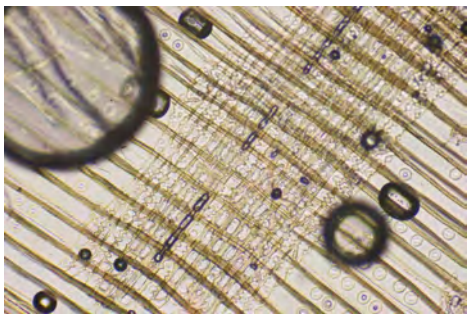
Principal rafter: radial section x100 I:\Arc



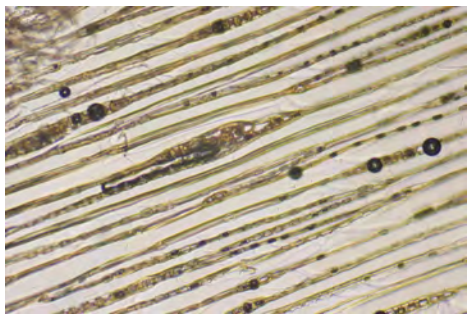
Principal rafter: tang. section x100 I:\Arc



Purlin: transv. section x100 I:\Arc



Purlin: radial section x100 I:\Arc



Purlin: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing THH-118C-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
attic space	centre	17/02/2016	10:20 am	13.6	55.8
attic space	E side	17/02/2016	10 am	14	54.7

roof space	centre	17/02/2016	11 am	10.1	72
roof space	E side	17/02/2016	10:40 am	10.8	66.1

Frame/Truss name all roof — See drawings THH-118C-2, THH-118C-

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack: E collar

Failed joints | Fungi attack: centre S purlin

Other: some wet areas in N purlins and side S purlin, shakes all along SE purlin, crack in E collar

Element name A east collar

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 22.5x9.2 | min. size (hxb) [cm]: 21x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 17 | tangential

Knots [min d/section h]: 4/21 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II



insect attack | I:\Arc

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: active

Way of identification: Estimated

Fungi attack ☐ | Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑ compression	unknown	
Crushing ☐		
Other ☐		

Estimated level of damage: medium | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☑ insufficient dimensions

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%]: 16.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 16.4 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%]: 17.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%]: 16.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name B north east purlin

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 21x27.5 | min. size (hxb) [cm]: 21x27 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 2 | tangential

Knots [min d/section h] 3/28 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☑ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a			
Moisture Content [%] 15.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	
Measurement Point b			
Moisture Content [%] 17.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	
Measurement Point c			
Moisture Content [%] 18.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	
Measurement Point d			
Moisture Content [%] 14.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	

Element name C south east purlin

Dating original construction | Signs of reuse

Timber treated ☐

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 21.7x28 | min. size (hxb) [cm] 21.5x28 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 1 | tangential

Knots [min d/section h] 1/27.5 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☑ | Other

Mechanical Damage

Type | Status | Role



wet close to wall & fungi on rafter | I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 16 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 15.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d
Moisture Content [%] 16.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D big east strut

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 23.2x8.7 min. size (hxb) [cm] 22x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential
Knots [min d/section h] 5.5/22 group Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 21.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 20.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 22 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name E north east hip rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 26x12.7 min. size (hxb) [cm] 26x12.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 1 tangential

Knots [min d/section h] 6/26 group Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Measurement Point a

Moisture Content [%] 14.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 15.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name F east principal rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 25.7x21.7 min. size (hxb) [cm] 25x21.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 2/22 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 18.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 15	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 15.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name G south east hip rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 27.5x14 min. size (hxb) [cm] 27.5x14 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Element name H east purlin

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19x23.7 min. size (hxb) [cm] 19x23 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 4/19 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects shakes all along south section

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 16.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name H' east purlin

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19.2x23 min. size (hxb) [cm] 19x23 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 5/19 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	25.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	14.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	16.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name I centre north purlin

Dating original construction Signs of reuse

Timber treated ☐

Past interventions 2 steel beams supporting the central section of the purlin

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 24.8x29 min. size (hxb) [cm] 24x28.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 12 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other



wet surface in central area I:\Arc

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 18.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 24 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 17.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point e

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point f

Moisture Content [%] 26.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name L centre south purlin

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions 2 steel beams supporting the central section of the purlin

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 23.8x29.1 min. size (hxb) [cm] 23x28.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 3/29 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



possible fungi attack near E gable I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☑ Type Unknown Status unknown

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type		Status	Role
Deformation ☐			
Cracks ☐			
Crushing ☐			
Other ☐			

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 18.3 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point e

Moisture Content [%] 18.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point f

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point g

Moisture Content [%] 24.5 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Element name M centre east collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 22.5x6.5 min. size (hxb) [cm] 22x6 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 2/7.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑ compression	unknown	
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☑ insufficient dimensions

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage medium Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 18.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name N centre west collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 23.2x7.5 min. size (hxb) [cm] 23x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 2/8 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type Status
Way of identification

Fungi attack ☐ Type Status
Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

	Type	Status	Role
Deformation ☐			
Cracks ☑	compression	unknown	
Crushing ☐			
Other ☐			

Estimated level of damage: medium

Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☑ insufficient dimensions

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

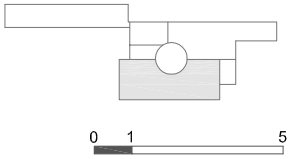
External actions ☐

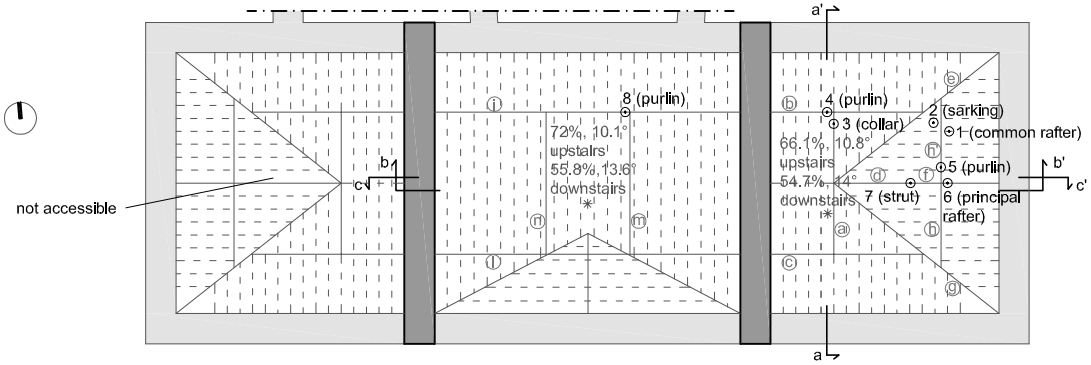
Other ☐

Measurement Point a			
Moisture Content [%]	16.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	17.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	14.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	18	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Plan 1:200

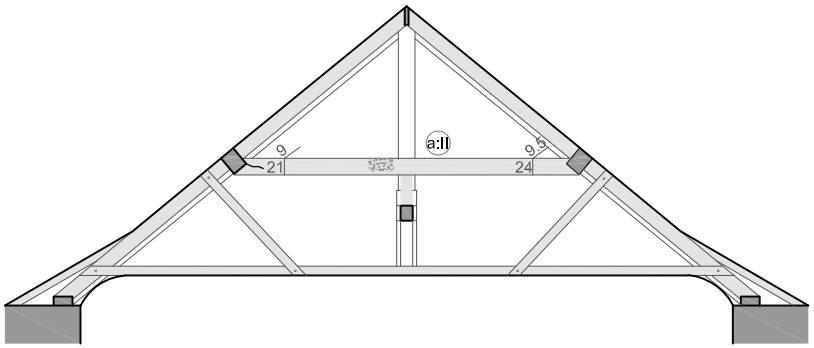
- ✳ air humidity and temperature
- ⊙ timber samples for species identification



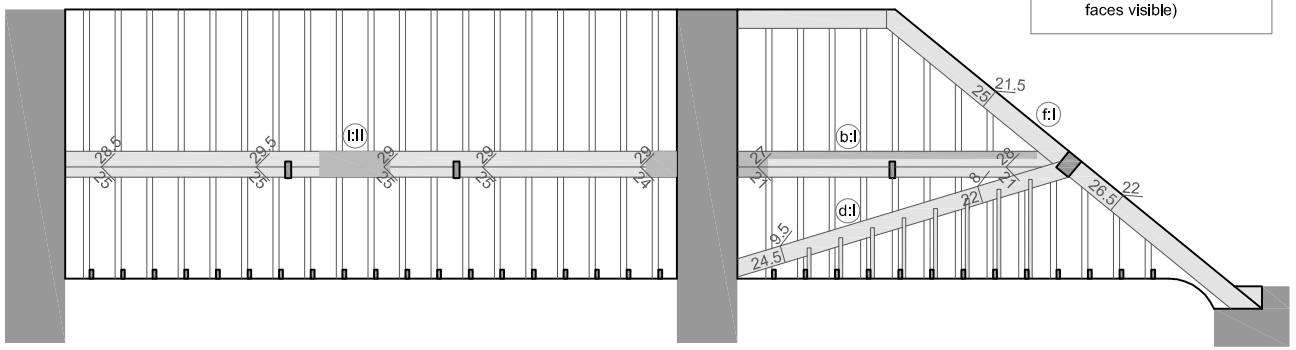


Visual inspection:
- shake
- crack
- wet surface
- fungi attack
- (x:x) element name : estimated strength class (na=less than 2 faces visible)

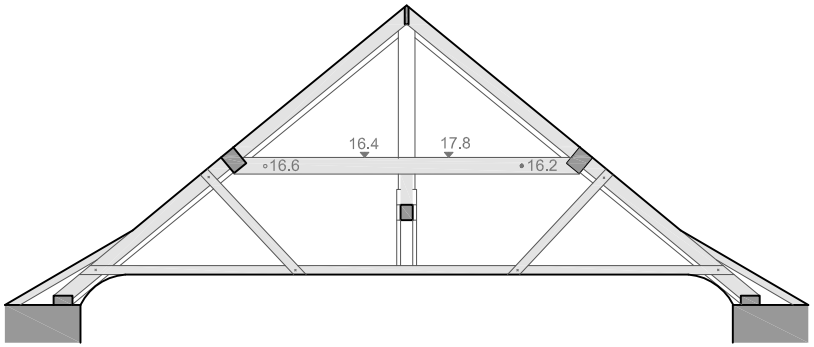
Section aa' 1:100

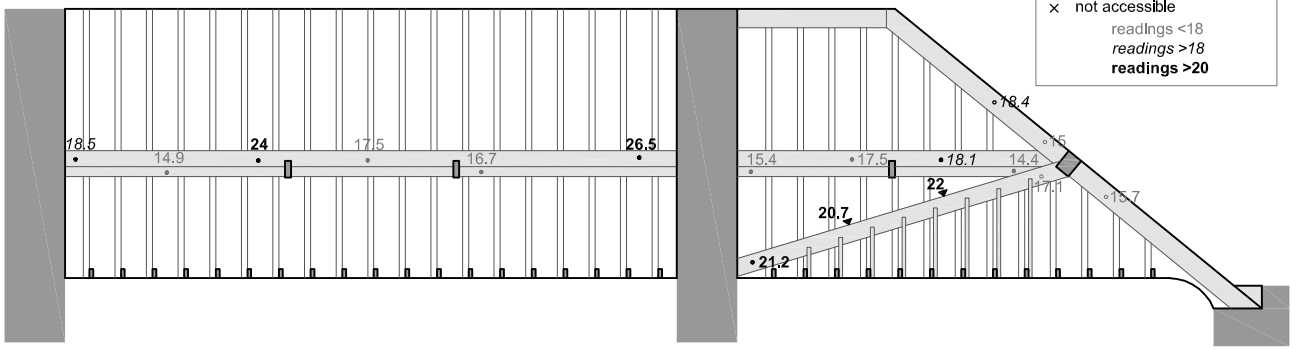


Section bb' 1:100



Moisture content readings:
- ▼ lower/upper/lateral face
- • visible face
- ◦ rear face
- × not accessible
- readings <18
- *readings >18*
- **readings >20**

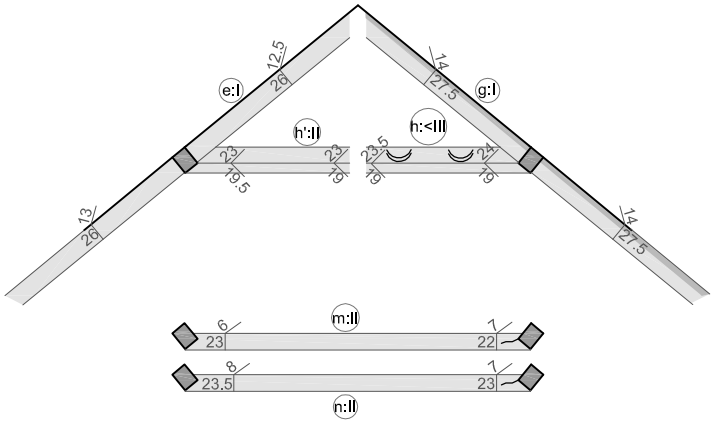




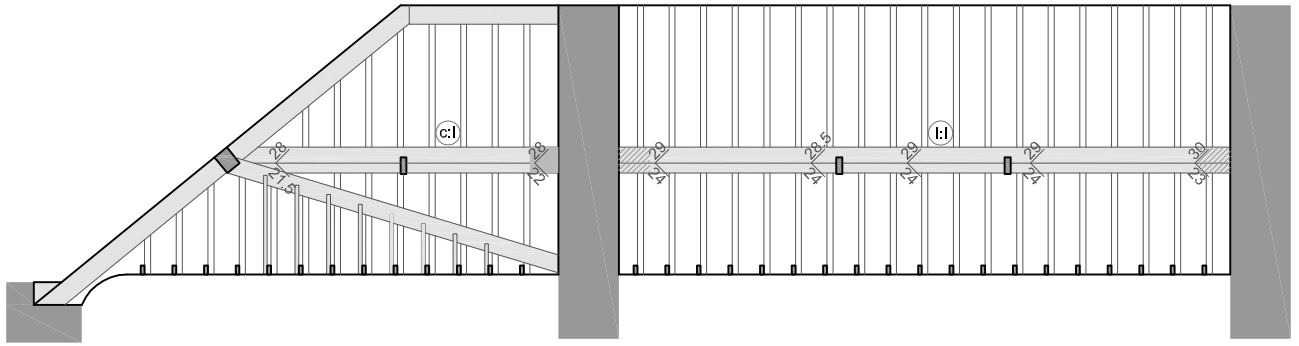
0 1 5

Visual inspection:
- shake
- crack
- wet surface
- fungi attack
- x:x element name : estimated strength class (na=less than 2 faces visible)

Section aa' 1:100

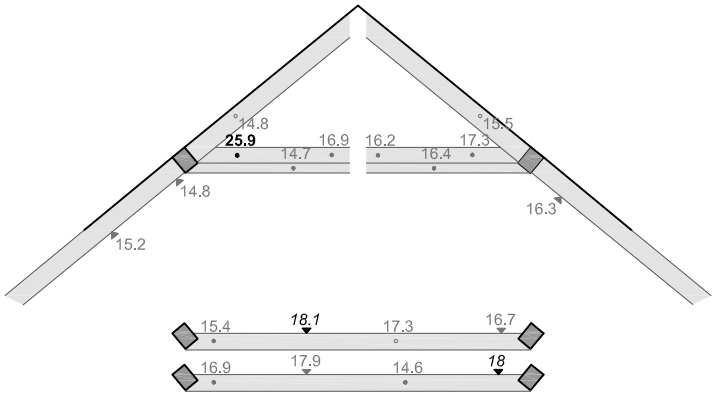


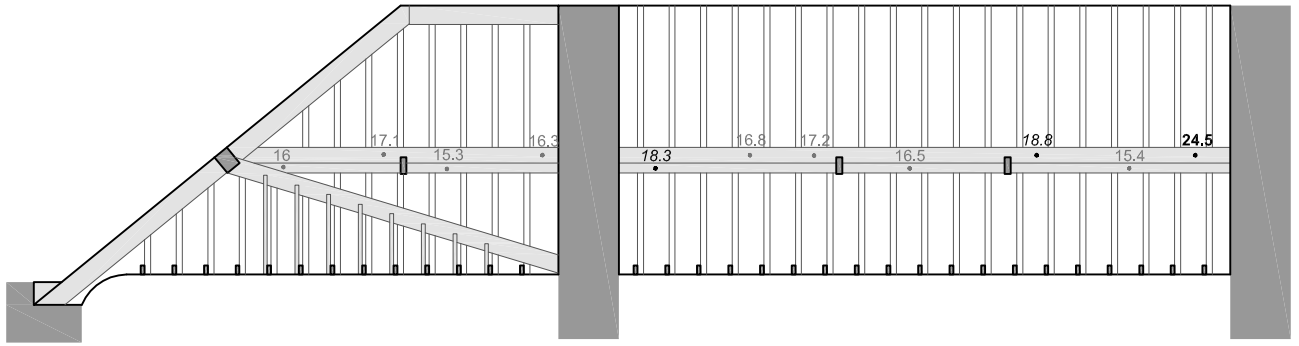
Section cc' 1:100



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20





0 1 5

DETAILED SURVEY **Building name** TOUCH HOUSE **Roof location** 2: 17C block

Survey date(s) 17/02/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings THH-217C-1, THH-217C-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
rafter	455	rectangular with wanes	bending, compression	pinus sylvestris	hand axed and hand sawn
upper collar	240	rectangular with wanes	bending, compression	pinus sylvestris	hand axed and hand sawn
loer collar	410	rectangular with wanes	bending, tension	pinus sylvestris	hand axed and hand sawn
sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

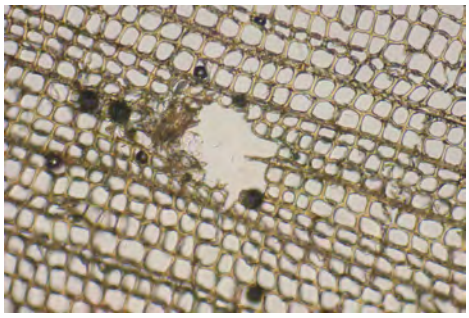
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings THH-217C-1, THH-217C-2

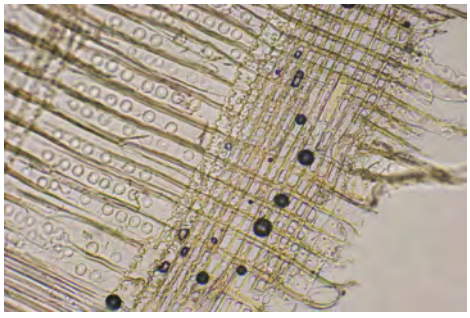
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner mortice & tenon	compression	wooden pegs	pinus sylvestris
rafter & collar	Encounter dovetail	compression, tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

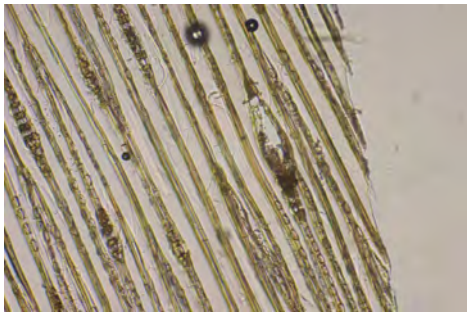
Microscopic identification of the timber species See drawing THH-217C-2



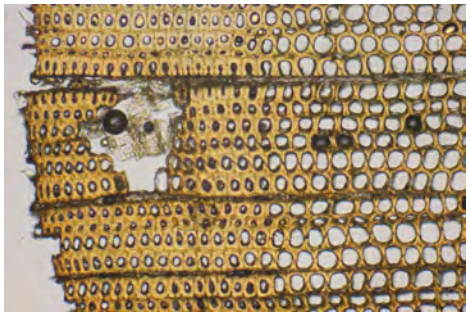
Rafter: transv. section x100 I:\Arc



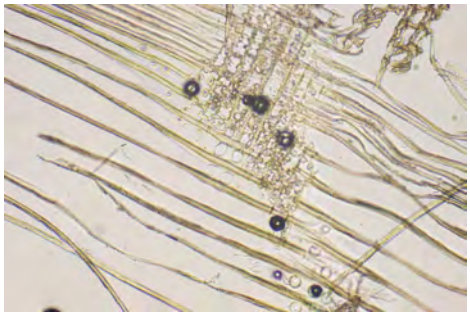
Rafter: radial section x100 I:\Arc



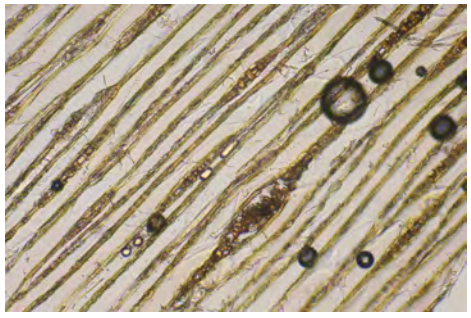
Rafter: tang. section x100 I:\Arc



Peg rafters' apex: transv. section x100 I:\Arc



Peg rafters' apex: radial section x100 I:\Arc



Peg rafters' apex: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing THH-217C-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	W side	17/02/2016	3:20 pm	10.4	67.3
roof space	E side	17/02/2016	3 pm	10.8	64
attic space	W side	17/02/2016	2:20 pm	10.5	60.7

attic space	E side	17/02/2016	2 pm	10.9	61.6	

Frame/Truss name non visible 13 | See drawing THH-217C-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints: between lower collar & N rafter | Fungi attack: S rafter

Other

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 12.5x9.5 | min. size (hxb) [cm]: 12.5x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 8 | tangential

Knots [min d/section h]: 1/13 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 16.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 17.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%]: 16.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name B north rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 12.2x12 | min. size (hxb) [cm]: 11.5x12 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 9 | tangential

Knots [min d/section h]: 1/11 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 17.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 17.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 17.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13.2x9.2 min. size (hxb) [cm] 12.5x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 3/9 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 18 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 21.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 19.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.2x10 min. size (hxb) [cm] 11x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 1.5/11 Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name non visible 9 See drawing THH-217C-2

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 10.5x8.2 min. size (hxb) [cm]: 10x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 10 tangential

Knots [min d/section h]: 3/8 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point	Moisture Content [%]	Visible Material Degradation	Not Accessible for: hygrometer
a	16.2	☑	☐
b	17.1	☐	☐
c	16.3	☐	☐

Element name B north rafter

Dating: original construction Signs of reuse

Timber treated ☐ Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 10.7x7.7 min. size (hxb) [cm]: 10.5x7.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 13 tangential

Knots [min d/section h]: 2.5/7.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other: sarking broken at rafters' apex



sarking broken at rafters' apex I:\Arc

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 19.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 19.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 18.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 11.7x7.2 min. size (hxb) [cm] 11.5x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 5 tangential
Knots [min d/section h] 3/11 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 18.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 19.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 18.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.7x11.5 | min. size (hxb) [cm] 11x11 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%] 8 | tangential

Knots [min d/section h] 3/11 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a			
Moisture Content [%]	19.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	18.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	19.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	20.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name non visible 5 | See drawing THH-217C-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints | Fungi attack

Other S rafter & upper collar wet

Element name A south rafter

Dating original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.2x13 | min. size (hxb) [cm] 11.5x13 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location side | Slope of grain [%] 26 | tangential

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	15.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	15.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	17.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.2x10 min. size (hxb) [cm] 11.5x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 4/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 19.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.7x8 min. size (hxb) [cm] 11x7.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential

Knots [min d/section h] 2/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Measurement Point a

Moisture Content [%] 19.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 19.3 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 20.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues only two faces visible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11x8 min. size (hxb) [cm] 11x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 2/11.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	16.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	16	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	15.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	15.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name non visible 1 See drawing THH-217C-2

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x8.7 min. size (hxb) [cm] 12x8.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 7 tangential

Knots [min d/section h] 5/8.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	22.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	21.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	20.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues partly buried under masonry dust

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13.2x9.5 min. size (hxb) [cm] 13x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification



masonry dust on collar I:\Arc

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 23.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 34.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 29.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name D lower collar

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues: buried under masonry dust, very little visible

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm] 10.7x12 | min. size (hxb) [cm] 9.5x12 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 7 tangential

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I



masonry dust on collar | I:\Arc

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☑ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

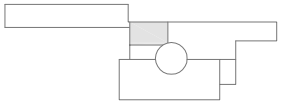
Estimated causes of primary damage

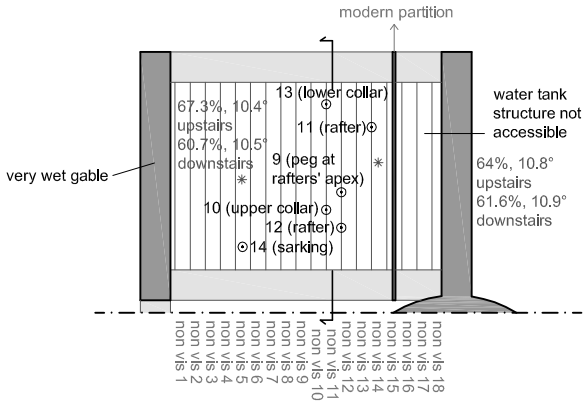
Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a		
Moisture Content [%] 33.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 26	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 24.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d		
Moisture Content [%] 28.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Plan 1:200

- ✳ **air humidity and temperature**
- ⊙ timber samples for species identification







Sections looking West 1:100

Visual inspection:
many small knots & diffuse insect exit holes on most timbers

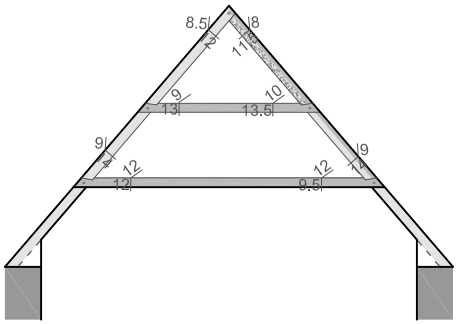
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- fungl attack
- Insect attack

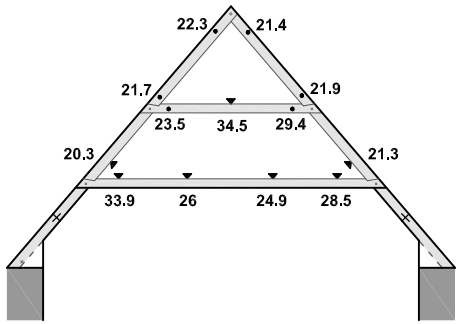
Moisture content readings:

- lower/upper/lateral face
- visible face
- rear face
- × not accessible

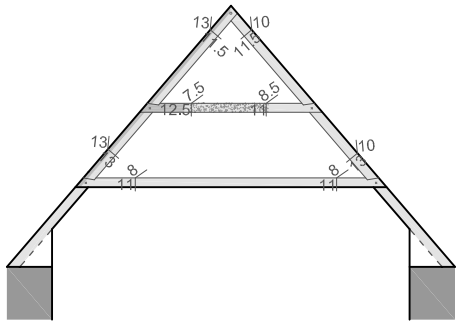
readings <18
readings >18
readings >20

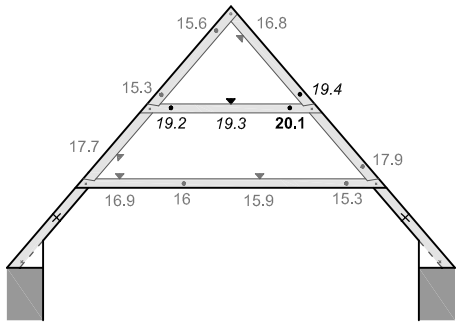
Frame non vis 1



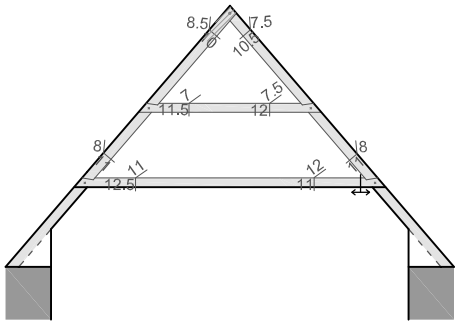


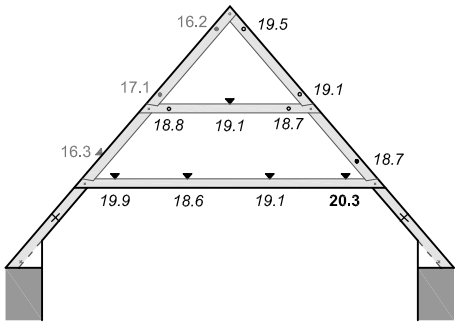
Frame non visible 5



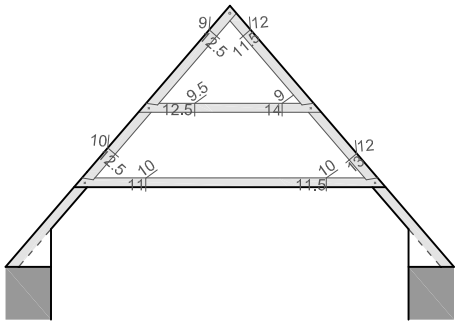


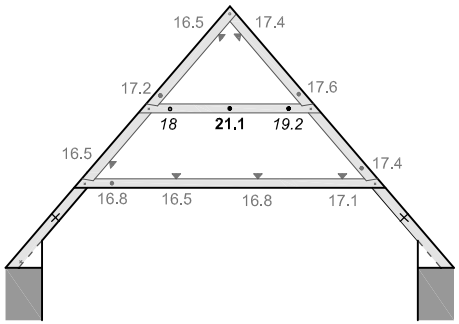
Frame non visible 9





Frame non visible 13







TOUCH HOUSE

Location: STIRLING | ST NINIANS
X coordinate: 275328 Y coordinate: 692755
Geogr. Referencing System: BRITISH NATIONAL GRID





Property status: PRIVATE
Rcahms ID: 46238
HS Listing: A

Original Use: Residential
Current Use: Residential

Freestanding: ☑ N. of floors above ground level: 3 Location link: I:\Arch\AD Building picture link: I:\Arch\ADCRU\1718cent s

INTERVENTIONS

Intervention type:	From:	To:	Description:	Reference:
CONSTRUCTION	1500	1599	Z PLAN TOWER HOUSE - TODAY ONLY SE TOWER AND LOWER PORTION OF NW TOWER REMAIN	HS

