University of Strathclyde, Glasgow

CONJECTURAL RECONSTRUCTION OF THE A FAMOSA FORTRESS IN MELAKA

by

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This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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ABSTRACT

This thesis develops a methodology for dealing with 3D virtual heritage reconstruction of a damaged heritage which has minimal extant resources. The fortress known as A Famosa in Melaka, Malaysia is used as the subject matter. The selection of this fortress has been based on its historical value as the oldest partially extant European building in the historic city of Melaka. Melaka was designated a UNESCO World Heritage in 2008. Presently, efforts to physically preserve this fortress are limited due to logistic and financial constraints. Considering the important role it plays in the history of Melaka and its potential as a tourist attraction. The 3D preservation of this heritage is of considerable national importance.

Due to the condition of the fortress (which has been largely destroyed) advanced digital reconstruction technology such as photogrammetry and laser scanning cannot be used to gather data for building a model. To address this issue, several case studies of similar 3D reconstruction projects have been conducted and compared. It is found that the only solution is to use the traditional 3D modelling approach. Prior to the 3D reconstruction process, various and extensive data verifications have been conducted on the different types of resources collected which relate to the fortress. There are visual data, textual descriptions and the existing remains. The establishing of a verifiable conjectural layout of the fortress is a major part of the thesis and the developed methodology makes an important contribution to the subject area.

The thesis includes methodologies such as original on-site research and data collection at various archaeological sites of similar fortress in India and Sri Lanka, the innovative application of mathematical analysis to determine 'best fit' plans from the conflicting documentary evidence available and also detailed on-site survey work which is resolving other previously unclear aspects of building construction.

The results are presented as a complete 3D model of the A Famosa fortress, followed by human evaluation to support the importance of this digital preservation of A

Famosa and identify future possible developments of this model in research, tourism, history and education.

DEDICATION

Thank God for giving me this opportunity to explore the beauty of this universe from the perspective of human civilization, heritage, science and technology. I was extraordinarily fortunate in having Telekom Malaysia as the main sponsor for this research.

I am heartily thankful to my supervisor, Professor Alan Bridges, Dr. Barnabas Calder, Dr. Michael Grant and all Architecture department staff whose encouragement, supervision and support from the preliminary to the concluding level enabled me to complete this research. Special thanks to British Council Prime Minister II Grant which enables me to travel to various places for data collection.

I gratefully thank my parents for their inseparable support and prayers. My beloved wife as a backbone and moral supporter next to me. My children for inspiration and friends for kind help and support.

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Chapter 1

INTRODUCTION

1.1 Background and motivation of the study

This thesis develops a methodology for dealing with the 3D virtual heritage reconstruction of the damaged heritage which has minimal resources. It describes how to deal with different source material such as visual data, textual descriptions and existing remains which can be combined, verified and analysed as an established reference for 3D virtual heritage reconstruction. The subject matter for this research is a fortress known as A Famosa in Melaka, Malaysia (Figure 1.1).

Figure 1.1 Remains of old Portuguese fortress in Melaka (2009), Porta de Santiago (Source: Author)

3D virtual heritage is still a relatively new branch of knowledge which is concerned with the preservation and representation of the data studied by archaeologists and historians in field of art and architecture. This includes 3D objects such as buildings, villages, cities, ornaments and statues (Koller, Frischer et al. 2009). Most of this digital reconstruction or preservation is done to document historic objects and create educational resources in the fields of history and culture (El-Hakim, Beraldin et al. 2003). Koller, Frischer et al. (2009) explains, "*There are three ways to support this data representation, existing objects can be preserved by using laser scanning or photogrammetry, damaged or no-longer extant objects can be modelled by using manual hand modelling and hybrid methods which combine both methods above."* Despite the advancement and sophistication of 3D virtual heritage technology, in some cases adopting manual approach is the best solution. Manual reconstruction is better in accuracy because it is based on the knowledge of experts (Matini, Einifar et al. 2009).

Most of the literature describes projects where the authors have access to the existing research objects. One example of the use of photogrammetry is the digital reconstruction of the medieval fortress at Kufstein in Austria. The digital model was made to record and document the condition of the fortress before commencing an extensive renovation programme (Hanke and Oberschneider 2002). Photogrammetry was selected due to the size of this fortress. It does, however, have problems as the method is not selective and captures all data equally rather than concentrating on areas where more detail may be needed. This results in a very large data file.

As a means of dealing with this problem the combination of image data in conjunction with photogrammetry can be utilised to focus detail on selected key features. This method was adopted by El-Hakim, Frischer et al. (2003) in the Abbey of Pomposa and Scrovegni Chapel in Italy. El-Hakim, Frischer et al. (2003) highlighted that using a single method is not an effective approach. However even a combination of more than one method cannot satisfy all the requirements of cultural heritage applications. Several problems have been identified such as dealing with large buildings require large scan numbers which also produce large data file. Another method used in this research is image-based modelling which also has problem with irregular surfaces. El-Hakim, Frischer et al. (2003) mentioned that the method's weakness is the amount of human interaction which still remains.

Another attempt to extend the effectiveness of 3D reconstruction is by integrating models from laser scanning, engineering drawings and digital images (aerial and close range images) (El-Hakim, Beraldin et al. 2005). Advanced image-based and laser scanning techniques are well known for realistic output, however accuracy issue is still elusive. For instance, laser scanning can provide complete details and accurate 3D models output but the equipment can be bulky, costly and technically challenging to operate. El-Hakim, Beraldin et al. (2005) introduces a hierarchical procedure based on data sources in which the details, accuracy and reliability increase from one data level to the next. In general, this method is only practical and applicable for projects that have comprehensive data sources such as images and

engineering drawings and where physical remains still exist for laser scanning purpose.

An example of a 3D reconstruction of a destroyed building is found in the case of the Bam citadel in Iran which has been reconstructed from an analytic interpretation (Matini, Einifar et al. 2009). The citadel was destroyed in a natural disaster in 26 December 2003. However it was not properly documented and the drawings before its destruction are not helpful. The research team used references from heterogeneous data such as photos, 3D cartographic map and video for 3D reconstruction. The first phase involves with manual 3D modelling process which led to confusion due to simultaneous application of these data and lack of knowledge in traditional architecture. This problem is solved in the second phase by developing a unified and precise data, and this is also helped by an architect with knowledge of traditional architecture. The use of relics after the disaster is very useful and helpful in making an analytic interpretation for digital reconstruction of a destroyed heritage.

This research also looks into three examples of 3D reconstruction of destroyed heritage, namely the Michelsberg synagogue, the Jewish Quarter in Regensburg and the old main church in Curitiba, Brazil. These buildings are no longer exist and not well documented as well. The researchers have put an effort in collecting the materials and evidences such as photographs and drawings for analysis and 3D reconstruction process. These three projects fully utilised manual 3D modelling process.

In case of A Famosa fortress, the building has been destroyed since 200 years ago. It does not have any sources like photographs, except for a few image drawings with various measurement systems due to different plans under three occupiers, the Portuguese, Dutch and British. The fortress also has minimal remains and textual descriptions.

1.2 Thesis outline

Chapter 1 describes the background of this research. It defines the research problems, objectives and scope of the study. A detailed discussion of the methodologies and overall processes involved throughout this research is presented.

In order to understand the form of this fortress, a discussion on establishing the data for 3D modelling is presented in chapter 2. A history of fortification and its features were explained. This includes fortification types, sites, elements and purposes. In addition, a background history of A Famosa and its timeline are also discussed. This is followed by a discussion of case studies based on site visits to the similar fortresses in India, Sri Lanka and Indonesia.

The 3D modelling process, data collection and analysis processes are discussed in Chapter 3. A major data collection of sources relating to A Famosa fortress was undertaken. Documents collected include reproductions of manuscripts, old drawings, paintings and books. The process began with the fortress layout determination and translating that into a conjectural layout. The conjectural layout was then matched with the limited extant reference points using the statistical procrustes analysis method. This was followed by a comparison of measurements from textual descriptions and visual data. The determination of fortress elements was determined to support this result. The findings outlined the fortress elements for the next stage of 3D modelling.

Chapter 4 discusses rebuilding the A Famosa fortress in a 3D model. To support the 3D modelling process, a study on other digital reconstruction projects was conducted. The main reason for this was to extract the similarities, analyse the methods used and to use the findings as guidelines for comparison with the A Famosa fortress. 3D modelling process started with the transformation of the determined fortress elements and layout into 2D sketches as visual references. These sketches were used for detailed 3D modelling of the fortress elements. The complete 3D models were applied with texture mapping, lighting and accomplished with rendering.

The evaluation of the project output was conducted in Chapter 5 to gauge respondents' knowledge on A Famosa particularly before and after watching the 3D model presentation. This is also to identify the importance of digital preservation of A Famosa in 3D. The result justified the importance of further development of the 3D model applications to be used in fields such as research, tourism and education in Malaysia.

This thesis is concluded in Chapter 6 by discussing the methodologies and process implemented in reconstructing the A Famosa fortress in 3D model. Finally, it recommends the future development and potential applications of this 3D model particularly in field of digital heritage preservation.

1.3 Research problems

At the moment, there is no attempt to restore this old heritage to the public in the form of 3D visualisation. Below is the summary of several challenges encountered in developing the digital archaeological reconstruction of the A Famosa Fortress:

1. The main problem faced in this research was the lack of authoritative documentation. Such documentation as exists is scattered all over the world. In addition, the only extant remains are the fortress gate and an excavated bastion site. The rest of the fortress was destroyed by the bombardment by the British in 1807. To trace these documents it was necessary to contact related bodies in the countries that were involved in the past occupation in Melaka such as Malaysia, Portugal, Netherlands and Britain. All these documents are very old and require translation.

2. The variety of measurement systems and graphical projections used in the early descriptions of the fortress requires a translation to be made into standard units. Other than that it is also need to compare its old graphical projections and match with other graphical and textual resources. Any similarity in these findings will strongly support our rationale.

3. The use of advanced methods such as photogrammetry and 3D laser scanning to develop the digital model are not possible due to the fortress having been largely destroyed. Physical reconstruction of the fortress requires a very long timescale of development and rebuilding the entire fortress on the site is nearly impossible because the fortress's location now has been developed into a busy city.

1.4 Hypothesis

Even though most of the physical aspects of the fortress have been destroyed, information and records of various the architectural aspects of the fortress are still available from various resources. By thoroughly analyzing these resources and comparing various fortress designs from other countries, it is possible to rebuild the fortress in 3D as accurate as possible to the original ones and to preserve this important historical relic in digital format.

1.5 Research Objectives

The objectives of this research are:

1. To study the historical development and architectural background of the fortress.
2. To collect, analyse and verify authoritative documents pertaining to this fortress and come out with a verifiable conjectural layout.
3. To reconstruct the fortress in 3D model based on verified data.
4. To evaluate the potential of using the developed 3D model in various fields such as education, research and tourism industry.

1.6 Scope of the study

The research scope is to represent the complete A Famosa fortress in 3D model. Since the fortress has undergone some changes during the occupation of Portuguese, Dutch and British, an attempt has been made to accommodate these changes into 3D model. There are 3 stages involved in this research which are:

1. Understanding the design of fortress: this includes the elements of a fortress, the purpose of the building and the material used. Case study of several selected fortresses which are better preserved were also made.

2. Gathering resources of the A Famosa Fortress and analysis: This involved extracting and translating information from map, transcript, painting or drawings and also fortress remains into one reliable design with all the required data such as shape, elements, size and material.

3. Modelling and evaluation. Based on the data from previous stage, a 3D model will be developed and human evaluation will be conducted to investigate the significance and effectiveness of the model for education and tourism.

1.7 Methodology

This research comprises of six stages of methodology as explained below:

1. Determining sources of information

Finding authoritative data and resources is the most crucial part in this research. As mentioned earlier, most of the documents pertaining to the A Famosa are scattered all over the world involving Malaysia, Portugal, Netherlands and Britain. It is also important to identify the type of materials to collect such as architectural sketches and drawings, historic descriptions, research paper, journals, existing fortress reference and measurement units. Locations for site visit have been determined based on its significance.

2. Data collection

The details of the fortress remains and documents in Melaka have been collected and compared with other data from other sources. This includes size, dimension and layout of other Portuguese and Dutch fortresses for reference purposes. The research had discovered that other fortresses which are still available and can be visited in India, Sri Lanka and Indonesia. These fortresses have some similarities with the A Famosa fortress in terms of architecture, fortress elements and building materials

which are useful for comparison and reference. A series of case studies has been conducted based on several evaluation aspects.

3. Site visit

Field trips have been conducted to Goa, India and Galle, Sri Lanka to obtain physical references and compare with the actual fortresses which were built in the same era by the same occupiers. This site visit has given an extensive observation and experience of being in the real fortress. The site visit has been recorded accordingly. This includes video taping of the research activity and more importantly, the data recording process such as photo taking of the evidence. The collected materials and construction details have been used for comparison, reference and texture mapping sources for 3D modelling process.

4. Data analysis and translation

The collected data (written and visual forms) have been analysed and translated into a standardised format with dimensions and legends. This data went through several verification processes in order to obtain the most accurate possible results. Related argumentation has been presented to support the assumptions and methods leading to the 'best-fit' model. Pre-visualisation sketches were prepared for 3D modelling stage based on the analysis and verification data.

5. 3D modelling process

Based on the analysis and results, the findings were transformed and visualised in 3D models. The 3D models were created with the surrounding and related elements where necessary. The rest of the processes were texture mapping, lighting and rendering.

6. Evaluation of result

Evaluation of A Famosa fortress 3D model has been used to assess the accuracy of the findings and results. This evaluation justified the methods that had been used in data collection and analysis. The result justified the effectiveness of this reconstruction

method for application in education, architecture, history and tourism. The final outputs were presented in 3D rendered images and short animation.

Chapter 2

ESTABLISHING THE DATA FOR MODELLING

This chapter focuses on establishing data for 3D modelling. This is crucial because as mentioned earlier, one of the main challenges in this research is the lack of authoritative documents and the inconsistency of the collected data. This chapter will review the available data based on the concept of fortification in general, an in-depth study of the A Famosa fortress in Melaka and finally, case studies of related fortresses particularly those built by the Dutch and the Portuguese.

2.1 Military history background

The needs of fortification happened long time ago when men need to fortify themselves from enemy assault and keeping the attackers put of their territory (Yule 1851; Glick, Livesey et al. 2005; AFP 2009).The timeline for fortification development can be divided into several historical eras such as ancient, medieval,

17th to 18th century and 19th century. This development was influenced by the developments in military engineering, fortification technology, war development and siege craft (Kagay and Villalon 1999).This thesis discusses about the scope of fortification within Melaka in the 16th to 18th century. Since this thesis focuses on reconstruction of the A Famosa fortress during the Dutch era, it is very significant to relate to the well known figures in fortification history who are Sébastien Vauban and Dutch contemporary engineer, Menno van Coehoorn.

Sébastien Vauban (15 May 1633 – 30 March 1707), commonly referred to as Vauban was a French military engineer. He was well known for his breakthrough skills in fortification design. Vauban introduced his major innovations in siege warfare and also a new system known as the system of parallels. His fortification system developed in three ways which covers stronghold attacking techniques, multiplication of outer works to reinforce defences and delay of penetration of the fortress (Figure 2.1). Two of the important criteria in his system were the use of bastion systems protecting one another and increasing number of defending walls. These important features have been clearly adopted by the Dutch when they took over Melaka from the Portuguese. The Dutch strengthen the walls by adding fausse breaie (second wall) and digging ditch to encircle the fortress.

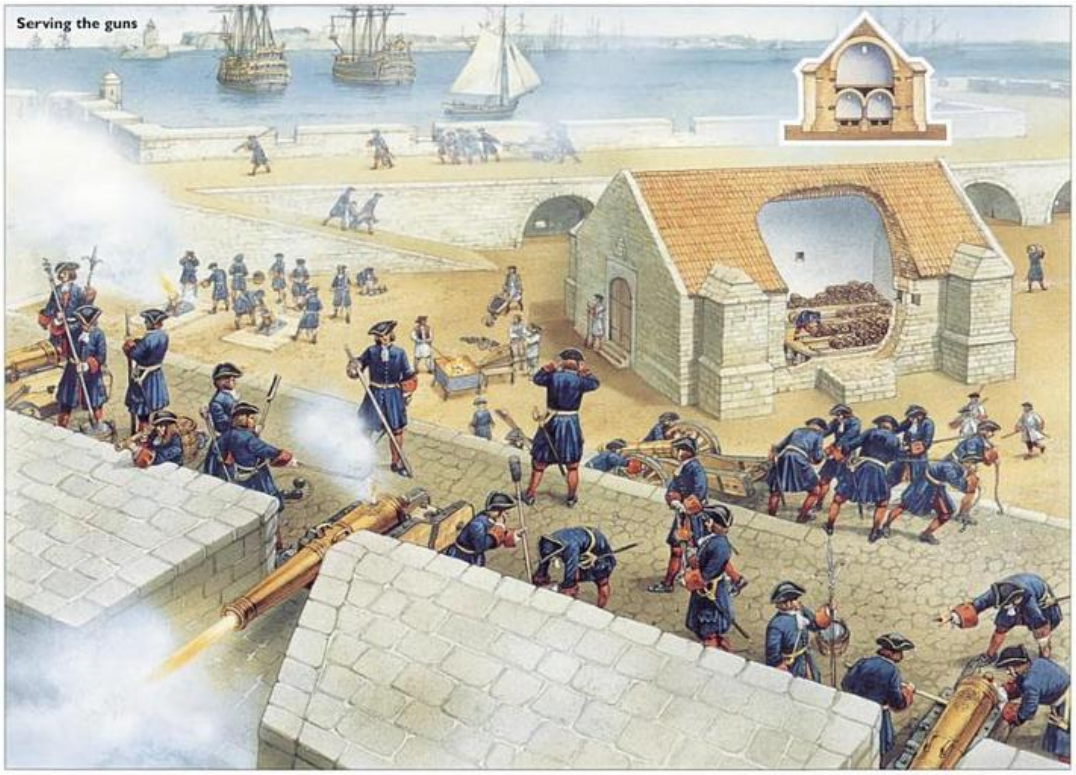


Figure 2.1 Illustration of the fortress by Vauban from The Vauban fortifications of France book (Griffith and Dennis 2006)

Menno van Coehoorn (March 1641 – March 17, 1704) was a Dutch military engineer and soldier. He made an innovative contributions in siege warfare and fortification. He was also known as the 'Hollandish Vauban' and responsible for the fortification in Netherlands during his term. Figure 2.2. illustrate some similarity between Coehoorn's Zutphen fortress (A: Source(Lepage 2010)) and the proposal for modification of A Famosa fortress during Dutch era (B: Source: (Irwin, 1962)). particularly from the context of military engineering innovation

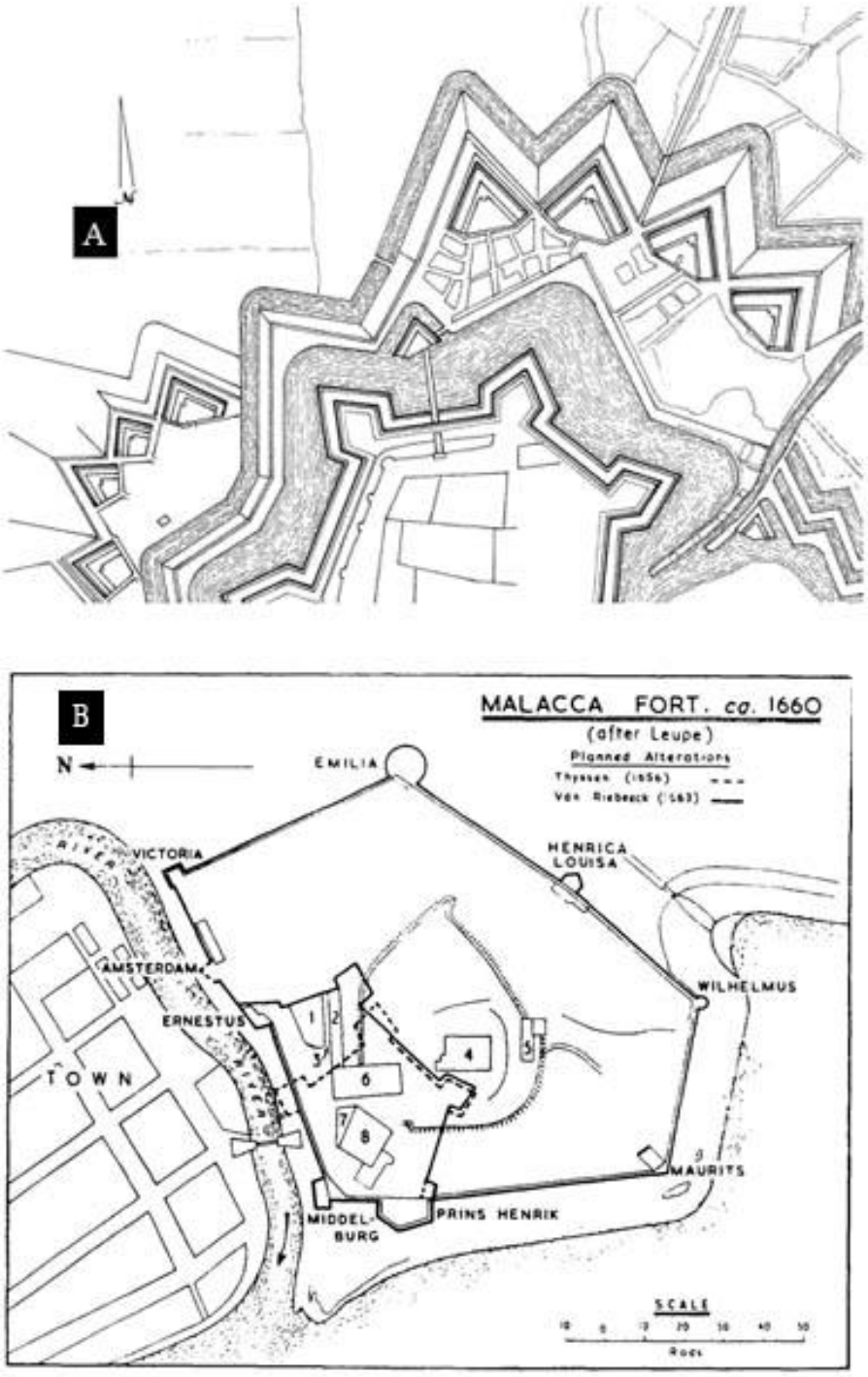


Figure 2.2 Illustration of some similarity particularly from the context of military engineering innovation between Coehoorn's Zutphen fortress (A: Source(Lepage 2010)) and the proposal for modification of A Famosa fortress during Dutch era (B: Source: (Irwin, 1962)).