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1600	1699	NW TOWER REBUILT AND EXTENDED EAST (TODAY NORTH RANGE)	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ADDITION, ALTERATION	1757	1762	MAIN BLOCK OF THE ORIGINAL BUILDING REPLACED	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
ADAM	WILLIAM	ARCHITECT	☑
STEINSON	JAMES	ARCHITECT	☑
GRAY	GIDEON	CONTRACTOR, MASON	☐
CLAYTON	THOMAS	PLASTERER	☐
PATERSON	GEORGE	WRIGHT	☐
GIBSON	HENRY	WRIGHT	☐
SETON	HUGH (SMITH)	COMMISSIONERPATRON	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1800	1899	RANGE OF OFFICES AT THE NE ANGLE	CANMORE

People involved:

Intervention type:	From:	To:	Description:	Reference:
ALTERATION	1810		ELLIPTICAL STAIRS	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
GILLESPIE GRAHAM	JAMES	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
ADDITION	1927	1930	RENOVATION OF INTERIORS, STRENGTHENING OF MAIN BLOCK ROOF AND REPLACEMENT OF NORTHEAST ROOF OF NORTH RANGE - POSSIBLY REPAIRS IN NORTHWEST ROOF OF NORTH RANGE AS WELL	BUILDINGS OF SCOTLAND COLLECTION

People involved:

Last Name	First Name	Role	Attributed
LORIMER	SIR ROBERT	ARCHITECT	☐

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR, DAMAGE	1968		CUPOLA FELL OFF DURING STORM - IT WAS REPLACED AND ROOF STRENGTHENED	OWNER

People involved:

Intervention type:	From:	To:	Description:	Reference:
CONSERVRESTOR	2013		FOUND DRY ROT IN A CORNER OF THE ROOF - IT WAS REPAIRED WITH TIMBER AND STEEL	OWNER

People involved:

LITERATURE REFERENCES

Author	Year	Unpubl.	Title	Pages
DAVID MACGIBBON & THOMAS ROSS	1971	☐	VOLUME IV. CASTELLATED AND DOMESTIC ARCHITECTURE OF SCOTL THE TWELFTH TO THE EIGHTEENTH CENTURY	405
GIFFORD J.	2002	☐	THE BUILDINGS OF SCOTLAND COLLECTION: STIRLING AND CENTRAL	

ARCHIVAL REFERENCES

Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	Account of materials				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	Letter from timber merchant to Mr Seton				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	transcription of account of timber				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	account of timber				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	Account for haulage from Stirling dock to Touch by James Danskin				
Archive	Private: Touch House	Doc.Num.	uncatalogued	Folios	
Title	account				
Archive	RCAHMS	Doc.Num.	LOR/T/1/5	Folios	
Title	Plans, sections and elevations of verandah, repairs to North wing roof and coal cellar. Plans and sections of new drive and forecourt				

Suggestions for further research

Consulted archive documents

LEGEND
normal text = summarized parts
italic = direct transcription
? = not sure of one or more letters in the word preceding the question mark
??? = one word not possible to read

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: Account of materials | Date: from | to

Contents:
[…]
13 roods of scleatting @ 4£ 10sh per rood £58 – 10 – 0
468 yards of roofing and sarking @ 5sh a yard £117 – 0 – 0
592 feet of sheet lead for flanks & etc @ 18d £44 – 8 – 0
[…]

Summary and comments: Not dated but according to A. Mackechnie it could be late 17C. Not sure what 'roofing' implies, but this is not enough to be the construction of the roof on the old range. It's probably repairs and resarking only.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: Letter from timber merchant to Mr Seton | Date: from 1751 | to

Contents:
Dundee 27 September 1751
Mr. Setton,
Sir
I send you inclosed an Account of Wood bought from me by Mr. Geo. Paterson, Wright in Edinburgh, for your use and to your account which receive from the Bearer. I delivered the Wood here to Henry Gibson, one of Mr. Geo. Patersons foreman who ordered the logs to be cut out for your use as ordered by the by said Mr. Geo. Paterson his Master.
Please write me on Receipt of this, if it be convenient to pay the within account in Edinburgh, and where I shall call for it, or if it be more convenient for you, to pay the same at Alloa to James Kirk, Merchant thee, whose Receipt for the same shall be sufficiently good as my own, either of which is agreeable to,
Sir,
Your most obedient servant,
Ja. Key
[…]

Summary and comments: Letter from timber merchant to Mr Seton with account of timber bought by George Paterson, who must be the wright in charge of the timber works, and maybe more. The logs are brought on the construction site and cut there.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: account | Date: from 1757 | to

Contents:
Mr Robert Leckie for Hugh Seaton of Touch Esqr. To William Brown
1757
[…]
October 3 To livering 4 hundred 10 single sardish? Deals 110 ballons? and 30 sawn logs 3sh
To shoardues? As for 6 hundred deals @ 10p hund. 5sh
To waiting on timber altnight? one man 6d
[…]
To freight and port charges of timber ??? 2£ 11sh 4d
To man for waiting on timber all night 8d

Summary and comments:

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: account of timber | Date: from 1757 | to

Contents:
Hugh Seton Esqr. Of Touch
Bo't of Haig Deas & Co.
1757
Nov. 9 2 Copenhagen Logs measr. 59 ½ foot [18.7m] *@ 14d 3 – 9 – 5*
Cutting 6 Draught @ 8d 4
1758
April 4 26 Copenhagen Logs measr. 700 foot [219.8m] *@ 14d 40 – 16 – 8*
3 clean d.o for plank measr. 87 foot [27.3m] *@ d.o 5 – 1 – 6*
Cutting 96 draught @ 4 d 1 – 12 – 0
One barrel Stockholm Tar 1 – 5 – 0
April 18 11 Copenhagen Logs measr. 72 foot [22.6m] *@ 14 4 – 4 – 0*
Cutting 20 draught @ 4d 6 – 8
June 16 11 Copenhagen Logs measr. 362 ?? foot [113.6m] *@ 14 21 – 3 – 1*
One plank 3 inch thick [7.8cm] *12 foot* [3.8m] *long 2 – 6*

Cutting 24 Draught about 20 foot [6.28m] *long each @ 5d* *10 – 0*
Cutting 30 d.o @ 4d *10 – 0*
August 5 18 Riga Logs measr. 492 ?? foot [154.5m] *@ 14* *28 – 14 – 4*
August 19 Cutting 24 Draught each 23 foot [7.2m] *long @ 6d* *12 – 0*
Sept. 2 36 Riga Logs measured 1036 foot [325.3m] *@ 11* *60 – 8 – 8*
10 Norway 10&12 foot [3.2/3.8m] *Deals @ 11d and one hundred double flooring nails @ 12d for making affloat* *10 – 2*

£ 169 – 10 – 0
August 8 By your Draught on Charles Smith Esqr. *100 – 0 – 0*
Balance *69 – 10 – 0*

Alloa 21st November 1758 Received by the hands of Mr. Robert Leckie Payment of the above sum of Sixty nine Pounds Ten Shillings Sterling which is in full of all accounts. Haig Deas & Co.

Summary and comments: Account of wood bought for Mr Seton: Copenhagen (Norway) logs, Riga (Russia) logs, Norway deals and other small cuts. The Riga logs, being of higher quality, have probably been used for the purlins, whilst the Copenhagen logs have probably been used for the common rafters.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: transcription of account of timber | Date: from 1757 to

Contents:
Mr Setton of Touch by Mr Geo. Paterson
Bought off Jas Key, Dundee
1757
September 10th
To 30 Redwood scots pine Logs 9,209 Solid feet @ 9d. *10 – 2 - 4*
To 410 Best Superfine picked Gotenburg 1 ¼ Inch Deals @ 8£ p *32 – 13 – 4*
To Carriage paid to the Ship *5 – 0*
To Cash paid to Customhouse for a permit *2 – 0*
---
48 – 12 – 8

Summary and comments: Account of wood bought by George Paterson for Mr Seton: 30 scots pine logs and 410 high quality deals from Gotenburg (Sweden). This timber is probably for the roofs of the new house - the deals are sufficient to make the sarking of the central block, the logs could be for the common rafters.

Archive: Private: Touch House | Doc. Num.: uncatalogued | Folios:

Title: Account for haulage from Stirling dock to Touch by James Danskin | Date: from 1758 to

Contents:
James Danskin, Account for Haulage from Stirling dock to Touch
An account of money paid for Livering free Stones and Wood and Lead and Sclates for the use of Mr Seaton of Touch at the Shor of Stirling
1758
[…]
August 23 For taking out the float of wood paid 6sh
[…]
For taking care of wood lying at the Shor 2sh
[…]

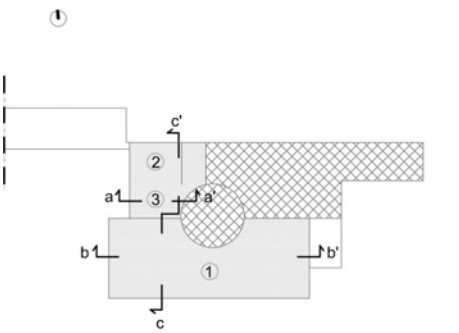
Summary and comments: Account of transport of materials to the house. No details on materials carried.

Archive: RCAHMS | Doc. Num.: LOR/T/1/5 | Folios:

Title: Plans, sections and elevations of verandah, repairs to North wing roof and coal cellar. Plans and sections of new drive and forecourt | Date: from 1928 to

Contents:

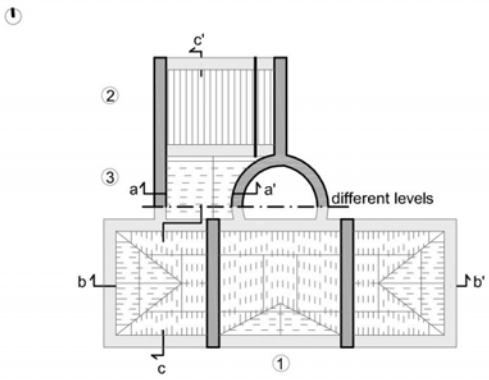
Summary and comments: Drawing by Lorimer showing replacement of the NorthEast roof of the North range in 1928



Legend (plans):

Plan 1:1000
- Surveyed roof
- Post-1800 roofs
- Not Accessible roofs

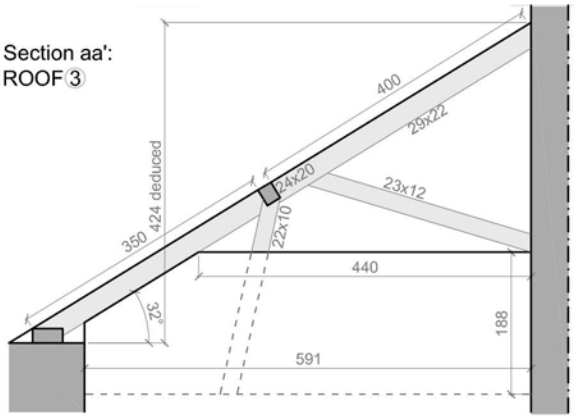
Plan 1:500
- Primary structure
- Secondary structure
- Past Interventions
- Carpentry marks



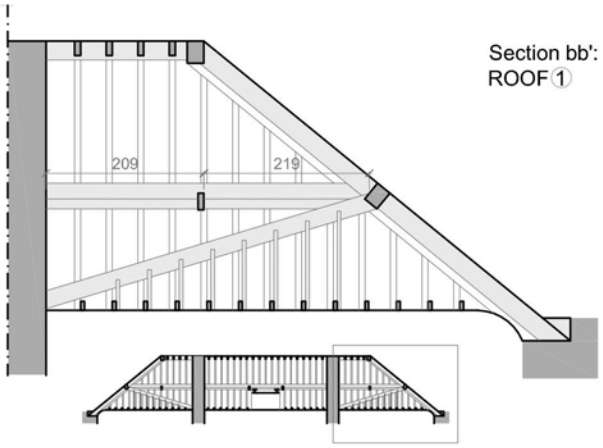
Plan 1:1000 I:\Arch\ADCRU\1718cent scott

Plan 1:500 I:\Arch\ADCRU\1718cent scottish buildings databas

Section aa':
ROOF 3



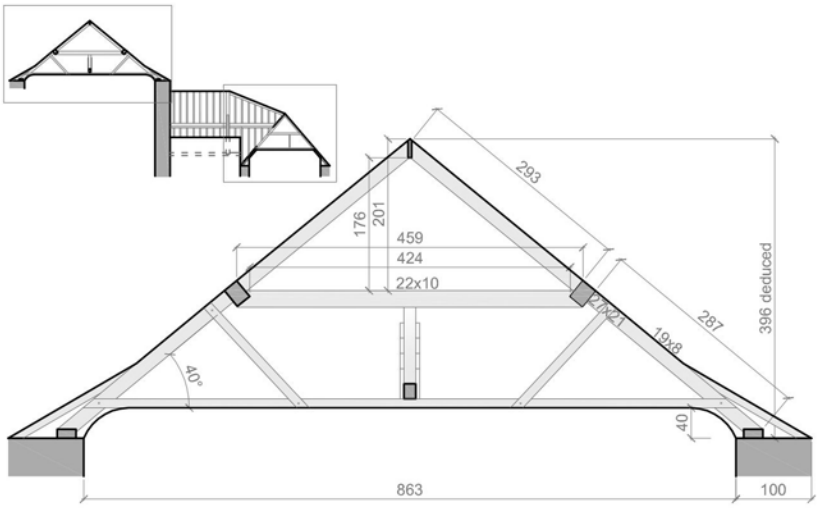
Section bb':
ROOF 1

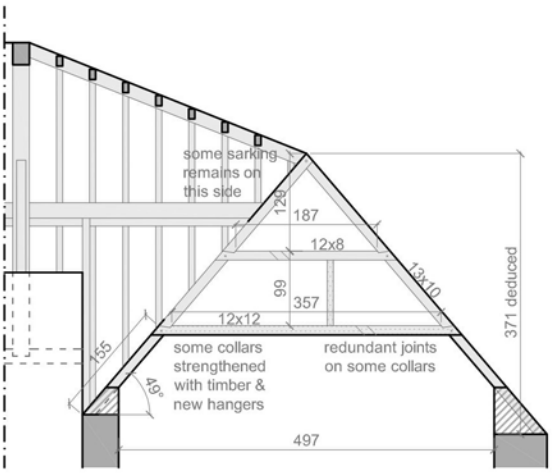


Legend (section):
- Past Interventions
- Assumptions (not visible)
- Timber pegs/dowels
- Metal nails/spikes

Dimensions in cm (where dimensions are not provided, it was not possible to take measurements)

Section cc': ROOF 1-3-2





Section 1: 100 I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber roofs key b

0 1 5

INITIAL SURVEY | **Building name** TOUCH HOUSE | **Roof location** 1: 18C block

Survey date(s) 12/08/2015 | See drawing: THH-MB-1

Roof Geometry: Hipped

Roof Max Span [m]: 8.6 | Roof Height [m]: 4

Roof Pitch/es [°]: 40 | Roof Length [m]: 23.4

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, sarking

Sarking boards: width [cm]: | thickness [cm]: 3

Connection with lateral walls: Wall-plate

Connection with gables: purlins

Roof Construction Period: From 1745 To 1755 | Identified by: Estimated

Roof General Description:

Hipped roof supported by two transversal walls and two longitudinal purlins, one on each side, and a slender ridge purlin. Horizontal struts, one on the sides and two at the centre, keep the purlins apart. The purlins support common rafters which in turn support the sarking. The ceiling is supported by collars that connect the common rafters. The pediment might be of later date, because there is sarking inside and the purlins have metal nails rather than timber pegs like the others.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: 27 | B 21

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description:

Between purlins and common rafters: double mortice and tenon with timber pegs not flush

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: strange marks (from scandinavia?)

Carpentry Marks Description:

only a few visible strange marks, not in sequence

Signs of reused timbers:

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Connection with wall | link I:\Arch\A



Timber dressing | link I:\Arch\A



Joints: purlin and common rafter | link I:\Arch\A



Carpentry marks | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☑ Insulation on sarking ☐

Decorative features

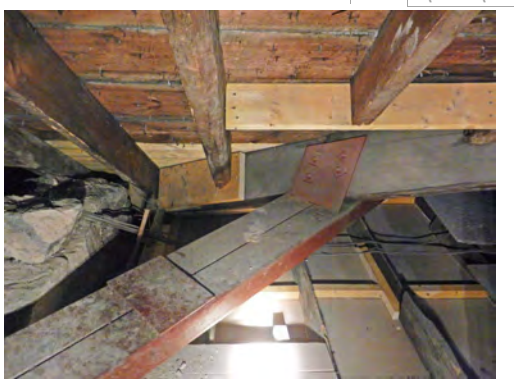
Unfavourable conditions: presence of pigeons/wasps/bats

Accessibility limitations: The west side of the roof is not accessible. There are bats everywhere.

Past interventions: The roof was strengthened in 1930s by Lorimer: he added two steel beams supporting the purlins in their central section. The steel beams sit on the external pediment and a wall extending from the rear wall. Dry rot was found in 2003 in the South East corner of the central part of the roof: a steel beam and new timber were added here to replace the rafter end.



Past interventions | link | I:\Arch\A



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains on purlins, sarking and common rafters. Possible fungi attack on South purlins near the gables.

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks	Active	Primary
Connection Damage			



Humidity stains on purlin | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Possible fungi attack on purlin | link | I:\Arch\A

Description of visible damage: Cracks in horizontal struts due to purlins' deflection.

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** TOUCH HOUSE | **Roof location** 2: 17C block

Survey date(s) 12/08/2015 | See drawing: THH-MB-1

Roof Geometry: Two-pitch gabled

Roof Max Span [m]: 4.7 | Roof Height [m]: 3.46

Roof Pitch/es [°]: 49 | Roof Length [m]: 8.96

Type of Primary Structure: 2D framing

Truss ☐

Frame ☑ Collar/s

Average Distance in between Primary Structure [m]: 0.45

Type of Secondary Structure: purlins, sarking

Sarking boards: width [cm] | thickness [cm]: 3

Connection with lateral walls: Unknown

Connection with gables: unknown

Roof Construction Period: From 1670 To 1700 | Identified by: Estimated

Roof General Description:

Gabled roof composed of 15 frames with two collars each. Ceiling is supported by lower collar. Connection with lateral walls not visible. Still reatains some of the original sarking inside, on the South side. Some timbers have redundant lap joints, they might have been reused. Others are not full logs but half logs, sawn in two. These are probably replacements of the 18th century.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular with wanes

Rafter Scantling [cm] H: 13 B: 10 | Or Purlin - H: B:

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: cleat, dovetail, lapped, mortice and tenon

Fasteners Types: Metal nail, Timber peg not flush

Joints description:

Rafters' apex: mortice and tenon with timber pegs not flush. Between rafters and collars: dovetail lapped with metal nails. Ther is a short purlin wityh cleats connecting some rafters on the north side.

Wood Species: all pinus sylvestris | Way of identification: direct micro

Carpentry Marks Types: big roughly cut roman numerals, strange marks (from scandinavia?)

Carpentry Marks Description:

Roman numerals not in sequence. Some strange marks.

Signs of reused timbers: Redundant lap joints on some collars

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Joints: rafter and collar | link I:\Arch\A



Joints: rafters' apex | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Redundant joints in collar | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions: poor maintenance, poor ventilation

Accessibility limitations: Connection with lateral walls not visible

Past interventions: Some lower collars reinforced in timber and hangers hadded, probably during repair works in 1930s. Sarking replaced on North side.



Past interventions | link | I:\Arch\A

Material Degradation: Fungi attack ☑ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

East gable is visibly wet and the masonry is disintegrating to dust and falling on the timbers and ceiling underneath. There is probably a problem of water ingress. The sarking is broken in some areas. A few areas might be affected by biotic attack.



East gable wet and disintegrating | link | I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage			
Connection Damage	Splitting	Unknown	Collateral



Sarking broken and biotic attack | link | I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☐
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐



Damage: splitting of connection | link | I:\Arch\A

Description of visible damage: Some collars seem to be splitting at the joint with the rafters. This doesn't seem to be affecting the overall performance of the roof.

Other Notes

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link

INITIAL SURVEY | **Building name** TOUCH HOUSE | **Roof location** 3: between 17C & 18C blocks

Survey date(s) 12/08/2015 | See drawing: THH-MB-1

Roof Geometry: Mono-pitch

Roof Max Span [m]: 3.7 | Roof Height [m]: 4.24

Roof Pitch/es [°]: 32 | Roof Length [m]: 5.5

Type of Primary Structure: Purlins

Truss ☐

Frame ☐

Average Distance in between Primary Structure [m]:

Type of Secondary Structure: common rafters, sarking

Sarking boards: width [cm] | thickness [cm]

Connection with lateral walls: Wall-plate

Connection with gables: purlins

Roof Construction Period: From 1745 To 1755 | Identified by: Estimated

Roof General Description:

A mono-pitch roof linking the 17C roof with the 18C one. Composed of one purlin running between the wall which separates the main block and the North range and a hip rafter ending on the cupola wall. The purlin supports a principal rafter in the centre of its length and common rafters all along. One strut goes from the wall to the principal rafter to hang the ceiling underneath. Another strut, almost vertical, supports the purlin and sits on a wall running East-West on which the 17th roof sits as well.

Roofing Material: slate

Roofing Material Fixing: Metal nails

Timber elements' Section Shape: Rectangular

Rafter Scantling [cm] H: | B: | Or Purlin - H: 24 | B 20

Timber elements' Dressing: rustic (hand-axed), rustic (hand-sawn) | Bark ☐

Joint Types: mortice and tenon

Fasteners Types: Timber peg not flush

Joints description: Between purlisn and common rafters: double mortice and tenon with timber pegs not flush

Wood Species: softwood, probably pine | Way of identification: estimated

Carpentry Marks Types: strange marks (from scandinavia?)

Carpentry Marks Description:

Signs of reused timbers: Redundant joints in purlin: probably a principal rafter was removed?

Timber Treated ☐

Other Materials:

Dendrochronology:



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Roof structure | link I:\Arch\A



Carpentry marks | link I:\Arch\A



Redundant joints in purlin | link I:\Arch\A

Roof space in use ☐ Insulation on ceiling ☐ Insulation on sarking ☐

Decorative features

Unfavourable conditions

Accessibility limitations: Connection with wall only partly visible

Past interventions



Humidity stains | link I:\Arch\A

Material Degradation: Fungi attack ☐ Insect attack ☐ Humidity stains ☑ Diffuse insect exit holes ☑

Humidity stains in sarking and common rafters



Damage: purlin deflection | link I:\Arch\A

	Damage Type:	Damage Status:	Damage Role:
Roof Damage			
Unit Damage			
Element Damage	Cracks, Permanent Deformation	Active	Primary
Connection Damage			



Damage: strut cracking | link I:\Arch\A

Estimated cause(s) of the primary damage:

- Poor Design ☑ inefficient overall arrangement, insufficient dimensions
- Poor Construction ☐
- Poor Maintenance ☐
- Material Degradation ☐
- Past interventions ☐
- Extreme actions ☐
- Other ☐

Description of visible damage: Purlin is deflected and strut that supports it is cracked. Intervention needed urgently.

link I:\Arch\A

Other Notes: Owner very helpful and eager to look into the building's history and problems

Attachments: I:\Arch\ADCRU\1718cent scottish buildings database\timber roofs\timber | link I:\Arch\A

DETAILED SURVEY **Building name** TOUCH HOUSE **Roof location** 1: 18C block

Survey date(s) 17/02/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings THH-118C-1, THH-118C-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
hip rafter	685	rectangular	bending, compression		hand axed and hand sawn
principal rafter	625	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
upper collar	460	rectangular with wanes	bending, compression		hand axed and hand sawn
side purlin	405	rectangular	bending, compression		hand axed and hand sawn
end purlin	225	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
central purlin	810	rectangular	bending, compression	pinus sylvestris	hand axed and hand sawn
common rafter	600	rectangular with wanes	bending, compression	pinus sylvestris	hand axed and hand sawn
sarking		sheet	bending, tension	pinus sylvestris	hand sawn
strut	460	rectangular	bending, compression		hand axed and hand sawn
lower collar	865		bending, tension		not visible
small strut	190	rectangular	tension		hand sawn

* estimated based on drawings because not fully accessible

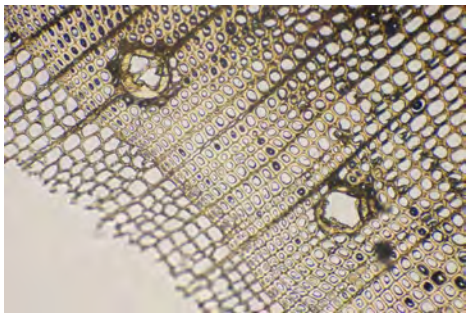
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings THH-118C-1, THH-118C-2

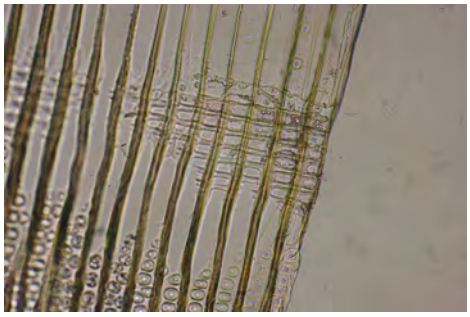
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
purlin & principal/hip rafter	Encounter mortice & tenon	compression	none	
common rafter & purlin	Encounter mortice & tenon	compression	wooden pegs	
rafter & lower collar	Encounter halved	tension	nails	
strut & rafter/collar	Encounter halved	tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

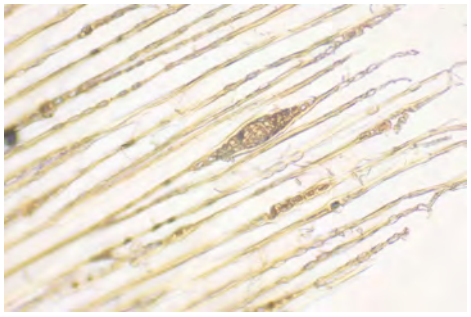
Microscopic identification of the timber species See drawing THH-118C-2



Principal rafter: transv. section x100 I:\Arc



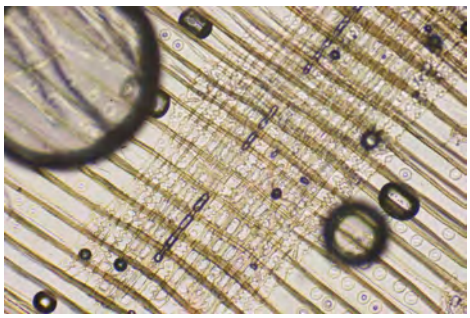
Principal rafter: radial section x100 I:\Arc



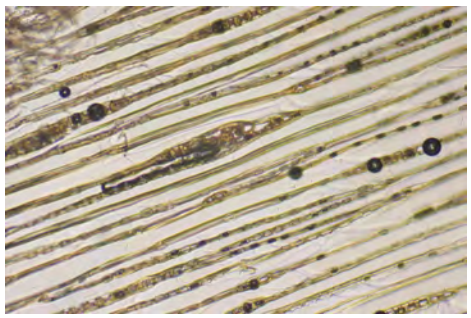
Principal rafter: tang. section x100 I:\Arc



Purlin: transv. section x100 I:\Arc



Purlin: radial section x100 I:\Arc



Purlin: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing THH-118C-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
attic space	centre	17/02/2016	10:20 am	13.6	55.8
attic space	E side	17/02/2016	10 am	14	54.7

roof space	centre	17/02/2016	11 am	10.1	72
roof space	E side	17/02/2016	10:40 am	10.8	66.1

Frame/Truss name all roof — See drawings THH-118C-2, THH-118C-

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack: E collar

Failed joints | Fungi attack: centre S purlin

Other: some wet areas in N purlins and side S purlin, shakes all along SE purlin, crack in E collar

Element name A east collar

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 22.5x9.2 | min. size (hxb) [cm]: 21x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 17 | tangential

Knots [min d/section h]: 4/21 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II



insect attack | I:\Arc

Material degradation

Insect attack ☑ | Type: Anobium Punctatum | Status: active

Way of identification: Estimated

Fungi attack ☐ | Type | Status

Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑ compression	unknown	
Crushing ☐		
Other ☐		

Estimated level of damage: medium | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☑ insufficient dimensions

Poor construct. ☐

Degradation ☐ | Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%]: 16.6 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 16.4 | Visible Material Degradation ☑ | Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%]: 17.8 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%]: 16.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name B north east purlin

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 21x27.5 | min. size (hxb) [cm]: 21x27 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 2 | tangential

Knots [min d/section h] 3/28 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☑ | Other

Mechanical Damage

Type | Status | Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a			
Moisture Content [%] 15.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	
Measurement Point b			
Moisture Content [%] 17.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	
Measurement Point c			
Moisture Content [%] 18.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	
Measurement Point d			
Moisture Content [%] 14.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐	

Element name C south east purlin

Dating original construction | Signs of reuse

Timber treated ☐

Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 21.7x28 | min. size (hxb) [cm] 21.5x28 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location centre | Slope of grain [%] 1 | tangential

Knots [min d/section h] 1/27.5 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☑ | Other

Mechanical Damage

Type | Status | Role



wet close to wall & fungi on rafter | I:\Arc

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 16 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 15.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d
Moisture Content [%] 16.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D big east strut

Dating original construction
Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 23.2x8.7 min. size (hxb) [cm] 22x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential
Knots [min d/section h] 5.5/22 group Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification

Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 21.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 20.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 22 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name E north east hip rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 26x12.7 min. size (hxb) [cm] 26x12.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 1 tangential

Knots [min d/section h] 6/26 group Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Measurement Point a

Moisture Content [%] 14.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 15.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name F east principal rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 25.7x21.7 min. size (hxb) [cm] 25x21.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 2/22 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 18.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 15	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 15.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name G south east hip rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 27.5x14 min. size (hxb) [cm] 27.5x14 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 2 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 15.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] Visible Material Degradation ☐ Not Accessible for: hygrometer ☑

Element name H east purlin

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19x23.7 min. size (hxb) [cm] 19x23 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 4/19 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects shakes all along south section

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 16.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name H' east purlin

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 19.2x23 min. size (hxb) [cm] 19x23 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 5 tangential

Knots [min d/section h] 5/19 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	25.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	14.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	16.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name I centre north purlin

Dating original construction Signs of reuse

Timber treated ☐

Past interventions 2 steel beams supporting the central section of the purlin

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 24.8x29 min. size (hxb) [cm] 24x28.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 12 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other



wet surface in central area I:\Arc

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 18.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 14.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 24 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 17.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point e

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point f

Moisture Content [%] 26.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name L centre south purlin

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions 2 steel beams supporting the central section of the purlin

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 23.8x29.1 min. size (hxb) [cm] 23x28.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location centre Slope of grain [%] 3 tangential

Knots [min d/section h] 3/29 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I



possible fungi attack near E gable I:\Arc

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☑ Type Unknown Status unknown

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Measurement Point a

Moisture Content [%] 18.3 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point e

Moisture Content [%] 18.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point f

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point g

Moisture Content [%] 24.5 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Element name M centre east collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 22.5x6.5 min. size (hxb) [cm] 22x6 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 2/7.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑ compression	unknown	
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☑ insufficient dimensions

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage medium Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 15.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 18.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.3 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 16.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name N centre west collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 23.2x7.5 min. size (hxb) [cm] 23x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 1 tangential

Knots [min d/section h] 2/8 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☑ compression	unknown	
Crushing ☐		
Other ☐		

Estimated level of damage: medium

Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

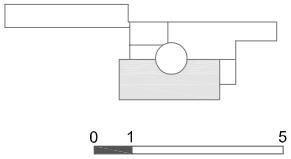
Estimated causes of primary damage

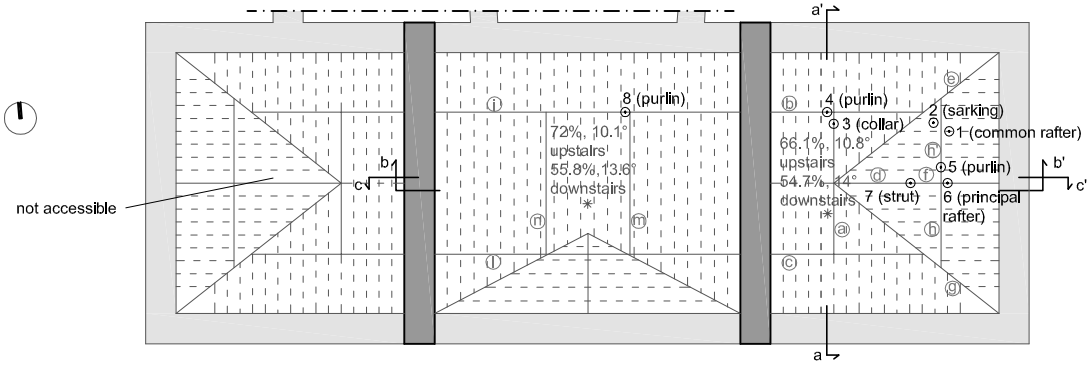
Poor design ☑ insufficient dimensions
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a			
Moisture Content [%]	16.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	17.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	14.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	18	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Plan 1:200

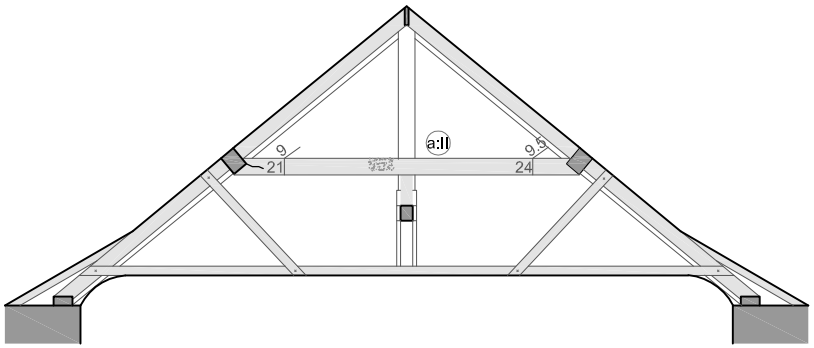
- air humidity and temperature
- timber samples for species identification



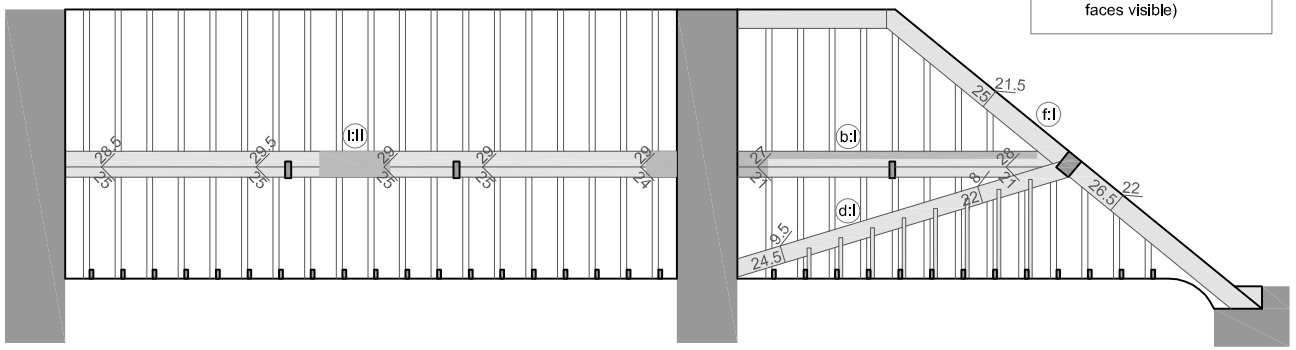


Visual inspection:
- shake
- crack
- wet surface
- fungi attack
- x:x element name : estimated strength class (na=less than 2 faces visible)

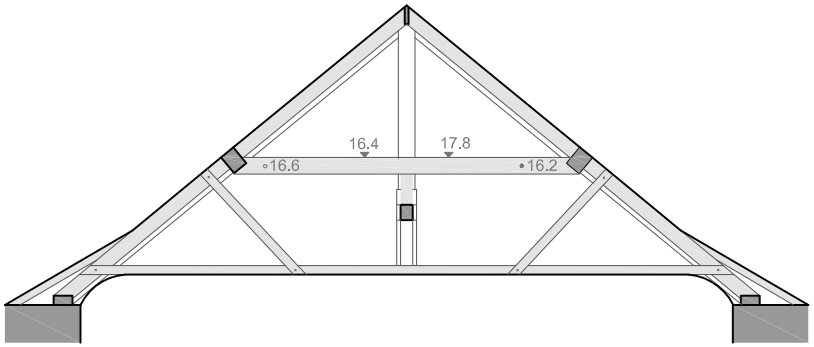
Section aa' 1:100

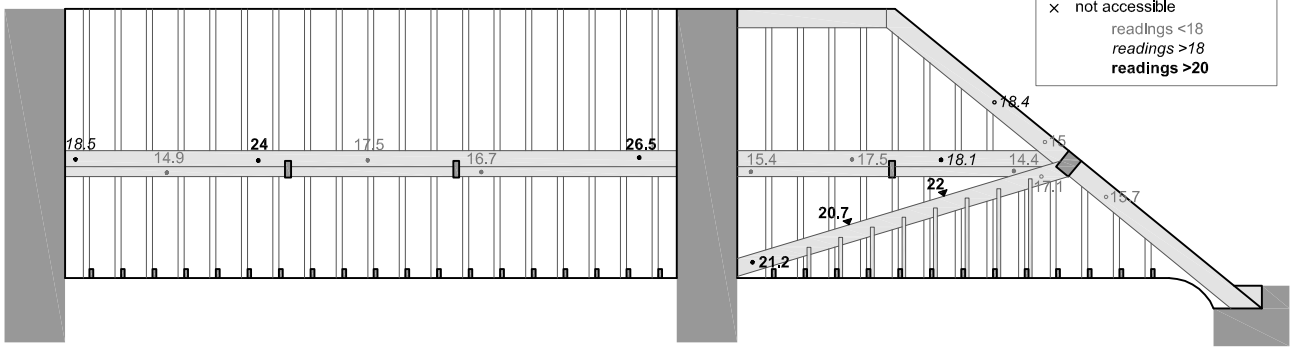


Section bb' 1:100



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible
- readings <18
- *readings >18*
- **readings >20**

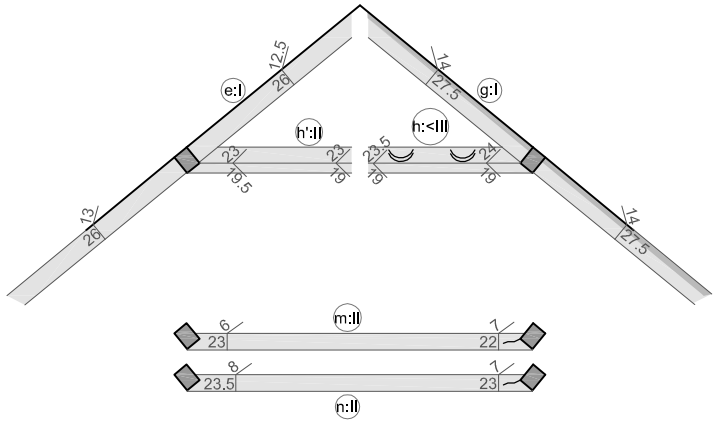




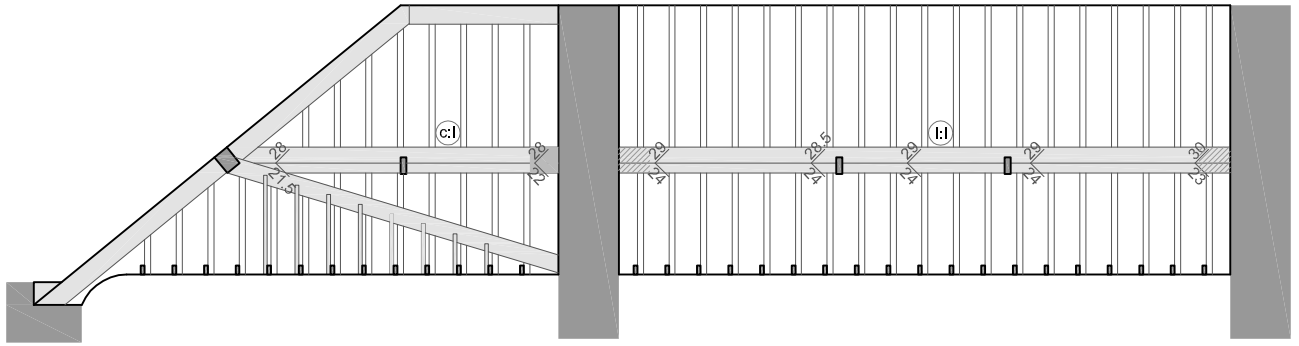
0 1 5

Visual inspection:
- shake
- crack
- wet surface
- fungi attack
- x:x element name : estimated strength class (na=less than 2 faces visible)

Section aa' 1:100

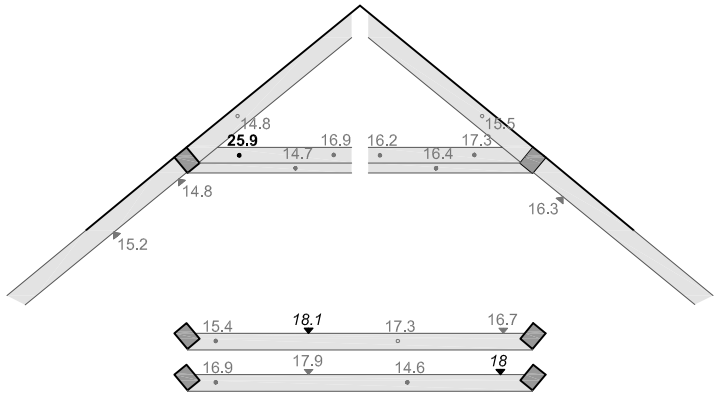


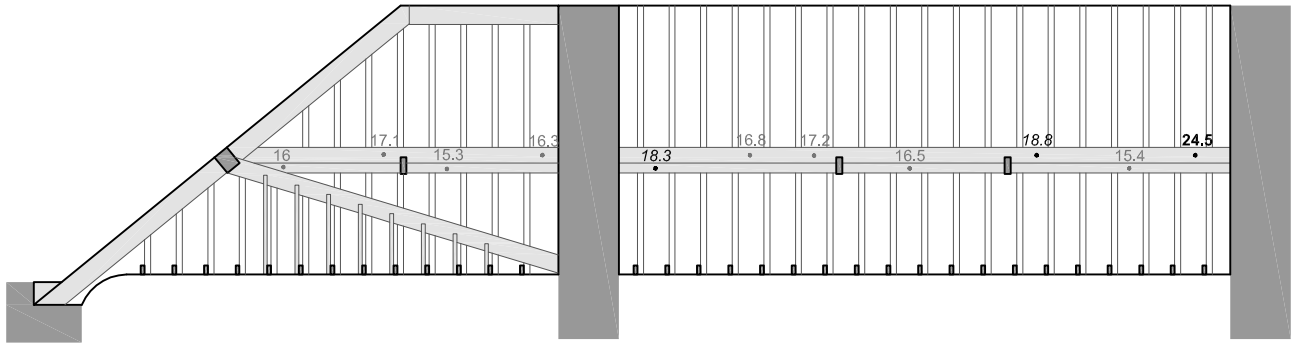
Section cc' 1:100



Moisture content readings:
- lower/upper/lateral face
- visible face
- rear face
- not accessible

readings <18
readings >18
readings >20





0 1 5

DETAILED SURVEY **Building name** TOUCH HOUSE **Roof location** 2: 17C block

Survey date(s) 17/02/2016

Elements: lengths, section shapes, stresses applied, timber species, timber dressing See drawings THH-217C-1, THH-217C-2

Element type:	Length [cm]	Section shape:	Working in (estimated):	Timber species # :	Timber dressing:
rafter	455	rectangular with wanes	bending, compression	pinus sylvestris	hand axed and hand sawn
upper collar	240	rectangular with wanes	bending, compression	pinus sylvestris	hand axed and hand sawn
loer collar	410	rectangular with wanes	bending, tension	pinus sylvestris	hand axed and hand sawn
sarking		sheet	bending, tension	pinus sylvestris	hand sawn

* estimated based on drawings because not fully accessible

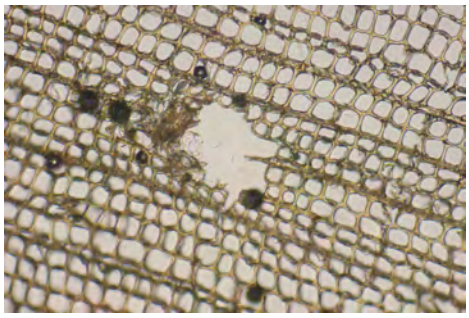
identified with a light transmission microscope analysing maximum 2 samples for each element type - based on visual inspection the other elements have been assumed to be of the same species

Joints: types, stresses applied and timber species See drawings THH-217C-1, THH-217C-2

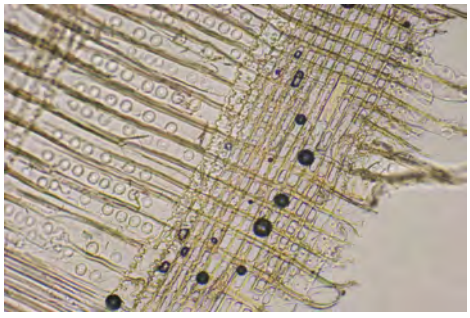
Joint position:	Joint type:	Working in (estimated):	Fastener type:	Timber species # :
rafter & rafter	Corner mortice & tenon	compression	wooden pegs	pinus sylvestris
rafter & collar	Encounter dovetail	compression, tension	nails	

identified with a light transmission microscope analysing maximum 2 samples for each fastener - based on visual inspection the other fasteners have been assumed to be of the same species

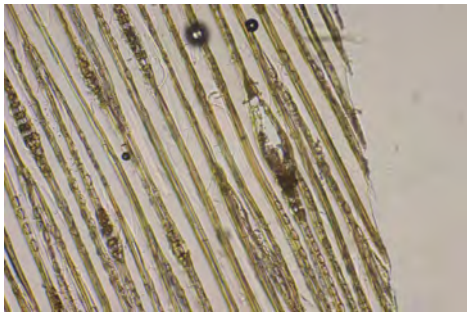
Microscopic identification of the timber species See drawing THH-217C-2



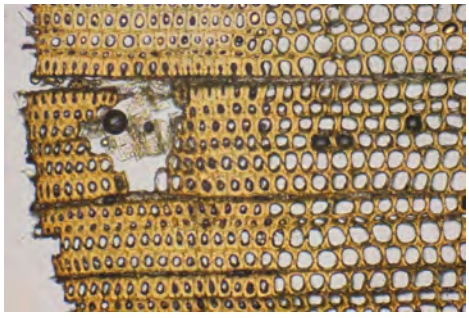
Rafter: transv. section x100 I:\Arc



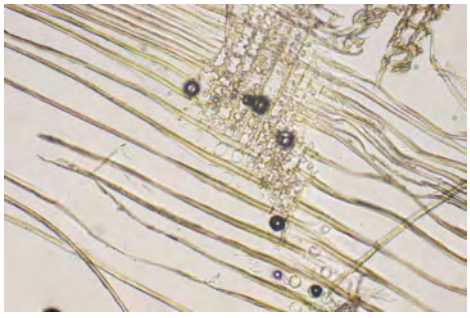
Rafter: radial section x100 I:\Arc



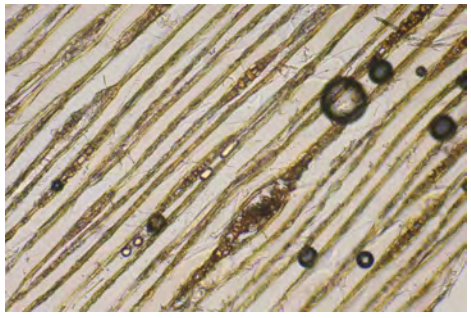
Rafter: tang. section x100 I:\Arc



Peg rafters' apex: transv. section x100 I:\Arc



Peg rafters' apex: radial section x100 I:\Arc



Peg rafters' apex: tang. section x100 I:\Arc

Air Temperature and Relative Humidity measurements See drawing THH-217C-2

Location	Location description	Date	Time	Air temperature [°]	Air relative humidity [%]
roof space	W side	17/02/2016	3:20 pm	10.4	67.3
roof space	E side	17/02/2016	3 pm	10.8	64
attic space	W side	17/02/2016	2:20 pm	10.5	60.7

attic space	E side	17/02/2016	2 pm	10.9	61.6	

Frame/Truss name non visible 13 | See drawing THH-217C-2

Missing elements | Elements with defects in critical area

Joints with decayed peg | Insect attack

Failed joints: between lower collar & N rafter | Fungi attack: S rafter

Other

Element name A south rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 12.5x9.5 | min. size (hxb) [cm]: 12.5x9 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 8 | tangential

Knots [min d/section h]: 1/13 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: I

Material degradation

Insect attack ☐ | Type | Status | Way of identification

Fungi attack ☐ | Type | Status | Way of identification

Corrosion ☐ | Wet surface ☐ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

Estimated causes of primary damage

Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a

Moisture Content [%]: 16.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%]: 17.2 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%]: 16.5 | Visible Material Degradation ☐ | Not Accessible for: hygrometer ☐

Element name B north rafter

Dating: original construction | Signs of reuse

Timber treated ☐ | Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 12.2x12 | min. size (hxb) [cm]: 11.5x12 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 9 | tangential

Knots [min d/section h]: 1/11 | single | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a		
Moisture Content [%] 17.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 17.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 17.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13.2x9.2 min. size (hxb) [cm] 12.5x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 3/9 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 18 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 21.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 19.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.2x10 min. size (hxb) [cm] 11x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 1.5/11 Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 16.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point d

Moisture Content [%] 17.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Frame/Truss name non visible 9 See drawing THH-217C-2

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 10.5x8.2 min. size (hxb) [cm]: 10x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 10 tangential

Knots [min d/section h]: 3/8 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a			
Moisture Content [%]	16.2	Visible Material Degradation ☑	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	17.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	16.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name B north rafter

Dating: original construction Signs of reuse

Timber treated ☐ Accessibilityissues: lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm]: 10.7x7.7 min. size (hxb) [cm]: 10.5x7.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location: side Slope of grain [%]: 13 tangential

Knots [min d/section h]: 2.5/7.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119: II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other: sarking broken at rafters' apex



sarking broken at rafters' apex I:\Arc

Mechanical Damage

Type Status Role

Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 19.5 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 19.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 18.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse
Timber treated ☐
Past interventions
Accessibilityissues
Differences compared to other elements of the same type
Section: nominal size (hxb) [cm] 11.7x7.2 min. size (hxb) [cm] 11.5x7 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 5 tangential
Knots [min d/section h] 3/11 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐
Other defects
Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status
Way of identification
Fungi attack ☐ Type Status
Way of identification
Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role
Deformation ☐
Cracks ☐
Crushing ☐
Other ☐
Estimated level of damage
Emergency interv. needed ☐
Mater.Degr. and Damage Extent
Way of identification
Estimated causes of primary damage
Poor design ☐
Poor construct. ☐
Degradation ☐ Poor maintenance ☐
Past interv. ☐
External actions ☐
Other ☐

Measurement Point a
Moisture Content [%] 18.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b
Moisture Content [%] 19.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c
Moisture Content [%] 18.7 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.7x11.5 min. size (hxb) [cm] 11x11 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 8 tangential

Knots [min d/section h] 3/11 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 II

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Measurement Point a			
Moisture Content [%]	19.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	18.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	19.1	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	20.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name non visible 5 See drawing THH-217C-2

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other S rafter & upper collar wet

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.2x13 min. size (hxb) [cm] 11.5x13 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 26 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	15.6	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	15.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	17.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name B north rafter

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues lower half not accessible

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 12.2x10 min. size (hxb) [cm] 11.5x10 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] 4/10 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 16.8 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 19.4 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 17.9 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11.7x8 min. size (hxb) [cm] 11x7.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 6 tangential

Knots [min d/section h] 2/12 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☑ Type Anobium Punctatum Status active

Way of identification Estimated

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated causes of primary damage

Poor design ☐ Poor construct. ☐ Degradation ☐ Poor maintenance ☐ Past interv. ☐ External actions ☐ Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent Way of identification

Measurement Point a

Moisture Content [%] 19.2 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Measurement Point b

Moisture Content [%] 19.3 Visible Material Degradation ☑ Not Accessible for: hygrometer ☐

Measurement Point c

Moisture Content [%] 20.1 Visible Material Degradation ☐ Not Accessible for: hygrometer ☐

Element name D lower collar

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues only two faces visible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 11x8 min. size (hxb) [cm] 11x8 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 2 tangential

Knots [min d/section h] 2/11.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	16.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	16	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	15.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d			
Moisture Content [%]	15.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Frame/Truss name non visible 1 See drawing THH-217C-2

Missing elements Elements with defects in critical area

Joints with decayed peg Insect attack

Failed joints Fungi attack

Other all timbers very wet

Element name A south rafter

Dating original construction Signs of reuse

Timber treated ☐ Accessibilityissues lower half not accessible

Past interventions

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13x8.7 min. size (hxb) [cm] 12x8.5 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 7 tangential

Knots [min d/section h] 5/8.5 single Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 lower than III

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☐ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a			
Moisture Content [%]	22.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b			
Moisture Content [%]	21.7	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c			
Moisture Content [%]	20.3	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name C upper collar

Dating original construction Signs of reuse

Timber treated ☐

Past interventions

Accessibilityissues partly buried under masonry dust

Differences compared to other elements of the same type

Section: nominal size (hxb) [cm] 13.2x9.5 min. size (hxb) [cm] 13x9 Single piece ☑ Jointed element ☐

Strength affecting defects

Pith location side Slope of grain [%] 3 tangential

Knots [min d/section h] Knotty element ☐ Defects in critical area ☐ Deep checks on both sides of element ☐

Other defects

Estimated Strength Class according to UNI 11119 I

Material degradation

Insect attack ☐ Type Status

Way of identification

Fungi attack ☐ Type Status

Way of identification

Corrosion ☐ Wet surface ☑ Other

Mechanical Damage

Type Status Role

Deformation ☐

Cracks ☐

Crushing ☐

Other ☐

Estimated level of damage Emergency interv. needed ☐

Mater.Degr. and Damage Extent

Way of identification



masonry dust on collar I:\Arc

Estimated causes of primary damage

Poor design ☐

Poor construct. ☐

Degradation ☐ Poor maintenance ☐

Past interv. ☐

External actions ☐

Other ☐

Measurement Point a

Moisture Content [%] 23.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 34.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 29.4	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Element name D lower collar

Dating: original construction | Signs of reuse:

Timber treated ☐ | Accessibilityissues: buried under masonry dust, very little visible

Past interventions:

Differences compared to other elements of the same type:

Section: nominal size (hxb) [cm] 10.7x12 | min. size (hxb) [cm] 9.5x12 | Single piece ☑ | Jointed element ☐

Strength affecting defects

Pith location: side | Slope of grain [%]: 7 tangential

Knots [min d/section h] | Knotty element ☐ | Defects in critical area ☐ | Deep checks on both sides of element ☐

Other defects:

Estimated Strength Class according to UNI 11119: I



masonry dust on collar | I:\Arc

Material degradation

Insect attack ☐ Type | Status | Way of identification

Fungi attack ☐ Type | Status | Way of identification

Corrosion ☐ | Wet surface ☑ | Other

Mechanical Damage

Type	Status	Role
Deformation ☐		
Cracks ☐		
Crushing ☐		
Other ☐		

Estimated level of damage | Emergency interv. needed ☐

Mater.Degr. and Damage Extent | Way of identification

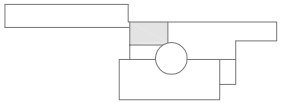
Estimated causes of primary damage

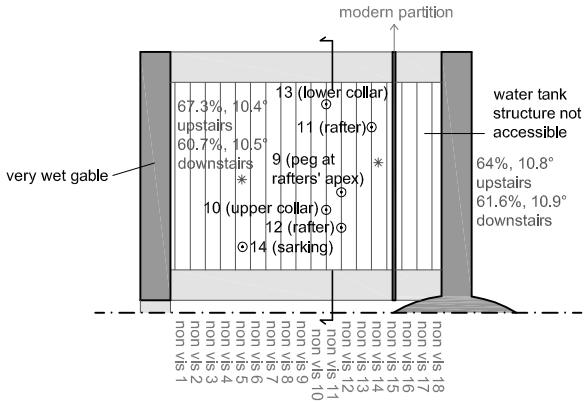
Poor design ☐ | Poor construct. ☐ | Degradation ☐ | Poor maintenance ☐ | Past interv. ☐ | External actions ☐ | Other ☐

Measurement Point a		
Moisture Content [%] 33.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point b		
Moisture Content [%] 26	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point c		
Moisture Content [%] 24.9	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐
Measurement Point d		
Moisture Content [%] 28.5	Visible Material Degradation ☐	Not Accessible for: hygrometer ☐

Plan 1:200

- ✳ air humidity and temperature
- ⊙ timber samples for species identification







Sections looking West 1:100

Visual inspection:
many small knots & diffuse insect exit holes on most timbers

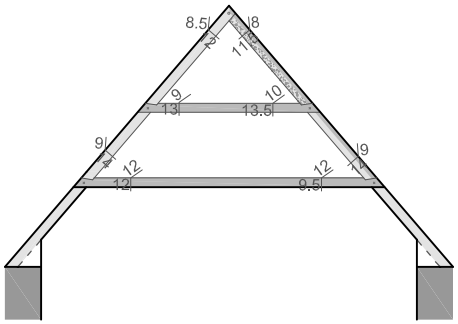
- open joint
- x:x element name : estimated strength class (na=less than 2 faces visible)
- wet surface
- fungl attack
- Insect attack

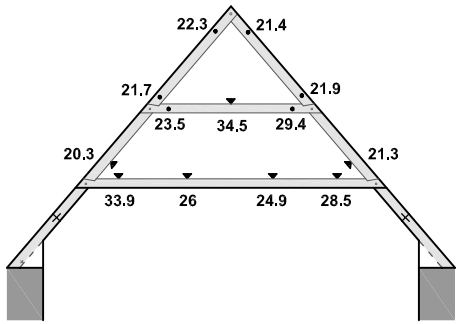
Moisture content readings:

- lower/upper/lateral face
- visible face
- rear face
- × not accessible

readings <18
readings >18
readings >20

Frame non vis 1





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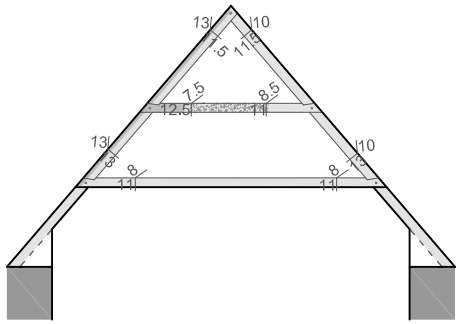

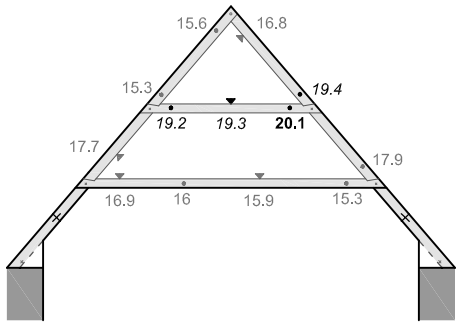

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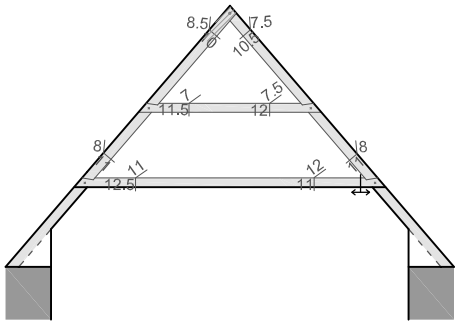

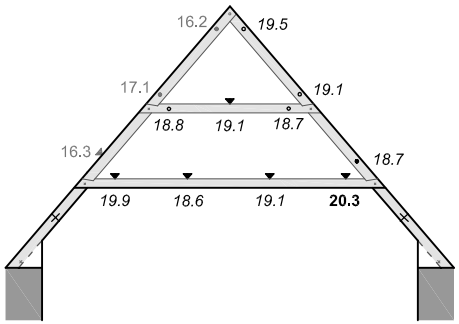

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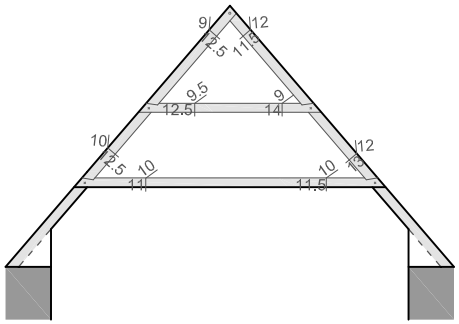

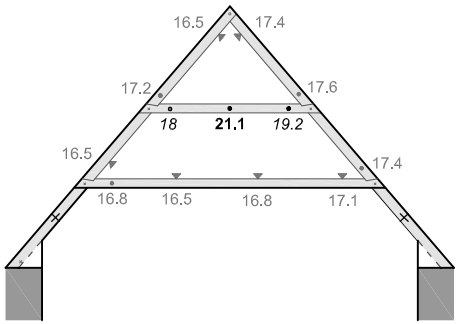



APPENDIX G

CONSULTED ARCHIVAL DOCUMENTS RELATED TO SEVENTEENTH- AND EIGHTEENTH-CENTURY TIMBER WORK OR WRIGHTS

ECA SL34/4/2 1706-1774. St Mary's Chapel Incorporation apprentices book. Edinburgh City Archives.