2.2 Fortification features

The term fortification has a very broad definition and related with other terms such as castle, citadel, fort and fortress. However in military architecture each term has different meaning. To have a good understanding about these terms, a brief description for each term is given. Kaufmann (2001), explains:

i- **Castle**: A private fortified residence in northwest Europe. However it does not carry the same meaning in other regions. To be accurate, it is a fortification of the High Middle Ages that has characters such as high walls, moat and towers.

ii- **Citadel**: Any strongpoint and can be used to refer to a castle or a section of city that has a fortified position similar to a castle in size.

iii- **Fort**: A small strongpoint that usually occupied by military personnel.

iv- **Fortress**: Referred to large non-medieval fortification and sometimes it refers to large castle-like fortification or heavily fortified city.

Based on the military architecture definition of fortification, this research used '*fortress'* as a standard term to refer to main subject matter. This is due to the characteristics of the subject matter which is mostly a fortified city. The early construction technology involved a very simple method consisting merely of an earthen mound and palisades. This was followed by a wall and a ditch which was added later to support the wall. This structure was a straight wall and it was not strong enough when it can easily be breached by enemy's battering-rams. To solve this, towers were added at short intervals from each other. These towers led to the design of the bastion.

Historically, in comparison to Melaka, the site was built as a fort which consisted of earthworks and surmounted by wooden stockades. This base has been used by the Portuguese captain, Alfonso d' Albuquerque in 1511 to strengthen the occupied area. Initially, he used wood, thick trees and abandoned Malay stockades as first materials to construct the fortress. This was strengthened and replaced by stones which were

taken from the ruins of the great mosque of Melaka, graves and buildings. The foundations of the wall was dug deeper due to the marshy nature of the site.

The original plan of the fortress was square in plan with the thickness of eight feet walls. It has one tower at one corner of the building with 120 feet height which was same level with the summit of St. Paul's hill. Unfortunately these walls which were supported by towers were not strong enough to resist the missiles of the besiegers and parapets of earth were introduced to improve their structure. What was built by Albuquerqe was considered obsolete and very old fashioned of fortification architecture due to the latest development during that time. System of *enceintes* had replaced European stone-built tower. The invention of gunpowder and cannon forced further design developments of the fortress. Earthen ramparts were added behind the thin walls of the ancient works (Halleck 1860).

The fortress no longer relied on the walls' height but it also depends on the width (Henig and Lindley 2001). One of the improvements to improve existing design of the A Famosa is by lowering and backing the walls with earth to give them greater resistance and solidity (Irwin 1962). The height of towers had to be reduced and converted into gun towers (Wright 1946). The use of high stone walls and towers had largely disappeared in the end of 15th century in European military scene (De la Croix 1972). In the 16th century, the Portuguese always called European military engineer to devise its defensive system in Melaka. All recommendations by the military engineer were taken into account for further improvement. In 1558, Melaka was fully walled and the old A Famosa tower within it. This old tower was referred to as the *Fortaleza Velha* (Old fortress).

From 1558 until its final destruction at the beginning of the 19th century, no major changes were made to the A Famosa either by the Portuguese or the Dutch. However, some improvements were suggested and carried out during the Dutch occupation. Joao Batista, a military engineer who inspected the fortress in 1580 recognised the fortress's designer familiar with the theory of 'bastioned trace' a fortification system that first appeared in Italy in the early 16th century. During Batista's time, one

weakness of the fortress was some parts of the fortress walls were made of wood which later were replaced by stone. This has given an advantage to the Dutch when they attacked Melaka in 1641. For the Dutch, the seizure of Melaka was the most important conquest in Asia which took them five months to breach the fortress walls and lost thousands of their people and soldiers.

Immediately after Melaka fell into the Dutch's hand, it was practically defenceless. The fortress was largely destroyed and the old A Famosa was badly damaged. The Dutch took effort to immediately rebuild the fortress to avoid any counter-attack by the Portuguese and any other potential enemies. The Dutch brought with them ideas on the theory and practice of fortification which differed from the Portuguese from their experience in a long war with Spain. The Dutch took advantage of the site which is close to the sea by digging a ditch. They also introduced fausse-braie, a new defensive device which has been introduced in the 17th century. From the perspective of science of military architecture, the fortress was influenced by the geometrical system of fortification which was introduced by Vauban. The word geometry implies exactness and symmetry. A fortress of this shape presented to an attacker a precisely similar front in all directions with no weak spots (Irwin 1962). A Famosa continued developing under the Dutch administration. Some proposals to reduce the size of the fortress has been made to reduce the administration cost in Melaka. Due to certain circumstances, none of the proposals were carried out and the fortress remained as it was. The A Famosa has its final form during Balthasar Bort's administration.

2.2.1 Types of fortification

Fortification can be divided into two types namely natural and artificial (Lendy 1857). As described by Duane (1810) natural fortification (Figure 2.3) uses natural obstacles to prevent the approach of an enemy. This could be chain of mountains, sea, river, woods and marshes that could be used to cover an army's front and protect its flanks or rear as it maneuvered or assumed a position to prepare for battle (McDuffie 2004). These criteria can be seen in the location of A Famosa fortress. The location was facing the sea and located next to the river. The Dutch later added a moat which made A Famosa fully surrounded by water.

Figure 2.3 Natural fortifications of Doura Europos (Source: Kester, 1999-2009)

Any hand made fortification by man is considered artificial as shown in Figure 2.4. This research studies and concentrates on the latter only. Artificial fortification can be divided into two categories; temporary and permanent. Permanent works are designed to stand for ages around important sites such as the arsenal and frontier and depends on the durability of the materials character (Halleck 1860; Orr 1939) such as bricks and stones. It is also capable of resisting the destructive effects of weather for long period.

A temporary fortification is typically built to defend a position, protect a bridge or a village. It is used to strengthen positions for a short period and limited to a single campaign. Temporary fortifications are also known as fieldworks and they are usually of earth, built in a day by troops. According to (McDuffie 2004) fieldworks were constructed using perishable, but readily available, materials (wood and earth) to defend positions of temporary strategic or tactical importance. Two basic components of fieldworks are the parapet and the ditch (Field 2005). The types of fortification can be summarized as in Table 2.1.

Figure 2.4 Artificial fortification: Fort of Aguada, 2009 (Source: Author)

Table 2.1 Fortification types

Criteria for Different Fortification types		
Natural	Artificial	
	Categories	
	Permanent	Temporary or fieldworks
Made from natural elements such as mountains, hills, river, woods and so on.	Built in important area, depends on materials durability. Material examples: brick and stone	Made of readily available and perishable materials such as wood and earth.

2.2.2 Purpose of fortification

As explained earlier, the main purpose of fortification is to defend a place or a position (Bromiley 1979; DeVries 1998). Sometimes it is used to protect the core of the kingdom, administration or important area and it is also used to conduct warfare (Ashworth 1991; Hooper 1995; Rocco 2008). Fortification creates a barrier to the enemy charge. Ashworth (Ashworth 1991) explains, *"Fortifications are therefore 'weapon systems' whose principle purpose is to compel an attacker to expend more time or resources on their capture than is expended on their defence."*

In the context of the Portuguese and Dutch fortification, the fortresses were built along the trading routes and occupied places based on their significance. Besides defence and protection, sometimes these fortresses served other purposes such as a

place to supply water and food to the ships. Other than that it is also used to control the sea and ship activities.

For example, before the Portuguese occupied Melaka, they have built many fortresses along their trading routes mostly in India and Africa. This was proven by the fortress of Aguada in Goa, India. The name of the fortress itself derived from its meaning '*water'* because it was used to provide water supply to the ships that stopped by.

2.2.3 Fortification sites

There are many criteria in choosing the best location for fortification purpose. Good terrain, ideal logistic and strategic geographical topology can give a good contribution to the fortress building and its surrounding. According to DeVries (1998), the selection of the sites is geographically and physically difficult to reach and the hindrances will be improved by adding artificial barriers. In case of Melaka, the fortress itself faced the sea and was located next to the river. This shows a very strong relation with the Roman fortresses location which were often designed near navigable river to facilitate the shipment of supplies (Campbell 2006).

The shape, form and design of the fortress was mainly being influenced by factors such as terrain, topology which plays part in moulding the form of strongholds (Gravett 2001). The military engineer and architect also have their role and rationale in designing the fortress particularly in the aspect of making decision such as the number of bastions, shapes, circulation, angles and so on.

A Famosa has been modified several times. Each successive occupier modified the fortress to reflect the advancement of technology, obsolete and weak design in the old fortress and new evaluation and suggestions by the military engineer and architect.

2.2.4 Fortress elements

A fortress consists of various elements and each element plays an important part to defend and protect the place. It comes in various sizes, forms and functions. These elements are standard components of the fortress and it may vary in certain cases. As so much of A Famosa fortress has been destroyed, illustrations sometimes were taken

from comparable existing Portuguese and Dutch fortresses in the same era and region. The next sections explain these elements and describe their functions, design and its relation with Melaka's A Famosa fortress.

2.2.4.1 Bastion

A bastion is a projected structure that comes out from the main enclosure of a fortification. Its main function is to defend the fortress against assaulting troops. The bastion may have different shapes. Figure 2.5, 2.6 and 2.7 show several types of these bastions.

Figure 2.5 Full bastion of the Rotterdam fortress, Makassar, 2009 (Source: Google Earth)

Figure 2.6 Various types of bastions at the Galle fortress, Sri Lanka, 2009 (Source: Google Earth)

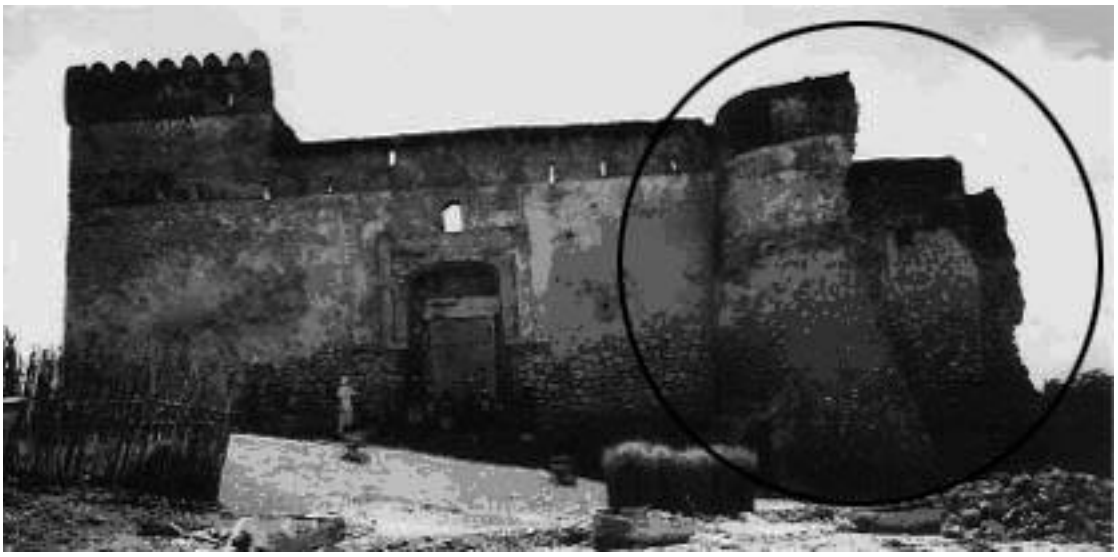


Figure 2.7 Round bastion of the Portuguese Kilwa Kisiwani fortress, East Africa, 2009 (Source: Utali Travel and Safaris Limited)

2.2.4.2 Parapet and breastwork

Both of these elements are for protection and defending purpose. Breastwork is normally being built by throwing an earthwork up to breast height and this can be for temporary or permanent purpose. This is shown in Figure 2.8. As for the parapet it is an earthen embankment raised high enough to provide cover from enemy fire, while

the ditch supplied soil to construct the parapet and served as an obstacle to impede an assault on the field work. It may also be a permanent structure which is made from stone. Figure 2.9 shows the parapet wall of the Aguada fortress.

Figure 2.8 Breastwork at Aguada Fortress, India, 2009 (Source: Author)

Figure 2.9 Parapet wall of the Aguada fortress, India, 2009 (Source: Author)

2.2.4.3 Ravelin

Figure 2.10 shows the ravelin which is a fortification outside a castle or fort (Viollet-le-Duc and Smith 1860). It is used to split an attacking force; composed of two faces, forming a salient angle whose gorge resembles a half-moon.

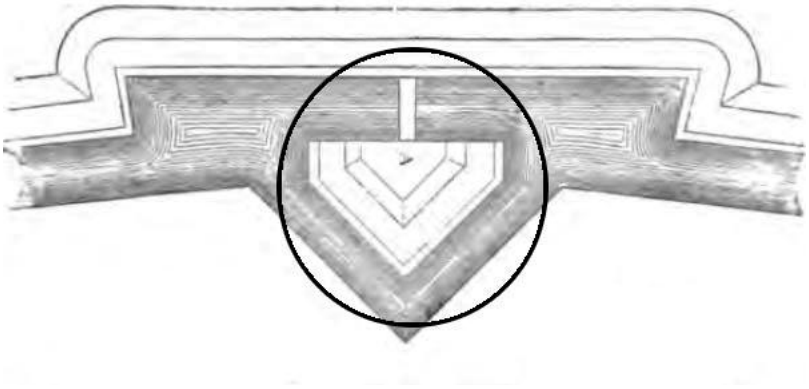


Figure 2.10 A circle shows the location of ravelin (Viollet-le-Duc and Smith 1860).

2.2.4.4 Casemates

Casemates also known as vaults destined to protect troop against vertical fire and constructed under the ramparts or elsewhere (Lendy 1857). Figure 2.11 shows the casemates (marked with circle) at the Aguada fortress, India.

Figure 2.11 The casemates, Aguada fortress, 2009 (Source: Author)

2.2.4.5 Vaulted cellars

A vaulted cellar is a space with an arch that is built under the parapet or bastion for gunpowder and ammunition storage purpose. This is shown in Figure 2.12.

Figure 2.12 Vaulted cellar at the Aguada fortress, India, 2009 (Source: Author)

2.2.4.6 Turret

A turret is a small tower extending above and at the corner of the building which is used as a gun enclosure. It can be found in most fortresses as it allows a line of fire along two walls. Figure 2.13 shows a turret at the Galle fortress in Sri Lanka.

Figure 2.13 Turret at Galle fort, Sri Lanka, 2009 (Source: Author)

2.2.4.7 Gatehouse

The gatehouse (Figure 2.14) plays an important role in the fortified city because it is the main access to enter the interior part and it is used to guard the main entrance. Usually it consists of a single archway or passage; a stout gate or drawbridge (Wyley 1998). According to Kaufman (Kaufmann and Kaufmann 2001), *"The gate house was considered the first part built into the walls. It is known also that the gate house and the keep were the first position to be made of masonry."*

Figure 2.14 Gatehouse at Aguada fortress, India, 2009 (Source: Author)

2.2.4.8 Drawbridge

The drawbridge, as shown in Figure 2.15, is a structure that uses chains and winches mechanism to function (Kaufmann and Kaufmann 2001; Field 2005). The drawbridge has a close relation with the gatehouses because both work together from aspect of security. The drawbridge is a type of bridge which is built over the moat or ditch. It can be raised to block the entrance.

Figure 2.15 Drawbridge at Melaka in 19th century, engraved by George Cooke and printed by Edward Hawke Locker. (Source: www.scholarsresource.com)

2.2.4.9 Fausse-braie

Fausse-braie in Figure 2.16 is a kind of second rampart constructed in front of the main breastwork (Franke 1855). It is slightly lower than the main rampart.

Figure 2.16 The fausse-braie at Galle fortress, 2009 (Source: Author)

2.2.4.10 Ditch and Moat

Generally a ditch, as shown in Figure 2.17, is created outside of the fortress wall and it functions as an obstacle to the attacking force. A ditch also plays role to slow down, impede and break up an attack. Based on medieval fortification architecture, a ditch was normally constructed in front of a defensive wall to avoid mining and escalade. According to Wyley (1998), a ditch can be left dry or filled with water. If it is filled

with water it is known as a moat. Both ditch and moat serve the same purpose. A moat can be found in two forms; man-made and natural water obstacles such as a lake or a river (Kaufmann and Kaufmann 2001).

Figure 2.17 A ditch at the Aguada fortress, India,2009 (Source: Author)

2.2.4.11 Stone sluice

The stone sluice in Figure 2.18 functions as a door for the moat. It controls the water level to come in and out.

Figure 2.18 Example of the stone sluice (Source: http://www.penninewaterways.co.uk)

2.2.5 Fortress materials

The construction materials for early fortified city come in various types. It totally depends on the available materials from the occupied area and more importantly they must have durable characteristics (Bromiley 1979). The earliest materials for

fortification purpose are timber, stones, ashlars, brick limestone and earthen mound or palisades. Bonding agents such sand, lime and water which are also used as a plaster for interior and exterior finishing (Halleck 1860; Viollet-le-Duc and Smith 1860; Gravett 2001).

The location of A Famosa was originally built on the site of an old fort of Melaka which was built by the Malays. It started with the use of earthworks and wooden stockades. When the Portuguese took over, they started to build a wooden fortress by using thick trees (Irwin 1962). To strengthen the fortress, the Portuguese used stones from the ruins of old buildings and laterite blocks from a nearby island. However, some parts of the fortress were surrounded by wooden palisade (Manguin 1988). In addition, a detailed study by (Khoo 1997) found that coral was also used as a construction material in the fortress.

2.2.6 Documentation of fortress data

Documentation of fortress data has been found in forms of sketches and drawings in parallel to the development of architectural drawing technology. In the early stage, architectural drawing, particularly measured drawings were rarely used in the building development. Most of them are in form of documents. For instance, fortification plans are littered with numbers and calculations from the beginning to the final design process (Lefe`vre, 2004). It is known the earliest drawings that appear to be practical construction aids found in the second quarter of the thirteenth century.

In the 14th and 15th century, drawings became more practical functions (Salzman, 1967). However, sometimes the drawings of the 14th and 15th centuries are not professionally presented. Most of the engineering drawings from the 14th and 15th centuries are preserved in the production of presentational manuscripts.Some of them do not resemble the orthographical plans and schematics which are used by the engineers today. Old drawings normally lack important details such as measurement and detailing. Understanding this scenario is important because most the materials in this research are from 15th to 18th century.

Previously, plans and elevations are not systematic for most of the constructional drawings. From 15th to 18th century, various developments occurred in field of art, engineering and architecture. One of the methods is projective geometry which makes the drawings more systematic and understandable (Maynard, 2005). In the early 16th century, orthogonal projection method has been developed in Rome (Lotz, 1977). After that working drawings were widely used for construction, in fact more remarkable method such as full-scale mold in wood or plaster had been used.

2.2.7 Measurement unit

Early architectural drawings use various types of measurement units. The most frequently occurring units used in the 14th to 17th century are furlong, fathom and rod. However, these measurement units have different conversion standard which usually depends on a particular nation. For example one Dutch foot might not be equivalent to one English foot and one Dutch rod itself can be equivalent to eleven, twelve or thirteen Dutch feet. Thus, extra verification which involves additional information would be needed before any conversion of old measurement units can be done. This issue will be further discussed in the next chapter.

2.3 The history of Melaka

Before the invasion by the Portugese, Melaka was a very strong Malay sultanate which is ruled by a few sultans. It started when Parameswara, a Malay prince of Srivijaya opened a port in Melaka after he took refuge from Temasek (Singapore) in his fight from his father in law, the emperor of Java major. He fortified himself on the crest of the hill, where he was safe and free from the fear of being killed (Godinho 1997). Hussein (2007) explains, *"The state has been developed from a fishermen's village into one of the busiest commercial ports in the 14th and 15th century"*.

Parameswara knew the only way to make this successful is by establishing commerce and traffic with surrounding peoples who came to the port. This trade made Melaka one of the richest and most magnificent states in the world. At one time it has been claimed as '*Venice of the east'* (Tome 1944). During that time, Venice was a very strong imperial power. The commodities traded in Melaka were numerous, ranging

from spices, fabrics, porcelain tobacco and shoes, silks, satins, medicinal root, gold and silver (Pintado 1990; Nadaraj 2003).

These traders came from all over the world: India, China, Borneo, Arabia and Europe (Godinho 1997). The location of Melaka as shown in Figure 2.19 is very strategic and Melaka also has an advantage of seasonal winds for the West and East to trade. This is illustrated in Figure 2.20 by Cribb (2002) in his *Historical Atlas of Indonesia.*

Melaka's popularity has attracted the Portuguese to expand their power in commercial dealings, military occupation and religion. The Portuguese believed that by controlling Melaka, they could monopolise spice trading which was a very valuable item in Europe and expand their military power. One said that Melaka's importance was nearly same with Venice which was a very important centre of commerce in the 13th to 17th century. Besides, the Portuguese also wanted to expand the influence of Christianity in this region and this could only be done by seizing Melaka.

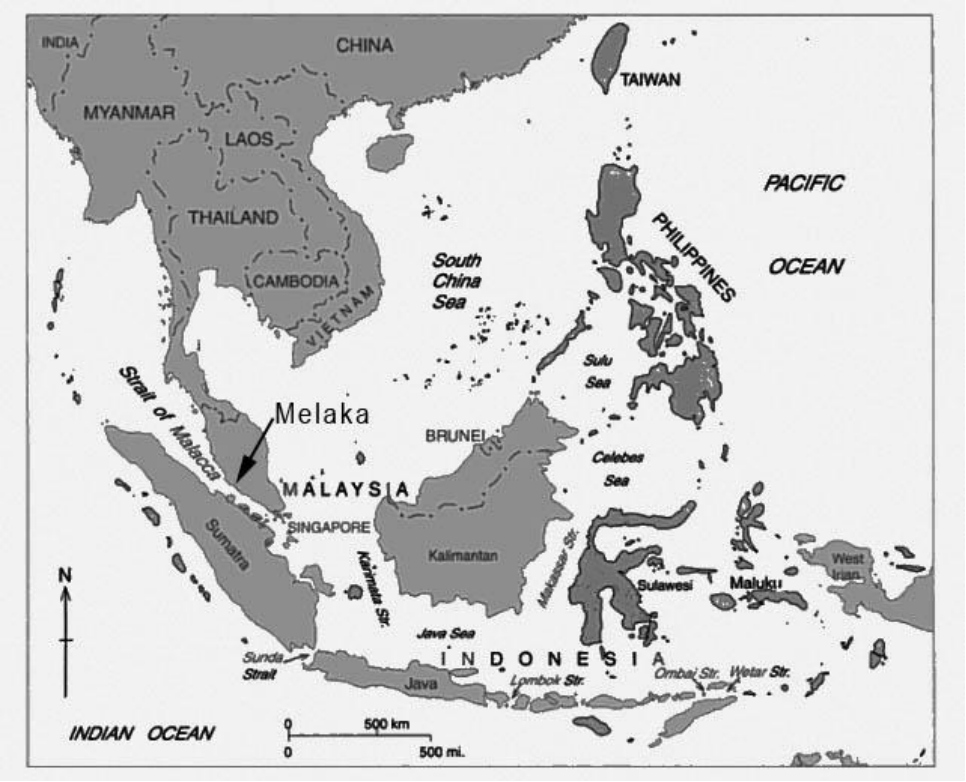


Figure 2.19 Location of Melaka in the Asia map (Freeman 2003)

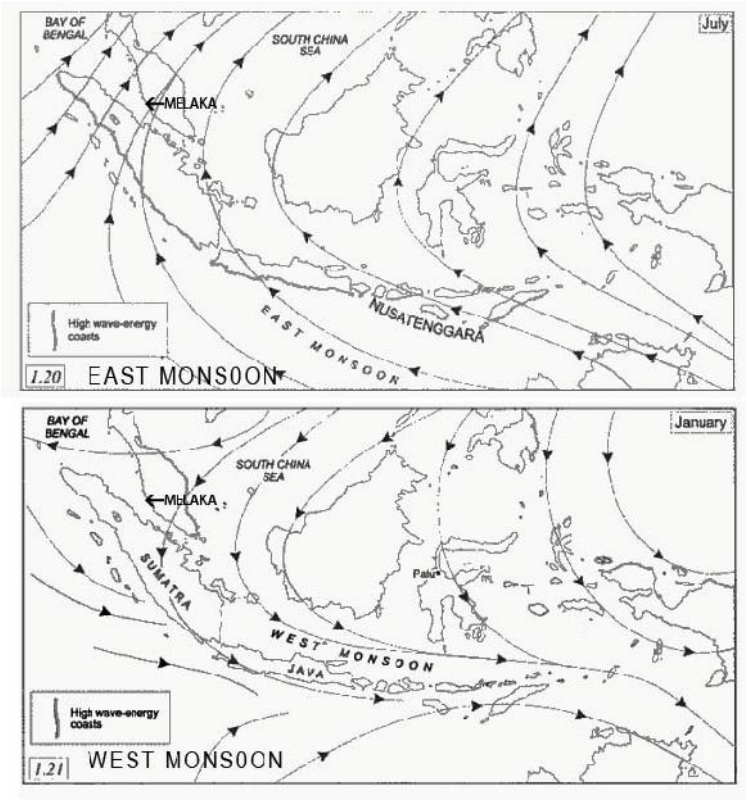


Figure 2.20 Wind patterns in Malaysia-Indonesia archipelago (Source: Cribb, 2000)

In 1511, the Portuguese, with fifteen small and great sails and with sixteen hundred fighting men laid siege to Melaka (Ryan 1960). With advanced strategy and weapons, the Portuguese managed to capture Melaka within three weeks and, on August 10th, 1511 Melaka fell into the Portuguese hands (Noonan 1989). Alfonso de Albuquerque was the captain for the new Portuguese government in Melaka. He immediately ordered a fortress to be built for defensive purpose (Godinho 1997).

2.3.1 The A Famosa fortress

The A Famosa fortress is located in a strategic location which is facing the Straits of Melaka and surrounded by hills. Fortifications in the straits settlement were always located along strategic coastlines (Fletcher 1975). Figure 2.21 shows the location of the A Famosa fortress in Melaka. This fortress was named as A Famosa which means the famous in Portuguese (Tracy 1991). It was the pride of the Portuguese because it was the biggest of all the forts built by the explorers in this region.

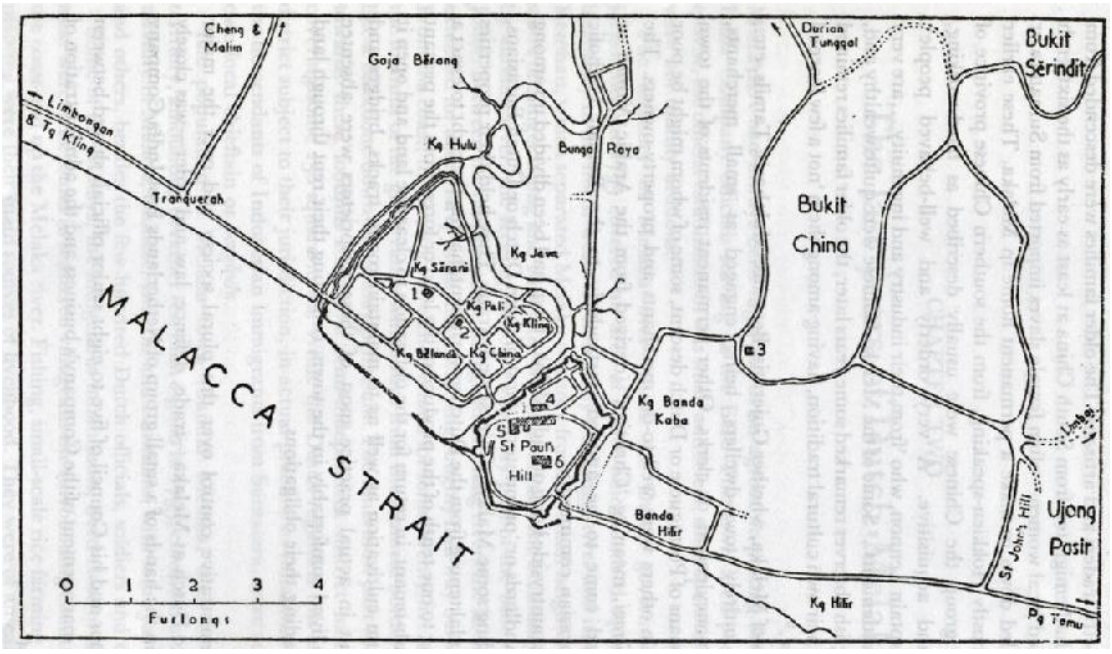


Figure 2.21 Location of the A Famosa in Melaka, Malaysia (Abdullah 1970)

The manpower behind this construction was day labourer, stone cutter and mason and it was built from stone and mortar at the bottom of the hill. It took five months to finish and the fortress's location on the narrow straits provided the Portuguese with both defensive and offensive postures. Portuguese ships could also attack rival ships passing through the straits (Hoyt 1993).

This fortress was built around St Paul's hill. The fortress was both large and strong, the sea washing the walls of one third part of it, and a deep, rapid, but narrow river, the west side of it, and a broad deep ditch the left of it (Pinkerton 1808). There are many descriptions and depictions about this fortress in the forms of visual documentations, old manuscripts and written evidences. Throughout this research, it is found that more than 15 drawings depicting Melaka from various aspects, this includes fortress ground plans, entire city maps and plans, surrounding and panoramic view.

The fortress proved victorious even though it has been attacked several times by Malay kings (Godinho 1997). A Famosa was besieged twenty four times through out the 130 years of Portuguese rule but was never breached. The Portuguese themselves

were well equipped with munitions and war materials. Tome (1944), said that "*Due to excellent fortifications and a strong garrison, the city was considered unconquerable by all Indian princes. Only a strong European army would have the good fortune to take it*".

However, in 1641, due to insufficient supplies and outbreaks of illness in the city, the Portuguese surrendered this fortress to the Dutch (Viana 1988). Prior to the occupation of the Dutch, they heavily bombarded the fortress which has critically destroyed part of the fortress. After they succeeded to conquer Melaka in 1641, the Dutch carried out major reconstruction on the fortress as part of their strategy to strengthen their power. This reconstruction involved the extension of the fortress walls and bastions (Leupe 1936).

The British took over the Dutch's position in 1795 through an agreement to prevent Melaka from falling into French hands and agreed to return it to the Dutch after that. But in 1805, the British were more interested in Pulau Pinang (Penang) and it was unnecessary to have two settlements at one time. The British ordered William Farquhar, a British captain in Melaka to demolish the fortress in 1807. The British had an attempt to invade Melaka after their temporary possession had ended, hence by destroying it will give an easy way for invasion. Other than that, Melaka was also becoming an expensive liability to the British because the Portuguese and the Dutch did not do much to promote trade or agriculture, and the income generated for the government officers were insufficient to sustain the city-port (Nadaraj 2003).

Indeed this fortress is very impregnable and hard to destroy. Several attempts had been made and it was unsuccessful. The final solution was to blast by using gunpowder. By doing this, the pride of the Portuguese *"exploded like thunder, and pieces of the fortress, as large as elephants, and even some as large as houses, were blown into the air and cascaded into the strait of Melaka"* (Abdullah 1970). The bombardment continued for a year (Harrison 1985). It was only stopped by Stamford Raffles, assistant secretary to the colonial government in Penang who came to Melaka

to recuperate and finally admonished Farquhar for the blasting and told him to retain the fortress for posterity.

Until today, the wall of the fortress had been completely destroyed and the only part left until today is Porta de Santiago (Choe 2007), a gate which facing Bukit China as shown in Figure 2.22. This is supported by Mackenzie (1954), *"Raffles visited Melaka in 1808 the fortress, except for that beautiful Gothic gateway, had already been destroyed and the settlement itself was in the process of broken up"*. The entire occupation timeline can be summarized in Table 2.2 but this research only focuses on the Portuguese and Dutch time.

Figure 2.22 Remains of an old Portuguese fortress in Melaka, Porta de Santiago gate (2009) (Source: Author)

Table 2.2 A timeline of occupation in Malaysia

Conqueror	Occupation
Portuguese	1511-1641
Dutch	1641-1795
British	1795-1957

2.3.2 Fortress design development

Based on the study of fortress history it is identified that the fortress design development is categorised into four stages namely:

1. The early stage: single building with a tower
2. Extension of fortress under the Portuguese occupation
3. The Dutch occupation
4. The British occupation

2.3.2.1 The early stage: single building with a tower

In the early Portuguese Melaka book, it describes Figure 2.23 as, *"Melaka in the first half of the 16th century according to a plate from 'Lendas da India' by Gaspar Correia"* (Thomaz 1991). The walls had not yet been raised and the central district, as weak as the district of Upeh is protected by a simple palisade. The Melaka fortress stands out, clearly shows medieval style, with its four storey keep and a single bastion to place artillery facing the sea. All the houses are apparently covered by a vegetal substance.

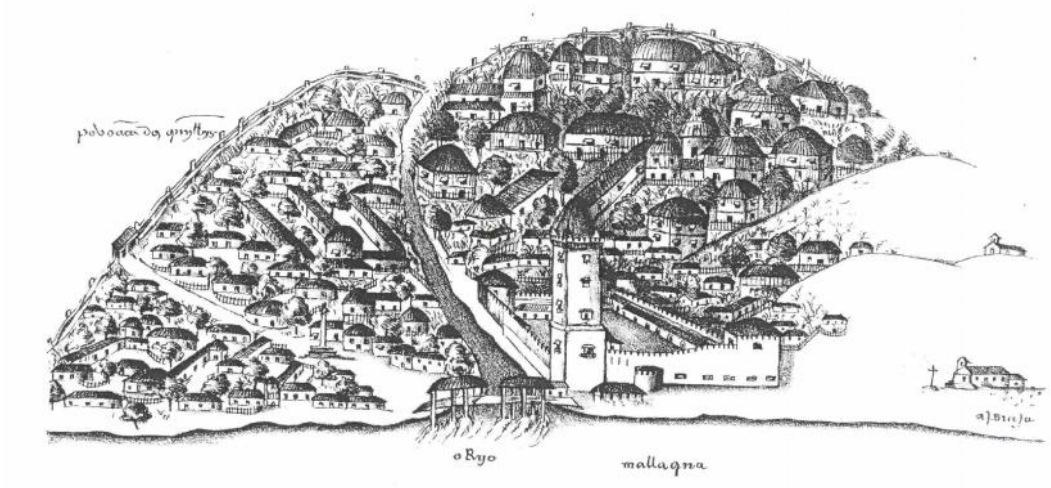


Figure 2.23 Fortaleza de Melaka, drawing by Gaspar Correia, 1527, in his manuscript works, "Lendas da India" (Source: Thomaz, 1991)

There are no convents yet, only the mother church, next to the fortress, and a small chapel on the hill. The sketch is obviously, rather schematic and does not convey the dimension of the city, which should, according to both the calculation of the Malay History and Portuguese, number about 200 000 souls. Figure 2.24 presents a more

detailed plan of the A Famosa built by Alfonso de Albuquerque in 1511. The tower called *'Fortaleza'* which served as residence of the captain, the small fortification also shown in Gaspar de Correia's sketch the courtyard with a well, the jail (*tronco*) and the magazine (*almazem*) where guns, ammunition and navigation implements were kept. A single door stood between the tower and the fortification, well protected.

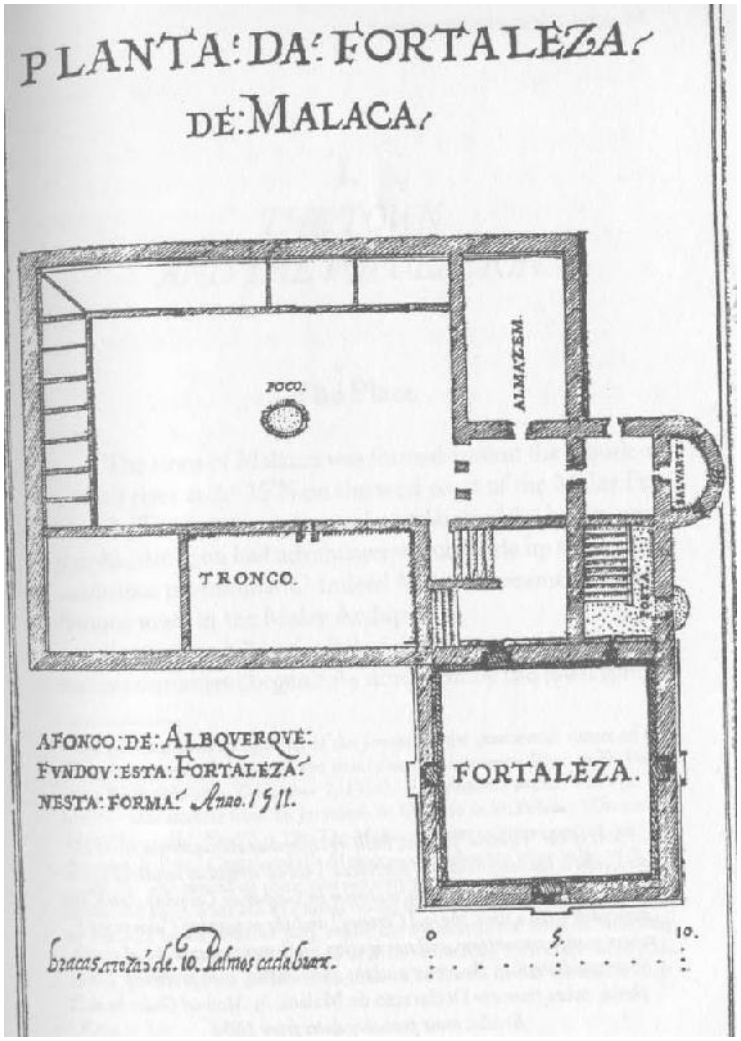
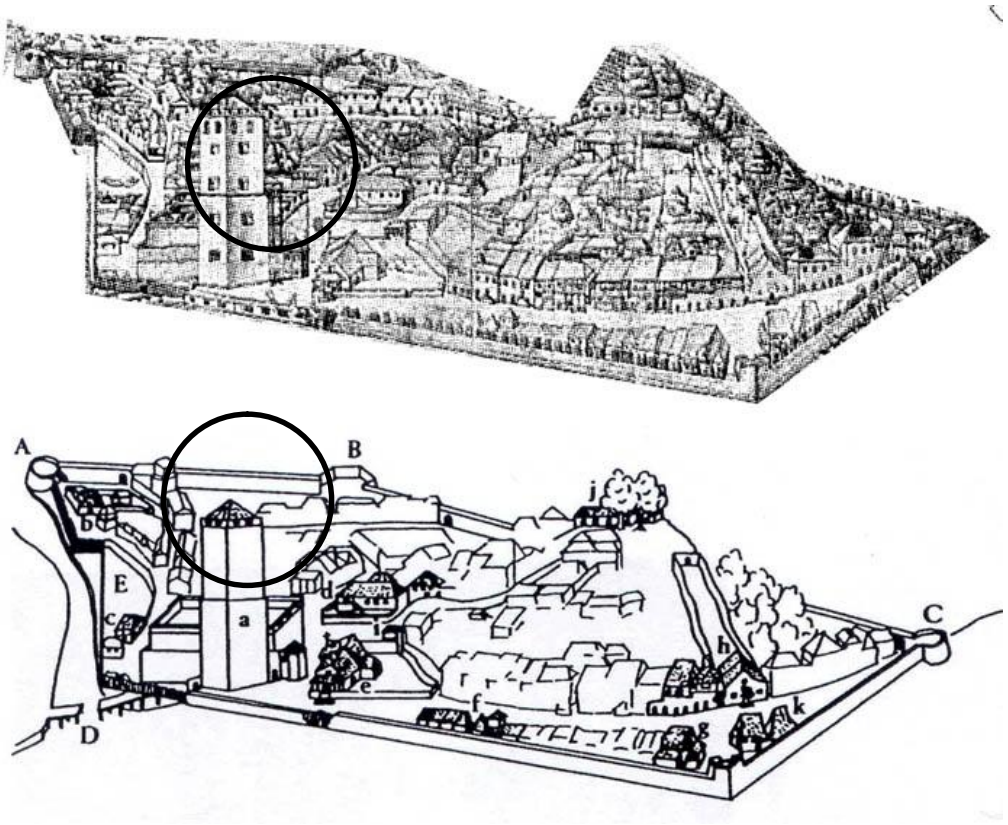


Figure 2.24 *Plan of the Malaca fortress*, built by Afonso de Albuquerque in 1511. The sketch, taken from the *Declaracao de Malaca*, by Manuel Godinho de Eredia, most probably dated from 1604. (Source: Thomaz, 1991)

2.3.2.2 Extension of fortress wall under the Portuguese occupation (within 1568-1604)

The upper image in Figure 2.25 shows the bird's eye view of Melaka dated 1568. Manguin came out with a proper drawing that describes the details of the buildings in the fortress (lower image of Figure 2.25). The drawing noticeably shows the wall

extension of former fort in Figure 2.24 (marked with a circle). Manguin had clearly indicated some of the most important fortress elements in his reproduced drawing such as the number and names of the bastions, hospital, churches, fortress gates and tower bridge.