ECA SL 34/1/7 1740-55. St Mary's Chapel Incorporation record 1740-1755. Edinburgh City Archives.

ECA SL 34/4/1 1706-74. St Mary's Chapel Incorporation apprentices book 1706-1774. Edinburgh City Archives.

EUL LAII87/1A 1684-7. Holyroodhouse, Stirling Castle, Dumbarton Castle, Edinburgh Castle Vouchers of expenditures on works (1684-87). Edinburgh University Library.

EUL LAII87/2 1684-5. Repairing Holyroodhouse for reception of the High Commissioner (8 vouchers). Edinburgh University Library.

EUL LAII87/3 1685. Timber for Holyroodhouse (1 voucher). Edinburgh University Library.

EUL LAII87/6 1684-6. Wright work at Holyroodhouse and Stirling Castle (4 vouchers, 1684-6). Edinburgh University Library.

EUL LAII87/7 1686. Timber for Holyroodhouse and fees of carvers (4 vouchers, 1686). Edinburgh University Library.

EUL LAII87/8 1684. Works at council chamber, privy chamber and oratory at Holyroodhouse (2 items). Edinburgh University Library.

EUL LAII88/1/1 1733-4. Accompt of Carpenter work performed at the Abbay of Holyroodhouse by Robert Mowbray wright 1733-4. Edinburgh University Library.

EUL LAII88/1/8 1733-4. Accompt of large tree beams furnished to the roof of Holyrood 1733-4. Edinburgh University Library.

EUL LAII88/2 1735-6. Accounts of several artificers employed in repairing Holyroodhouse 1733. Edinburgh University Library.

EUL LAII88/3 1721-1805. Note of money paid for repairs on Holyroodhouse since the union (1721-1806). Edinburgh University Library.

GH DRAWING 1908. George Heriot's School. Proposed additional class rooms. Uncatalogued plan and sections showing the roof of the East and West ranges.: Private archive at George Heriot School.

GH REPORTS 1997. Reports on repair works carried out on the roofs of George Heriot Hospital. Private archive at George Heriot School.

HES CONDITION REPORT 1999. Uncatalgued report on Pinkie House condition survey. Historic Environment Scotland.

HES LETTER BY RENTOKIL 1973. Uncatalogued letter from Rentokil (Ratsouris Scotland Ltd) detailing proposed insecticidal treatment of main roofspace at Pinkie House and provision of a thermal quilt (July 1973). Historic Environment Scotland.

HES REPORT BY ADAMS 1954. HES uncatalogued technical report by Adams W R. Histioric Environment Scotland.

ML SHANKS 152/T6 1955. Survey of the Trades House of Glasgow and alterations by Wylie Shanks Architects *Wylie _Shanks Architects.* drawings ed.: Mitchell Library, Glasgow City Archives.

ML T-TH 1/1/7 1787-98. Trades House: docquetted minute book and Collectors' Accounts, Feb 1787 - 17 May 1798. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/1/12 1853-65. Trades House: docquetted minute book and Collectors' Accounts, 13 Oct 1853 – 8 Sep 1865. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/8/2 1855-7. Accounts of the Trades House. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/17/1 1791-98. Copies of Trades House Accounts in MSS 1711 – 1713, 1720 – 1817 and abstracts of same. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/34/1 1791-2. Estimates for building and plasterwork by masons, wrights and plasterers. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/34/3 Undated. The ceiling of the great hall in Glasgow Trades Hall. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/34/4 1878-83. New buildings proposed in 1883 & report of the building committee in 1878. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/40/7 Undated. The Craig family of Glasgow. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/97/2 1877. New design for Glasgow Trades Hall proposed by architects James Salmon and Son. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 1/97/3 1931. Plans and section of Glasgow Trades Hall by John Laird. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 5/19/15 1791. James Jaffray designs for the Trades Hall 8th June 1791. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 5/19/16 1792. Minutes of Building Committee 26th January 1792. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 5/19/17 1792. Minutes of Building Committee 10th March 1792. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 5/28/7 1795. Incorporation of Weavers: new tenement in Weaver Street – estimate for wright work by John Brown for the building proposed to be erected, 1 April 1795. Mitchell Library, Glasgow City Archives.

ML T-TH 9/4/2 1731-1811. Incorporation of Wrights: membership roll, 1731 - 1811. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

ML T-TH 9/4/3 1811-70. Incorporation of Wrights: membership roll, 1811 - 1882. *Glasgow Trades House.* Mitchell Library, Glasgow City Archives.

NLS ACC 70/56 1711-33. Box 1: Miscellanea from St Mary's Chapel Incorporation. National Library of Scotland.

NLS MS1646 Z.02/18A 1719. Stirling Castle, November 1719, plan and sections of the Palace, Jelfe Andrews (Architect) and Moore Thomas (Engineer) *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS1646 Z.02/18B 1719. Stirling Castle, November 1719, plan and sections of the Great Hall, Jelfe Andrews (Architect) and Moore Thomas (Engineer) *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS1646 Z.02/18D 1719. Stirling Castle, November 1719, plan and sections of ancillary buildings (chapel, powderhouse, ...), Jelfe Andrews (Architect) and Moore Thomas (Engineer) *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS1646 Z.02/47A 1752. Plan Elevation and Section of the Guard House in the Ravelin at Fort George, 1752, No.3. By William Skinner (engineer) and Charles Tarrant (draughtsman). *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS1646 Z.02/50A 1753. Plan and Elevations with Sections of the Barracks for 1600 Men and Officers Fort George. By William Skinner (engineer) and Charles Tarrant (draughtsman). *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS1646 Z.02/50B 1754. Plan Elevations and Sections of the North Pile of Barracks Shewing how High they were rais'd in the Year 1754. By William Skinner (engineer). *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS1647 Z.02/55A 1762. Plan Elevation and Sections of the Store-House for Provisions, and Barrack-Masters Stores 1762 by William Skinner (Engineer). *Military Maps of Scotland (18th century).* National Library of Scotland.

NLS MS10694 1757-9. Board of Ordnance account book for Fort George. National Library of Scotland.

NLS MS14493/37 1660. Transcription by Aonghus Mackechnie of works at Holyroodhouse. National Library of Scotland.

NLS MS14493/38 Undated. Transcription by Aonghus Mackechnie of account of materials left at Holyroodhouse. National Library of Scotland.

NLS MS14551/22 1729. Contract between W. Adam and the Marques of Tweeddale for works at Yester. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/24 Undated. Contract between W. Adam and the Marques of Tweeddale for works at Yester. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/109 1742-49. Contract between W. Adam and the Marques of Tweeddale for works at Yester. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/112 1742-48. Account of timber furnished by William Adam for Yester House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/115 1750. Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/116 1750. Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/126 1753. Letter from John Adam to the Marquess of Tweeddale. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/128 1753. Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/130 1750. Account of repairs done by John Adam probably at Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14551/137 1755. Letter from John Adam to the Marquis of Tweedale probably regarding Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14637 1667-75. Account of work by James Baine for the Marquis of Tweeddale at Tweeddale House, Yester House and Pinkie House. National Library of Scotland.

NLS MS14665 1750-6. Accounts by Thomas Dunlop for repairs to Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14680 1779-82. Works at Tweeddale House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS14716 1768-78. Repairs to roofs at Pinkie House. *Hay of Yester Papers.* National Library of Scotland.

NLS MS25783/77 1710. Transcription by Joe Rock of payments to various wrights for work at Newhailes House. National Library of Scotland.

NLS MS25783/144 1717. Transcription by Joe Rock of payment to John Young wright for work at Newhailes House. National Library of Scotland.

NLS MS25791/95 1720-1. Transcription by Joe Rock of payments to various builders for works at Newhailes House. National Library of Scotland.

NLS MS25818/42 1720. Account of John Young wright 1720. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25818/49 1721. Account of Andrew Cuthbertson slater 1721. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25818/50 1718. Account of John Young wright 1718. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25833/222 1709. Transcription by Joe Rock of account of work at Newhailes House by Edward Isaac wright. National Library of Scotland.

NLS MS25834/9 1710. Transcription by Joe Rock of account of stones furnished by John Young wright for Newhailes House. National Library of Scotland.

NLS MS25834/36 1710. Transcription by Joe Rock of account of work at Newhailes House by Edward Isaac wright. National Library of Scotland.

NLS MS25834/110 1711. Transcription by Joe Rock of account of work at Newhailes House by Edward Isaac wright. National Library of Scotland.

NLS MS25834/113 1711. Transcription by Joe Rock of account of deals furnished by James Sutherland merchant for Newhailes House. National Library of Scotland.

NLS MS25834/117 1711. Transcription by Joe Rock of account of deals furnished by James Sutherland merchant for Newhailes House. National Library of Scotland.

NLS MS25834/139 1711. Transcription by Joe Rock of account of work at Newhailes House by Edward Isaac wright. National Library of Scotland.

NLS MS25835/82 1715. Transcription by Joe Rock of account of work at Newhailes House by John Young wright. National Library of Scotland.

NLS MS25836/43 1719. Transcription by Joe Rock of account of work at Newhailes House by John Young wright. National Library of Scotland.

NLS MS25836/87 1719. Transcription by Joe Rock of account of slates furnished by Patrick Stewart for Newhailes House. National Library of Scotland.

NLS MS25836/206 1719. Transcription by Joe Rock of account of lead furnished by Joseph Forester for Newhailes House. National Library of Scotland.

NLS MS25836/208 1721. Transcription by Joe Rock of account of work at Newhailes House by John Young wright. National Library of Scotland.

NLS MS25836/224 1720. Transcription by Joe Rock of account of timber furnished by George Mackenzie for Newhailes House. National Library of Scotland.

NLS MS25836/236 1721. Transcription by Joe Rock of account of timber furnished by Thomas Curie for Newhailes House. National Library of Scotland.

NLS MS25836/237 1721. Transcription by Joe Rock of account of timber furnished by James Craig for Newhailes House. National Library of Scotland.

NLS MS25837/15 1722. Account of timber furnished by John Young wright for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/35 1722. Account of timber furnished by John Young wright for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/43 1721. Transcription of Joe Rock of account of work at Newhailes House by John Young wright. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/53 1722. Account of deals furnished by John Wilson for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/55 1722. Account of deals furnished by John Wilson for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/75 1722. Account of timber furnished by John Young wright for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/78 1722. Account of timber furnished by John Young wright for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/81 1722. Transcription of Joe Rock of account of timber for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/88 1721-2. Account of work at Newhailes House by John Young wright. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/101 1722. Transcription by Joe Rock of account of work at Newhailes House by John Young wright. National Library of Scotland.

NLS MS25837/109 1722. Account of timber furnished by John Young wright for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/131 1722. Transcription of Joe Rock of account of timber furnished by John Wilson for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/140 1723. Transcription of Joe Rock of account of work at Newhailes House by John Wilson. *Newhailes Estate Papers.* National Library of Scotland.

NLS MS25837/157 1723-4. Account of timber for Newhailes House. *Newhailes Estate Papers.* National Library of Scotland.

NRS CS96/2243 1736-47. Account book of Thomas Dunlop, wright, Edinburgh, 1736-1747, Court of Session processes. National Records of Scotland.

NRS DGD124/15/216/2 1701. Letter to the Earl of Mar from the Marquis of Annandale. Annandale has urged the Lords of Treasury to do something for the Castle of Stirling - 11 Apr [1701]. National Records of Scotland.

NRS E36/30 1671-1678. Sir William Bruce of Balcoskie: Holyrood, Stirling, Edinburgh, the Bass, 4 Mar. 1671-8 Jan. 1674, rendered 9 July 1674. National Records of Scotland.

NRS E37/24 1682. Estimate of materials required for reparation of Holyroodhouse, with notes of unfinished rooms their work to be done by Robert Mill under contract and of buildings and repairs necessary at Stirling Castle (1682). National Records of Scotland.

NRS E37/33 1699-1703. Duplicate account of work in Stirling Castle, bearing copy treasury warrant discharging Earl of Mar for sums required (1699-1703). National Records of Scotland.

NRS E661/107 1681. Forfeited Estates: Winton: Estater papers and vouchers prior to forfeiture: Accounts for timber bought for the Earl of Winton by David Balfour, his chamberlain (1681). National Records of Scotland.

NRS E661/107 1681. Forfeited Estates: Winton: Estate papers and vouchers prior to forfeiture: Accounts for timber bought for the earl of Winton by David Balfour, his chamberlain, 1681. National Records of Scotland.

NRS GD29/92 1671. Warrant by the Lords Commissioners of the Treasury to Sir W. Bruce of Balcaskie as Surveyor General to repair the roof and alleyways at Sterling Castle, provide for wright and glass-work of the rooms there (1671). National Records of Scotland.

NRS GD29/94 1679. Contract between Sir William Bruce of Balcaskie, Surveyor General, Sir William Sharpe of Stainiehill, the King's Cash-keeper, and Robert Mylne, the King's Master Mason, for the building and repair of Halyrudehouse (1679). National Records of Scotland.

NRS GD29/95 1673. Warrant by the Lords Commissioners of the Treasury to Sir William Bruce of Balcaskie, as Surveyor General to repair the Lord Chancellor's and the Duke of Hamilton's lodgings in Holyrudhous. Signed by the Lord Commissioners - 6/8/1673. National Records of Scotland.

NRS GD29/100 1678. Two copies of an order signed by Lauderdale terminating Sir William Bruce's appointment as Surveyor General, the building and repairing of Holyrudhouse [Holyroodhouse, Edinburgh] being completed - 30 May 1678. National Records of Scotland.

NRS GD45/18/1616/21 1694. Contracts between James, Earl of Panmure, and James Baine, the King's Master

Wright, for mason, wright, plaster and stone work at Brechin Castle. Petition by Baine defending his work. National Records of Scotland.

NRS GD45/18/1616/25 1694. Contracts between James, Earl of Panmure, and James Baine, the King's Master Wright, for mason, wright, plaster and stone work at Brechin Castle. Additional artickles of work done by Ja:baine (consented to) att brechin Castle and valued by Tobias bauchop november 1694. National Records of Scotland.

NRS GD124/11/37 1687. Letter to the Earl of Mar from the Privy Council, authorising him to repair roof etc of Stirling Castle. National Records of Scotland.

NRS GD124/15/207/3 1700. Letter to the Earl of Mar from the Earl of Seafield. Difficulty in obtaining money to repair Stirling Castle - 9 Apr 1700. National Records of Scotland.

NRS GD124/15/216/2 1701. Letter to the Earl of Mar from the Marquis of Annandale. Annandale has urged the Lords of Treasury to do something for the Castle of Stirling - 11 Apr [1701]. National Records of Scotland.

NRS GD124/15/471 1707. Letter to the Earl of Mar from Mr James Smith, surveyor of Her Majesty's works, in Edinburgh. He describes the dismal state of the Palace of Holyroodhouse and the Castle of Stirling (1707). National Records of Scotland.

NRS GD124/15/506/23 1707. Letter to the Earl of Mar from the Earl of Glasgow. Sensible of Mar's diligence in the above matter. Payment made for repair of Stirling Castle - 19 Jun 1707. National Records of Scotland.

NRS GD124/15/567 1707. Letter to the Earl of Mar from Col John Erskine, his step-father, at Alloa. Family matters. Negotiations with Balgowan. Repairs to Stirling Castle necessary - 16 May 1707. National Records of Scotland.

NRS GD421/5/2 1633-42. Records of George Heriot's Trust, Edinburgh, Accounts and other Financial Papers of George Heriot's Hospital and Trust, Treasurer's accounts. National Records of Scotland.

NRS GD421/5/3 1642-52. Heriot’s Hospital Treasurer’s Accounts 1642-1652. National Records of Scotland.

NRS GD421/5/4 1652-69. Heriot’s Hospital Treasurer’s Accounts 1652-69. National Records of Scotland.

NRS GD421/10/68 1685. Detailed account and discharge by Thomas Sandilands, wright, to the treasurer of George Heriot's Hospital for £683 Scots for timber and wright work performed on the chapel and lodge (or summer house) in the Easter garden, 16 Jan 1685. *Records of George Heriot's Trust, Edinburgh, Administrative records of Heriot's Hospital and school statutes, foundationers, staff building, housekeeping.* National Records of Scotland.

RCAHMS DP 043860 1959. Neidpath Castle Digital copy of west elevation and section looking East and North elevation and section looking South. Copy of PBD 258/19.: Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS DP 043862 1964. Neidpath Castle Reconstruction drawing: first floor plan. Copy of PBD 258/29.: Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS DP 055037 1891-2. Sections through quadrangle including interior elevations of chapel, dining hall and classrooms. Title: 'GEORGE HERIOT'S HOSPITAL EDINBURGH'. Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS DP 143824 2012. Oblique aerial view of Drochil Castle, looking to the E. *RCAHMS Aerial Photography Digital.* Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS DP 161383 2013. Darnaway Castle. Ground floor. Hall. Hammerbeam roof.: Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS DP 222837 2015. Oblique aerial view of Darnaway Castle, looking NE. *RCAHMS Aerial Photography Digital.* Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS DPM 1940/110/4 1948-52. Heating plans. Plans and details of West wing affected by dry rot. Plans, sections and details of roof.: Royal Commission on the Ancient and Historical Monuments of

Scotland.

RCAHMS LOR/M/17/5 1953. Plans and elevations showing additions and alterations. Details showing new floor to painted gallery. Details showing roof over painted ceiling and catwalk.: Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS LOR/T/1/5 1928. Plans, sections and elevations of verandah, repairs to North wing roof and coal cellar. Plans and sections of new drive and forecourt. Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS MLD 69/29 1947. Pinkie House. Section and elevations. Copies C 39421 P, C 39421 S.: Royal Commission on the Ancient and Historical Monuments of Scotland.

RCAHMS SC1202662 Undated. Dundee, Claypotts road, Claypotts Castle. View of plans of castle. Copy of A 50130.: Royal Commission on the Ancient and Historical Monuments of Scotland.

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APPENDIX I

PAPERS PUBLISHED BY THE AUTHOR RELATED TO THE PHD RESEARCH

SERAFINI, A. & GONZALEZ LONGO, C. 2015a. The design and construction techniques of eighteenth century timber roofs in Scotland: Glasgow Trades Hall and Tweeddale House in Edinburgh. *In:* BOWEN, B., FRIEDMAN, D., LESLIE, T. & OCHSENDORF, J. (eds.) *5th International Congress on Construction History.* Chicago.....1123

SERAFINI, A. & GONZALEZ LONGO, C. The Roof Structure of George Heriot's Hospital Chapel and the Roof Design of its period in Scotland (in review). The architecture of Scotland in its European setting: 1660-1750, 2015b Edinburgh.....1131

SERAFINI, A. & GONZALEZ LONGO, C. Seventeenth and eighteenth century timber roof structures in Scotland: design, pathologies and conservation. *In:* VAN BALEN, K. & VERSTRYNGE, E., eds. 10th International Conference on Structural Analysis of Historical Constructions, 2016 Leuven. Taylor and Francis. 1144

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THE DESIGN AND CONSTRUCTION TECHNIQUES OF EIGHTEENTH CENTURY TIMBER ROOFS IN SCOTLAND: GLASGOW TRADES HALL AND TWEEDDALE HOUSE IN EDINBURGH

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Scotland, Timber, Roofs, Structures, Eighteenth Century, Wright

Abstract

The few open roofs mentioned in literature seem to represent an exception rather than the rule: most Scottish timber roofs are hidden behind timber or plaster ceilings and characterised by a much simpler common rafter form. From the eighteenth century onwards they presented hipped and trussed arrangements as well as other more complex solutions developed to meet the requirements of evolving architecture. This paper attempts to shed some light on the design and construction techniques of eighteenth century Scottish timber roofs with the preliminary results obtained from the creation of a relational database of 1250 buildings (including structures, professionals, dates), related mapping, survey of 29 roofs across Scotland and a more detailed study of those at Tweeddale House in Edinburgh, and Glasgow Trades Hall. Both buildings have roofs from the period in which the Adam brothers worked on them as architects. The original sixteenth century Tweeddale House was remodeled by the Adams in 1752-3 and almost forty years later Robert Adam designed the Glasgow Trades Hall (1791/4), although the building was completed after his death with a modified design. Archival research combined with surveys has allowed to make an initial appraisal of the design and construction processes involved in the two projects. Many questions arise concerning the specific involvement of architects and wrights in the successive transformations of the roofs and an attempt to identify local and foreign influences has been carried out by analyzing the typology of roofs and joints.

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INTRODUCTION

Scottish roof structures seem to have been a neglected area within the construction history studies. Emerging research (Hanke 2006, Newland 2010, Crone and Mills 2012) has started to shed some light, although it is still fragmented. The main focus so far has been on spectacular open structures (Stell and Baillie 1993) or on roof structures up to 1647 in a restricted geographical area (Hanke 2006).

Our ongoing research considers a more comprehensive geographical area (Scotland) and chronological period (seventeenth and eighteenth centuries). This paper presents some initial results on the design and construction techniques of eighteenth century Scottish timber roofs. From an extensive relational database of 1250 buildings, a selection of 29 groups of buildings has been surveyed throughout Scotland. From these, Tweeddale House in Edinburgh, and Glasgow Trades Hall, both with a distinctive construction phase by the Adam family, have been identified as suitable case studies to start understanding the origin, development, influences and authorship of Scottish roof structures.

SEVENTEENTH CENTURY TIMBER ROOFS IN SCOTLAND

Although the evidence for medieval Scottish carpentry is scarce, the few surviving roofs seem to testify Scotland was aligned with the English tradition of hammer-beam roofs (Hanke 2006). From the sixteenth century onwards, as suggested by Hanke and confirmed by our own surveys, most Scottish roofs are gabled with a simple, closely spaced, common rafter form and their structure is hidden behind timber or plaster ceilings. They are A-shaped frames of square uniform scantling with no distinction between principal and common rafters. There is absence of wall-plates, tie-beams and purlins. The longitudinal rigidity is assured by the gable walls and the sarking: two layers of sawn deals that run horizontally and vertically and comprise in-between a sort of fleece for insulation. Additional rigidity is sometimes provided by the rafter foot whose ashlar post is extended downward on the masonry. Joints are mortice and tenon, or lapped. Dovetail joints appeared in Scotland only by the end of the seventeenth century.

This common rafter form is part of the Romanesque Northwest European school of carpentry. The use of sarking and the rafter foot, and the absence of wall-plates and purlins, are nevertheless distinctive Scottish features (Hanke 2006). Remarkably, this characteristic common rafter form is found in Scotland up to the eighteenth century, whilst side purlins and queen/king struts in England (Hewett 1980) and trestle-based structures in Continental Europe (Ostendorf 1908, in Hanke 2006) had already been introuced since the thirteenth century.

THE INTRODUCTION OF THE TRUSSED ROOF IN SCOTLAND

Before classical architecture became the norm in Britain, both English and Scottish wrights (carpenters) understood timber elements in roofs as behaving in compression and refrained from using tension-absorbing elements to counteract the tie-beam deflection, as was instead common practice in Italy (Valeriani 2005). With the introduction of classical architecture in England by Inigo Jones (1573-1652) hipped roofs, mansard roofs, domes and other complex arrangements started being used. Gable walls disappeared and roofs had to be shallower and cover bigger spans; local traditional roofing methods became inadequate and the trussed roof had to be adopted (Yeomans 1992). The simpler trussed roof form, the king-post truss, has a central vertical element suspended from the apex of the 'timber arch' formed by the principal rafters; in this way the post acts as a tie and supports the tie-beam, preventing its deflection. Whilst the first English

trussed roofs can be seen in Jones' buildings, Sir Christopher Wren's later designs were undoubtedly the most innovative and influential (Yeomans 1992). They were both influenced by Italian treatises (Valeriani 2006).

Classical architecture arrived in Scotland in the seventeenth century with Sir William Bruce and James Smith who built the first hipped and mansard roofs but still using common rafter roofs. Since they often remodeled old buildings, they benefited from intermediate spine walls reducing the roof span, as in Holyrood Palace (1671-9) or Dalkeith House (1702-11). The first known drawing of a trussed roof for a Scottish building is the 1720's William Adam's New College Library in Glasgow (Hanke 2012) with a simple king-post roof (fig. 1). The joggles shown at the top and base of the king-post can also be found in English roofs of the period (Yeomans 1992). Joggles are shown in some Italian treatises: 1449 Mariano di Jacopo (Barbisan and Laner 2003) and 1600 Serlio. Since William did not visit London until 1727, it is likely that his reference was the copy of Serlio's treatise he owned (Rowan 1990), which illustration also shows the post dovetailed in the tie-beam (fig. 2). Unfortunately the building has now disappeared so it is not possible to see if this design was realised. Other of Adam's buildings of the period, such as Duff House (1735-40) and Arniston House (1726-33), do not have trussed roofs. This brings to the hypothesis that Adam's design intention to build trusses clashed with the lack of familiarity of local wrights with these emerging structures.

The earliest trussed roofs we have identified so far in Scotland are Oakshaw Trinity church in Paisley (1754-6), a queen-post roof (approx. 20m), whose arrangement suggests an inspiration from Wren's St Michael's Paternoster Royal (1690), and Auchinleck House (1755), a king-post roof (approx. 10m) with a curious 'bulb' shape at the top of the post (fig. 6).

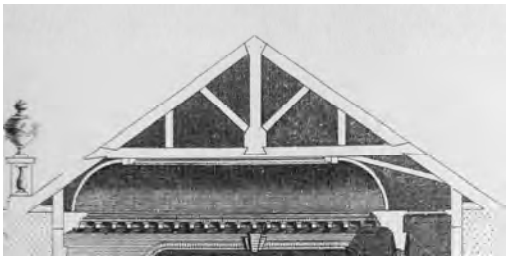

Figure 1: W. Adam's design for the Glasgow New College Library, 1720 (Adam 2011)

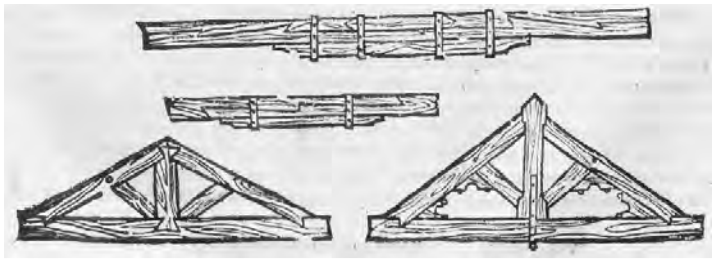

Figure 2: A post with joggles and a post dovetailed in the tie-beam as shown in Serlio (1600)

Common rafter roofs anticipating the trussed system: Tweeddale House in Edinburgh

The introduction of the trussed system in Scotland was slow and gradual: many eighteenth century roofs still show a common rafter form. A good example is Tweeddale House's roof. The house was built in sixteenth century as a small rectangular single pile mansion, with a projecting stair tower, and around 1600 it was extended to the north, transforming it into a double pile (Gifford 1984). Throughout the seventeenth century it was renovated and in 1750-6 the 4th Marquess of Tweeddale commissioned its reconstruction to John and Robert Adam (Gifford 1984). Deacon Thomas Dunlop, who had previously done other works for the Marquess (NRS CS96/2243), was the wright and contractor. The roof was completely dismantled and rebuilt (NLS MSS.14665). Some repair works were done later in 1779-82 (NLS MSS.14680) and in 1791 the house was extended to the west (fig. 3).

Although only partly visible today we can appreciate that the structure is the one reconstructed by Dunlop in 1750-6. Additional rafters (fig. 3, f) have been later added on top of it, perhaps

as part of the 1779/82 works to stop water ingress from damaging the bottom part of Dunlop's rafters, which had in fact to be substituted with prosthesis during the works in 1980s.

Tweeddale's roof retains many features of seventeenth century common rafter roofs. The pitch is steep (40°) compared to contemporary trussed roofs, such as Oakshaw Trinity church (34°) (fig. 4). The frames are very closely spaced (50cm max) and they do not have tie-beams nor wall-plates, like in Balcaskie House (1668). Though the span is quite wide (11.4m), due to its double pile configuration, a spine wall reduces it to 6.2m, just like in Holyrood Palace (1671).