A São Domingos bastion
B Madre de Deos bastion
C São Tiago bastion and neighbouring gate [The Onze Mil Virgens bastion is hidden by Melaka Hill]
D Bridge over the Melaka River
E Riverside slip (*ribeira*)
a *A Famosa* fortress
b São Domingos Church and Convent
c Customs House (*alfândega*)
d Bishop's Palace
e N.S. da Asumpção Cathedral
f Municipal Council and prison (*câmara* and *aljube*)
g Pauper Hospital
h *Misericórdia* (Church and seat of the Confraternity of Mercy)
i Bell tower
j Church of N.S. da Anunciada and Jesuit College
k Royal Hospital

Figure 2.25 Upper image: Anonymous Portuguese drawing of the Melaka fortress, dated 1568. The original is kept at the Biblioteca Nacional, Rio de Janeiro, Brazil (Correa 1858-66) Lower Image: Sketch of the original image indicating the main buildings of Potuguese in Melaka. (Source: Manguin, 1999)

The extension of A Famosa is also supported by Thomaz (1991), which explained Figure 2.26 as *"The walled section of Melaka in 1604 according to a sketch by Manuel Godinho de Eredia. The wall is already completed, encompassing the former fortress, with its tower, all public buildings (town hall, bishop's place, Santa Casa da Misericordia, two hospitals, the school of the Jesuits and several churches and convents)."* The wall features seven strongholds destined for artillery, both on land and sea sides as shown in Figure 2.26. The sketch notes the contours of a new outline, broader, on the land side, that was to remain only a project. The walled section encompasses a green area on the hillside, where the school of the Jesuits stood, accessible through three staircases.

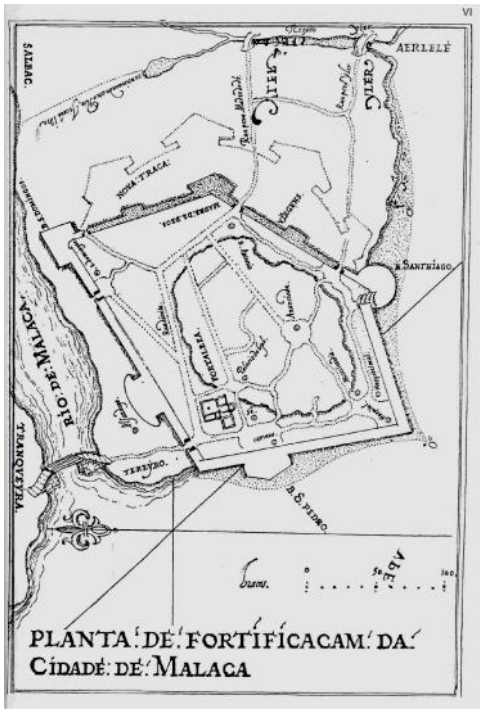


Figure 2.26 Eridia's drawings (1604) of the fortress of Melaka (Source: Godinho, 1977)

Figure 2.27 shows another illustration of the extended wall of A Famosa during Portugese occupation. It is entitled "Plan of Melaka" by Manuel de Faria e Sousa, Portuguese chronicler, from a work entitled "Asia Portuguese", published in Madrid in the 1660's (Kennedy 1962).

Figure 2.27 Sousa's drawing on Melaka, 1660's (Source: http://www.nationaalarchief.nl/)

2.3.2.3 The Dutch occupation

During the Dutch occupation more detailed drawings were produced as a record for the Dutch government in Melaka. These drawings are more accurate compared to the Portuguese drawings (Hussin 2009). Figure 2.28 illustrates A Famosa during the Dutch era by Heydt which was a very detailed drawing complete with scale and legends. This was in 1735 – 1744. The drawing clearly shows some of the additional elements such as walls and bastions. The fortress itself has a few changes particularly outside the walls which are surrounded by the moat. It is also found that the size of the fortress has been extended during the Dutch era as compared to during the Portuguese era.

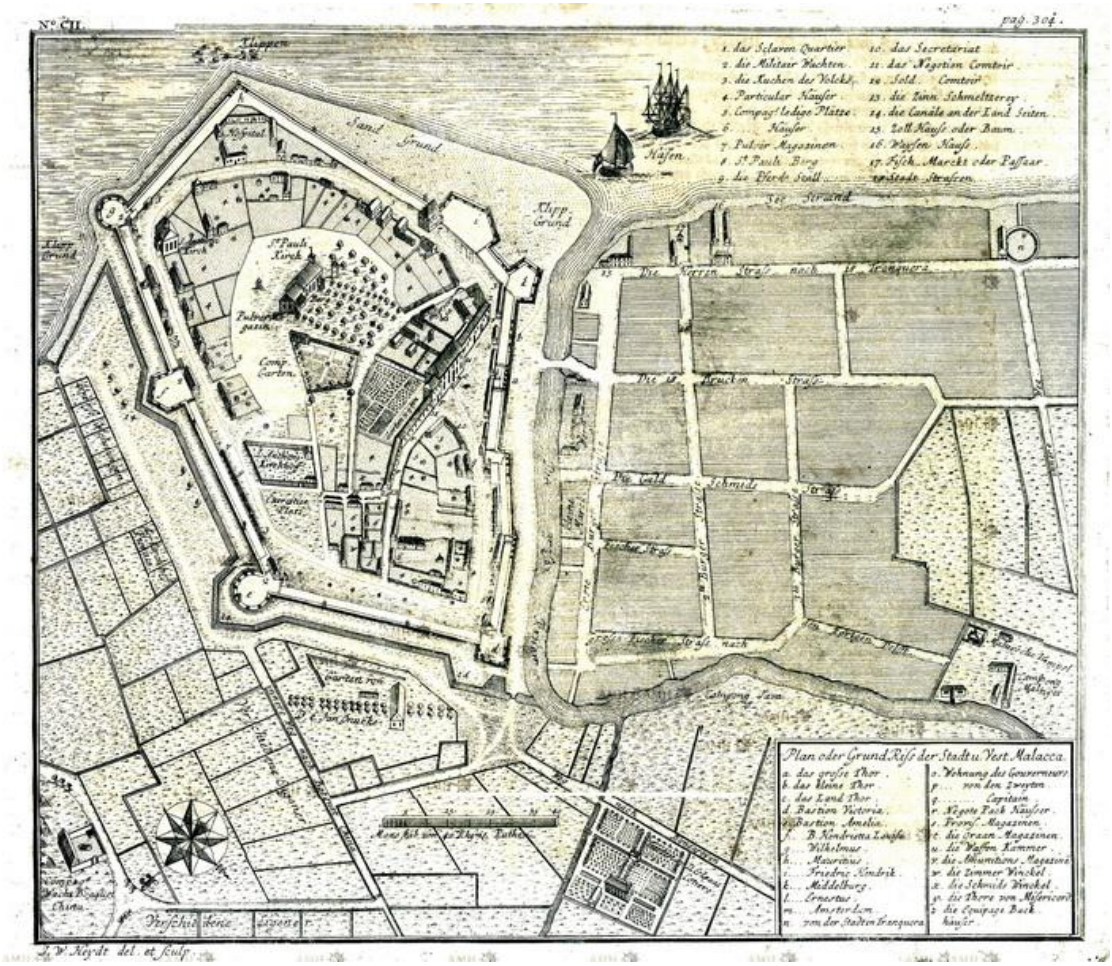


Figure 2.28 The Dutch drawing, Copperplate printing of Plan oder Grund Riss der Stadt u. Vest. Malacca by Helydt, Johan Wolfgang,1735-1744 (Source: http://www.nationaalarchief.nl)

Most of the drawings during the Dutch era are more accurate, well organised and properly described. It also includes the measurements and elements of the fortress.

2.3.2.4 The British Occupation

According to the history, after Melaka fell into British hands, it had long since ceased to be of any commercial importance, and in order to avoid the expense of maintaining the fort and to prevent it from becoming danger if it fell again into other hands, the walls of fortress were destroyed in 1807 by William Farquhar, the British captain. As the result, the only evidence left today is a gate to access the fortress which is known as Porta de Santiago.

2.4 Case studies on the existing Portuguese and Dutch fortresses

Nowadays, there are several fortresses which belong to the Dutch and the Portuguese which are still intact. They are located in various parts of the world. Since the A Famosa itself has been largely damaged and all the available information are in 2D data, it is decided that case study on some of these existing fortresses are crucial for this research. This is to give an idea on visual understanding of how the actual fortresses look like now.

After considering the location and condition of these existing fortresses, three fortresses have been chosen for the case studies namely Aguada fortress in India, Galle fortress in Sri Lanka and Rotterdam fortress in Indonesia. This fieldtrip was funded by the British Council. The reasons for this selection are based on several factors namely:

1. **The builders:** These fortresses were built by the Portuguese and Dutch who were the same builders for A Famosa fortress.
2. **Timeline of the fortress:** Most of these fortresses were built within the same era with A Famosa fortress in the 15^{th} to 17^{th} century
3. **Location:** The locations for these fortresses were in Asia region and some were built along the trading route to Melaka.

2.4.1 Aguada Fortress, India

2.4.1.1 Background

Aguada fort in Figure 2.29 was built in 1612 by the Portuguese and it is located in Goa, India. Its purpose is to guard against the Dutch and also plays role as a reference point for European vessels. The fortress has prison, underground water chamber, lighthouse, bastions and gunpowder room. The fortress has been designed by an Italian military architect who was appointed by the Portuguese government in Lisbon. The fortress was defended with a very thick wall and has four main sides. Besides defence purpose, this fortress was also used as a prison.

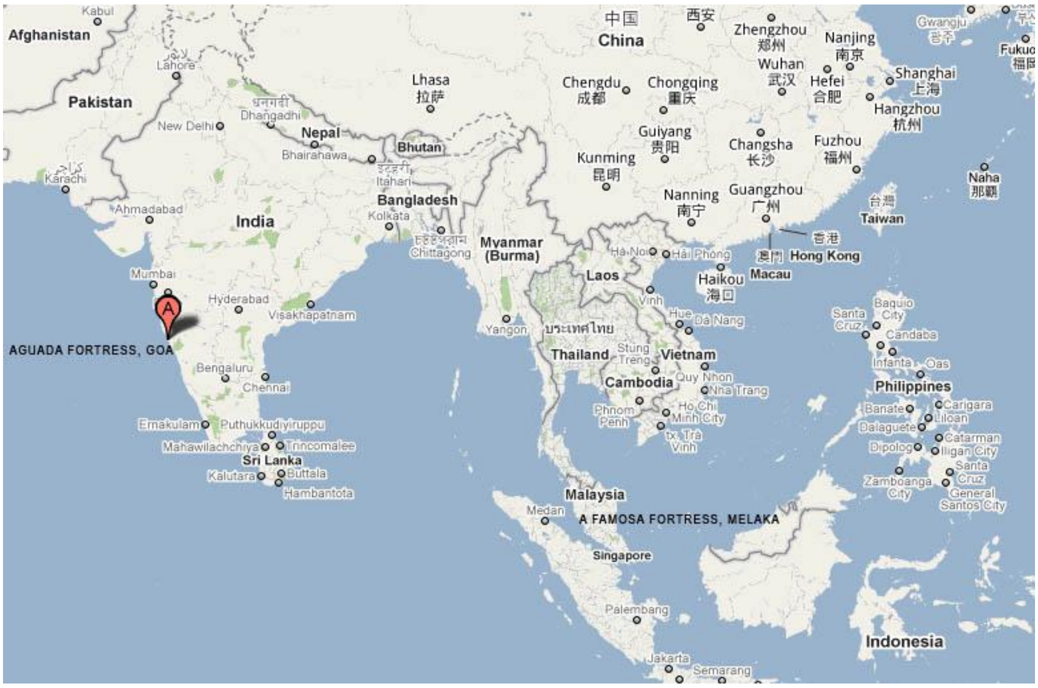


Figure 2.29 Top figure shows location map of the Aguada fortress, Goa and below is the satellite plan view, 2009 (Source: Google Earth)

2.4.1.2 Location

The fortress stands on the rocky cliff in the beach area of Candolim. It is located at the highest point facing the sea and surrounded by a ditch. Figure 2.30 shows this strategic location which is very important for the Portuguese to monitor any sea activities. Besides, it is also very ideal for seaward and landward defence. This fortress is connected with hundred steps of stair to the sea level.

Figure 2.30 Higher point of the fortress facing the sea, 2009 (Source: Author)

2.4.1.3 Materials

From observation during the site survey, the main construction material used is laterite. This material has been widely used for most of the old buildings in Goa particularly in this area. A similar material is found within the A Famosa fortress and the construction method of bonding using this material is also found at A Famosa as can be seen in Figure 2.31.

Figure 2.31 The use of laterite as main material in both fortresses, Aguada fortress (left) and Porta de Santiago gate of the A Famosa fortress, 2009 (right) (Source: Author)

2.4.1.4 Fortress elements and similarity with the A Famosa fortress

1. Bastion

Figure 2.29 shows the overall plan of the Aguada fortress with three prominent bastions. Figure 2.32 shows one bastion and passageway from inside the fortress.

Figure 2.32 One of the bastions in Aguada fortress, 2009 (Source: Author)

2. Gateway

The main gateway of this fortress is separated by a ditch and connected by a narrow bridge as seen in Figure 2.33 (An arrow shows the main direction to the interior). The design of the main gateway has been provided with the ramp leads to the inner fortress which curves off at a sharp angle and has steep steps up to the battlements. This gives some difficulties to the invaders to access. There is a half round magazine located next to the main gate to deflect any enemy shots (marked with a rectangle).

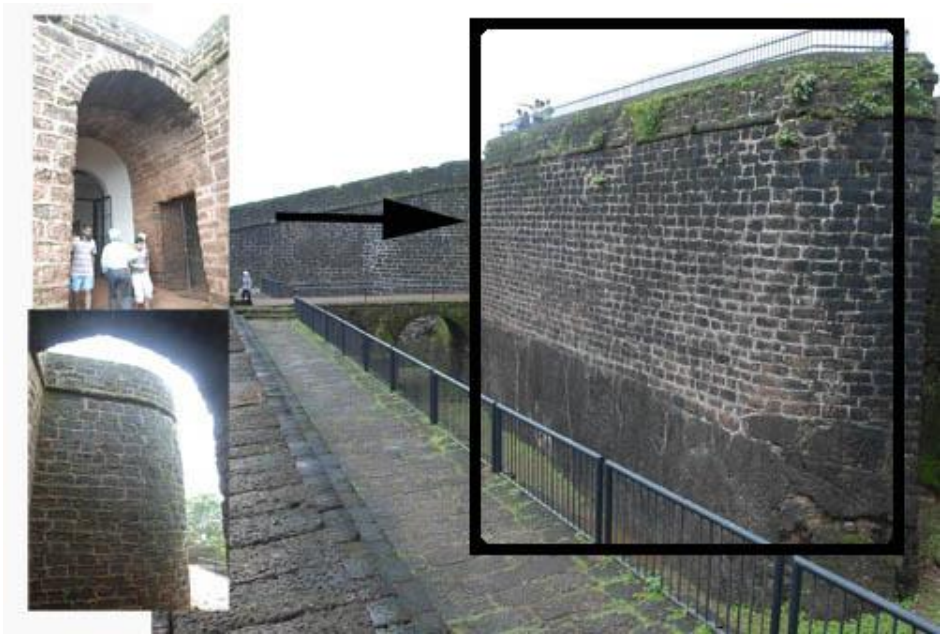


Figure 2.33 The main entrance, 2009 (Source: Author)

3. Passageway

Figure 2.34 shows the passageway of the fortress which has different widths. Underneath the passageway there are vaults which are filled with laterite. This passageway connects the bastions and sometimes its width is very narrow as shown in Figure 2.35.

Figure 2.34 Passageway of the fortress, 2009 (Source: Author)

Figure 2.35 A narrow passageway which only can be used by one person at one time, 2009 (Source: Author)

4. Parapet

The parapet in Figure 2.36 shows the connection between bastions and next to it, there is a passageway which surrounds the fortress. The height of the parapet varies from one point to another point.

Figure 2.36 The parapet that encircles the fortress, 2009 (Source: Author)

5. Crenel/Embrasure

Crenels in Figure 2.37 are one of the most important elements in any fortresses since they provide holes and spaces for placing cannons. In the Aguada fortress it is found that most of these crenels are placed in the bastion area. It is slightly different compared to the A Famosa in which these crenels are also found along the parapet wall.

Figure 2.37 Crenels at one of the bastions, 2009 (Source: Author)

6. Ditch

The fortress is surrounded by a dry ditch. Figure 2.38 shows a part of the ditch in between two bastions. Its size varies from one wall to another wall.

Figure 2.38 The ditch, 2009 (Source: Author)

7. Tower

Since the fortress is located at the highest point, a tower which acts a lighthouse (Figure 2.39) with four storey height was built in 1834.

Figure 2.39 A lighthouse at the Aguada fortress, Goa, 2009 (Source: Author)

8. Wall

Most of the walls at Aguada fortress have different heights and some parts follow the topology of the landscape. This can be seen in Figure 2.40. The style of the wall has a similarity with the standard fortress cross section in Figure 2.2. It has scarp and counterscarp on the side, and the entire wall is divided by a ditch. According to Mathew (1988), the wall is fifteen feet high and four feet wide.

Figure 2.40 Wall of the fortress, 2009 (Source: Author)

2.4.1.5 Summary of Aguada fortress

This Portuguese fortress was built for defence purpose and monitoring the sea activities. Beside that, it functions as a water supply source for the ships. Geographically its location differs from the A Famosa fortress because it stands on the rocky cliffs while the A Famosa fortress on the ground level surrounding a hill. The design has been accomplished by an Italian military architect who was assigned by the Portuguese government. The A Famosa was purely designed by the Portuguese.