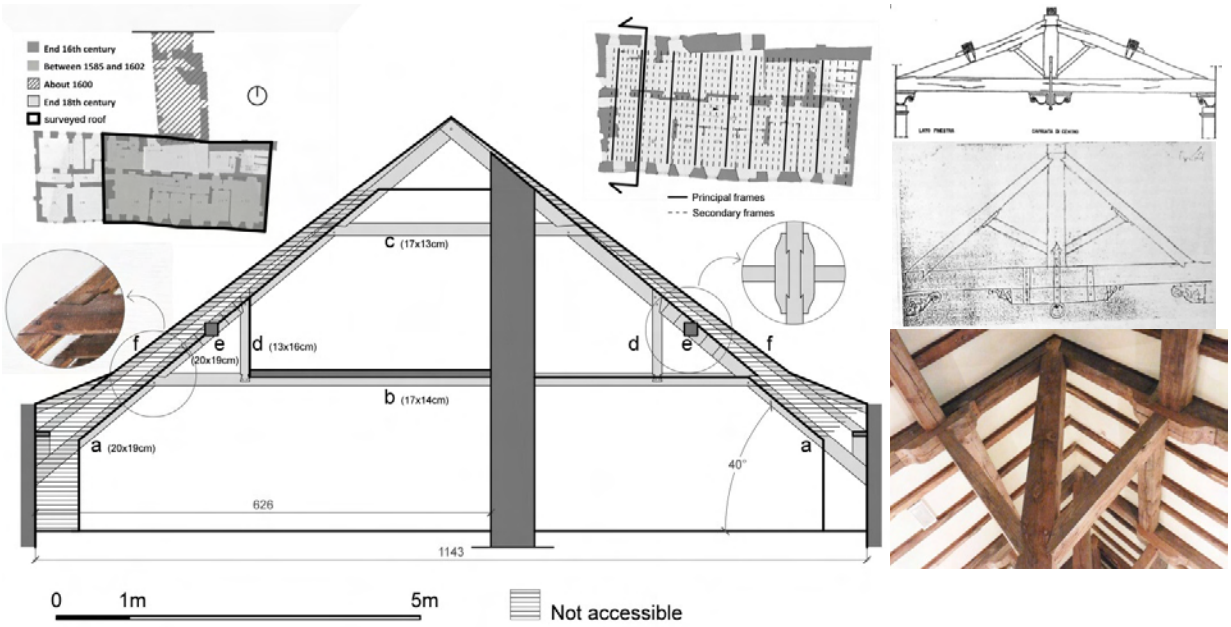

Figure 3: On the left the transversal section of Tweeddale house roof structure with reference plan (Anna Serafini); on the right from top to bottom cleats used in church of Sant'Agata di Mugello in Scarperia, Florence (Tampone 2001), a truss drawn by Mariano di Jacopo (1449 in Munafò 2002), Brodie Castle Stables (Anna Serafini)

Other features of the roof anticipate the emerging trussed system. The frames are divided in principal and secondary frames. Two purlins (fig. 3, c), one on each side, connect the principal frames together: they are tenoned in cleats (fig. 3, d) that are in turn dovetailed on the sides of the rafters to reinforce their section where the purlins abut. Whilst purlins are normally employed in trussed roofs, cleats seem to be a more common feature in Italy, in both buildings and treatises (fig. 3). In Scotland we have identified them also in Oakshaw Trinity church and in Brodie Castle stables (end 18C) (fig. 3). Other interesting features are the two vertical struts (fig. 3, e), one on each side, hanging from the rafters and giving additional support to the raised tie-beam. These tension-absorbing members suggest an awareness of the problem of beam deflection, and can be seen as an antecedent of king/queen-posts (Hanke 2008). They appear also in Stirling Castle Palace (Hanke 2008 suggests beg. 18C) and Newhailes House (1730). However, the solution does not show a full understanding of their role as they create additional load on the rafters. The use of dovetail joints shows awareness that the jointed elements act in tension.

We do not know who designed this roof. John and Robert Adam, the architects in charge, were also working at Yester House for the Marquess at the time (Dunbar 1972) and this could explain why Dunlop had a wider commission in the building, as wright and masonry contractor (NLS MSS.14665). Dunlop had been apprentice to John Montgomery in Mary's Chapel, the incorporation of masons and wrights, from 1700 to 1711 (ECA SL 34/4/2). He was probably one

of the foremost wrights in Edinburgh at the time: he was Deacon of the incorporation and had eight apprentices through his life (ECA SL 34/4/2). The exact role of wrights in Scottish projects at the time needs further research. The word 'wright' has disappeared from English construction vocabulary, superseded by 'carpenter' (for heavier structural work) and 'joiner' (for furniture and fittings). The Oxford English Dictionary defines 'wright' as a generic "constructive workman" or "one who deals with wood, a carpenter, a joiner". In fact wrights in Scotland used to deal with all the timber work, from roofs, to flooring, to windows, furniture, etc., and started working as contractors in the seventeenth century (Dunbar 1976, Newland 2010), just like carpenters in England (Yeomans 1992). Their role was increasingly important in the construction site, and they outnumbered masons in the incorporation (ECA SL 34/4/2). It is therefore reasonable to think that in case of minor works, such as Tweeddale House, the roof structure was both designed and built by Dunlop.

Scottish trussed roofs: Glasgow Trades Hall

The brothers Adam's earliest trussed roofs known in Scotland are in Fort George: the Museum and Staff block (1762), the Ordnance Store (1759/61) and the Chapel (1763) (fig. 4). In all of them, the purlins are misplaced as they should be where the struts meet the rafters, in order to avoid additional load. Again it is not easy to conclude who might have designed these roofs. At the time only John was in Scotland, Robert, James and William were in London. William had died in 1748 but he may have brought skilled English carpenters from his London trip. Lewis (2006) noted that in 1760s-70s his son Robert hired men in London whose names are found in the Edinburgh New Town ten years later. Another possible source could have been Price's new treatise (1733) at the Adams' library (Rowan 1990). This could explain the misplaced purlins, since Price never showed the purlins' location in his drawings.

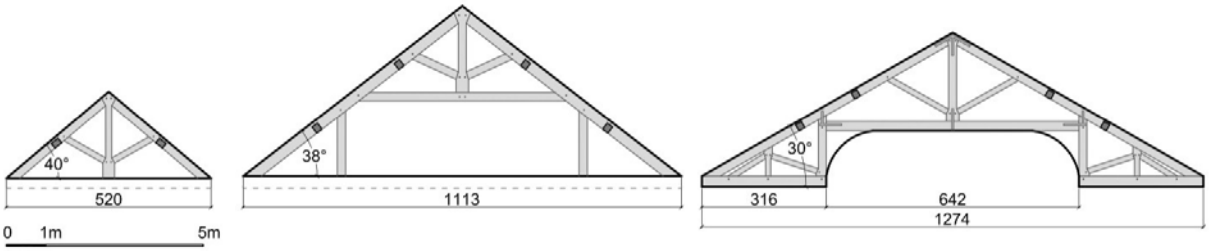

Figure 4: Roofs at Fort George, from left to right: Staff block (1762); Ordnance Store (1759/61); Chapel (1763) (Anna Serafini); the graphic scale relates to all drawings.

Further considerations can be made by comparing Robert Adam's design for Glasgow Trades Hall (1791-4) with the structure built after his death in 1792 (fig. 5). Adam's design was chosen by the Trades Incorporations in 1791 through an invited competition between him, James Jaffray and John Craig (GCA T-TH 1/1/7). The extra land required for Adam's additional lateral wings was never bought: the design for a building ca. 33.5m long had to be adapted to a plot only 30.5m long. If we compare Adam's drawings with the present structure (fig. 5) we can see the overall proportions distorted and the diameter of the dome dramatically decreased (Sutherland 2005). After Robert's death, the wright John Brown was appointed contractor under the supervision of James and William Adam (GCA T-TH 1/1/7) who did not seem to have been involved in the design process. It seems therefore reasonable to think Brown took on a leading role in the works.

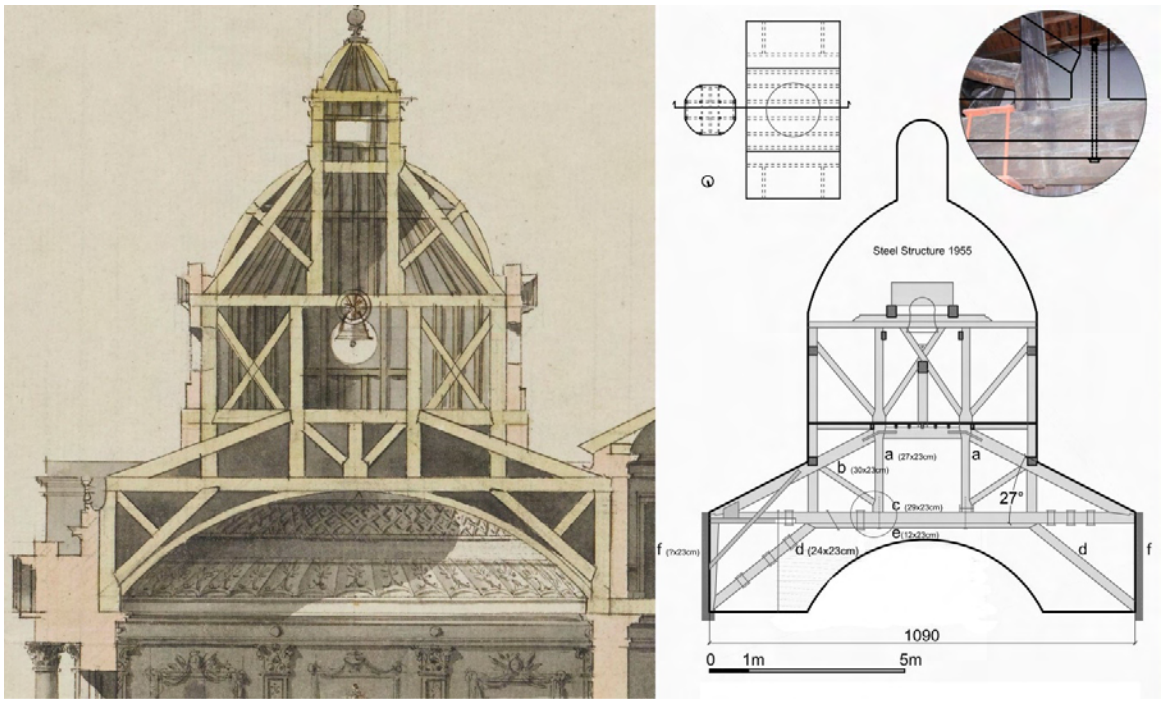

Figure 5: Transversal section of the roof structure at Glasgow Trades Hall, as designed by R. Adam on the left (SM Adam vol.48/25), and as built on the right (Anna Serafini); the graphic scale relates to both drawings.

The present structure (fig. 5) is composed of 8 parallel queen-post trusses; the 4 middle ones support a drum, dome and lantern above, and leave space for a dome below (originally wider). The span is not excessively wide (10.9m) but the structure is quite tall (10.5m below the lantern). The joints are correctly designed with joggles and iron straps so that the queen-posts (fig. 5, a) hang from the principals (fig. 5, b) and support the tie-beam (fig. 5, c). The bottom of the post is connected to the tie-beam with a system of cotters and folding wedges passing through the elements (fig. 5): a detail developed in England at the beginning of the nineteenth century, according to Yeomans (1992). It could thereafter be one of the very first uses of this device. The trusses sit on a lower 'arch' system, formed by two slanted braces (fig. 5, d) and a horizontal beam (fig. 5, e). The slanted braces spring from the base of timber posts (fig. 5, e) that are partly (on the left) or completely (on the right) embedded in the walls. On these posts sit the tie-beams.

This is one of the two weak points of the structure. The lateral posts and the wall-heads behind them are unable to counteract the horizontal thrust coming from the truss above. The lower 'arch' system partially opened in time and wooden wedges had to be inserted between the slanted braces and the horizontal beam. The wall-head was reconstructed and steel rods and plates were added with the same purpose. The other weak point is the insufficient longitudinal rigidity. Even though the sarking is still employed, the trusses do not rest on wall-plates - or if they do, they are embedded in the wall and therefore probably rotten - and they only have a few purlins connecting one to the other. This is probably why the dome structure had to be replaced in 1950s with a new steel structure (GCA Box 152 Drawing T6/7).

The structure drawn by Robert Adam in 1791 (fig. 5) shares the above mentioned critical points and also shows an improper design of the joints, which causes the posts to behave in compression, enhancing the tie-beam deflection instead of counteracting it. The built structure has some faults but it shows a better understanding of the trussed system and its construction details.

We do not have evidence of who designed this dome, the first in Glasgow, and little information could be found on John Brown, the wright/contractor at the Trades Hall, from whom no other building seems to remain. Brown was member of the Glasgow incorporation of wrights from 1790 until his death in 1816 (GCA T-TH 9/4/2 and T-TH 9/4/3). His appointment as contractor for such a major work as the Trades Hall only one year after becoming a member of the incorporation suggests he could have been brought from elsewhere by the Adams.

CONCLUSIONS

The existence of an independent Scottish school of carpentry has been denied by scholars such as Ostendorf (1908, in Hanke 2006) and Yeomans (1992). Overall conclusions are hindered by the lack of a more systematic research about the roof structures of the period. However, an outlined picture is emerging which shows characteristic patterns and practices in Scotland.

Hanke (2006) has identified distinctive Scottish features in sixteenth and early seventeenth centuries roof structures: the persistent use of the common rafter form, the sarking, the rafter foot, the absence of purlins and tie-beams. Thanks to the survey of the 29 groups of buildings, and the further research and study of Tweeddale House in Edinburgh and Glasgow Trades Hall, both by the Adam family, some initial conclusions can be tempted on the development of roofs in Scotland in eighteenth century, including when, how and by whom trussed roofs were introduced. Trussed roofs start slowly appearing from mid eighteenth century in Scotland. Whilst there is an unquestioned English influence in their arrangements, some details seem to indicate other sources. The 'joggle' detail, found in most Scottish structures, has been always considered a distinctively English feature but could originate from Serlio (1600). Moreover, examples as Brodie Castle Stables, show that notches were used as well as joggles (fig. 3). The characteristic Scottish sarking remains in use, even though butt-purlins are introduced. Cleats, extensively used in Italy too, reinforce the elements' section in critical points. King-posts sometimes have a "bulb" shape at the top, a detail whose origin remains uncertain so far (fig. 6).

The Adams knew the trussed roofs thanks to treatises and pattern-books in their library, and to their travels to London and Italy. Nevertheless, their drawings often show little understanding of the trussed system. William was the first to draw a trussed roof for a Scottish building in 1720, but none of the Adams buildings in the first half of the eighteenth century has trussed roofs. This brings to the hypothesis that, at least in the case of the Adam family, the design of roof structures was responsibility of the wright, rather than the architect. Although architects aspired to build trusses, it seems that at the beginning wrights were unable or unwilling to construct them. An external influence, from England and/or beyond, was necessary for the eventual establishment of trussed roofs in Scotland, as suggested by the heterogeneity of solutions and details.



Figure 6: The "bulb" shape at the top of the posts in (from left to right) Aunchinleck House (1755); Stirling Tolbooth (1785); Culzean Castle (end 18th century) (Anna Serafini)

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The Roof Structure of George Heriot's Hospital Chapel and the Roof Design of its period in Scotland

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ABSTRACT

The great developments in seventeenth- and eighteenth-century architecture in Scotland corresponded to a gradual development of roof construction techniques and structural arrangements: the challenge was to pass from large spans covered by open purlin structures, to large spans covered by shallower roofs carrying heavy plaster ceilings. Whilst the few remaining Scottish open purlin roofs have been widely investigated, little research has been carried out on the roof structures hidden behind timber and plaster ceilings, which, according to our surveys, are the vast majority in Scotland in that period. This paper investigates the timber roof structure of George Heriot Hospital's Chapel in Edinburgh, an original seventeenth-century common rafter roof with later alterations, and compares it with earlier and later examples in order to discuss the development of Scottish roof structures during the period, looking at the different constructional arrangements, the design process and the influence of the timber trade with North-East Europe.

1. INTRODUCTION

Timber roof structures in Scotland, as in other places, have been scarcely researched due to their location - hidden behind decorated timber or plaster ceilings. This has created a lack of awareness of their structural, technological and cultural importance. Despite recent contributions[1], it is still difficult to establish the extent and nature of historic timber roofs in Scotland, and to understand whether they are the result of local or international influences, or both. The authorship of these structures and the identity of wrights (Scottish for 'carpenter') also remains an unexplored aspect.

In Medieval times, large spans were covered in Scotland by open purlin structures such as the one in the fourteenth-century Darnaway Castle[2]. These structures have been extensively researched, because they are visible and quite spectacular. Nevertheless, the challenge for seventeenth- and eighteenth-century wrights was to pass from open purlin structures to shallower structures capable of supporting heavy plaster ceilings, which became fashionable at the time; little research has been dedicated to these hidden roof structures, although they are actually the vast majority of structures remaining in Scotland. Hanke has researched some of these, up to the mid seventeenth century, in Midlothian[3], primarily relying on previous literature and archival material but nevertheless conveying a valuable contribution. Newland[4], Thomson[5] and Crone[6] have instead researched about the timber sourcing and trade during seventeenth and eighteenth centuries, providing us with extremely helpful information on the timber species employed and their provenance.

This paper aims to build upon these previous valuable studies and start tracing the development of timber roof structures in Scotland. The work is part of a wider research on seventeenth- and eighteenth-century Scottish built heritage being carried out by the Architectural Design and Conservation Research Unit (ADCRU), within the Department of Architecture of the University of Strathclyde (Glasgow). Roof structures from the period have been identified as a priority area of research. A sample of 74 timber roof structures in 56 buildings has been surveyed, selected from the ADCRU database now including 1600 Scottish buildings from seventeenth and eighteen centuries. The development of roof structures in Scotland through these two centuries is discussed by looking at the roof structure of George Heriot's Hospital Chapel and comparing it with earlier and later examples, considering the different constructional arrangements, the design process and the influence of the timber trade with North-East Europe.

2. THE ROOF STRUCTURE OF GEORGE HERIOT'S HOSPITAL'S CHAPEL

The roof structure of the Chapel in George Heriot's Hospital (1628-84) illustrates well the impressive development that Scottish timber roof structures achieved through seventeenth and eighteenth centuries. At first it seems to be composed simply of closely spaced (about 30cm) rafter couples, with two collar beams connecting each couple transversally and slanted braces supporting the ceiling (Figure 1). The rafters are connected longitudinally by thick timber boards ('sarking' in Scottish), forming a continuous surface on which the lead is fixed with metal nails. Almost like an upside-down ship. The connection with the wall is not visible, unfortunately. The roof is quite steep (about 50°) but not excessively large (the span is 6.8m). The timbers are hand-axed softwoods connected with mortice and tenon joints secured by timber pegs. Big roughly sawn roman numerals mark all the frames, though not in sequence.

Walking through the roof space, it becomes clear that something different happens in the central part of the roof: here the structure is supported by two additional low-pitched queen-post trusses, inserted in-between the original timbers (Figure 2). The timbers composing these trusses have much bigger sections and have been machine-sawn. They are connected again with mortice and tenon joints, but secured with iron straps. The tie-beam is composed of two elements, joined with a scarf joint. Small neatly chiseled roman numerals mark each piece of timber. Two longitudinal purlins sit on top of the trusses and support the upper collar beams of the original roof. Two other purlins hang from the trusses - supported by iron rods and plates - and support the rafters of the original roof, which have been cut.

Although these trusses are clearly a later addition, their date remains uncertain, as well as the reason for their insertion. None of the roof timbers have been analysed with dendrochronology, the only technique that can identify precisely their date and provenance. Nevertheless, the analysis of available evidence and the comparison with earlier and later examples can help in drawing some possible conclusions.

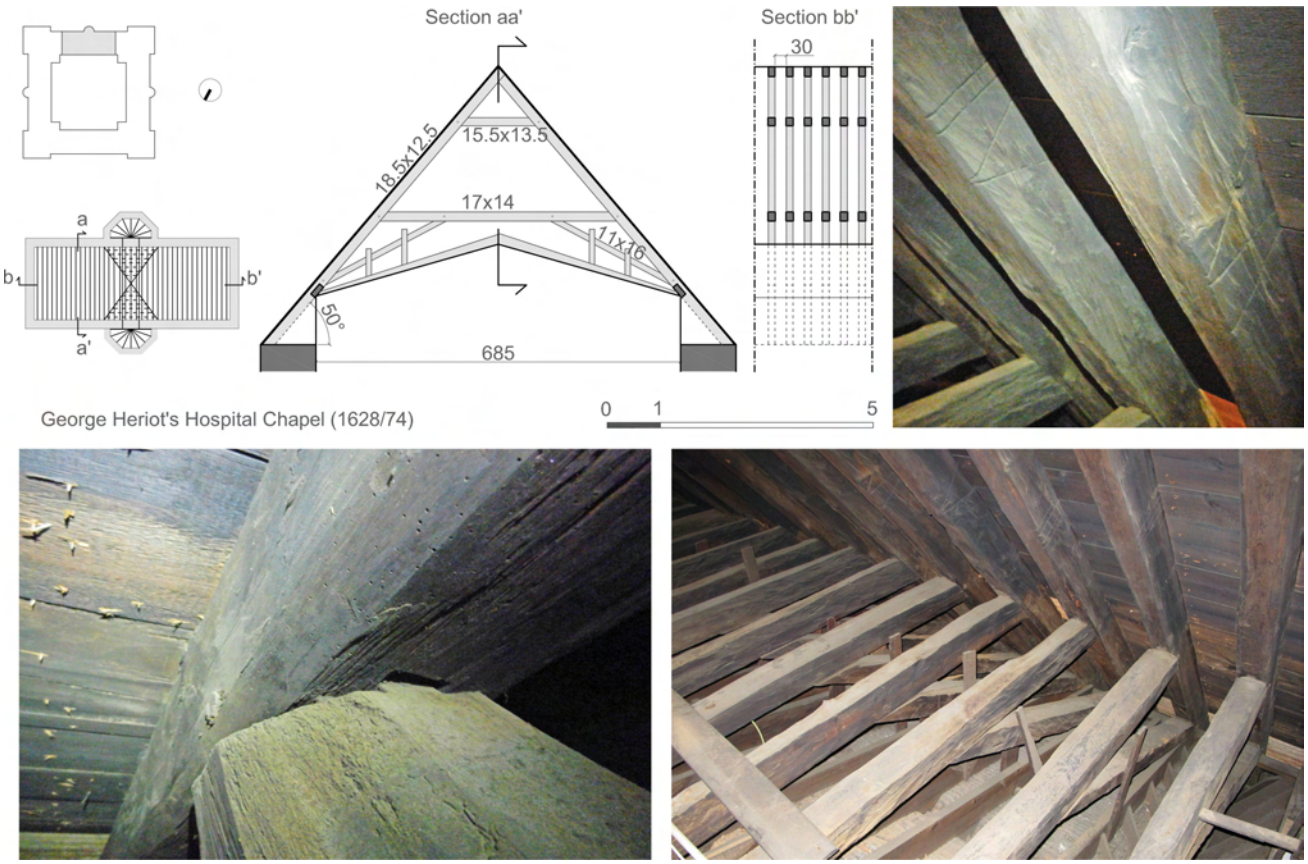

Figure 1. The common rafter roof covering the Chapel of George Heriot's Hospital (1628-74) (A.).

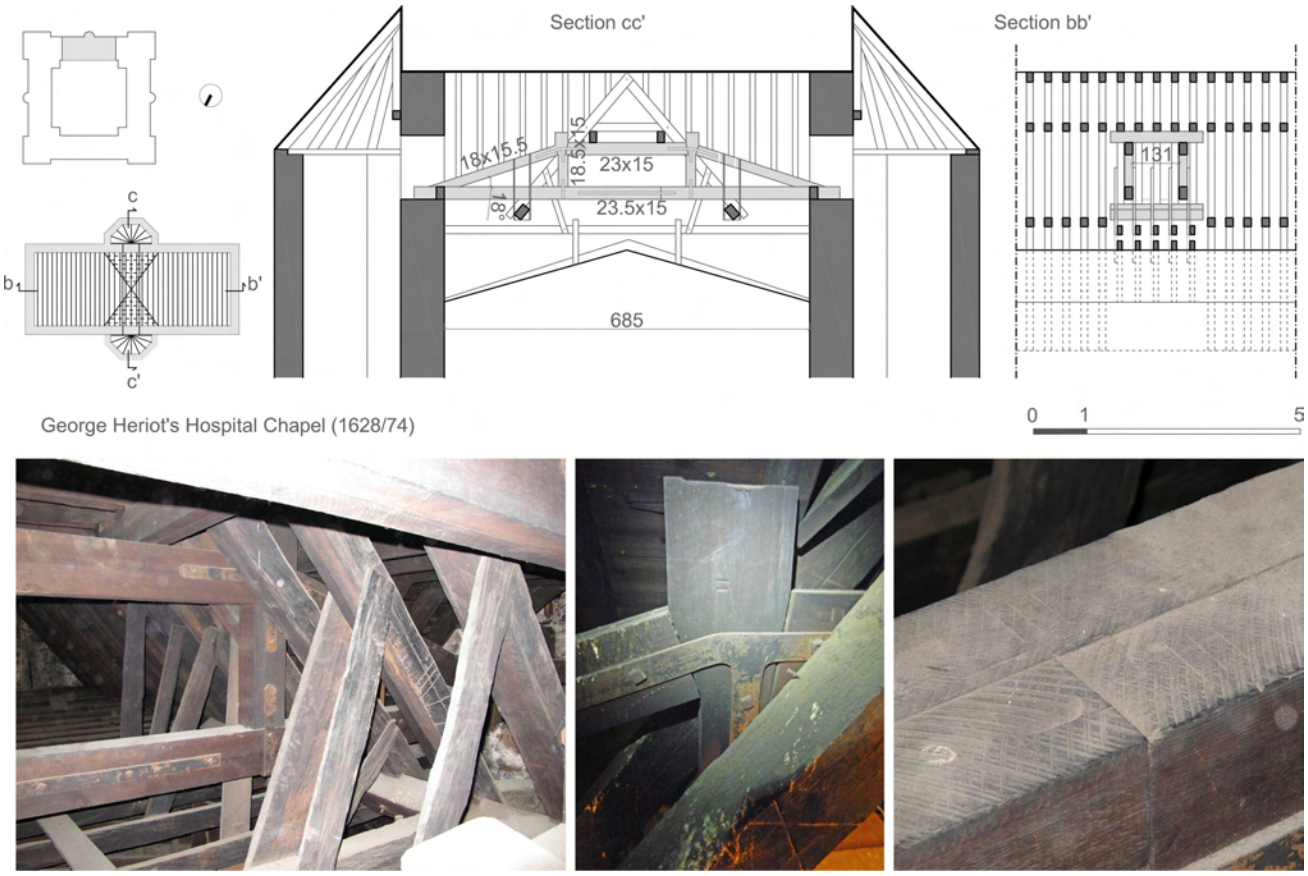

Figure 2. The trusses in the central part of the roof of George Heriot's Hospital Chapel (1628-74) (A.).

3 THE TIMBER SOURCING AND THE DESIGN PROCESS: NORWAY AND ROYAL MASTER WRIGHT JOHN SCOTT

Timber for works at George Heriot's Hospital was brought from Dalkeith, but large timber was imported from Norway[7]. This was a common practice from early sixteenth century up to early eighteenth century[8]. In fact, in 1503 the parliament declared that Scotland's woods had been 'utterly destroyed' and Acts were passed to protect local woods from over use. There were also accessibility problems and Scottish timber had a reputation for being of poorer quality compared to imported timbers, which where thus preferred[9]. Typical cuts of timber bought by the Scottish skippers from Norway included sawn boards for the sarking (deals), and beams between 4.4-11.4m in length for the rafters/collars, of either redwood (scots pine) or whitewood (common spruce)[10]. Scots pine is stronger than spruce and was therefore preferred for structural work. Such timber products were exactly what was needed to make a roof like the one covering George Heriot's Chapel: boards for the sarking and pine beams less than 7m in length (the longest timbers in George Heriot's are the rafters: 6.9m).

In December 1633 the mason John Ronald was paid for lintels for the wall-heads of the Chapel of George Heriot's Hospital[11]. In the same moment the Hospital's governors decided to cover the Chapel with lead[12] and in 1635 the work was contracted to John Bland, an English plumber from Newcastle[13]. In early 1637 the Hospital's Governors ran out of money and sent Bland back to Newcastle until they needed further lead work[14]. This makes us think that by 1633 the Chapel walls had reached the roof level and that by 1637 the Chapel had been roofed with lead already. However, the first wrights' account only appears in the Treasurer's accounts of 1638-9 with the wright John Scott as leader of a 6 men team[15]. It is highly unlikely that the Chapel roof structure was built without wrights on-site, but it seems that Scott was not much involved in the design of the Hospital roofs since in 1648 he suggests to dismantle the pavilion roof of the South-West tower for structural reasons, saying that 'it was never his opinione that the said southwest torret should be built in the way that it now standis'[16]. Other roofs were plat-formed as well in those years: the roofs of the North towers in 1642[17], the North range before 1647[18], and the South East tower in 1649[19]. These alterations, just a few years after the original construction, suggest that Scott hadn't been much consulted on the roofs' design in the first place.

In that same period Scott, Master Wright to Edinburgh from 27 January 1637 and Royal Master Wright from 9 June 1641, was also busy at the Edinburgh Parliament Hall (1631-40)[20] and Tron Church (1636-47), whose tailor-made structures (Figure 3) certainly needed more attention than the simple common rafter roof of George Heriot's Chapel. The two arch-braced open purlin roofs in the Parliament Hall and Tron Church show us that Scott knew very well how to design and construct complex roof structures. Nevertheless he chose to do something very simple in George Heriot's Chapel. One reason could be that the roof structure was never meant to be visible, as suggested by the slanted braces that were probably supporting the original ceiling (Figure 1). Economic constraints could be another reason, since the Hospital Governors often ran out of money and had to interrupt the construction works. A further hypothesis is that put forward by other scholars[21] according to whom the reliance on imported timber favoured timber structures characterized by few standardised items: deals (timber boards for the sarking) and straight, relatively short beams. If 'ready-to-build' timber roofs were available from Norway, that would have certainly been a cheaper solution than paying Scott to design the roof himself, and it would have allowed the Hospital's architect (whose attribution is still controversial) to simply order the timber himself, bringing in wrights only when the construction started.



Figure 3. Parliament Hall in Edinburgh (1631-40) on the left, and Tron Church in Edinburgh (1636-48) on the right (A.).

4 SCOTTISH COMMON RAFTER ROOFS

The common rafter roof in George Heriot's Chapel is not an isolated case. The roofs on which research has focused until 1990s are mainly the hammer-beam or open purlin roofs of fourteenth and fifteenth century that we find in the great halls of Darnaway Castle[22], Stirling Castle[23] and Edinburgh Castle[24], and the seventeenth-century Edinburgh Parliament Hall[25] and Tron church (1636-47) (Figure 5). All these roofs, however, seem to represent an exception rather than the rule, because Hay[26], Stell[27], Hanke[28] and Ruddock[29], all agree in suggesting that from the Middle Ages up to nineteenth century, the majority of Scottish roofs were characterized by a much simpler, closely spaced common rafter form, just like the one in George Heriot's Chapel. There are exceptions, like the purlin roof in Newark Castle (1597-99)[30], or the more elaborate common rafter roofs in Glasgow Cathedral (thirteenth century)[31] and Moray House (seventeenth century)[32] with their scissor braces, or even the low pitched roof structure with posts and purlins covering Stirling Holy Rude Church (end fifteenth century). These exceptions confirm that Scottish wrights had the skills and expertise to design and construct more complex structures, when needed. However, when the spans were reduced and the structures weren't visible they opted for very simple structures: our surveys confirm the impression that most Scottish roofs of seventeenth and eighteenth-century are of simple common rafter form. This is remarkable considering the wider European context, where common rafter roofs were used earlier, up to thirteenth century[33].