The Aguada fortress is very impregnable with its thick and high wall which separated by a ditch. As for construction material, both fortresses share the same material which is laterite. The fortress comprises of elements such as bastion, gateway, rampart and crenel. It is found that some of the elements in the A Famosa fortress are missing here for instance turret, ravelin and fausse-braie. However, overall observation of this fortress has given a very clear idea about how the Portuguese fortress looks like and the existing elements are very useful for main reference and comparison with the 2D data of the A Famosa fortress.

2.4.2 Galle Fortress, Sri Lanka

2.4.2.1 Background

Historically, Galle Fortress has similar pattern of occupation to Melaka. The Portuguese landed in Galle, Sri Lanka in 1505 and transformed Galle into a military base by constructing a fortified city (Schellinger and Salkin 1996). The construction of the fortress was completed in 1652. Originally it was a small fortress with three guard rooms (DS 2009). In 17th century the Dutch occupied the city and modified the fortress for their interest. Figure 2.41 shows the fortress plan in 1726. In 1796 Galle was captured by the British (Aves and Bradnock 2003) and in 1947 Ceylon gained its independence from the British.

The fortress encloses mosques, churches, a clock tower, a light house, police barracks, houses, schools and other structures. Other similarities with the A Famosa are such bastion shapes, names and layout. This fortress was declared as UNESCO World

Heritage site in 1988 (Aves and Bradnock 2003). Nowadays the fortress is used for living, social activities and small businesses such as restaurant and shops.

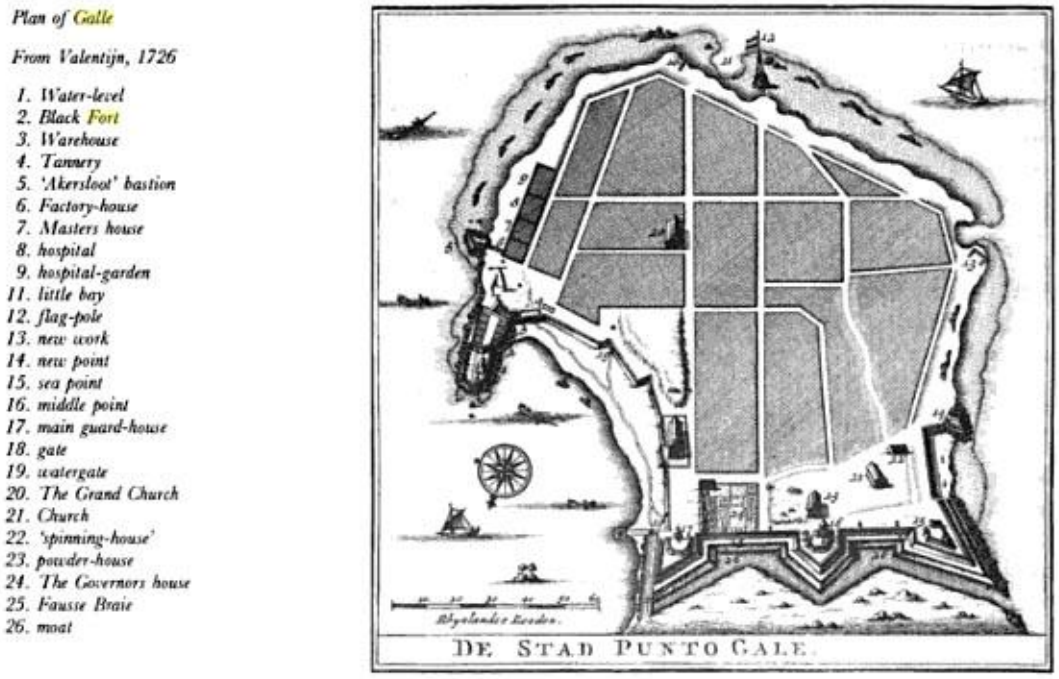


Figure 2.41 The layout of Galle fortress, 1726 (Source: De Silva and Beumer, 1988)

2.4.2.2 Location

Geographically, the Galle fortress located in a very strategic location which is on a low rocky promontory and waterfront (Fellowes, Philalethes et al. 1817). Figure 2.42 shows the location map of this fortress in Sri Lanka. The fortress itself is a peninsula and natural harbour. It is surrounded by hills and covered by with wood. This unique geographical factor as shown in Figure 2.43 has been used for defensive purpose by the Portuguese (De Silva and Beumer 1988). After the fortress changed hand to the Dutch, some enlargements and modifications have been made. The total size of this fortress is 40 hectares (ASD 1998) .

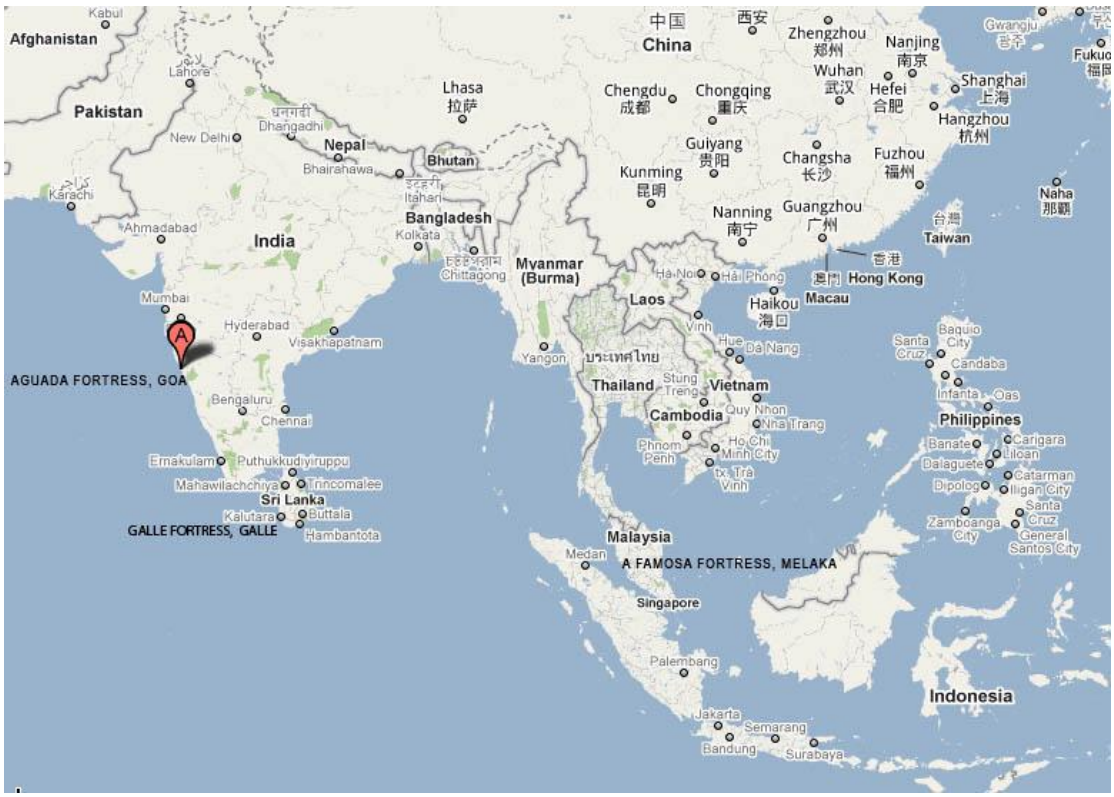


Figure 2.42 Location map of Galle fortress, Sri Lanka, 2009 (Source: Google Earth)

Figure 2.43 Aerial view of the Galle fortress (from postcard), 2009 (Source: Author)

2.4.2.3 Materials

The fortress was originally constructed as a simple bulwark using timber and earth bricks. The Dutch strengthened the fortress by using coral lime, solid stone and stucco

(Schellinger and Salkin 1996). The local stone type is granite (DS 2009) as shown in Figure 2.44, however despite the local stone being different to that at A Famosa the style of building the fortress has a strong connection.

Figure 2.44 Solid granite stone as the main material of Galle fortress, 2009 (Source: Author)

2.4.2.4 Fortress elements and similarity to the A Famosa fortress

The elements in the Galle fortress are of a similar period to A Famosa and have a strong similarity in term of shape and form. Galle is longer than A Famosa but the similarities in the key features are very useful for reconstructing elements of A Famosa. The similarities are explained as below:

1. Bastion

Galle fortress has fourteen bastions and some of them are given names such as Sun, Zwart, Aurora, Point Utrecht, Triton, Neptune, Clippenberg, Aeolus, Star and Moon. Three of these bastions are the commonly occurring round bastion (Figure 2.45).

Figure 2.45 Round bastion at Galle fortress, 2009 (Source: Author)

2. Gateway

There are two gateways to access the interior part of the fortress. These are known as the main gate and the old gate. Figure 2.46 shows the main gate which was built by the British for heavy traffic use and the old gate was inscribed with the coats of arms of VOC (Vereenigde Oost-Indische Compagnie) by the Dutch. These are similar to the Custom gate and Porta de Santiago at A Famosa.

Figure 2.46 The old gate (left) and the main gate (right), 2009 (Source: Author)

3. Passageway

The passageway of the Galle fortress is earthen. Figure 2.47 shows the rampart and Figure 2.48 shows the passageway connecting two bastions. The width of this passageway varies due to the indefinite form of its ditch and mound construction. Figure 2.48 shows the location of the passageway in Galle fortress.

Figure 2.47 Rampart at Galle fortress, 2009 (Source: Author)

Figure 2.48 Aerial view shows the location of the passageway, 2009 (Source: Google Earth)

4. Parapet

Figure 2.49 shows the parapet along the wall of the fortress. Attached to the parapet is the breastwork.

Figure 2.49 Parapet wall at Galle fortress, 2009 (Source: Author)

5. Crenel/ Embrasure

Crenels can easily be found in most of the bastions in this fortress. The sizes of these crenels vary based on the width of the wall. It is found that the crenels here have been referred for reconstructing the Middelburgh bastion of the A Famosa fortress in Melaka. Figure 2.50 shows crenel at the Galle fortress and the A Famosa fortress.

Figure 2.50 Crenel at the Galle fortress (left) and the reconstruction at A Famosa fortress (right), 2009 (Source: Author)

6. Turret

Galle fortress has several turrets (Figure 2.51) and by comparing with the existing turret at the A Famosa fortress in Figure 2.52, it is found that it has similar style and design.

Figure 2.51 Turret at one of the bastions at the Galle fortress, 2009 (Source: Author)

Figure 2.52 Turret at Porta de Santiago gate, 2009 (Source: Author)

7. Fausse-braie

The existence of fausse-braie at Galle fortress is clearly shown in Figure 2.53. In case of the A Famosa fortress, fausse-braie has been mentioned several times in Bort's

(Bort, Bremner et al. 1927) report and it is also shown in the Dutch plan of this fortress.

Figure 2.53 Example of the faussie-braie at Galle fortress, 2009 (Source: Author)

8. Tower

There are two towers in this fortress. Figure 2.54 shows a clock tower built by the British next to the guard room of the moon bastion. This is within the main gate area. Another tower is a lighthouse which is facing the sea. However, these towers serve different purpose compared to the A Famosa tower which is mainly for defensive purpose. The A Famosa tower collapsed due to heavy bombardment by the Dutch. Figure 2.55 shows the location of the Portuguese's tower in its early day in Melaka.

Figure 2.54 Clock tower within the main gate area, 2009 (Source: Author)

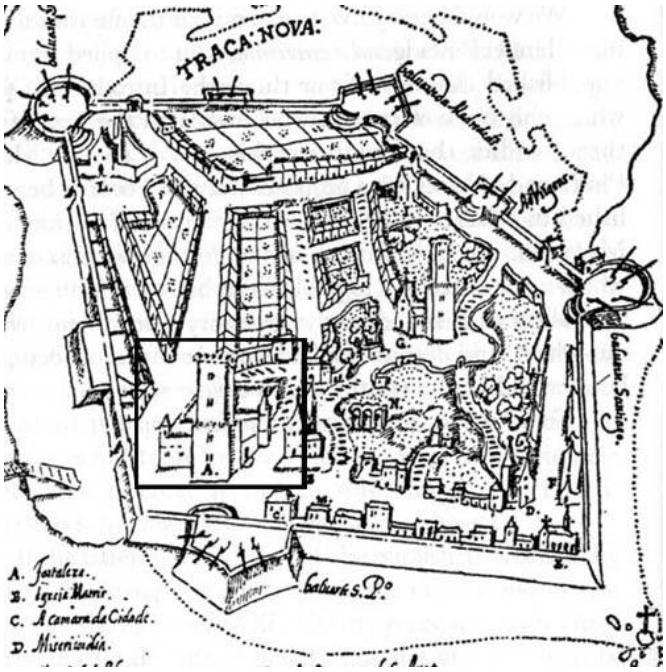


Figure 2.55 The location of Portuguese tower known as the keep according to Godinho Eredia, 1604 (Source: Godinho,1997)

9. Wall

Initially the early wall was built by the Portuguese from earth and palisade. Later, it has been replaced with stone walls. The walls were connected to each other by the bastions and sometimes there were crenels for the cannons to peep through.

According to the Divisional Secretariat (2009), the walls' height is about 5 to 7 meters and the width is about 5 metre. The wall location is nearly same with the A Famosa fortress which some part of the walls were washed by the sea wave.

2.4.2.5 Summary of Galle fortress

The Galle fortress has a strong similarity with the A Famosa fortress from various aspects such as occupation sequence, building style, layout and administration. Both of these fortresses are recognised as the World Heritage site by the UNESCO. Like the A Famosa, Galle fortress was initially occupied by the Portuguese and later by the Dutch. The fortress itself was enlarged and strengthened by the Dutch until it fell into the British hand. The same thing also happened to the A Famosa. Geographically these two fortresses are located facing the seaside and at one glance their layout of the plans are similar to each other except for their sizes.

2.4.3 Rotterdam Fortress, Makassar, Indonesia

2.4.3.1 Background

This fortress is located in Makassar, Indonesia (Figure 2.56). A mock up model of this fortress is shown in Figure 2.57. It is a simple quadrangle shape fort with bastion on its angles as shown in Figure 2.58. Makassar plays an important role as a trading centre in Nusantara Archipelago. It has similar character with Melaka and the history of Makassar began with the fortress (Sumalyo 2002). The fortress originally belongs to the king of Gowa and formerly known as Fortress Ujung Pandang. In 1667 the Dutch took over this place to monopolise the spice trade. During the transition, the Dutch destroyed some of the fortresses except this fortress which was used as the Dutch headquarter. Other than that it also has other functions such as living quarters, defence, trading and as a port (Sumalyo 2002).

This fortress was chosen by the Dutch as an administration centre due to its natural geographical factor which is more appropriate to be the port. This fortress was under Admiral Speelman's administration and the name of the fortress itself was taken from his place of birth. Unlike A Famosa, this fortress was used for administration purpose and comprises offices, church, prison, police station and armoury. Architecturally, the fortress shows a strong European influence and resembles medieval style.

Figure 2.56 Location map(top) and satellite view of Rotterdam fortress(below), Makassar, 2009 (Source: Google Earth)

Figure 2.57 Mock up model of the existing Rotterdam fortress made in 2009 (Source: www. museumindonesia.com)

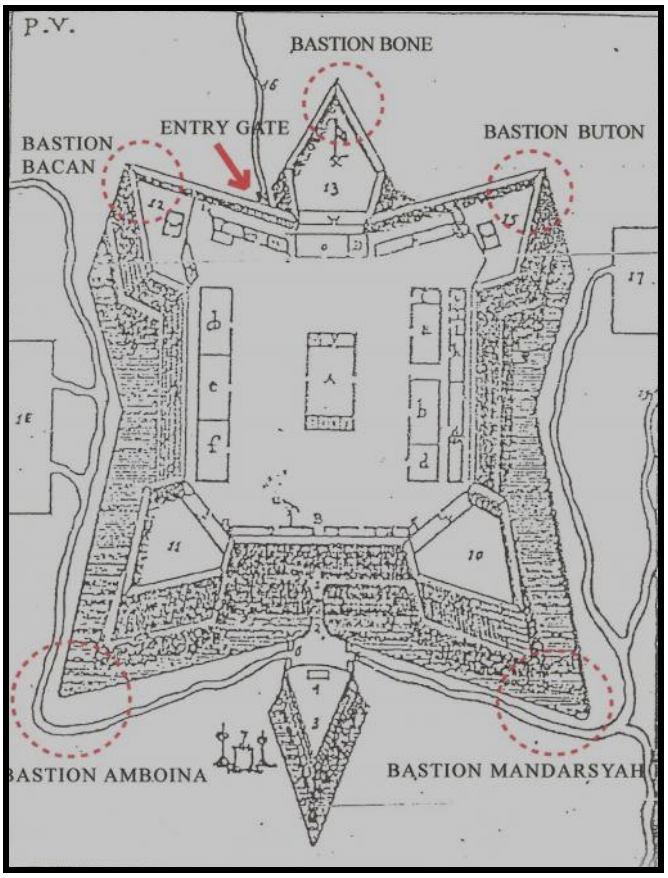


Figure 2.58 The plan of the fortress, 1613 (Source: NTQT,Malaysia)

2.4.3.2 Location

The location of the fortress in Figure 2.59 is very strategic which is facing the seaside. This is probably one of the reasons the Dutch chose this location because it is also appropriate to be the port.

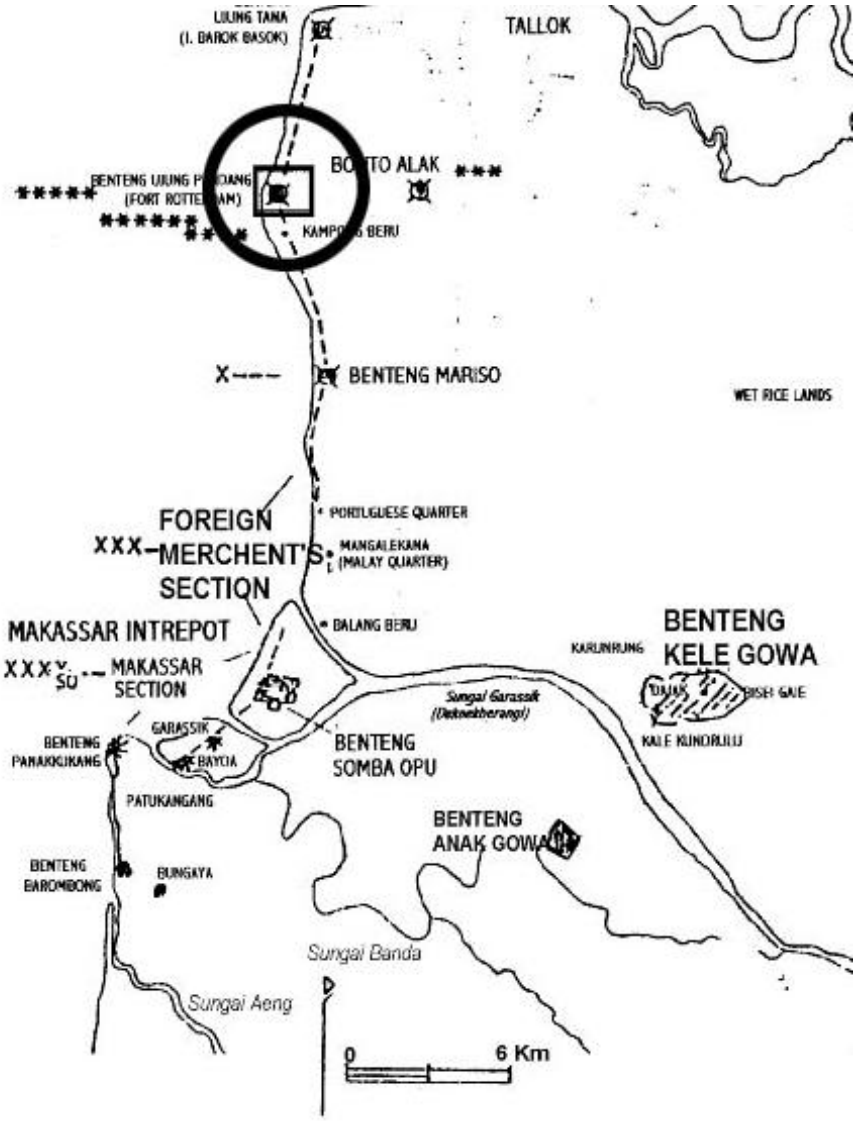


Figure 2.59 Location (circle) of the Rotterdam fortress in Makassar, 1613 (Source: Sumalyo, 2002)

2.4.3.3 Materials

Before 14th century the fortress was made of clay mixed with rocks and after that it has been replaced with limestone and brick by the Sultan of Gowa. When the Dutch took over, the design of this fortress has been modified accordingly to fit tropical

climate and most of the buildings and elements are referring to the Dutch architecture (Figure 2.60). It is also found that some of the materials used for this fortress like marble and tile were brought from Europe (Sumalyo 2002).