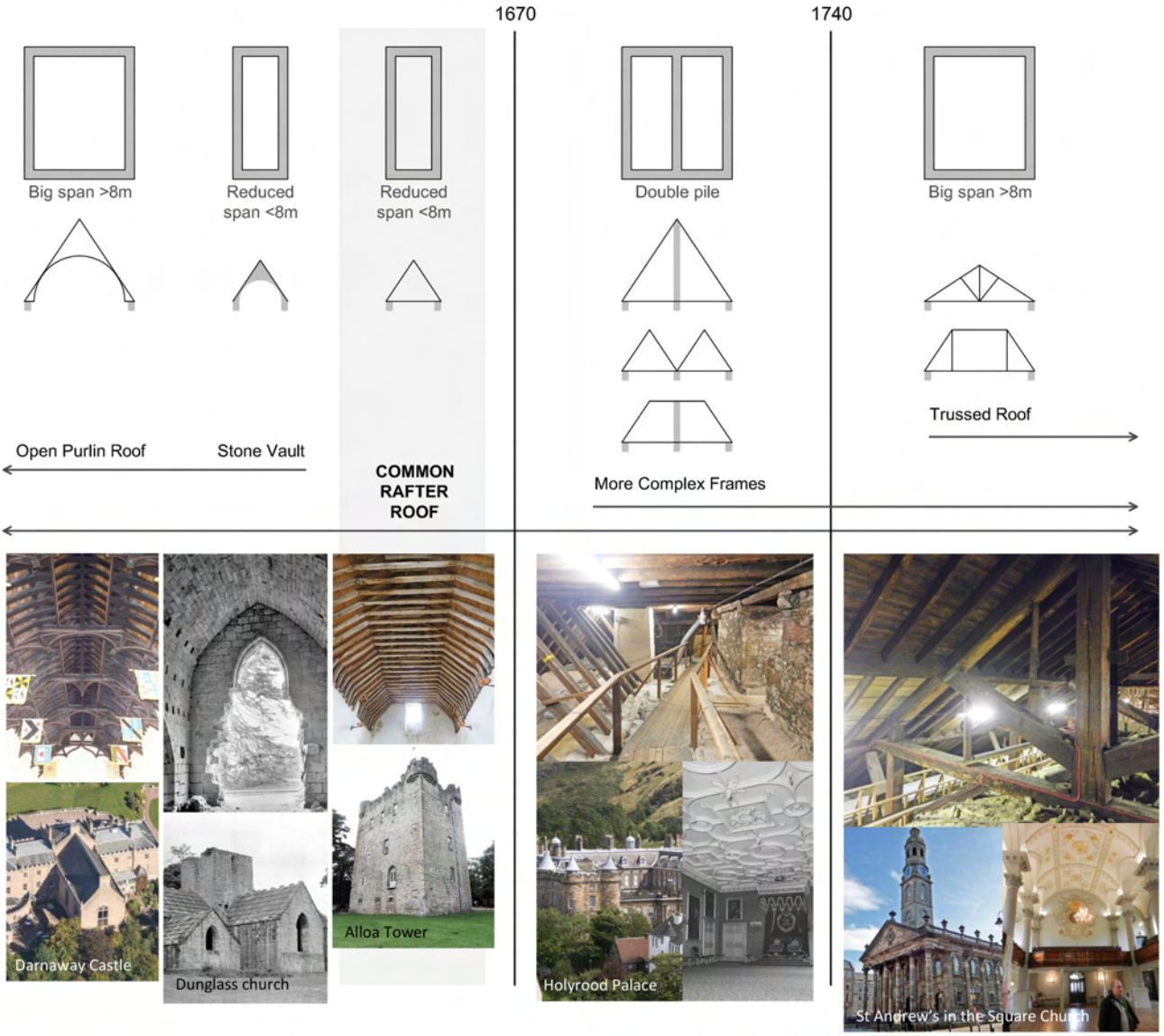

Figure 4. The development of Scottish timber roof structures. From left to right: Darnaway Castle (RCAHMS), Dunglass Church (RCAHMS), Alloa Tower (A.), Holyrood Palace (ceiling RCAHMS, exterior and roof space A.), St Andrew's in the Square Church (A.).

The reason for this extensive use of simple roof structures throughout the centuries lies in the development of Scottish architecture of the time and in the availability of material. Before 1500 Scottish architecture was characterized by single pile buildings, with square or rectangular plans mainly. From the few remaining roof structures of the period, one can deduce that tower houses, castles, churches, chapels, tollbooths were all covered with simple roofs sandwiched between two masonry gables. It was not until late sixteenth century that intersected roofs started being used, as testified by buildings such as Northfield House (c. 1590) and Newark Castle (1597-99)[34]. However, George Heriot's Chapel roof with its two end gables shows that even in the first half of the seventeenth century intersected roofs were still not common practice. The internal structure depended on the span to achieve: open purlin roofs, or hammer-beam roofs in case of big spans (more than 8m), and stone vaults or simple timber common rafter roofs in case of reduced spans (Figure 4). The oldest surviving Scottish common rafter roof we know of is in the thirteenth-century Glasgow Cathedral[35], which differs from the common form with its scissor braces. The roof in Alloa Tower, first mentioned in 1497 but maybe older[36], could be another good candidate. These first examples are all open roofs, visible from underneath. However, painted timber and then plaster ceilings became fashionable even before 1600, relieving timber roof structures from any aesthetical requirements.

We have surveyed 30 common rafter roof structures from the period between the end of sixteenth century and 1700 across Scotland. As the roof in George Heriot's Chapel, they are generally simple gabled roofs composed of rafter couples, spaced 30-60cm, each with one or two collar beams (Figure 5). The rafters are connected longitudinally by sarking boards and they are often simply sitting on the wall-head (as in Pinkie House, figure 5), or on a sole piece tenoned into an ashlar post extended downward on the masonry (as in Cockenzie House, figure 5) - this arrangement is called 'Scottish rafter foot'. The space in-between the rafter feet is often infilled with rubble masonry to increment the lateral rigidity. The timber elements are generally made of a whole log roughly squared with an axe to 8-15cm scantlings, often preserving some bark on the corners[37]. The joints are normally mortise and tenon (as in Pinkie House, figure 5), or later simple lap (as in Cockenzie House, figure 5), secured with timber pegs (as in Pinkie House, figure 5), or later metal nails (as in Cockenzie House, figure 5). The spans are usually less than 7m, and the pitches are quite steep (50°-60°). The frames are normally numbered with roughly sawn roman numerals that cover the entire section of the elements. As already suggested by Hay[38], it seems that these carpentry marks were used mainly to understand which rafters and collars composed a single frame - once the frames were complete, it didn't matter if frame I was placed before or after frame II, which is why the frames are often not in sequence (as in Pinkie House, Cockenzie House and George Heriot's Chapel).

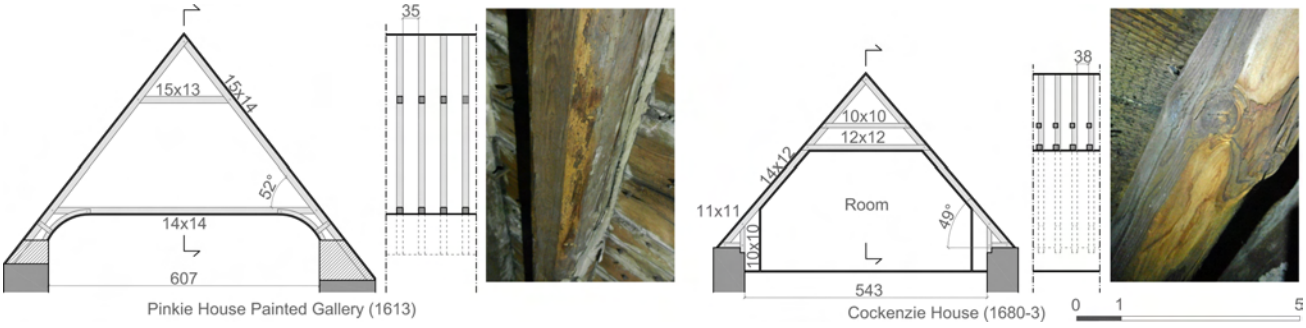

Figure 5. The common rafter roofs at Pinkie House's painted gallery (1613) on the left, and Cockenzie House (1680-3) on the right (A.).

The common rafter roof in George Heriot's Chapel is in line with contemporary Scottish common rafter roofs as regards to its general arrangement, span, pitch, joints and carpentry marks. However, the timbers are a bit bigger and more rectangular (the rafters are 18.5x12.5cm - height x base) than other contemporary roofs we've surveyed, and, although hand-axed, they've been more carefully squared and finished, leaving no bark on the corners (Figure 1). Furthermore, the slanted braces that connect the lower collar to the rafters, and that probably supported the original ceiling, is a detail that hasn't been found in many other Scottish roofs. Earlier roofs generally employed arched braces supporting painted timber ceilings (as in Pinkie House, Figure 5), and later roofs generally had the plaster ceiling directly attached to the rafters and the lower collar (as in Cockenzie House, Figure 5). The use of such braces was however not uncommon in other Northern and Central European common rafter roofs[39]. Scottish common rafter roofs are in fact similar to European ones in many respects, but, as already stated above, the extensive use in Scotland of this simple form of roof throughout the centuries up to today is somehow unusual since in England and Northwest Europe king/queen struts and side purlins were introduced already in thirteenth century[40]. Moreover, Scottish common rafter

roofs do differ from the English and European ones in some aspects, as confirmed by our surveys: they have no tie-beam up to 1700[41]; they never have additional longitudinal bracing (such as purlins) other than the sarking boards up to the first half of the seventeenth century[42]; they have no wall-plates up to late seventeenth century[43] but sometimes provide additional rigidity through the Scottish rafter foot. The Scottish rafter foot has always been thought to be a distinctive Scottish character but was actually already known by the late twelfth and early thirteenth century Dutch and French carpenters[44]. Nevertheless, just like the sarking, which is not unknown in Europe[45], it seems to have never been so extensively used as in Scotland.

5. LATE SEVENTEENTH CENTURY INNOVATIONS

The roof of George Heriot's Chapel, with its bigger timbers more carefully finished, anticipates the characteristics and innovations of late seventeenth-century Scottish roofs. From 1670s onwards common rafter roofs had in fact to adapt to the new geometries and aesthetical requirements of classical architecture, introduced in Scotland by the architects Sir William Bruce and Mr James Smith. It was no longer fashionable to see the timber roof structure, which was now hidden behind heavy plaster ceilings. At the same time, it was also no longer fashionable to have gabled high pitched roofs: architects now wanted shallow roofs, or platform roofs, more in keeping with the classical facades that they designed. M roofs, hipped and platform roofs were introduced (Figure 4), but internal timber structures took some time to evolve and become efficient enough to be able to carry heavy plaster ceilings over big spans.

An early attempt can be seen in Holyrood Palace (1671-9) (Figure 6). The structure is still a common rafter roof, with no longitudinal connection other than the sarking boards, but it spans above a double pile plan and uses the intermediate spine wall as additional support. Double piles had already been introduced since sixteenth century: Drochil Castle (1578) has one of the very first known double pile plans - the roof hasn't survived unfortunately, but from what remains we can hypothesize that it was gabled, probably with a common rafter structure spanning over the double pile, supported by one or two of the intermediate spine walls. This type of structure was used up to mid eighteenth century, as testified by Tweeddale House in Edinburgh (1754-56)[46]. Sir W. Bruce did the same in Holyrood Palace, but introduced the platform roof and other innovative features, such as tension absorbing joints (dovetail joints, highlighted in black in Figure 6). It must be underlined that up to then Scottish wrights understood timber elements as behaving in compression only: in structural terms the fifteenth, sixteenth and seventeenth-century open purlin roofs and common rafter roofs resemble barrel vaults, because all the elements that compose them are behaving in compression, just like voussoirs in stone arches[47]. The use of tension absorbing joints allowing timber elements (collars in the case of Holyrood Palace) to work as ties, in tension, is therefore an important innovation.

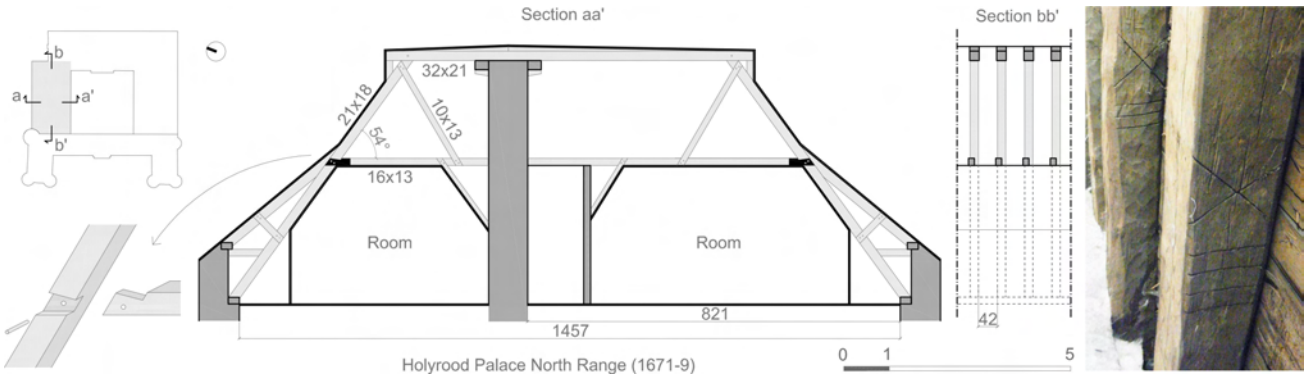

Figure 6. The roof structure of Holyrood Palace (1671-9) with the tension-absorbing joints and members highlighted in black (A.).

Holyrood's roof achieves a shallower external geometry, but fails in attaining an undisturbed big span inside, since it still relies on the intermediate spine wall as support. Roof structures had to evolve a bit further to be able to get rid of this wall. It was eventually necessary to import from elsewhere a completely different structural type: the trussed roof.

6. THE INTRODUCTION OF TRUSSED ROOFS

In the first half of the eighteenth century butt-purlins were introduced as additional longitudinal bracing and rafters started being distinguished into primary and secondary ones, which significantly reduced the amount of timber needed. The roof covering the central hall of Yester House (1729-48) is the first known example of primary rafters ('a' in Figure 7) spaced about 2.5m apart and connected by purlins ('b' in Figure 7), which in turn support the common rafters ('c' in Figure 7). The timbers' scantlings and dressing changed as well: they became bigger and more and more rectangular. Holyrood Palace's rafters are already bigger compared to the previous common rafter roofs (21x18cm - height x base), but Yester House's rafters are even bigger and more rectangular (27x17cm – height x base). Moreover, some of their faces are hewn rather than axed: the use of pit and frame saws was not unknown in seventeenth-century Scotland, but it became common only in the following century, when Scotland started importing from the Eastern Baltic area big timber baulks, often large enough to be processed further by wrights on-site into narrower joists or rafters[48].

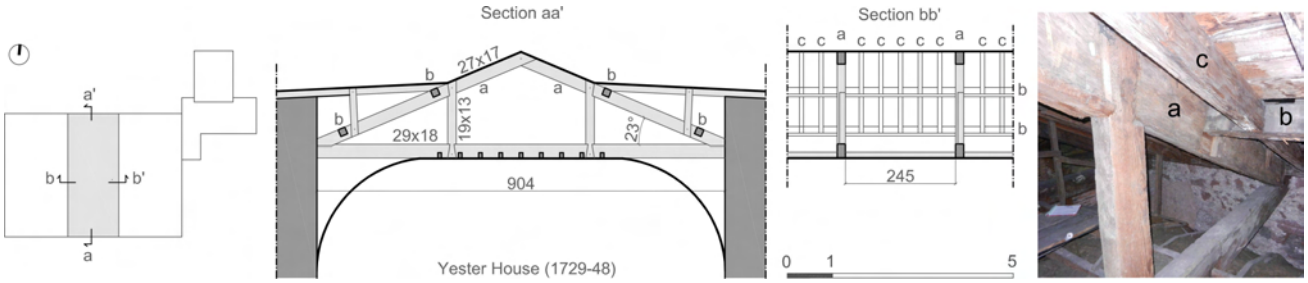

Figure 7. The roof structure of Yester House (1729-48) (A.).

Yester House's roof has a structural behaviour closer to that of a trussed roof, rather than to that of a common rafter roof. It can thus be seen as an antecedent of trusses, just as Tweeddale House[49]. In the second half of the eighteenth century the trussed roof was in fact introduced in Scotland (Figure 4)[50]: our surveys suggest that from 1740s/50s king-post trusses started being used to cover reduced spans (as in Fort George Museum and Staff blocks, 1762-6), and princess-post/queen-post trusses to cover bigger spans (as in St Andrew's in the Square Church, 1739-56).

We have surveyed 13 trussed roofs across Scotland, including the one above the Trades Hall in Glasgow (1791-4) (Figure 8), which lends itself to an interesting comparison with the truss in George Heriot's Chapel. The Scottish trusses surveyed so far have quite different external geometries and internal arrangements, some developing veritable 3D structures (as in St Andrew's and St George's Church, 1782). The spans reach their maximum in Oakshaw Trinity church (1754-6) with about 20m, and pitches vary between 44° and 27°. The sarking is always retained, even though butt-purlins are always employed as well. Posts normally have joggles, which could be an English influence[51], but traces of other influences can be identified too[52]. Joints are all mortice and tenon with timber wedges and sometimes timber dowels; scarf joints are rare and metal straps are seldom used - in some cases they are a later addition, as testified by the Trades Hall truss where the metal straps have been added 50 years after the construction of the building[53].

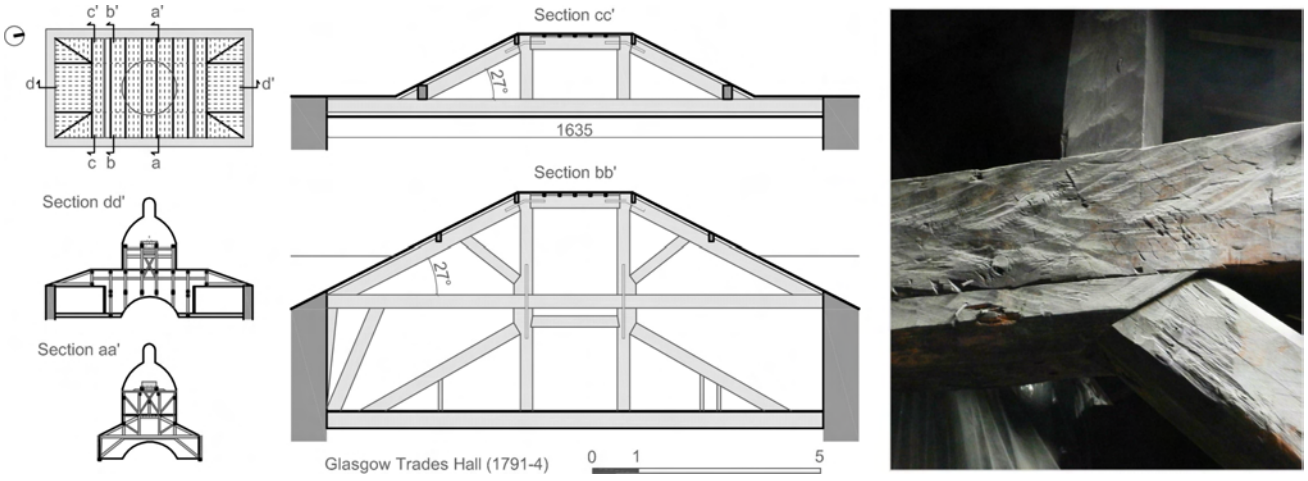

Figure 8. The roof structure of the Trades Hall in Glasgow (1791-4) (A.).

The two queen post trusses in George Heriot's Chapel are not that different from the ones in the Trades Hall (Figure 2 and section cc' in Figure 8). In order to understand when and why they have been added to the original structure, it's necessary to have a look at the Chapel's construction history from were we left it in 1637, once the roof had been covered in lead. The interiors remained incomplete until Thomas Sandilands, one of Scott's apprentices, was contracted in 1683 to finish the work[54]. Sandiland's account unfortunately does not provide us with enough details to understand how the ceiling of the Chapel might have looked like after his works. In this period plaster ceilings were gradually substituting timber ones, but the latter were still in use. The Chapel's roof structure with its slanted braces would have easily accommodated a painted timber ceiling like the 1626 one in Provost Skene's House (Figure 9a). Nothing as grand as this is mentioned anywhere though, therefore the most probable hypothesis is that a simple timber or plaster ceiling was installed until further funds were found.

In 1787 the chapel was refitted with a new ceiling[55]. Robert Adam might have been involved since he had been consulted previously for other matters[56]. An undated drawing held in RCHAMS shows a decorated ceiling that seems to match with evidence found in the roof space (Figure 9b and c). The central part of the roof structure was altered at this time to allow for this new ceiling to be installed. The rafters were cut ('a' in Figure 9-10), leaving exposed the mortice and tenon joints were the lower collars used to be (Figure 10 right). A purlin was inserted on each side to support the cut rafters ('b' in Figure 9-10). The purlins were kept in place by a collar ('c' in Figure 9-10) spanning transversally in-between them, and two struts ('d' in Figure 9-10) pushing on the lateral walls. Ceiling joists ('e' in Figure 9-10) were then placed beneath and connected to the rafters with timber struts ('f' in Figure 9-10).

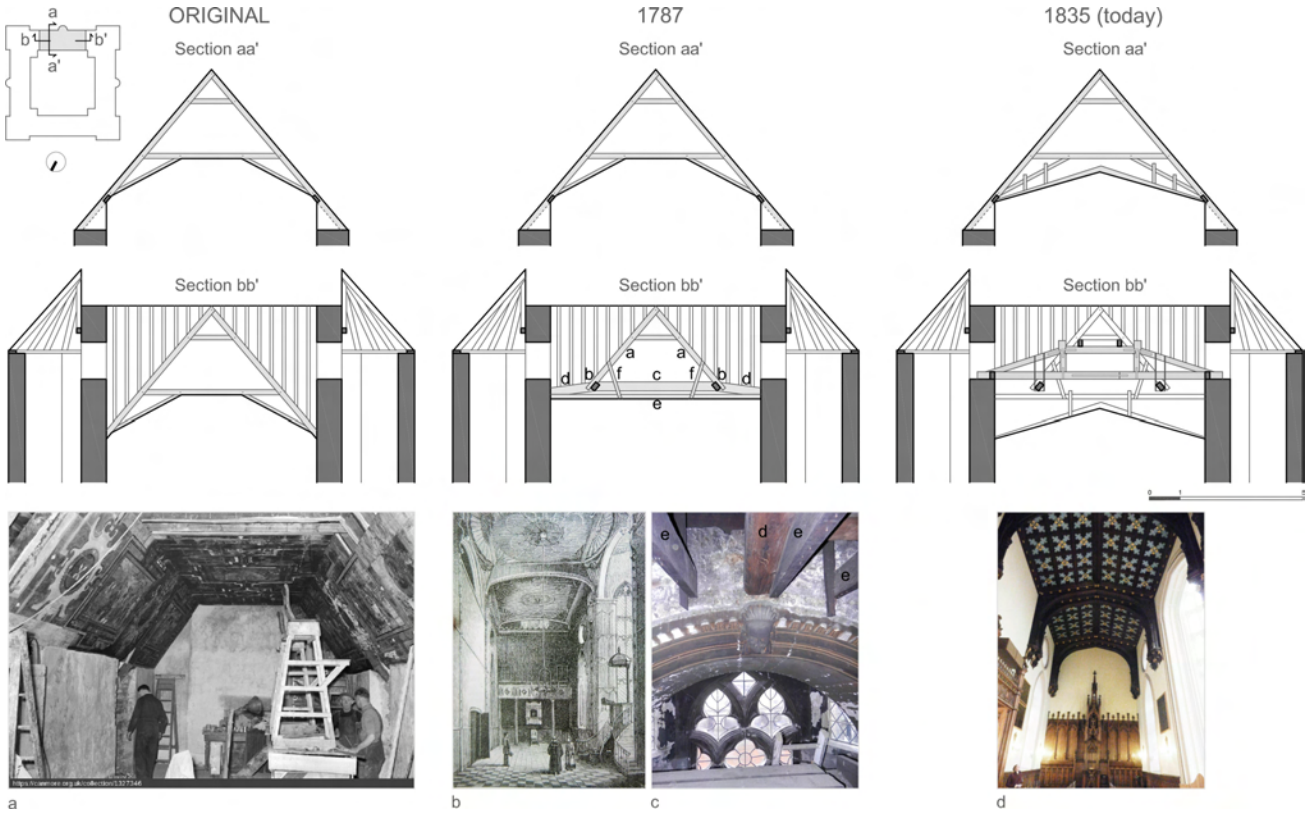

Figure 9. Alterations in time to the roof structure and ceiling of George Heriot's Chapel. From left to right: a) the original ceiling might have been a timber ceiling similar to the 1626 one in Provost Skene's House (RACHMS); b) an undated drawing (RCAHMS) shows what the 18th century ceiling might have looked like after the renewal in 1787; c) remains of the 18th plaster decorations are visible in the roof space (A.); d) a view of the ceiling today, as renewed in 1835 (A.).

In December 1833 the governors ordered to replace the whole plaster-work for structural reasons[57]: James Gillespie Graham prepared a design and the works were carried out in 1835 with the collaboration of the cabinetmaker William Trotter[58]. Gillespie's work is what we see today (Figure 9d). The two trusses were added at this time to reinforce the central part of the roof structure, which had been weakened by the late eighteenth-century interventions. They are clearly of nineteenth century dating because their pitch (18°) is much lower than that of late eighteenth-century Scottish trusses: the truss above the Trades Hall in Glasgow (Figure 8) is the shallowest we've surveyed so far

with its 27° pitch. Moreover, the timber elements composing the trusses in George Heriot's Chapel have been machine sawn. We know that mechanical sawmills started being employed in Scotland only from early nineteenth century and became common after 1820[59].



Figure 10. Alterations in time to the roof structure and ceiling of George Heriot's Chapel (A.).

7. CONCLUSIONS

Seventeenth- and eighteenth-century architecture in Scotland has not been sufficiently researched from the point of view of its structural and constructional configuration. Timber roof structures in particular have been very rarely researched due to their location - hidden behind timber or plaster ceilings – and to the lack of awareness of their structural, technological and cultural importance.

Building upon the few previous studies on Scottish roof structures and timber trade and thanks to the survey of 74 timber roof structures in 56 buildings across Scotland we can start tracing their development through seventeenth and eighteenth centuries. Research so far has focused on few medieval open purlin roofs, but our surveys confirm the impression that most Scottish roofs of seventeenth and eighteenth centuries are of simple common rafter form hidden behind timber or plaster ceilings, like the one in George Heriot Hospital Chapel (1628-84). The Chapel roof illustrates well the impressive development that Scottish timber roof structures achieved through seventeenth and eighteenth centuries, as it still retains the original seventeenth century roof structure with later alterations and additions.

The Chapel's original roof structure, built in 1630s, is a simple common rater roof. The timber used was imported from Norway as was common in that period, since local Scottish timber was difficult to transport and of low quality. John Scott, Royal Master Wright, was in charge of the timber works at George Heriot's. In the same period he was also working at the Edinburgh Parliament Hall and at the Tron Church, whose roof structures suggest that he had the skills and expertise to design and build complex structures. Nevertheless he chose to do something very simple in George Heriot's Chapel, probably because of economic constraints and because the structure wasn't meant to be visible. The influence of the timber trade with Norway was also another important aspect, as it probably simplified the roofs' design and construction processes, allowing for wrights to be little involved in the design.

The Chapel roof is in line with other contemporary Scottish common rafter roofs, but it has some characteristics that anticipate the innovations of end seventeenth century, when common rafter roofs had to evolve and adapt to the new geometries and aesthetical requirements of classical architecture. From 1670 wrights started employing tension absorbing joints and members, as in Holyrood Palace. Timbers became bigger and with more rectangular sections, and they were sawn rather than axed only. Primary rafters connected by purlins were introduced, reducing the amount of timber needed, as in Yester House. However, in order to avoid the use of an intermediate spine wall and attain a big undisturbed span it was eventually necessary to import from elsewhere a completely different structural type: the trussed roof. Trusses started being employed in Scotland from 1740s in the vast majority of public buildings and big country houses, and they were soon used even for reduced spans, as In George Heriot's Chapel: the central part of the

Chapel's roof structure has in fact been altered repeatedly to accommodate different ceilings, and at the beginning of the nineteenth century two trusses were introduced as reinforcements. Their dating to nineteenth century is suggested both by the pitch, a lot lower than that of late seventeenth-century Scottish trusses such as the one above the Trades Hall in Glasgow, and by the dressing of the timber, which is machine-sawn.

8. NOTES

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[7] Lockhart, B. R. W. (2003), *Jinglin Geordie's Legacy: A History of George Heriot's Hospital and School*, Edinburgh., p. 29: following the orders of the Town Council, the Hospital Treasurer commissioned in July 1627 two Leith ship-owners to transport a shipload of large timber from 'Norroway', and other timber kept being imported in the following years. Unfortunately the primary source on which Lockhart's statement is based, the Minutes of Heriot's Hospital, are not available for consultation anymore, and it is therefore impossible to know more about the type of timber products that were imported. The following timbers, which have probably been used for the Hospital's roof structures, are mentioned in the treasurer's accounts between 1636 and 1639: 207 great trees, 19 draught long trees, 125 double trees, 1200 deals (National Records of Scotland - NRS, Records of George Heriot's Trust, Edinburgh, Accounts and other Financial Papers of George Heriot's Hospital and Trust, Treasurer's accounts 1633-1642, GD421/5/2).

[8] Newland 2010, op. cit.

[9] As argued by Thompson 1991, op. cit., softwoods need short hot summers and long cold winters to form sound timber of slow growth. Scottish climate is instead cool, humid and temperate, which is why home grown Scottish softwoods are not very strong and durable, even today. Scandinavian/Russian softwoods are instead slow grown and therefore of better quality. On top of scarcity and low quality, high extraction and transportation costs restricted the use of Scottish timber: not many rivers were adequate for timber floating and there were often disputes with the fishermen. Moreover, Scotland was characterised by a technological backwardness in sawmilling, which improved only from the end of the eighteenth century.

[10] Thompson 1991, op. cit.

[11] 'two grait stones to the chappell zet heid' citation in Lockhart 2003, p. 53.

[12] 'theak the Chapel with lead' ibid.

[13] Lockhart 2003, op. cit., p. 53.

[14] 'till he sould be written for be the counsell qhen they would have adoe to cast mair lead' citation in Lockhart 2003, op. cit., p. 54.

[15] NRS GD421/5/2, op. cit.: Scott was paid 6£ weekly, just like William Aytoun, leader of the masons.

[16] Citation in Lockhart 2003, op. cit., p. 57-58.

[17] Lockhart 2003, op. cit. p. 56.

[18] As proved by the view drawn by Revd. James Gordon of Rothiemay in 1647 (in Lockhart 2003, op. cit., p. 57).

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[22] Stell and Baillie 1993, op. cit.

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[28] Hanke 2006, op. cit.

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[30] Hanke 2012, op. cit.

[31] Oldriev, W. T. (1916), ' The ancient Roof of Glasgow Cathedral', *Proc. Soc. Antiq. Scotl*., 50, 155-172.

[32] Hanke 2004, op. cit.

[33] For the development of timber roof structures in England and Europe see: Blaha, J. (2006), 'The evolution of roof timber frame in the Southern part of Bohemian-Moravian Uplands from 14th century to the 19th century, in M. Drdacky (ed.), *European Research on Cultural Heritage: State of the Art studies*, Prague; Hewett, C. A. (1980), English Historic Carpentry, Chirchester; Hoffsummer, P. (2011), *Les Charpentes du XI au XIX siecle – Grand ouest de la France*, Turnhou; Janse, H. (1989), *Houten Kappen in Nederland 1000-1940*, Amsterdam; Ostendorf, F. (1908), *Die Geschichte des Dachwerks*, Leipzig; Pompejano, F., S. Podesta', C. Chesi, (2015), 'Preliminary studies on the structural behaviour of traditional timber roofs in Gjirokastra, Albania', In J. Jasienko & T. Nowak (eds.), *Structural Health Assessment of Timber Structures*, Wroclaw, Poland, 9-11 September 2015; Szabo, B., I. Kirisan (2006), 'Continental historic roof structures in central Europe', in M. Drdacky (ed.), *European Research on Cultural Heritage: State of the Art studies*, Prague; Tampone, G. (2006) ,'Coverings of the Italian architectural heritage', in M. Drdacky (ed.), *European Research on Cultural Heritage: State of the Art studies*, Prague; Tsakanika, E. (2007), 'Byzantine and Post-Byzantine Historical Timber roofs in Greece. Typical failures, misunderstanding of their structural behaviour, restoration proposals', ICOMOS (Wood Committee), 16th International Conference and Symposium "From material to structure", Florence, Venice and Vicenza, 11-16 November 2007.

[34] Hanke 2012, op. cit.

[35] Oldriev 1916, op. cit.

[36] Ruddock 1995, op. cit.

[37] As noted also in Crone and Mills 2008, op. cit., p. 28.

[38] Hay 1976, op. cit., pp. 31-32.

[39] See for example Ostendorf 1908, op. cit., and Janse 1989, op. cit.

[40] Blaha 2006, Hoffsummer 2011, Janse 1989, Ostendorf 1908, Szabo and Kirisan, 2006, op. cit., Yeomans, D. T. (1992), *The trussed roof: its history and development*, London.

[41] The heavy stone walls of medieval and renaissance Scottish buildings easily counteracted the horizontal thrust resulting from these roofs without tie-beams. The first known Scottish roof with a tie-beam is in Yester House and dates probably to the construction works of 1699-1715.

[42] The first known Scottish roof with purlins is in Yester House and dates probably to the construction works of 1729/48.

[43] The first known Scottish roofs with wall-plates are in Gardyne's Land in Dundee (possibly end 17th century) and Methven Castle (1678/81).

[44] Courtenay, L. T. (1985), ' Where Roof Meets Wall: Structural Innovations and Hammer-Beam Antecedents, 1150–1250', *Annals of the New York Academy of Sciences*, 441, 89-124.

[45] Sarking boards are in use in Greece and Albania: Pompejano et al 2015, Tsakanika 2007, op. cit.

[46] Serafini, A., C. Gonzalez Longo (2015), 'The design and construction techniques of eighteenth century timber roofs in Scotland: Glasgow Trades Hall and Tweeddale House in Edinburgh', in Donald Friedman et al (eds.), *Proc. 5th Intern. Constr. History Congress*, 3-7 June 2015, Chicago.

[47] This has been suggested by Hanke 2006, op. cit., p. 30.

[48] Thompson 1991, op.cit.

[49] Serafini and Gonzalez Longo 2015, op. cit.

[50] It seems that trussed roofs were in use in Italy since roman times (Valeriani, S. (2006), 'The roofs of Wren and Jones: a seventeenth-century migration of technical knowledge from Italy to England', Working papers on the nature of evidence: how well do 'facts' travel?', Department of Economic History, London School of Economics and Political Science), and were employed in England since mid seventeenth century, when classical architecture was introduced by Inigo Jones (Yeomans 1992, op. cit.). As stated above, in Scotland trusses started being used about 100 years later, but it's not clear who was responsible for their introduction into the country. An analysis of drawings and buildings of the Adams suggests that although architects aspired to build trusses, wrights were initially unable or unwilling to construct them (Serafini and Gonzalez Longo 2015, op. cit.).

[51] Yeomans 1992, op. cit.

[52] Serafini and Gonzalez Longo 2015, op. cit.

[53] An uncatalogued drawing held in the basement of the Trades Hall shows a survey of the timber roof structure carried out by the architect Charles Wilson in October 1856 and the interventions that he carried out to repair it, including the addition of iron bars.

[54] National Records of Scotland (NRS). Records of George Heriot's Trust, Edinburgh, Administrative records of Heriot's Hospital and school statutes, foundationers, staff building, housekeeping, Detailed account and discharge by Thomas Sandilands, wright, to the treasurer of George Heriot's Hospital for £683 Scots for timber and wright work performed on the chapel and lodge (or summer house) in the Easter garden, 16 Jan 1685, GD421/10/68. Prior to Sandiland's intervention the Hospital's governors had fitted the Chapel with materials from the dismantled kirk of Cromwell's citadel in Leith: the timber seats, steeple, stone and glass work were taken for the chapel's repair in April 1673 (Lockhart 2003, op. cit., p.67). The walls were nevertheless left bare and the roof left with little ornament (Lockhart 2003, op. cit., note 98, p.47).

[55] Lockhart 2003, op. cit., note 98, p.351.

[56] Lockhart 2003, op. cit., p.101.

[57] It was reported that the 'the plaster which is overloaded with ornament is unsafe and consequently that both lath and plaster ought to be immediately taken down', even because the 'ceiling has been slightly and injudiciously executed, and the decorations also executed in a style unworthy of, and incompatible with, the architectural character of the Edifice', citations in Lockhart 2003, op. cit., pp. 121-2.

[58] Lockhart 2003, op. cit., pp.121-3.

[59] Crone and Mills 2008, op. cit., p. 32.

Seventeenth and eighteenth century timber roof structures in Scotland: design, pathologies and conservation

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ABSTRACT: Seventeenth and eighteenth century architecture in Scotland has not been sufficiently researched, despite its importance in both quality and quantity. Most scholars tend to investigate the external architectural composition of these buildings rather than their overall constructional configuration. In particular, timber roof structures are very rarely considered even though the integrity of the overall building depends largely on them. This lack of knowledge hinders good conservation practice. This paper aims to increase awareness about the extent, nature, value and condition of historic timber roofs in Scotland in order to understand what their conservation needs are. Preliminary results obtained from the creation of a relational database of 1550 buildings, related mapping, survey of 56 buildings of the period across Scotland and historical/archival research, are discussed. This has allowed for an initial understanding of the different structural types of Scottish timber roofs of the period as well as their pathologies.

1 INTRODUCTION

This work is part of a wider research on seventeenth and eighteenth century architecture in Scotland being carried out by the Architectural Design and Conservation Research Unit (ADCRU), in the Architecture Department of the University of Strathclyde. The aim is to recognize the value of this important built heritage, which has not been sufficiently investigated so far, in an integrated and comprehensive way, beyond the usual external descriptions.
A relational database of 1550 buildings from the period has been created. It includes information on structures, designers, craftsmen, clients and the different interventions. During this research it became apparent that timber roof structures are one of the most neglected topics of research and as consequence their value is not appreciated and many of the original roofs are replaced. Research on the use of timber in Scottish architecture has been widely published but there has been little focus on its structural use, particularly in roofs. Despite the recent work of scholars such as Hanke (2006), Newland (2010), and Crone (Crone and Mills 2012), we are still unable to say what is the extent and nature of original Scottish timber roofs, even because the research done is based more on archival documents and literature than on surveys. Moreover, no research has been carried out on the present condition of these structures. This lack of knowledge hinders good conservation practice: the value of Scottish timber roof structures is not recognized and their structural behaviour is often misunderstood, resulting in their replacement or over-consolidation.
The assessment of historic timber structures can be challenging, being timber an organic material with variable properties. Professionals are often uncertain about the safety of a timber roof structure, due to the lack of training and knowledge on timber structural behaviour, the limited amount of regulations for historic timber structures and the difficulty to determine in situ the timber species and properties. The available testing and modeling methods require a lot of experience and can be expensive and labour intensive. As consequence, the original timber structure is often replaced or over-consolidated with what is considered a "safer" material (steel or concrete).
This paper aims to increase awareness about the extent, value and nature of seventeenth and eighteenth century timber roofs in Scotland and to understand what their conservation needs are. An initial survey and assessment of 56 buildings across Scotland has allowed identifying different roof structural types, their design, development and their pathologies and possible causes.
Future work will comprise an in-situ testing campaign to further investigate the critical areas identified and to address specific issues and limitations that professionals might encounter during the assessment of these structures. The aim is to develop a method for the initial assessment of timber roofs that can contribute in improving local practice.

2 METHOD

2.1 *A database of seventeenth and eighteenth century buildings in Scotland*

In order to assess the extent, nature and condition of seventeenth and eighteenth century Scottish timber roofs, the first step was to identify Scottish buildings of the period. A database and related mapping has been developed with Microsoft Access and ArcGIS: this tool has been used to locate the buildings and record their history, based on data from the databases of Historic Scotland - now Historic Environment Scotland - (HS 2015), the Royal Commission on Ancient and Historical Monuments of Scotland (RCAHMS 2015) and the Buildings at Risk Register (BARR 2015), as well as literature on Scottish Architecture (Glendinning & Mackechnie 2004). The results from the surveys and archival/historical research are being added to the database as the research progresses; it now includes 1550 buildings.

2.2 *Selection of key buildings*

The database has been used to select key buildings to survey, according to the following criteria:

- designed by architects and of a certain scale;
- no flat roofs;
- major interventions in seventeenth and eighteenth century and no major alterations after 1800;
- key moments in Scottish architectural history;
- roof or wrights' names mentioned in literature or in HS/RCAHMS/BARR;
- original plaster ceilings;
- analysed with dendrochronology;
- owned by HS or NTS (for accessibility);
- in the Scottish central belt (for accessibility);
- designed by Sir W. Bruce, J. Smith or W. Adam, leading architects of the period (Serafini & Gonzalez-Longo 2015, Gonzalez-Longo, 2012, Gonzalez-Longo & Theodossopoulos, 2012).

The owners of 139 buildings have been contacted and 80 of them replied: 66 granted access and 8 informed of the replacement of the roof after 1800 (Fig. 1). Visits to 56 buildings (or groups of buildings, as in Fort George) were eventually arranged (Fig. 2). Of these buildings one had no accessibility to the roof structure and 9 had roofs replaced after 1800. The other 46 buildings/groups of buildings had one or more original roof structures for a total of 76. A building has been considered as having more than one roof structure when these are structurally independent, separated by masonry walls. Thanks to literature references 20 other buildings have been identified as having the roof structure completely replaced after 1800, for a total of 37 (Fig. 1).

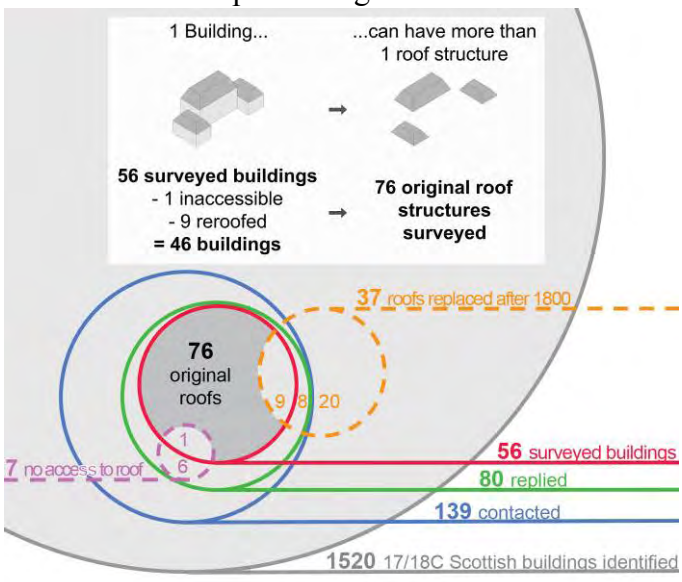

Figure 1. The key buildings' selection process

2.3 *Surveys*

The objective of the surveys was to gain first-hand knowledge on the roofs' construction techniques and typologies and to start assessing their present condition. As suggested in guidelines for the assessment of historic timber structures (Cruz et al 2015), a desk survey was carried out prior to the visits to gather all the necessary information on the buildings, then a preliminary visual and measured survey was done. A tape meter, a laser meter and a digital camera were used. A series of fixed parameters have been recorded during the surveys in order to compare the structures and draw some conclusions from a historical, typological, technological and structural point of view. The parameters recorded include:

- roof form (gabled, hipped, dome, etc);
- roof geometry (span, pitch, length, etc);
- structural arrangements (common rafter roof, purlin roof, etc, as well as the type of frame/truss);
- connection with walls;
- elements' scantlings and section shape;
- timber dressing (hand-axed, hand-sawn, etc);
- joint types and fasteners;
- timber species (if known);
- roofing material and its fasteners;
- carpentry marks;
- evidence for reused timber.

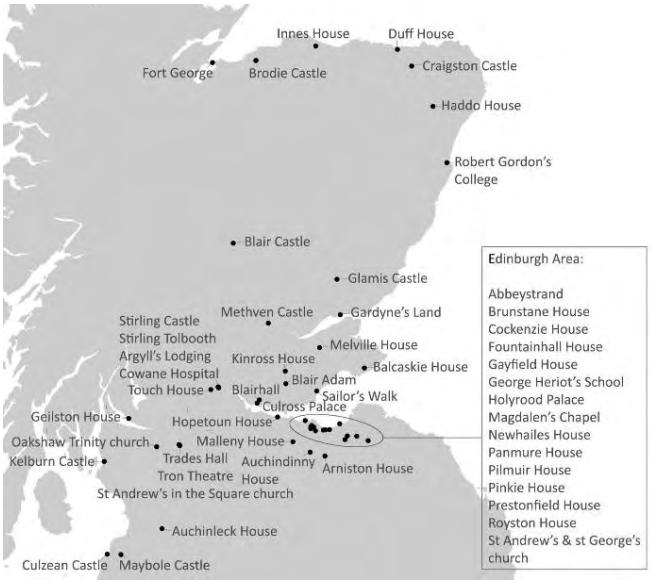

Figure 2. The 56 buildings surveyed across Scotland

Signs of damage have been recorded as follows:
- mechanical damage (deformations, cracks, etc);
- material degradation (fungi/insect attack, etc);
- past interventions;
- unfavorable environmental conditions (poor ventilation, etc) and poor maintenance;

Natural defects (knots, checks, etc) have not been documented at this stage. All the information has been collected in a structured form integrated within the database. The form has been produced in collaboration with COST Action fp1101 and further developed to meet the purposes of this research.
The surveys have helped identifying different structural types and their pathologies, as well as issues in their assessment.

2.4 *Archival Research*

Archives have been searched for information on the surveyed buildings and on wrights of the period. The research has focused on archives in Glasgow and in Edinburgh. The documents consulted include mainly accounts and correspondence that have been used to understand the design and construction processes, the timber procurement, past repair works, the people involved and, in particular, the role of architects and wrights. The study of carpentry manuals of the time (Gomez Sanchez 2006) has helped understanding what knowledge the wrights had access to and if there has been migration of technical knowledge.

3 THE IDENTIFICATION OF STRUCTURAL TYPES AND THEIR DEVELOPMENT

The development of timber roofs' design and construction is closely related to material availability and to the development of the architecture of the period: its layouts, spans and overall composition. The challenge in Scotland at the time was to pass from large spans covered by open purlin structures such as the fifteenth century Darnaway Castle (Stell & Baillie 1993), to large spans covered by shallower roofs carrying heavy plaster ceilings, fashionable from seventeenth century (Fig. 3). Whilst the few remaining Scottish open purlin roofs have been widely investigated, little research has been done on roof structures hidden behind timber and plaster ceilings, which, according to our surveys, cover the vast majority of Scottish buildings throughout the centuries. Hanke (2006) is the only scholar who has previously investigated these roof structures, but he considered mostly documents related to buildings up to 1647 in a restricted geographical area. Newland (2010), Thomson (1991), Crone and Mills (2012) have researched the timber trade of the period.

3.1 *Common rafter roofs*

Before 1500, local Scottish timber was used; oak was considered to be the most valuable, due to its strength and resistance, and used whenever possible for the construction of high status buildings (Newland 2010). From the few remaining roof structures of the period, one can deduce that single pile buildings were covered with gabled roofs whose internal structure was an open purlin roof in case of big spans, and a stone vault in case of reduced spans (Fig. 3). It is not clear when common rafter roofs started being employed. The oldest surviving one could be that of Alloa Tower, first mentioned in 1497 (Ruddock 1995).
In sixteenth century double piles were introduced and common rafter roofs were used with the intermediate spine wall acting as additional support (as in Drochil Castle, Fig. 3). In this period it was hard to find local timber suitable for building construction, due to accessibility problems and low quality: thus oak and pine started being imported from the eastern Baltic, Denmark, Sweden, and Norway soon dominated the market (Newland 2010).
The sixteenth and seventeenth century common rafter roofs we have surveyed (see for example Culross Palace, Fig. 4) are generally simple, composed of rafter couples, spaced 30/60cm, with one or two collar beams, almost square scantlings of 10/15cm, and mortise and tenon or simple lap joints secured with timber pegs. The spans are usually less than 7m, and the pitches are quite steep (50°-60°).
The extensive use in Scotland of very simple common rafter roofs throughout the centuries up to today (Fig. 3) is somehow unusual, considering that in England and Northwest Europe structures started changing already in 13C, when king/queen struts and side purlins were introduced (Hanke 2006). Moreover, Scottish common rafter roofs have some characteristics quite different from the English and European ones, as confirmed by our surveys: they have no tie-beam up to 1700; they never have additional longitudinal bracing other than the sarking (longitudinal timber boards fixed to the rafters and supporting the roof covering); they have no wallplates up to late seventeenth century but sometimes provide additional rigidity through the rafter foot, with the ashlar piece extended downward on the masonry.
As Hanke (2006) suggests, the simplicity and uniformity of Scottish common rafter roofs could be explained by the reliance on imported timber, which seems to have favoured timber structures characterized by few standardised items: deals (timber boards for the sarking) and straight, relatively short beams. According to our surveys, this could be true only up to 1670s, when structures start evolving (Fig. 3).

3.2 *End 17C and 18C: more complex frames*

From 1670s onwards common rafter roofs had to adapt to the new geometries of classical architecture, introduced in Scotland by the architects Sir William Bruce and Mr James Smith. M roofs, hipped and

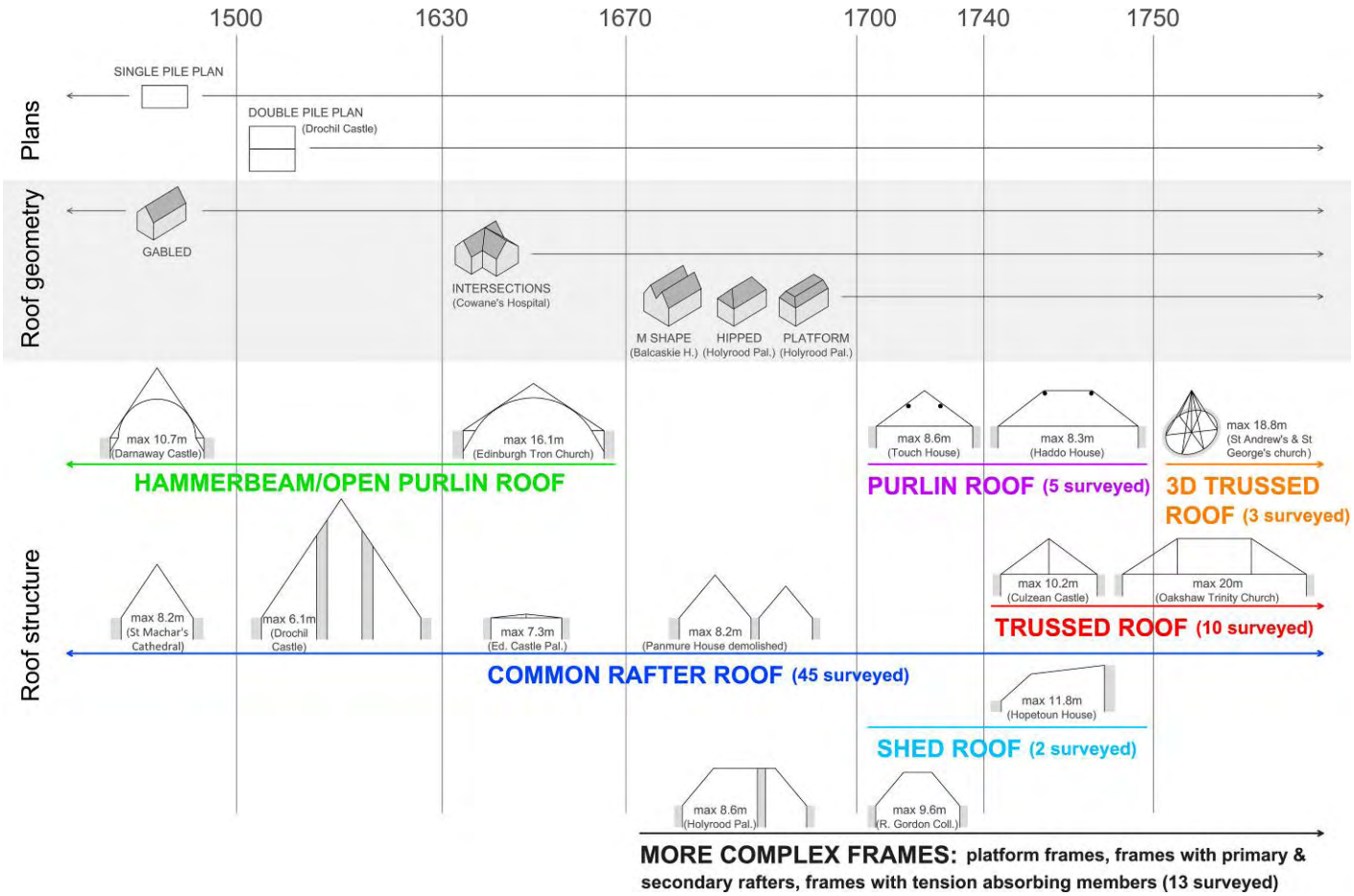

Figure 3. Construction development of Scottish timber roof geometries and structures

platform roofs were introduced (Fig. 3). Wall-plates started being used, as well as tie-beams and tension absorbing joints (dovetail) and members, which shows an understanding of the fact that timber elements can behave in tension too. The internal structure of platform roofs were solved in a quite particular way, as in Melville House (Fig. 4).

Later in eighteenth century the spans increased (up to 9.86m in Duff House 1735), and the pitches became shallower (down to 23° in Yester House 1729, Fig. 4), forcing the internal structures to become more efficient: the elements' sections became more rectangular and butt-purlins were introduced. Rafters started being distinguished into primary and secondary ones, which significantly reduced the amount of timber needed. In Yester House (1729, Fig. 4), for example, primary frames are connected by purlins, which in turn support the common rafters. This arrangement is quite different from those of Culross Palace and Melville House (Fig. 4), where all the rafters and frames are the same, with no distinction between primary and secondary. The 'more complex frames', such as the one at Yester House, seem to have a structural behaviour in-between common rafter roofs and trusses, and could be antecedents of the latter (Serafini & Gonzalez Longo 2015).

3.3 *Purlin roofs*

In eighteenth Norway declined as supplier of timber due to the over-exploitation of its natural resources; its role was taken first by Sweden and then by the eastern Baltic area, exporting balks, to be sawn to meet individual needs, and deals of pine (Thomson 1991). In this period home-grown pine was used as well (Crone & Mills 2012). In the second half of eighteenth century timber was also imported from the Americas, as was happening in England (Yeomans 1992): the West Indies sent exotic hardwoods such as mahogany and American Colonies and Canada provided oak and walnut (Thomson 1991).

The change in the timber trade mirrors changes in construction. Purlin roofs started being employed from late seventeenth century (Fig. 3): Melville House (1697/1703) is the earliest purlin roof we've surveyed (Fig. 4). Unfortunately, the limited number of surveyed examples makes it difficult to draw conclusions on their development. Nevertheless, it is interesting to note that purlin roofs were often coupled with other structural types in the same building, with no apparent reason driving the choice of one structure or the other. This could suggest that either the different timber structures have been constructed in different periods, or, if they appear to belong to the same period (as is the case of Melville House, Fig. 4), that wrights/architects were experimenting.

3.4 *Trusses*

Our surveys suggest that from 1740s/50s king-post trusses started being used to cover reduced spans (Fig. 3), and princess-post trusses and queen-post

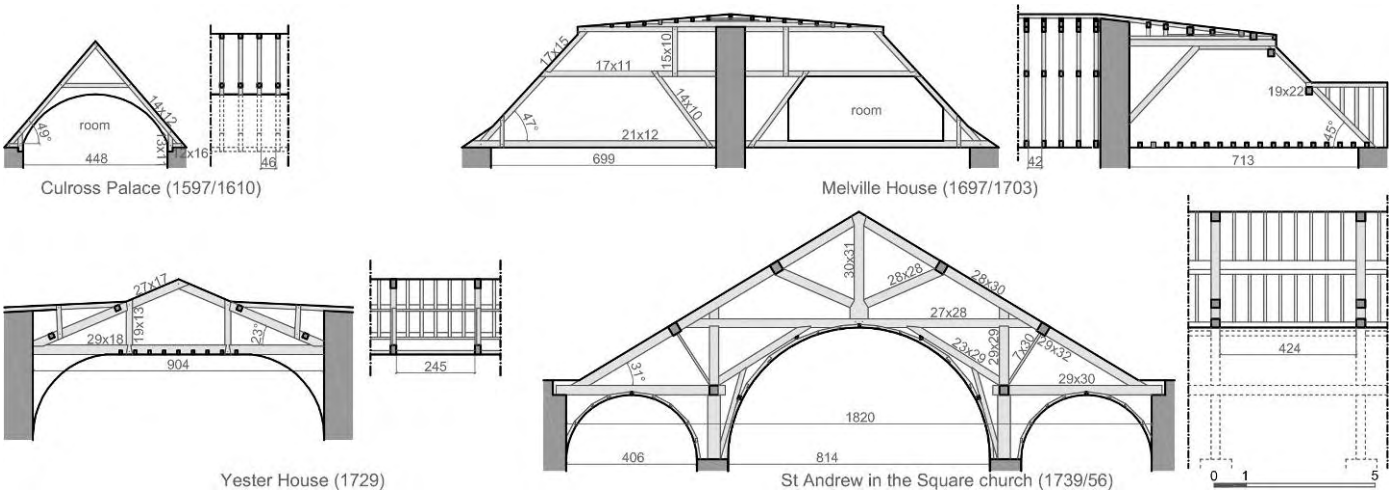

Figure 4. Top left: common rafter roof in Culross Palace (1597/1610); top right: platform frame and purlin roof in Melville House (1697/1703); bottom left: more complex frame in Yester House (1729); bottom right: princess post truss in St Andrew in the Square church (1739/56).

trusses to cover bigger spans (as in St Andrew's in the Square church 1739/56 – Fig. 4). Spans reach their maximum in Oakshaw Trinity church (1754/6) with 20m, and pitches vary between 44° and 27°. The sarking is retained, even though butt-purlins are always used. Joints are all mortice and tenon with no fasteners or timber dowels; scarf joints are very rare. Metal straps are seldom used as well - they are often a later addition. Posts normally have joggles, which could be an English influence (Yeomans 1992), but traces of other influences can be identified too (Serafini & Gonzalez Longo 2015).

It is still not clear how the truss was introduced in Scotland. The arrangements and construction details of the earliest Scottish trusses show little understanding of their structural behaviour. The truss in St Andrew in the Square church (Fig.4), for example, shows an improper design of the joint between the post and the raised tie-beam: it's a simple mortice and tenon joint with no fasteners, which cannot work in tension and counteract the tie-beam deflection. An analysis of drawings and buildings of the Adam architects suggests that although they aspired to build trusses, wrights were initially unable or unwilling to construct them. An external influence was probably necessary for the introduction of trusses in Scotland (Serafini & Gonzalez Longo 2015).

4 PATHOLOGIES AND POSSIBLE CAUSES

4.1 *Assessment of historic timber structures*

The assessment of timber structures can be challenging because of the organic nature of the material and its variable properties.

Recent research has outlined a methodology for the on-site assessment of historic timber structures (Feio & Machado, in press, Cruz et al 2015). They suggest a preliminary assessment based on a desk survey followed by an on-site visual and measured survey, where moisture content readings and Visual Strength Grading (VSG) are carried out. Resistance Microdrilling can be used to assess invisible decay and structural analysis can identify highly stressed areas. The information gathered can then be used in a final structural analysis to verify if the structure complies with the ultimate state requirements. If it fails, a more detailed survey (using other non-destructive/semi-destructive tests – NDT/SDT) must be carried out and the structural analysis updated.