Figure 2.60 Brick and limestone as the fortress's material, 2008 (Source: NTQT,Malaysia)

2.4.3.4 Fortress elements and similarity to the A Famosa fortress

Not all of the elements in the A Famosa fortress can be found in the Rotterdam fortress, however certain key features provide important references.

1. Bastion

In total, there are five bastions available in this fortress. These bastions are known as Butung, Bone, Bacan, Ambonia and Mandar Syah. Figure 2.61 shows that these five bastions forms the shape of a turtle with one head and four feet. The bastion which acts as the head has a close similarity with the bastion of Frederick Hendrick and Henriette Louijse in the A Famosa fortress as can be seen in Figure 2.28. The Malaysian archaeologist and conservationist referred to this as one of the case studies for the reconstruction of Middelburgh bastion.

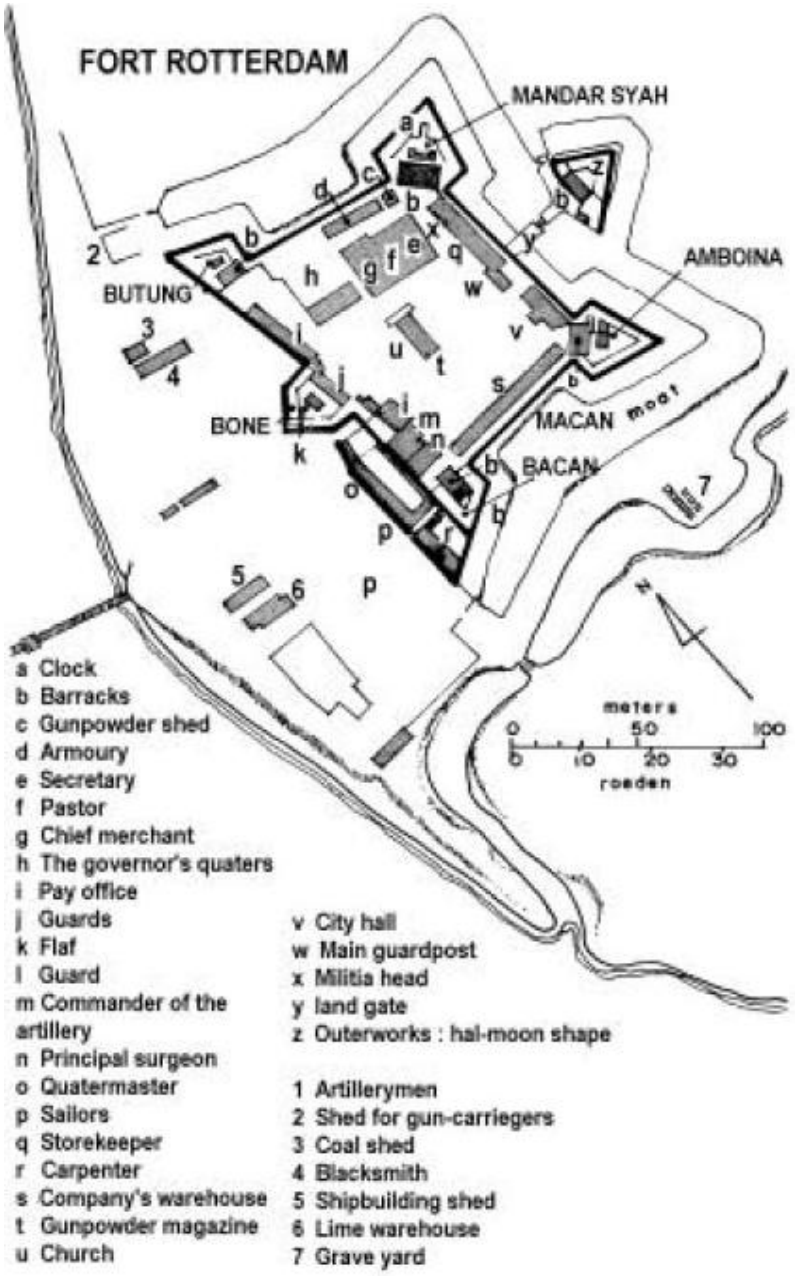


Figure 2.61 The bastions at Rotterdam fortress, 1613 (Source: Sumalyo, 2002)

2. Gateway

The fortress has two main gateways. These gateways are known as the eastern gate on the landside and the western gate on the seaside. Figure 2.62 shows the western gate in 1988 and 1930. Besides, there are also small gates for quick access for the soldiers.

Figure 2.62 The western gate in 1998 (left), photo by (Source: Dirk Teeuwen) and in 1930 (right) (Source: Heshusius)

3. Passageway

By looking at the model of this fortress, it is found that the passageway in Figure 2.63 has different widths. It also encircles the entire fortress. In some parts, it has similar width with the Aguada fortress, where only one person can use the passageway at one time.

Figure 2.63 The passageway, 2008 (Source: NTQT, Malaysia)

4. Parapet

The parapet in this fortress does not have the same height. Mostly the parapet on the bastion side is higher than the passageway side. This is also can be seen in other fortresses like Aguada and Galle. Figure 2.64 shows the parapet of the Rotterdam fortress.

Figure 2.64 The parapet, 2008 (Source: NTQT, Malaysia)

5. Crenel/Embrasure

Most of the crenels are found in the bastions area. Figure 2.65 shows the crenels at that fortress.

Figure 2.65 Crenel at the bastion of Rotterdam fortress, 2008 (Source: NTQT, Malaysia)

6. Wall

The wall which surrounded the fortress has some similarities with the A Famosa fortress. By looking closely at the A Famosa plans, they show that some of the buildings are parallel to the wall and some are attached to the wall. The wall itself has some degree of angle. The width for the wall is approximately 2 meters and the height is 5 to 7 meters.

2.4.3.5 Summary of Rotterdam fortress

This fortress can be summarised as one of the best references for certain elements for reconstruction purpose. This fortress has been mainly referred by the conservation team in Malaysia for reconstructing the Middelburgh bastion. The elements of the fortress have not much different from other fortresses by the Dutch and the Portuguese. Makassar and Melaka, both have similar role as an important port for spice trading. The fortresses have the same functions as living quarters, defence and trading. Geographically the location of this fortress is located at the seaside which is similar to the A Famosa and it was encircled by a ditch.

As for materials Rotterdam fortress used brick and limestone, whereas A Famosa used laterite. Since the fortress is smaller than A Famosa, it has smaller number of the bastions compared to A Famosa. It has two main gateways compared to the A Famosa which has four, but only two of them were used as the main gateways. Other elements such as rampart, parapet, breastwork and passageway are common elements for any fortresses. Other obvious similarity is the attachment of the buildings to the wall which is clearly can be found in any of the A Famosa's plans.

2.5 Summary

In this chapter, a historical study on the fortress in general has been discussed. It covers fortification criteria and features in relation with the A Famosa fortress in Melaka. This followed by a study on historical background of Melaka and A Famosa fortress. Finally, three fortress sites within the same era of the A Famosa fortress have been chosen and a field trip study has been conducted to these sites. These field trip studies explain about the location, background, fortress elements and their

similarities compared to the A Famosa fortress. The findings from these case studies will be used to compare with the textual descriptions and 2D visual information of the A Famosa fortress in the next chapter. These findings such as similarity of the elements and detailing are very important because it demonstrates the existing elements of the intact fortresses which belong to the same occupiers of Melaka. It also helps the process of translating and visualising the 2D information to the next stage; draft sketches before the final stage of 3D modelling.

Chapter 3

DATA COLLECTION AND VERIFICATION

This chapter discusses about the process of tracing, collecting and analysing all related data to the A Famosa fortress. It presents and discusses several methods which have been used to verify the credibility and accuracy of the collected data. In addition to using numerical methods for data verification, reference to case studies and literature reviews presented in chapter two help to explain the findings and results. The results from this chapter will be used as the main reference for building this fortress in 3D model.

3.1 Tracing A Famosa

In order to trace this old fortress an extensive study has been carried out. Apart from there being very minimal physical evidence of the fort available today, there is also a lack of a systematic historical and documental history of Melaka (Viana 1988).

Various resources that describe A Famosa have been consulted in the preparation of this thesis, they include;

1. Books/journals
2. Old manuscripts
3. Old drawings and photos
4. Early maps and cartography
5. Paintings
6. Remains of the fortress and similar fortresses

With those available resources sometimes it leads to ambiguity hence comparison of the collected data is very important, this is also supported by textual descriptions. Discussions have also been held with architectural historians, Culture, Arts and Heritage Ministry of Malaysia (WARISAN) and conservation team. Hence, there are possibilities to share some data and exchange resources. WARISAN is one of the bodies that responsible to reconstruct some of the fortress vital portions for conservation and tourism purpose. These parties held several important data particularly on drawings and reports. While this research extensively focused on collection, analysis and verification of the collected data and finally transform them into visual analysis before proceed with 3D reconstruction process.

The team itself has done a thorough study about this fortress and it would be helpful to compare with the findings from this research. Another specialised study on this fortress was carried out by Professor Pierre Yves Manguin. His work concentrates on extracting some of the important details, bird's eye view perspective and study of the old perspective drawing by unknown artist (Manguin 1988). This study does not provide detailed measurement for the entire fortress and the output of his study is in form of hand drawn perspective drawing which is still insufficient for full 3D reconstruction. However its detailed explanation is very useful for data collection.

3.1.1 Types of data

After getting the resources, the relevant data has been extracted and classified into different forms. They are listed below.

3.1.1.1 Textual descriptions

Drawings extracted from the reports, books, journals, paper and many more are usually further explained in textual forms. In not to scale drawings, some of the measurements are described in the text explaining the drawings. Even though the information is quite scattered compared to the visual form, proper extraction can give important information on the fortress material, height, position, elements and functions which can give a better understanding of the fortress. This can be an important reference and supporting data for translating the visual data.

3.1.1.2 Visual data such as drawings, paintings and maps

Most of the visual data of the A Famosa are extracted from the books, journals and national archives. Among them are old drawings dated from year 1500 to 1900 recorded by various artists, draftsmen and architects from the Portuguese era until the British era. For the purpose of analysis, they have been categorized into two types which are not to scale drawing and scaled drawings.

3.1.1.2.1 Not to scale drawings

All the drawings from the Portuguese era are not to scale. Even if the drawings come with scale, they are very brief and seemed questionable. Most drawings are in form of painting and perspective drawings. The drawings are strongly related to the skills of the draftsmen or artist, development of the art movement in that era and availability of the architectural technology during that time. Unfortunately, data from not to scale drawings are not very reliable for extracting the measurement of the fortress. However, it still can be used to illustrate data such as shape, materials, surrounding, elements, location and position of the fortress.

3.1.1.2.2 To scale drawings

Most of the drawings during the Dutch era are scaled drawings. They are in the form of plans, drawn according to scale with specific measurement unit. However, the measurement unit used are old units such chain, rod, furlong and fathoms which are no longer used nowadays. Besides, even the same unit might use different conversion value such as listed in Table 3.1.

Table 3.1 Conversion Of Old Units (Hoffman 2007)

Name	Conversion (1 unit equivalent)
Dutch foot	11 Dutch inches 11 3/8 English inches
English foot	12 inches
Dutch rod	Sometimes 11,12 13 Dutch feet
English rod	16.6 English feet[1]

3.1.1.3 Physical data

The physical data of the fortress is the most accurate data to represent the fortress. Initially, the only available remains of the fortress after the British era is Porta de Santiago, which was one of the gates to the fortified city of Melaka. Figure 3.1 gives detailed plan of the Santiago gate extracted from the original site.

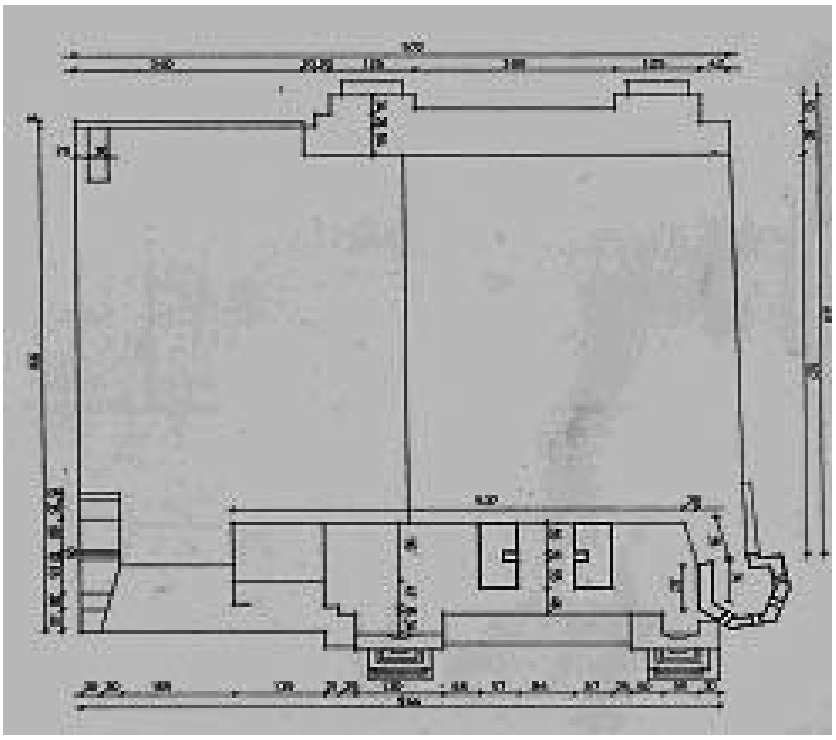


Figure 3.1 Detailed plan of Porta de Santiago, 1988 (Source: Viana, 1988)

However, after years of excavation and conservation works, a bastion known as Middleburgh has been successfully reconstructed. Figure 3.2 shows the detailed plan of the Middleburgh bastion, received from the excavation team.

[1] Russ Rowlett, "English Customary Weights and Measures"in A Dictionary of Units of Measurement (http://www.unc.edu/~rowlett/units/custom.html)

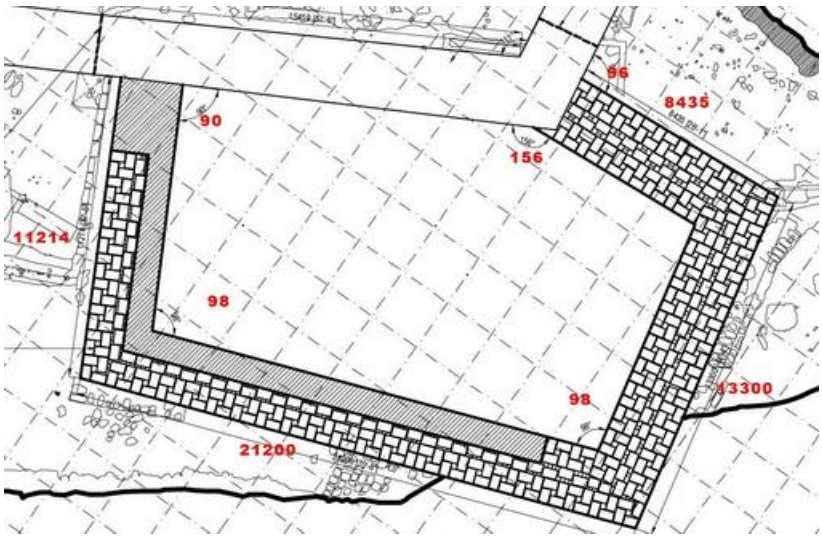


Figure 3.2 Plan of the Middleburgh bastion, 2008 (Source: NTQT, Malaysia)

At the moment, the excavation team is working on reconstructing another bastion, known as Frederick Hendrick. The data obtained from the physical inspection of the fortress can be used as the main reference in analysis and can be projected to the findings from visual and textual data in order to get a complete accurate data of the whole fortress wall.

3.2 Fortress layout determination approach

The main challenge in this research is to determine a verifiable conjectural layout of the A Famosa fortress. This is because not only the physical remnant of the fortress is very minimal, there is also lack of authoritative documentation and inconsistency in the early descriptions of the fortress due to the use of various old measurement systems and graphical projections. Because of this issue, few approaches have been adopted to verify all the collected data as discussed in the following sections. Another important consideration is to start tracing the fortress from Dutch era because it is realized that data during the Dutch era have more details compared to the Portuguese.

Among all of the collected data, a report of Governor Balthasar Bort in Melaka dated 1678 (Bort, Bremner et al. 1927) was found to be the most authoritative. This is because the report was prepared for the Government of the Dutch as technical study and as a reference for their successors at that time. The research has shown that this

data was the most reliable data to be authoritative. It contained the most complete information on the measurement and physical condition of the fortress compared to other manuscripts which were written by either journalist or ordinary people for personal record. Other sources by François Valentijn's in "Oud en nieuw Oost-Indien" referred to by Bort (Bort, Bremner et al. 1927) is a Dutch East Indies "civil-servant's" report mainly concerned with ship movements. With regard to Melaka he provides a brief history of the town, but with no reference to A Famosa. He seems fascinated by the Chinese residents of Jonkers Street, but the main bulk of the references to Malakka are details of the ships passing through the port and their cargoes (Valentijn 1724).

However, there are some inconsistencies and ambiguity identified in the report. The report also did not contain any visual illustration which made it hard to understand some of the terminologies used during that era which are no longer available nowadays. Thus, it is decided to run detail verification analysis on the information extracted from the report and translate it to visual form for better understanding.

3.2.1 Translating textual data into conjectural layout

The first analysis is to verify the fortress wall measurement. In Bort's report, there is a detailed measurement for the wall connecting each bastion. Table 3.2 and Table 3.3 present the data extracted from the report. For a better understanding, the location of each bastion is shown in the plan of A Famosa during the Dutch era as shown in Figure 3.3.

Table 3.2 Fortress lengths data extracted from Bort's report

Points	Innermost polygon			Outermost lines		
	Rod	**Feet[2]**	**Meter[3]**	**Rod**	**Feet[2]**	**Meter[3]**
Fredrick Hendrick to Middleburgh	16	192	55.47	18	216	62.40
Middleburgh to Ernestus	41.3	495.6	143.19	40.3	480	138.6
Ernestus to Amsterdam	16.8	201.6	58.24	15.9	190.8	55.12
Amsterdam to Victoria	26.4	316.8	91.53	28.6	339.6	98.11
Victoria to Emelia	56	672	194.15	62.8	753.6	217.73
Emelia to Henriette Louijse	46	552	159.48	49.2	590.4	170.58
Henriette Louijse to Wilhelmus	39	468	135.21	42.4	508.8	147.00
Wilhelmus to Mauritius	40.8	489.6	141.45	43.11	517.32	149.46
Mauritius to Frederick Hendrick	59.9	718.8	207.67	64.11	769.32	222.27
Total circumference	342.2	4106.4	1186.44	364.42	4373.04	1261.27

Table 3.3 Fortress angles data extracted from Bort's report

Bastions	Fortress angles
Middelburgh	133^{o}
Mauritius	102.5^{o}
Wilhelmus	117.5^{o}
Emelia	126^{o}
Victoria	87^{o}

2 1 rod is equivalent to 12 feet, Rhenish measure. (Extracted from the report)

3 The conversion is based on 1 Dutch feet equivalent to 11.375 English inch (Refer Table 1)

1 English inch = 25.4 mm thus 1 Dutch feet equivalent to 11.375 x 25.4 mm = 288.925 mm

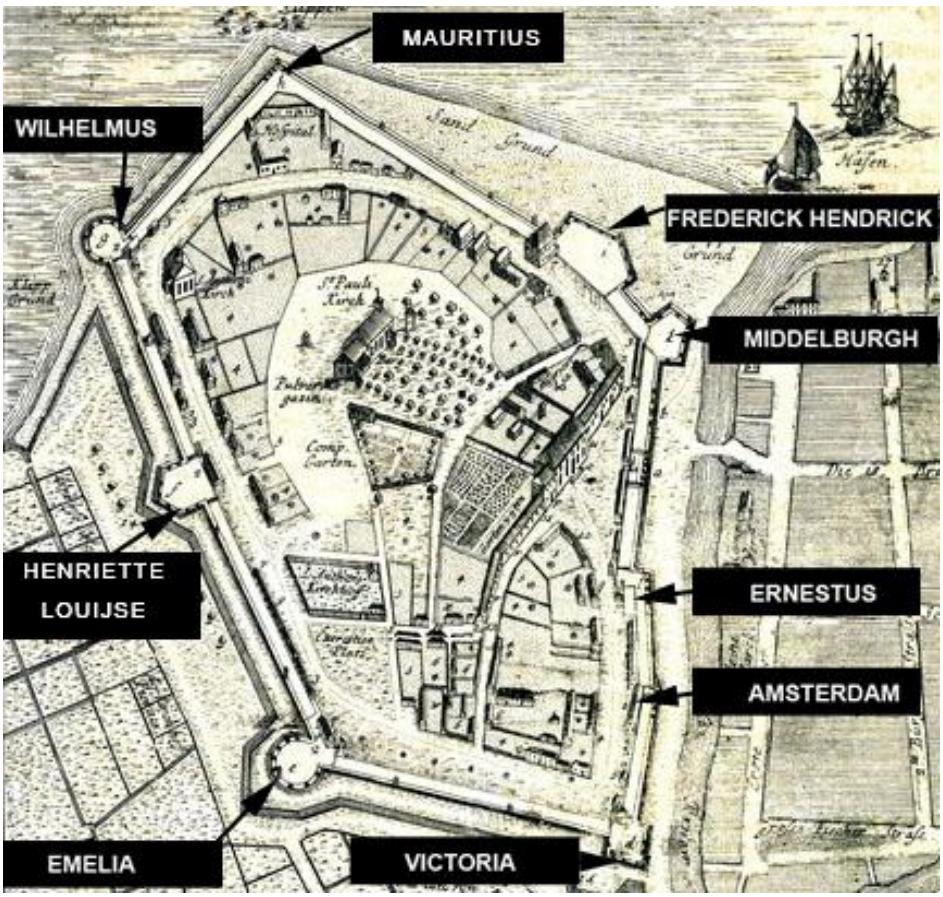


Figure 3.3 Location of the bastions in A Famosa fortress, 1735-1744 (Source: Refer Figure 2.28)

3.2.1.1 Construction of innermost polygon

From the given data, an attempt has been made to transform it into visual form by first constructing the innermost polygon. Figure 3.4 gives the visual representation of the data according to the angle and measurement given.

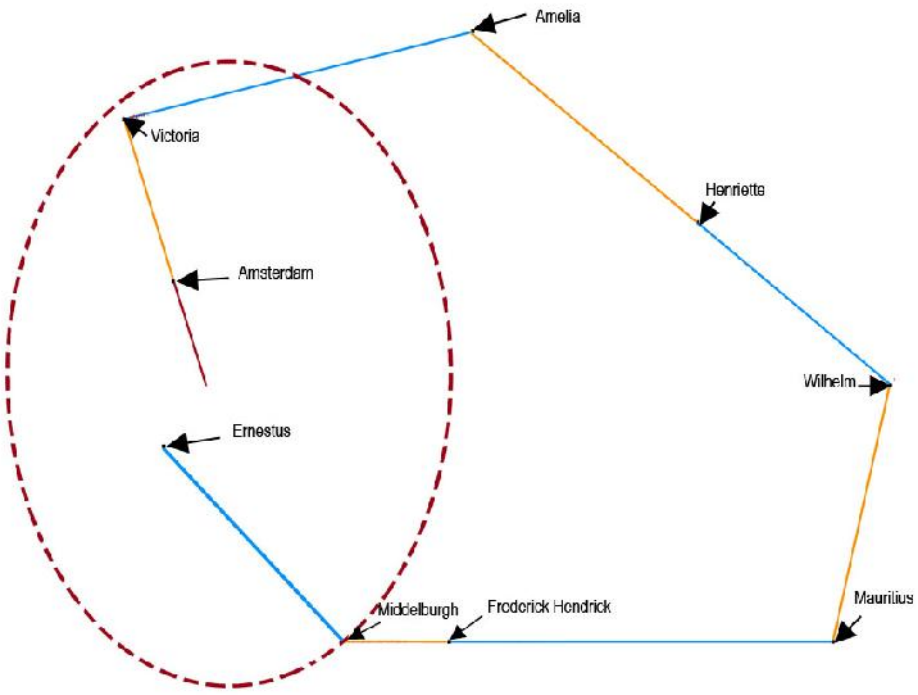
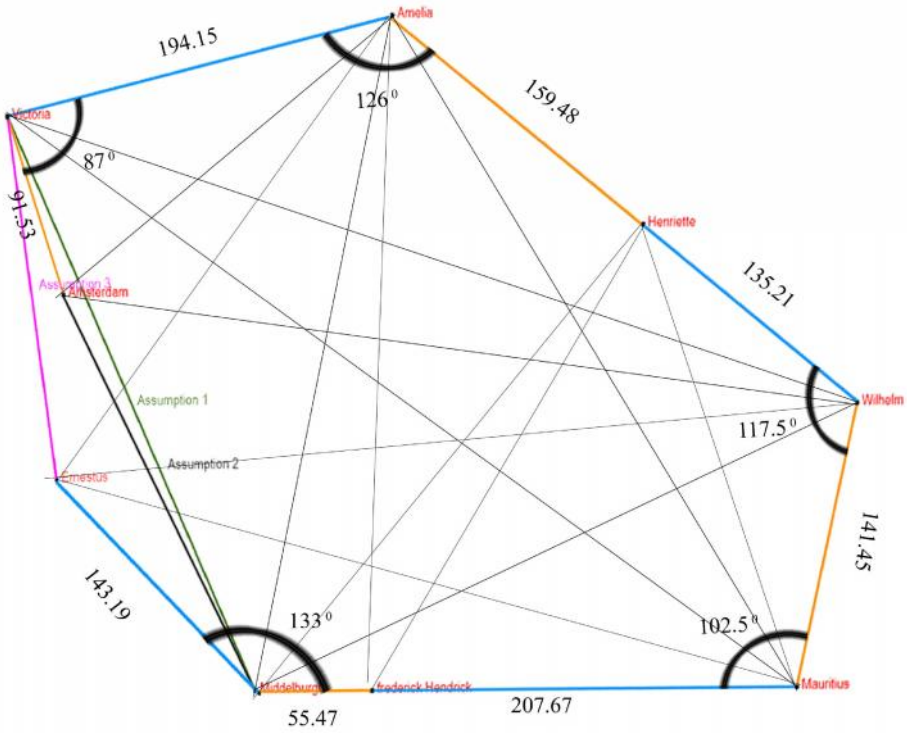


Figure 3.4 Visual representation of the data according to scale (Source: Author)

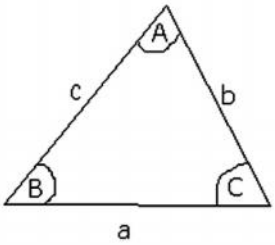
From the Figure 3.4, there are some inconsistencies in the highlighted area as discussed below:

1. According to the report, there is no inner polygon angle for Ernestus and Amsterdam because they are laid together on a straight line. However, given the inner polygon angle for Middleburgh and Victoria, there is no way that Ernestus and Amsterdam would lie on a straight line.
2. The innermost polygon distance given for Middleburgh to Ernestus and Ernestus to Amsterdam is questionable because it is longer than the outermost lines. This is impossible if the Ernestus and Amsterdam are built out of a straight line.

To clarify this ambiguity, a step has been taken to confirm the given angles and distances using the rule of sine and the rule of cosine. For this purpose, the innermost polygon in Figure 3.4 has been divided as into small triangles as illustrated in Figure 3.5.



If a, b and c are the distance of the sides opposite the angles A, B and C in a triangle, then:



1) To get a distance using Sine rule:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

2) To get an angle using Sine rule:

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

3) To get a distance using Cosine rule:

$c^2 = a^2 + b^2 - 2abcosC$

which can also be written as:

$a^2 = b^2 + c^2 - 2bccosA$

4) To get an angle using Cosine rule:

$$cosC = \frac{a^2 + b^2 - c^2}{2ab}$$

which can also be written as:

$$cosA = \frac{b^2 + c^2 - a^2}{2bc}$$

Figure 3.5 Illustration of measurement verification using Sine and Cosine rule

Then the calculation of the angles and distances are done based on various assumptions:

1. Assuming the Ernestus and Amsterdam lies in a straight line. The result is shown in Table 3.4.
2. Assuming the angle for Victoria and distance from Victoria to Amsterdam is correct. The result is shown in Table 3.5.
3. Assuming the angle for Middleburgh and distance from Middleburgh to Ernestus is correct. The result is shown in Table 3.6.

Table 3.4 Result for assumption 1: Assuming the Ernestus and Amsterdam lies in a straight line

Inner polygon shape	Victoria to Middleburgh			Inner polygon angle			
Circumference: 345.7rod	Inner polygon	Inner polygon	Outermost line	Victoria		Middleburgh	
	From the report	From the calculation	From the report	From the report	From the calculation	From the report	From the calculation
	84.5	88	84.8	87°	80.78°	133°	113.2°

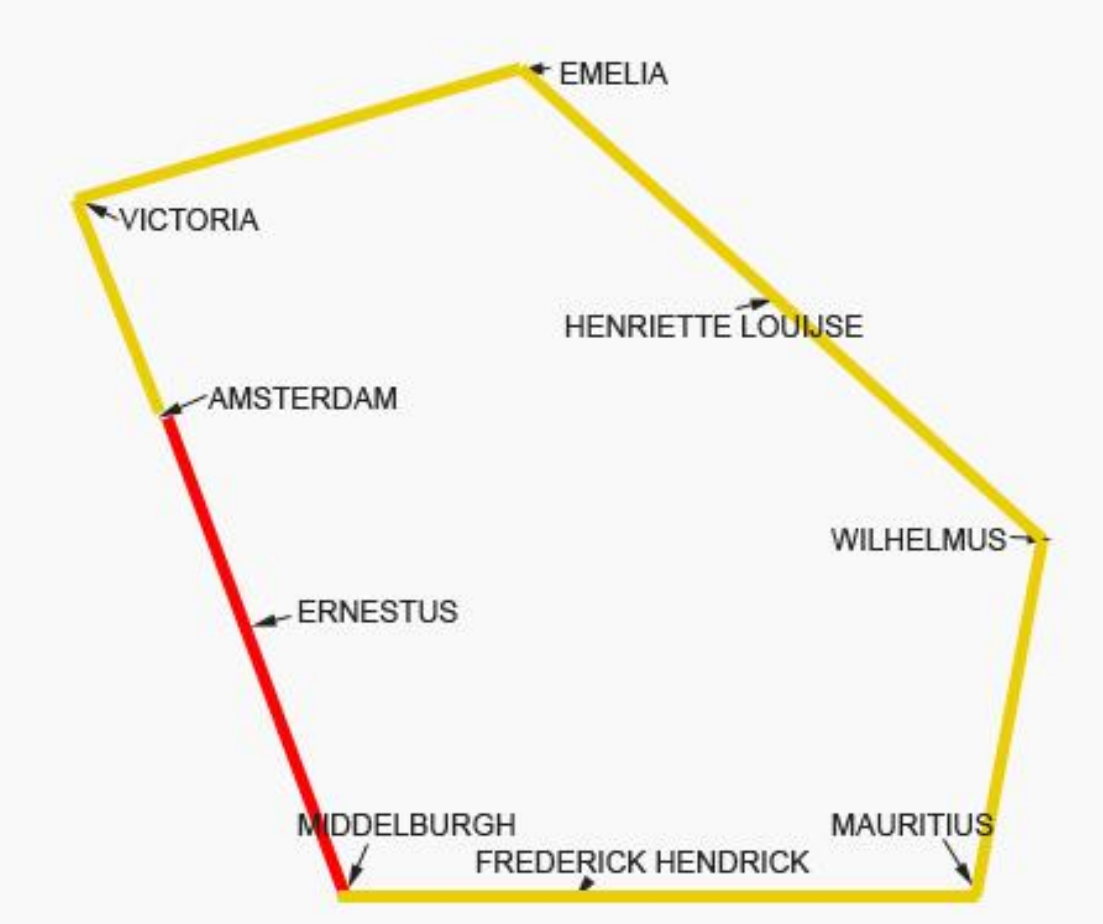


Table 3.5 Result for assumption 2: Assuming the angle for Victoria and distance from Victoria to Amsterdam is correct.

Inner polygon shape	Amsterdam to Middleburgh			Inner polygon angle			
Circumference: 345.98rod	Inner polygon	Inner polygon	Outermost line	Amsterdam		Middleburgh	
	From the report	From the calculation	From the report	From the report	From the calculation	From the report	From the calculation
	58.1	61.88	56.2	180°	171.5°	133°	115.5°

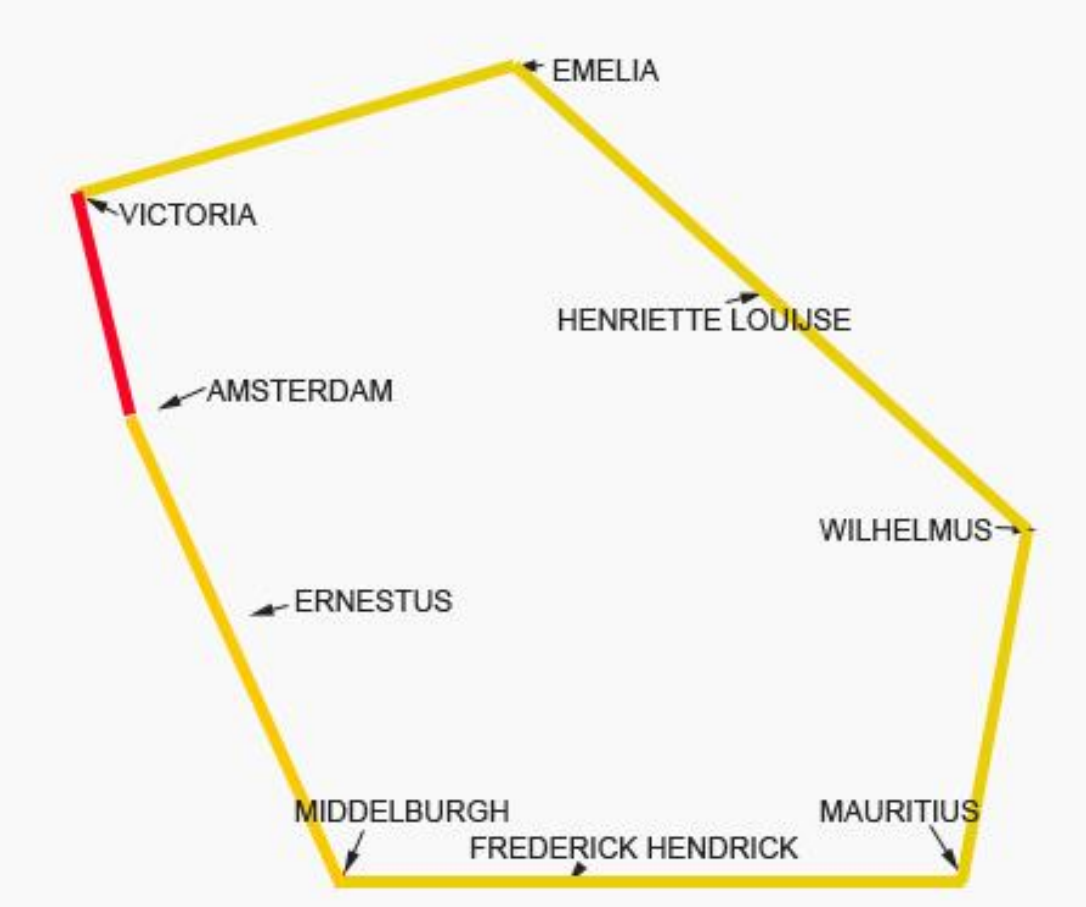
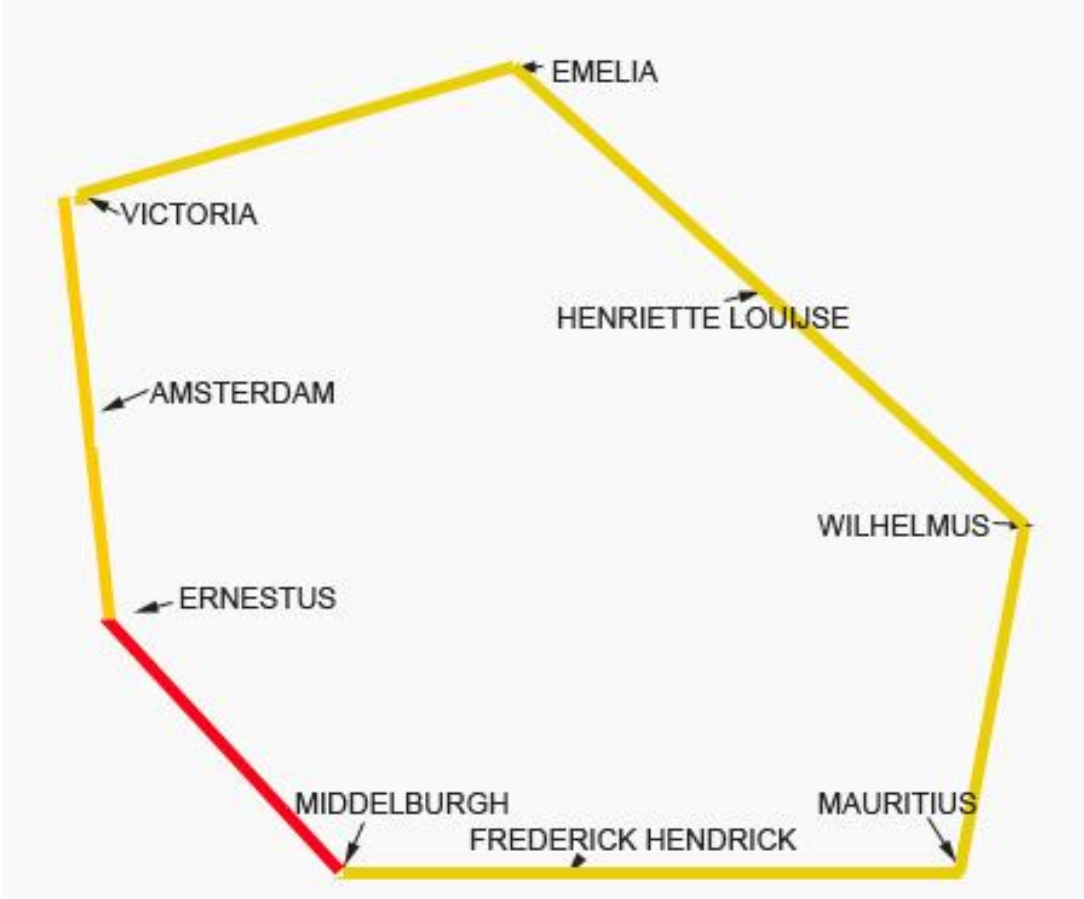


Table 3.6 Result for assumption 3: Assuming the angle for Middleburgh and distance from Middleburgh to Ernestus is correct.

Inner polygon shape	Victoria to Ernestus			Inner polygon angle			
Circumference: 350rod	Inner polygon	Inner polygon	Outermost line	Victoria		Ernestus	
	From the report	From the calculation	From the report	From the report	From the calculation	From the report	From the calculation
	43.2	51	44.5	87°	96.6°	180°	144.4°



After analyzing the shape based on the 3 assumptions, it is decided to remove the result from assumption 3. This is because the error between the calculated value and the report is very big (more than 15%) in most cases for assumption 3. Another finding that is observed from this assumption is that the outermost line for Victoria to Middleburgh should be longer compared to the distance given in the report which implies that the total circumference would also be bigger than the value from the report.

3.2.1.2 Construction of outermost polygon

Based on the inner polygon shape, it is decided to construct the outermost line. The Bort's report has stated 7 bastions and 2 angles as detailed in the Table 3.7. There are few challenges in validating the measurement of the outermost line. The challenges are listed below.

1. The Bort's report did not specify whether the measurement of the outermost line include the size of the bastions. There is also no explanation on the size of the bastion or any visual information on the shape.
2. It also gives inconsistent value on the circumference of the outside wall. The circumference of the outside wall is stated to be 365.5 rod, while the detail point to point value (as shown in Table 3.2) total up to be 364.2 rod.