VSG is a powerful method but it has limitations: the subjectivity and low experience of the inspector, limited accessibility, non-visible internal decay, and lack of specific criteria in most national standards. It also requires the timber species identification, which is often not doable (Macchioni 2010). Alternatively, mechanical properties can be estimated with SDT (Kloiber et al, in press) or stress waves methods.

Unfortunately, NDT and SDT also have many drawbacks: poor correlation with material properties; the information obtained is often qualitative/local; the test procedure and the results' interpretation require a lot of experience; it is not clear how to use the collected data; some devices are not on the market yet.

This is why most professionals don't use NDT/SDT but rely mainly on experience, even though this can lead to underestimating the structure's condition and replacing or over strengthening the whole roof.

4.2 *Typical damage in Scottish timber roofs and possible causes*

As explained in section 2, it is known that 17 buildings out of 80 (~20%) have been reroofed after 1800 (mainly in 20C), because thought to be structurally unsafe. 20% is quite a high percentage and suggests either a conservative approach on the professionals' side, leading to the replacement of structures even when not necessary, or poor maintenance on the owners' side, leading to damage/degradation beyond repair. In both cases it is clear that the value of these structures is not recognized and that good conserva-

tion practice is hindered by lack of information, training and method. In order to overcome these limitations, a preliminary visual inspection was carried out to start identifying the typical pathologies and possible causes of the different structural types.

4.2.1 *Poor initial design*

Poor initial design (overall structural arrangement, joints, timber dressing) seems to play a key role in causing damage in all of the roofs surveyed, which is not unusual (Tampone 2007).

Common rafter roofs show joint disconnections/splitting that can be associated with an overall transversal opening of the roof. As already stated, up to about 1670 simple lap or mortise and tenon joints are used, secured with timber pegs. These joints are not capable of resisting tension forces, which the lower collars and rafter feet are subject to. The timber pegs fail easily (also because of biotic attack) and the joints start opening (Fig. 5 left). Even in later roofs, dovetail joints can fail if the timber cracks and splits around the metal nail (Fig. 5 center).

Other common rafter roofs have a problem in the longitudinal direction, with the frames stacking up and losing stability (Fig. 5 right). This seems to happen when the distance between the frames is more than the common 50cm, because the longitudinal rigidity is provided only by the sarking boards.

Trusses with spans below 10m are generally in good conditions, whilst those covering bigger spans sometimes have deflections in rafters and tie-beams, joint disconnections and cracks (Fig. 6), which suggest an



Figure 5. Mechanical damage in common rafter roofs. From left to right: joint disconnection in Sailor's Walk (Kirkcaldy, Fife), joint splitting in Touch House (St Ninians, Stirling), stacking up in Geilston House (Cardross, Argyll and Bute).



Figure 6. Mechanical damage in Trussed roofs. From left to right: joint disconnection in Fort George Ordnance Store (Ardersier, Highland), joint disconnection in Oakshaw Trinity Church (Paisley, Renfrewshire), crack in rafter in Glasgow Trades Hall.



Figure 7. Mechanical damage in purlin roofs. From left to right: deflected purlin in Melville House (Monimail, Fife), deflected purlin in Touch House (St Ninians, Stirling), crack in strut in Touch House (St Ninians, Stirling).

overall deflection and opening of the roof structure. One of the causes is the improper design of arrangements and joints: timber elements are often too long and do not have sufficient propping provided; joints are almost exclusively mortise and tenon secured by timber dowels or nothing, which work only in compression (Fig. 6, left); metals straps are very seldom used and sometimes they are a later addition; scarf joints, when used, are very simple (Fig. 6 center), and again unable to absorb tension forces.
Purlin roofs often have deflected purlins and cracked struts (Fig. 7), caused by insufficient dimensions or lack of supports.
Common rafter roofs also have material degradation problems (fungi, insects, etc), that might be caused, amongst other, by the rough dressing of the timber elements, which often retain some bark and sapwood, more subject to biotic attack (Ridout 1999). Trusses and purlin roofs seem to be less vulnerable, probably because the timber for these bigger and more complex structures was carefully selected to be of high quality, and carefully squared and finished.

4.2.2 *Past interventions*
Past alterations and repairs contributed in creating/accelerating damage in some cases.
Gardyne's Land (end seventeenth century), for example, has deflected collars in the central part of the roof, where a pediment was added in early 18C (Fig. 8 left). Another example is Oakshaw Trinity church, where the heavy plaster ceiling was probably added/replaced in nineteenth century, causing deflections and joint disconnections due to the additional dead load (Fig. 6 center).
There is often no documentation on past repairs and why they have been done. Temporary interventions often become permanent, and their effect on the structure is not monitored. Whilst in eighteenth and nineteenth century timber was used to either replace the whole roof or double its structure (Fig. 8 center), in the twentieth and twenty-first century steel became more fashionable. The weight of steel is often a problem for the masonry and the plaster ceilings. For example, timber posts and steel beams were added in Oakshaw Trinity church to support the hip rafters that were deflecting (Fig. 8 right); this intervention actually increased the loads on the tie-beams, increasing their deflection and joints' opening (Fig. 6 center), and on the masonry, causing cracks. Checks and cracks, with no distinction, are often filled with resin. Checks are natural cracks that develop along the radius of a log, when the timber dries. They rarely are a structural problem. Filling them actually weakens the timber preventing it from 'breathing', and can cause further cracks to develop.

4.2.3 *Inadequate environmental conditions, accessibility issues and poor maintenance*
As already stated, many of the surveyed common rafter roofs suffer from material degradation problems. Besides the timber dressing, other factors probably contribute as causes. Common rafter roofs generally cover dwelling houses, where the lower part of the roof spaces is plastered and occupied by rooms. This part of the structure (and in particular the connection with the wall) is often not visible/accessible, which hinders its maintenance. The upper part is generally quite small, with poor ventilation and sometimes over insulation, and uncovered water tanks that increase humidity. On the other hand trusses are normally employed in public buildings with bigger roof spaces and better ventilation.
The presence of pigeons, wasps, and bats hinders accessibility and maintenance: access to many properties has been denied because of the presence of bats/wasps, and a few of the surveyed roofs proved to be problematic because of pigeons droppings'.
Finally, owners and estate managers do not always know how to access roof spaces and do not have the necessary equipment to do it (ladders, torches, etc).

4.3 *Future work*

Future work will comprise an in-situ testing campaign aiming at complementing the initial analysis carried out through visual inspection. NDT and SDT will be used to further investigate the critical areas identified and to address specific issues and limitations in the assessment of these structures. The intention is to use equipment that is available to professionals in Scotland, in order to develop a method that can contribute in improving local practice.



Figure 8. Past interventions. From left to right: Steel beam and ties counteracting the collars' deflection in Gardyne's Land (Dundee), 18C and 21C timbers strengthening the original 17C timbers in Panmure House (Edinburgh), timber posts/struts and steel beams/straps counteracting the hip rafters' deflection in Oakshaw Trinity church (Paisley).

5 CONCLUSIONS

Seventeenth and eighteenth century Scottish built heritage has not been sufficiently researched. In particular, very little is known about timber roof structures, which are very seldom inspected. This lack of information hinders good conservation practice: the roofs' value is not recognized and their structural behaviour is often misunderstood, resulting in their replacement or over-consolidation.

A relational database and mapping of seventeenth and eighteenth century Scottish buildings has been developed and used to select 56 key buildings to survey. A preliminary assessment based on historical/archival research and visual/measured on-site survey has been carried out. This has allowed identifying different structural types, their design and development, pathologies and possible causes, and issues in their assessment.

Research so far has focused on few medieval open purlin roofs. However, our surveys suggest that the vast majority of Scottish roofs throughout the centuries were common rafter roofs, purlin roofs and trusses, hidden behind timber/plaster ceilings. The apparent simplicity and uniformity of Scottish common rafter roofs could be explained by the reliance on imported timber from Norway, but this could be true only up to 1670s when common rafter roofs evolve and adapt to the new geometries of classical architecture. In eighteenth century wrights and architects start experimenting with purlin roofs and trusses. Considering the limited number of surveyed purlin roofs, it seems that their use remains restricted. Trusses are instead employed from 1740s in the vast majority of public buildings and big country houses, and they are soon used even for reduced spans. However, their arrangements and construction details suggest that their structural behavior was not always understood.

No research has been previously carried out on the present condition of Scottish timber roofs. Our surveys have highlighted how all of the structural types show damage that seems to be caused mainly by poor initial design, but also by past alterations and repairs, poor environmental conditions and poor maintenance. Common rafter roofs seem to suffer of material degradation more than others. In order to assess hidden parts of the structure and verify the hypothesized causes of damage, future work will comprise an in-situ testing campaign, with the aim to contribute in improving local practice.

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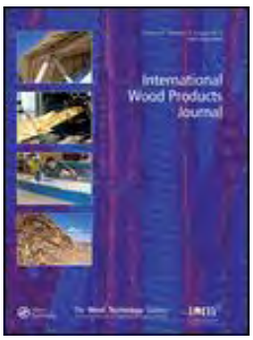

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A database model for the analysis and assessment of historic timber roof structures

A. Serafini*[1], M. Riggio[2] and C. González-Longo[1]

Visual inspection assisted by well-structured forms allows experts to collect homogeneous data in order to report about typical damage/vulnerabilities of structures. This is the basis for deriving vulnerability factors to predict failure mechanisms and identify urgent interventions. A database model with an associated structured form for the assessment of historic timber roof structures has been developed during a two-week Short Term Scientific Mission (STSM) in May 2015 at CNR IVALSA Institute in San Michele All'Adige (Italy). The aim is to assist during inspection in recording all the necessary information and later in analysing data from several inspections, allowing to identify typical damage and its causes. The database model, starting from the work of COST Action FP 1101 and further developed and digitalised during the STSM, has been initially populated with data previously collected by the University of Strathclyde through visual assessment of 29 historic timber roofs in Scotland.

Keywords: Timber, Roof, Structures, Historic, Database model, Structured form, Assessment, Diagnosis

Introduction

Visual inspection is the basis of any structural assessment, which is a prerequisite for further analysis, assessment and intervention. Different factors and their interdependency must be considered during the assessment, such as: form, material, loads and environment. The original characteristics and any later alteration/damage must be examined and their causes identified. There are many assessments of single case studies in literature, but their methodology is heterogeneous. The use of structured forms to guide visual inspections can overcome this problem: it provides a uniform approach in the assessment, even when different professionals are involved, thus facilitating comparison of different case studies and identification of vulnerabilities.

Structured forms have been used since 1980s for vulnerability surveys and post-event damage recognition surveys. Benedetti and Petrini's form (1984) was developed to assess the seismic vulnerability of masonry buildings in Italy. More recent research has produced different types of forms to assess seismic damage (Baggio *et al.* 2007), to assess causes of failures in twentieth-century timber roof structures (Frese and Blas 2011; Hansson 2011; Toratti 2011) and to assess the seismic vulnerability of traditional Italian timber roof structures (Parisi *et al.* 2013). In all of these studies the first step was a visual examination of the structures according to a codified procedure: a series of characteristics that determine or influence the specific aspect studied were identified and then a classification criteria was defined to be able to compare different cases, identify urgent interventions and make a plan for risk reduction in the territory.

Toratti's form (2011) was developed with a two-fold purpose: to help the experts in the assessment, making them aware of the relevant questions that need answers; to produce uniform results that can be analysed in order to draw conclusions on typical damage and related causes. The form developed by Task Group 1 (TG1) of Working Group 1 (WG1) of COST Action FP1101 (Riggio *et al.* 2015) had the same purpose but focused on traditional timber roof structures, which had not been addressed so far. Starting from this work a database model and associated form have been developed during a two-week Short Term Scientific Mission (STSM) in May 2015 at CNR IVALSA Institute in San Michele All'Adige (Italy). This paper describes the outcome of this STSM.

The database model and associated structured form

Approach

TG1 identified a series of objectives that the form should fulfil (Riggio *et al.* 2015):

- Allow collecting a significant amount of data reporting typical damage/vulnerabilities;
- Support multi-level analysis (visual inspection, in-situ tests, lab-tests, etc.);
- Define structural types (considering the European built asset) and a damage taxonomy to provide a unified approach to the evaluation of structural damage;

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- Distinguish between material degradation and mechanical damage.

Before the STSM the TG1 form was in word format, which did not allow for the analysis of a big amount of data and was not suitable for quick inspections, due to the considerable amount of pages involved. Moreover, a tree-like organisation had been implemented but structure types and damage taxonomy for each level (system, unit, element, connection) had not been clearly identified. The inclusion of Visual Strength Grading (VSG) regulations (such as UNI 2004) had to be defined too, and graphics were needed to support the relevant terminology. Moreover the form needed to be validated by applying it to real case studies. The STSM work focused on the reorganisation of the contents of the TG1 form in both format and structure using Microsoft Access software and data from visual inspections carried out in summer 2014 by ADCRU (Architectural Design and Conservation Research Unit at University of Strathclyde) in 29 timber roof structures in Scotland. The software was chosen because it allows managing and multiple-querying a big amount of data and also because it would allow an easy integration with a mobile phone application being developed in the frame of Working Group 2 of COST Action FP1101 to assist professionals in the selection of interventions on timber roofs (Harte *et al.* 2015).

Since the data available was related to seventeenth- and eighteenth-century timber roofs in Scotland, it was decided to focus on the development a form for the inspection of historic timber roof structures. Once validated, it will be possible to extend the work to the development of a form for other roof structure types and other load-bearing systems.

Content

The aim was to organise the form in order to fulfil a twofold purpose, as in Toratti (2011):

- Assist professionals during inspections in recording and organising all the information needed, pointing out critical aspects that need special attention;
- Assist the analysis of data from several inspections allowing to draw conclusions regarding construction history and typical damage and causes.

The tree-like organisation of the TG1 form has been retained and enriched with a classification of types of structures and damage for each level (Fig. 1). The first part of the form deals with general information on the BUILDING, then each building can have one or more roofs (SYSTEMS), composed of a PRIMARY and a SECONDARY structure; each of these can be composed of UNITS (groups of elements repeated with the same arrangement), and of ELEMENTS and CONNECTIONS between elements.

Each part of the form has a first section on geometrical and typological aspects (Fig. 2), and a second section on damage. Structural types have been grouped into families according to their structural behaviour rather than their geometrical arrangement. Clearly, not all local variations have been considered. Past interventions (alterations, repairs, etc.) can be recorded too. As highlighted by Parisi *et al.* (2013) the effect of past interventions is particularly critical to evaluate, as they can be localised or involve the whole structure, and differently affect the original behaviour/concept of the structure. Thus the form includes only a description and picture/drawing of past interventions, not their evaluation.

Building

General information on the building's name, location, property, protection status, use, interventions, references and geometrical aspects can be recorded in this section. X and Y coordinates and the geo-referencing system have been included in order to be able to plot the results. Values, rather than categories, have been used for seismic, snow and wind loads, and the protection status has been simplified to 'UNESCO', 'National' and 'Regional', to suit every country. Inspections can be linked to each building, specifying: the date, the inspector's name, the parts of the building inspected. Foreseeing the development of forms for the inspection of other load-bearing systems (vertical, floors, foundations), the load-bearing system inspected can be specified too.

Roof

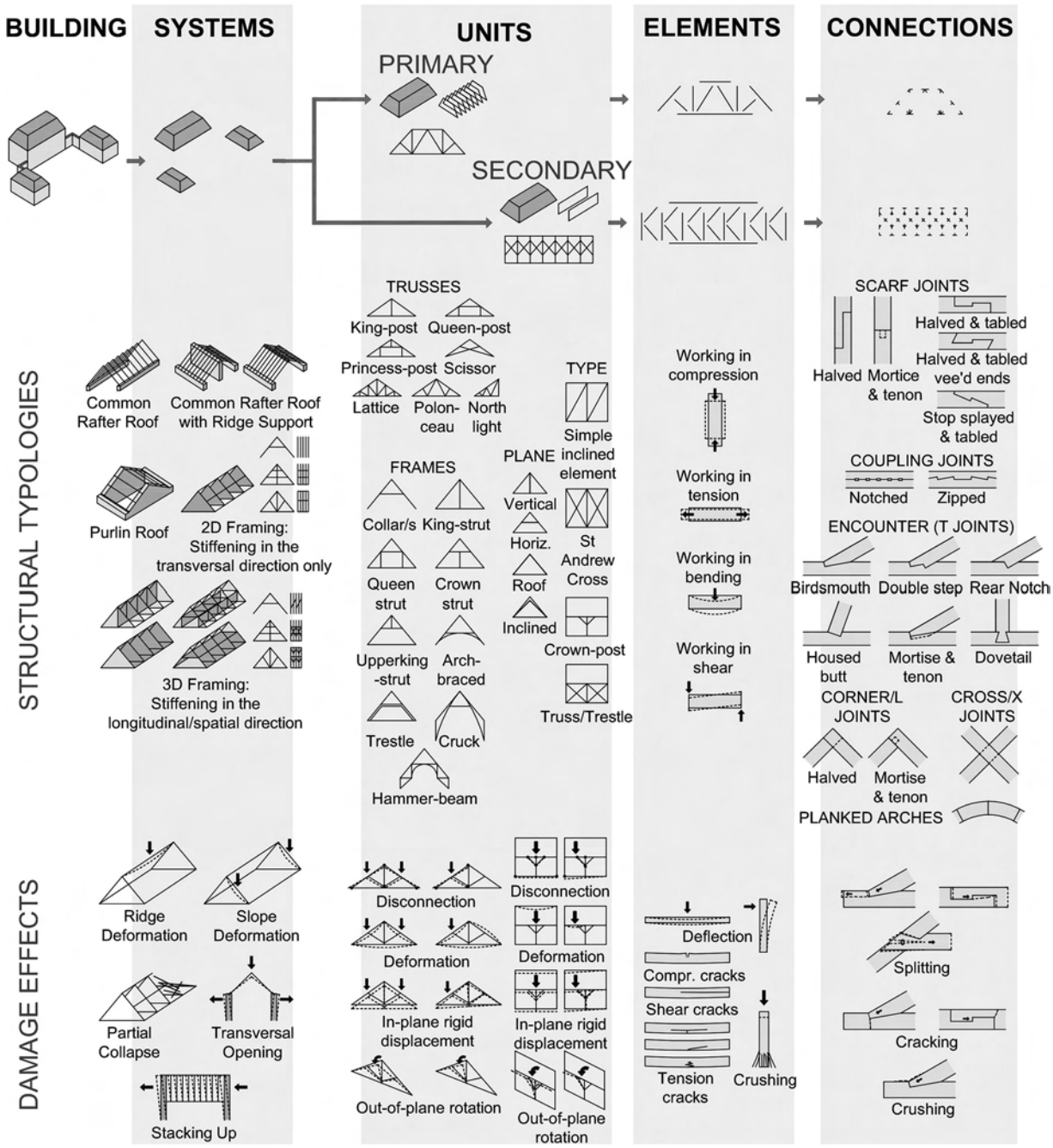
The shape, construction period, roofing material, height, span(s), structure type of each roof can be recorded (Fig. 2). The roof structure can be composed of elements only (common rafter roofs, common rafter roofs with a ridge support, purlin roofs), or units too, in one direction (2D framing), and in two or more directions (3D framing). Other information include if the roof space is in use and if there are accessibility limitations, which can affect the possible interventions. The Eurocode 5 Service Class can be estimated.

Unit

Units have been divided into trusses and frames, as defined by Yeomans (1992, pp. 26–28). It is important to record if the original structural concept is different from the present behaviour: e.g. a unit might have been designed as a king-post truss but is actually behaving as a king-post frame, because of poor design, poor construction, etc. A series of data can be recorded if homogeneous in the whole unit: the timber dressing (rustic or civil, which affects the kind of intervention that can be done), the timber species (grouped in softwoods and hardwoods), the section shape (round, rectangular, rectangular with wanes, trapezoid), the timber treatment, carpentry marks, signs of reused timber.

Element

Elements have been classified as working in compression, in tension, in bending or shear, or a combination of the above (Fig. 1). The dating of the element can be specified, if different from the rest of the unit, as well as all the other information related to the timber dressing, treatment, section shape, etc. Strength affecting defects/natural features (knots, checks, etc.) and material degradation (fungi attack, insect attack, metal corrosion) have been included in this part only, as they cannot be homogeneous for a whole unit or roof. Since most countries have regulations for VSG of new timber but not for VSG of in-situ historic timber, it was decided to include only the natural defects that can significantly alter the structural behaviour or reduce the strength of an element: the position of the pith, the slope of grain, knots in the tensile area and horizontal deep checks which alter the section inertia. The



1 The tree-like organisation of the form, with structural types and damage effects

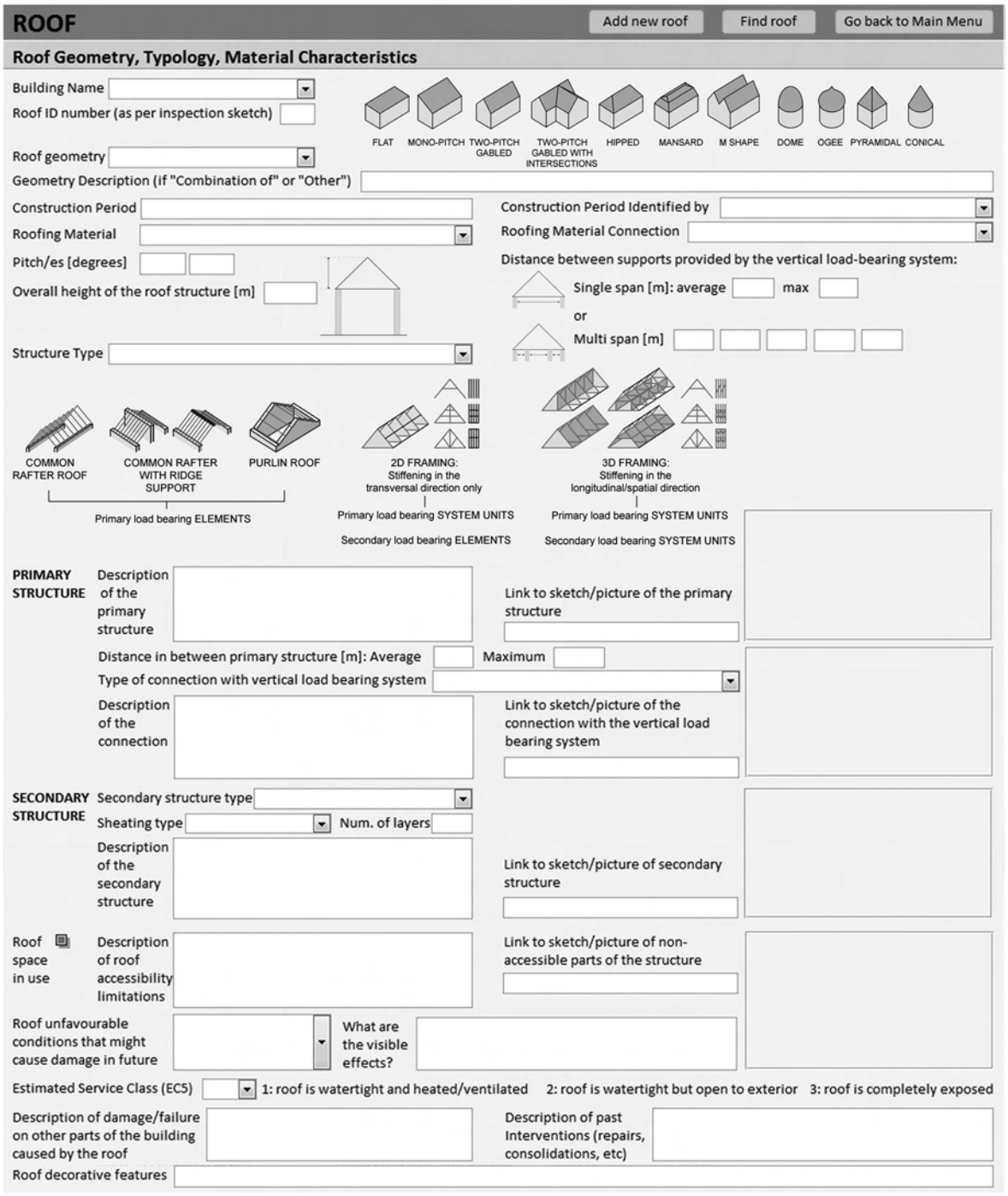
type, extent and status of material degradation can be estimated.

Connections and secondary structure

The part on connections and secondary structure is organised in the same way, the only difference being the types of connections, bracing systems and damage (Fig. 1).

Damage

An important distinction has been made between damage effects and causes. During an assessment, we record the visible effects of damage and estimate their causes. The form guides the inspector in doing that: lists of damage effects (deformations, displacements, rotations, cracks, etc.) are suggested for each level (system, unit, element, connection), and for each of the effects selected the damage status and role can be estimated. Tampone's work (1996, 2016) was very useful to build the damage taxonomy (Fig. 1), as well as the work of Task Group 3 of WG1 of COST Action FP 1101 on traditional carpentry joints (Sobra *et al.* 2015). Regarding the status, a damage can be 'active' or 'non-active', but it is not always possible to judge. Therefore, a simple 'intervened on' can be chosen, meaning that an intervention has been done to repair the damage but no evaluation on its effectiveness is given. Regarding the role, a structure is often affected by a sequence of damage rather than a single one, and it is important to identify the first one that caused all the others. This first one is defined as 'primary' damage, while all the others are defined as 'secondary' ones.



DROP-DOWN MENUS:
- Building Name: any building included in the 'building form' will appear in the list
- Roof Geometry: flat, mono-pitch, two-pitch gabled, two-pitch gabled with intersections, hipped, mansard, m shape, dome, ogee, pyramidal, conical, combination of, other (as in graphic legend)
- Construction period identified by: estimated, reported, dendrochronology
- Roofing material: slates, timber shingles, copper plates, lead plates, tiles, thatch, other, unknown
- Roofing material connection: timber pegs, metal nails, other, none, unknown
- Structure type: common rafter, common rafter with ridge support, purlins, 2D framing, 3D framing, other (as in graphic legend)
- Type of connection with vertical load bearing system: timber wall-plate, steel wall-plate, reinforced concrete wall-plate, reinforced masonry wall-plate, timber discontinuous, steel discontinuous, other, none, unknown
- Secondary structure type: sheating, purlins, common rafters, bracing, other
- Roof unfavorable conditions that might cause damage in future: poor design, poor construction, poor maintenance, poor ventilation, presence of pigeons/wasps/bats
- Estimated Service Class (EC5): 1, 2, 3

2 Form screenshot (section related to roof geometry, typology and material characteristics) with list of terms included in the drop-down menus

The causes of primary damage have been grouped in:

- Poor design (insufficient dimensions, inefficient joints, inefficient overall arrangement);
- Poor construction (poor material quality, poor seasoning, poor treatment, poor detailing, alterations of design);
- Material degradation (fungi attack, insect attack, metal corrosion);
- Poor maintenance;
- Interventions (increase of dead loads, repair/consolidations);
- Extreme actions (wind, fire, earthquake, snow, impact loads, settlements).

The specific type of causes vary in each part (roof, unit, element, connection) but the groups remain the same. The forms previously discussed (Frese and Blas 2011; Hansson 2011; Toratti 2011) have helped in defining the possible causes of damage.

Poor design, poor construction and all the other, can also be recorded as potential causes of damage, called 'unfavourable conditions'. This means they have not caused damage yet but might be a problem in the future, which is why they should be recorded nonetheless. Other unfavourable conditions have been included too, such as poor ventilation and the presence of bats/wasps/pigeons.

While the geometrical/typological aspects remain the same, damage can change in time, and its evolution and development must be recorded. Thus the date of inspection has been included in the damage part.

Form

A main menu and linked forms have been created, to allow for an easier use and visualisation of the form. Instructions have been included in the main menu, explaining how the form is organised and the nomenclature used.

Drop-down menus with fixed lists have been included to help users in both filling the data, as they give suggestions, and in analysing it afterwards, as data filled in as free text is always less homogeneous and less easily searchable (Fig. 2). Items can be added to the drop-down lists and more than one choice can be selected where appropriate. 'Other' and 'unknown' have been included as choices in every drop-down menu, to not force users in choosing something that does not match their judgment. The possibility of adding descriptions and pictures/sketches has also been provided.

The form is suitable for both quick and more thorough assessments. Some fields have been repeated (such as the timber dressing, the timber species, etc.) at different levels, so that if they are homogeneous for the whole roof, or a whole unit, they do not need to be repeated for each element. Moreover, while providing space for all the information that one might want to record, all the fields have been left as 'non-required', so that they can be left blank: only the information that is available and useful for the specific purpose of that inspection should be recorded. Data can be changed and added any time later on.

There are many terminology issues, as types of roof structures, elements and connections have different names in different countries, and even the terminology associated to different damage/failures types is not always clear for English-as-a-second-language speakers. It was decided to solve this problem with drawings/sketches, which work as legends for the drop-down menus and other terms that might be misinterpreted (Fig. 2). Many terminology issues remain though: a work on terminology is a complex and long activity that was outside the scope of this work.

Future developments

The database model and form were presented and discussed at the COST Action FP 1101 meeting held in Trondheim, Norway, on 18th/19th June 2015, and at the COST Action FP 1101 final conference in Wroclaw, 8th September 2015. The feedback received was used to revise it. The form has been distributed among TG1 members for further revision and validation. There is also the possibility of it being implemented in an online version, in collaboration with a research group who has developed a semantic database model for the assessment and diagnosis of historic structures (Cacciotti *et al.* 2015).

Future developments include extending the methodology to the development of forms for other load-bearing systems, incorporating data also from non-destructive/minor-destructive testing in order to quantify the damage in addition to characterising it.

The data collected through the form could also be useful to associate each type of damage with the most suitable repair intervention (Harte *et al.* 2015).

Conclusions

A database model and associated form for the assessment of historic timber roof structures has been developed based on the work of COST Action FP1101 and ADCRU at the University of Strathclyde. The aim is to guide visual inspection through a structured digital form, collecting a relevant amount of homogeneous data recording and reporting typical damage/vulnerabilities of structures. This is the basis for deriving vulnerability factors to predict failure mechanisms and identify urgent interventions. The development of this data collection and analysis procedure will support professional practice and increase knowledge on existing timber structures. Once validated, the approach used (the tree-like organisation of the form, the flexibility for its use in both quick and in-depth inspections, the graphics explaining the relevant terminology, etc.) could be applied to develop forms for the analysis and assessment of other structural systems.

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