Table 3.7 List of bastions and shapes extracted from the report

No.	Bastion	Shape
1	Middleburgh	Half bastion
2	Ernestus	Half bastion
3	Amsterdam	Angle
4	Victoria	Full bastion
5	Emilia	Round
6	Henriette Louise	Full Bastion
7	Wilhemus	Round
8	Mauritius	Obtuse Angle
9	Fredrick Hendrick	Full bastion

To solve this ambiguity, two approaches have been used. Firstly, the bastion shape and size are ignored. In this approach it is assumed that the measurement presents just a straight line connecting the bastions. Figure 3.6 shows the complete visualisation of the innermost polygon and the outermost line of the A Famosa based on this approach. The total circumference calculated from Figure 3.6 is 1.29 km, slightly longer than the circumference calculated from the report (1.26 km, as in Table 3.2).

In the second approach, the shape and size of the bastions have been adopted from general observation on the collected drawings and plans and included into Figure 3.6. An adjustment to the original point to point measurement has been made so that it would include the bastions size and tried to minimize the total circumference. The result is shown in Figure 3.7 with the circumference increased to 1.475km.

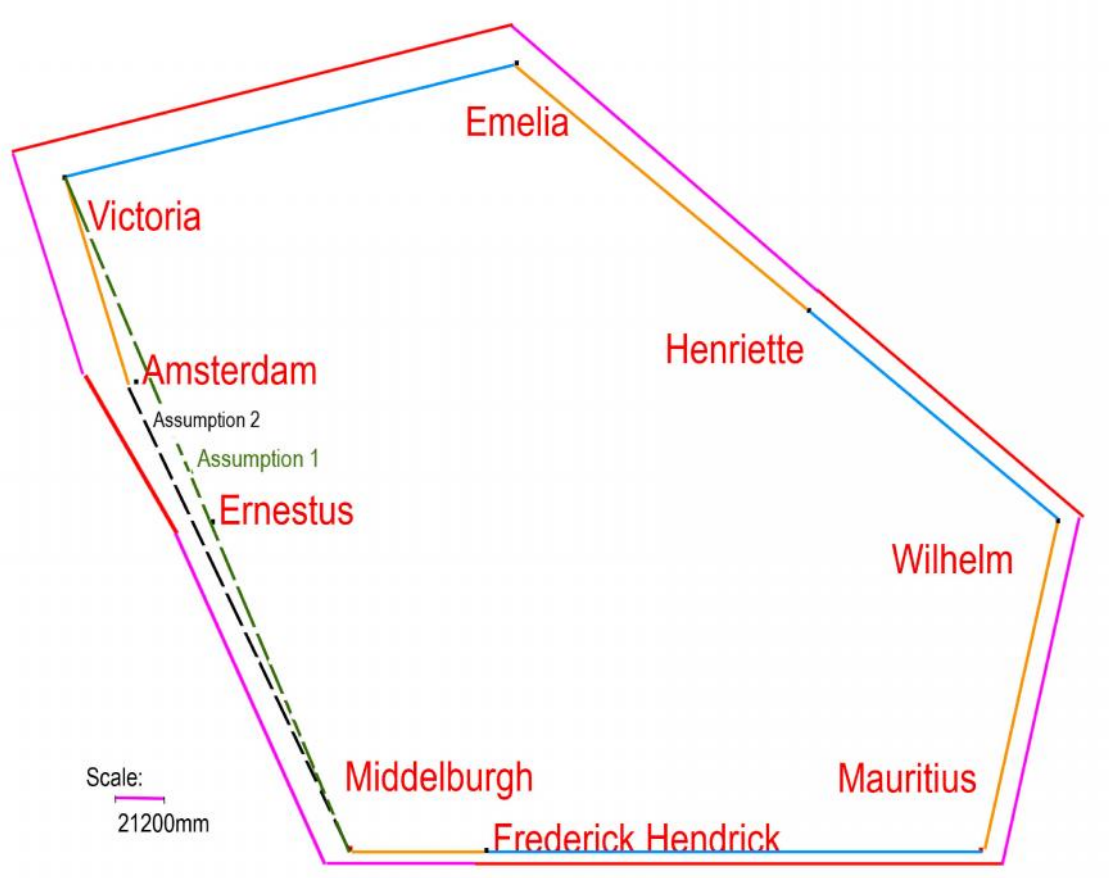


Figure 3.6 Complete visualization of innermost polygon and the outermost line of A Famosa without the bastions (Source: Author)

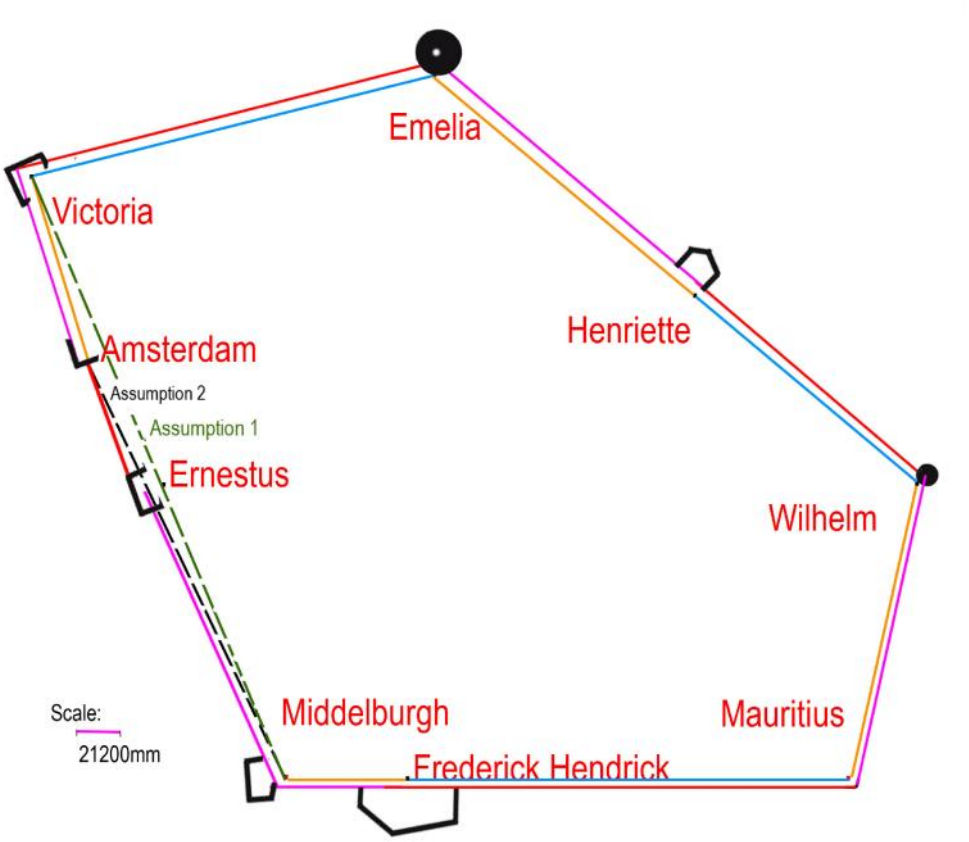


Figure 3.7 Complete visualization of innermost polygon and the outermost line of A Famosa including the bastions (Source: Author)

To further verify the circumference measurement, the data has been compared with the description about A Famosa during the Portugese era given by Manuel Godinho De Eredia in 1604 (Godinho de Eredia & Mills, 1997). The result is presented in Table 3.8. The result is analysed in 2 groups which are circumference 1 and circumference 2. For circumference 1, some modifications were done on the fortress during Dutch era such as the bastion of Victoria was extended to 1/3 of its original size and the addition of Middleburgh bastion, which is not exist during the Portuguese era.

Thus it is clearly shown that the value from Eredia's description is smaller compared to Bort's report. On the other hand, the value calculated from Figure 3.7 is bigger compared to Bort's report. This is consistent with the previous finding which has verified that the actual measurement from Middelburgh bastion to Victoria bastion should be longer than the one reported in Bort's report.

Table 3.8 Comparison of the measurement from Bort's (Bort, Bremner et al. 1927) and Godinho de Eredia (Godinho 1997)

Points	Bort's report		Figure 3.7	Manuel Godinho De Eredia	
	Meter (1 Dutch rod = 12 Dutch feet)	Meter (1 Dutch rod = 13 Dutch feet)	Meter	Fathoms	Meter (1 fathom =1.82m)
Fredrick Hendrick to Victoria	354.23	386.152	452.3	150	273
Victoria to Emelia	217.73	235.89	222.51	100	182
Circumference 1	571.96	622.042	674.81	250	455
Emelia to Henriette Louijse	170.58	184.79	269.88	100	182
Henriette Louijse to Wilhelmus	147.00	159.25	163.24	100	182
Wilhelmus to Mauritius	149.46	161.92	179.69	75	136.5
Mauritius to Frederick Hendrick	222.27	240.80	188	130	236.6
Circumference 2	689.31	746.76	800	405	737.1
Total circumference	1261.27	1368.80	1474.81	655	1192.1

In the case of circumference 2, the measurement from Emilia to Fredrick Henrick should be similar since there is no modification reported. However it is found that Bort's report has given the smallest value compared to the other two measurements. It is difficult to say which is the most accurate measurement because the measurement from both sources used very old unit and there might be a small error in converting the old unit to the current metrics unit. For example according to the table of conversion (Table 3.1) unit extracted from Murray, (Hoffman 2007), 1 Dutch rod can be equivalent to 11, 12 or 13 Dutch feet. In this case, we have taken 1 Dutch rod to be 12 feet based on what given in the report. By taking the measurement 1 Dutch rod equivalent to 13 Dutch feet as shown in Table 3.8, it will give a bigger value for Bort's measurement which will be more consistent with Eredia's description.

In overall, it is also observed that the value calculated from Figure 3.7 is bigger compared to the other two sources. This is actually expected because calculation for Figure 3.7 includes detail measurement of the bastion which resulting bigger circumference. Whereby, the other 2 sources might have not considered the actual size of the bastions. At this point it is not possible to clarify the size of any bastions because it was not mentioned in Bort's report or Eredia's descriptions. Thus, in order to do this, the data collected so far need to be compared to the visual data.

3.2.2 Matching the conjectural layout to visual data using Procrustes Analysis

To compare the layout that has been constructed in Figure 3.7 with the collected visual data, Procrustes analysis approach has been used. Procrustes analysis is a rigid shape analysis that uses isomorphic scaling, translation, and rotation to find the "best" fit between two or more landmarked shapes. In this case, a least-squares orthogonal generalized procrustes analysis (least-squares orthogonal mapping) is used. It applies nonlinear mapping algorithm to find best fit, i.e. to find a reference cluster of landmarks, so that the distance of each reference landmark to its corresponding experimental landmark is minimized. Firstly, to proceed with this analysis, identification and selection of appropriate drawings must be done.

3.2.2.1 Selection of visual data

A total of 12 plans with scale from the Dutch era were collected to be compared to the constructed layout. Having these scaled drawings is very important to eliminate inconsistencies and variations which are caused by improper drawings scale. The selected plans are shown here with the descriptions of their source.

3.2.2.1.1 Map of the city and fortress at Malakka, ca. 1780

This Figure 3.8 dated ca. 1780 belongs to P. Elias who was a land surveyor and mapmaker for VOC, active ca. 1790. According to the Leupe catalogue (NA), the original title reads: *Hoofdplan van de stad en Kasteel Malacca, volgens gedane meeting*. Among his other drawings are *Design for fortifications at Amboina, Indonesia ca. 1780*, *Map of Colombo and environs ca. 1790 and Map of Fort Oranje on Ternate, Indonesia ca. 1790*.

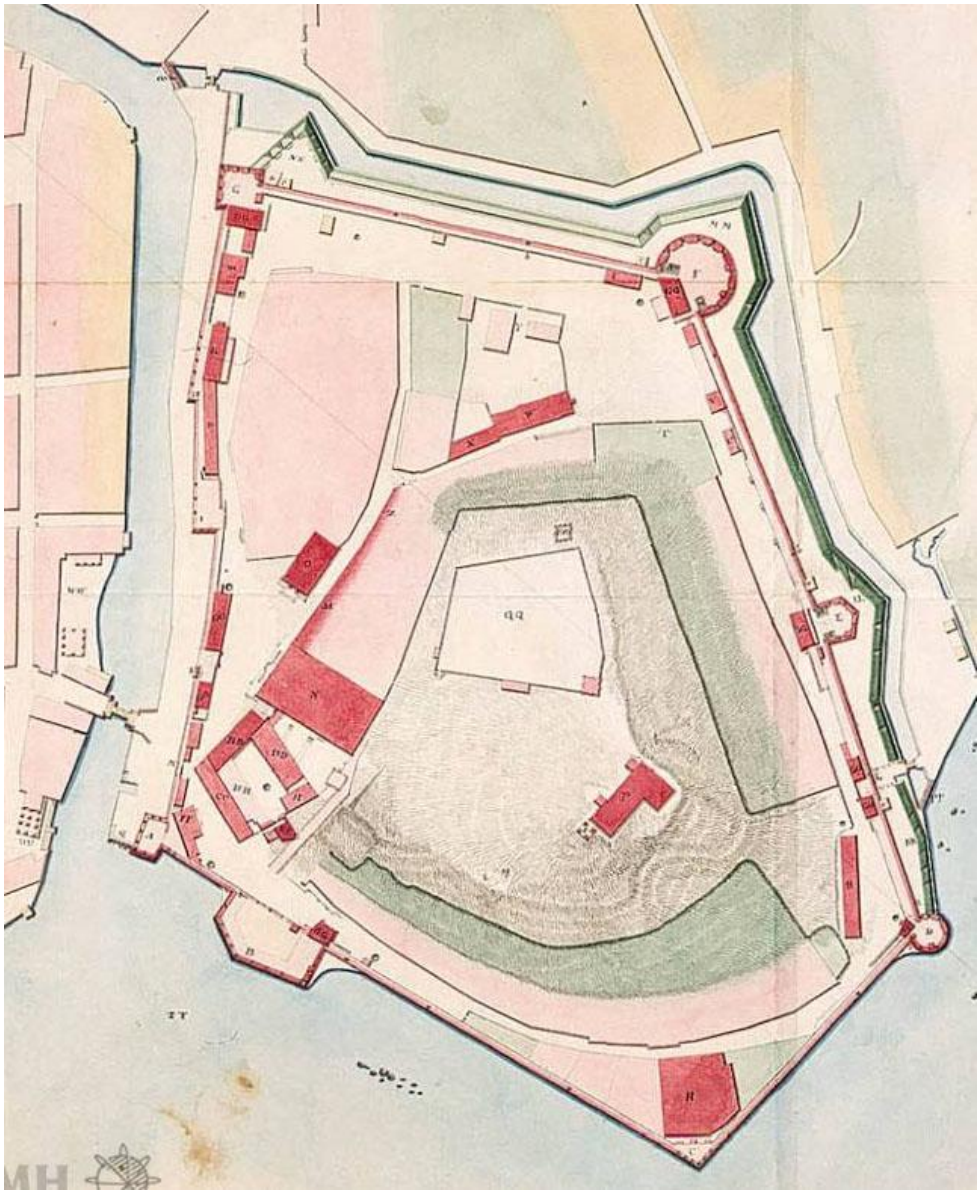


Figure 3.8 Map of the city and fortress at Malakka (Referred to the analysis as Plan 1) (Source: NA,2007)

3.2.2.1.2 Dutch map of Malacca town, 1824

The artist of this drawing is unknown. Figure 3.9 is extracted from the book by Malacca Centenary Committee written by W Langham Carter entitled "The Town and Fort of Malacca: A Guide Book Published to Commemorate the Centenary of the British Occupation of Malacca, 17th March, 1824".

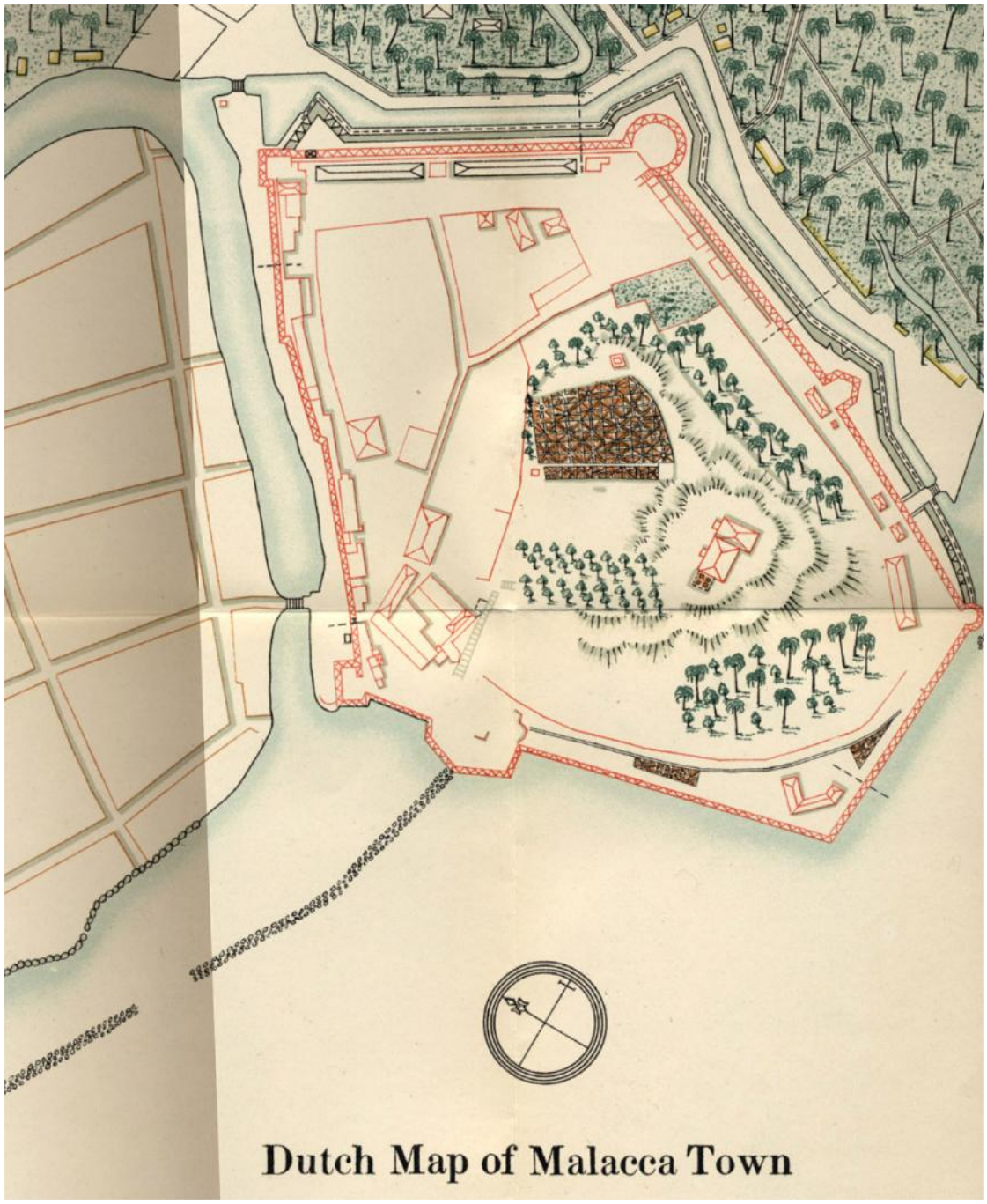


Figure 3.9 Dutch map of Malacca town (Referred to the analysis as Plan 2) (Source:MCC,1924)

3.2.2.1.3 Map of Malacca and environs, before AD 1800

This drawing (Figure 3.10) was drawn by Carl Friedrich Reimer and dated before AD 1800. Reimer was a German who was employed as an engineer in 1777 by the VOC, first in Ceylon (Sri Lanka) and later in Batavia. During his last years in Batavia he was appointed as the Director of fortifications (Biography extracted from Rijksmuseum Amsterdam).

Figure 3.10 Map of Malacca and environs (Referred to the analysis as Plan 3) (Source: NA,2007)

3.2.2.1.4 Malacca fort. ca. 1660

This drawing (Figure 3.11) dated 1858 was a clearer reproduction of Malacca Fort ca. 1660 image by P.A. Leupe. Irwin (1962) has analysed the original map and redrawn it to indicate two reduction plan proposals by Thyssen and Van Riebeeck. Leupe was a former major of the Marine Corps. This drawing was compiled by him and most of his collections can be found in the National Archives of Netherlands. After his retirement, he was appointed to a position in the *Rijksarchief* in 1863, and remained there until his death in 1881. He thus had access to original documents, and his work, which is highly regarded and frequently quoted by Dutch historians, is therefore of particular value (Mutch 1942).

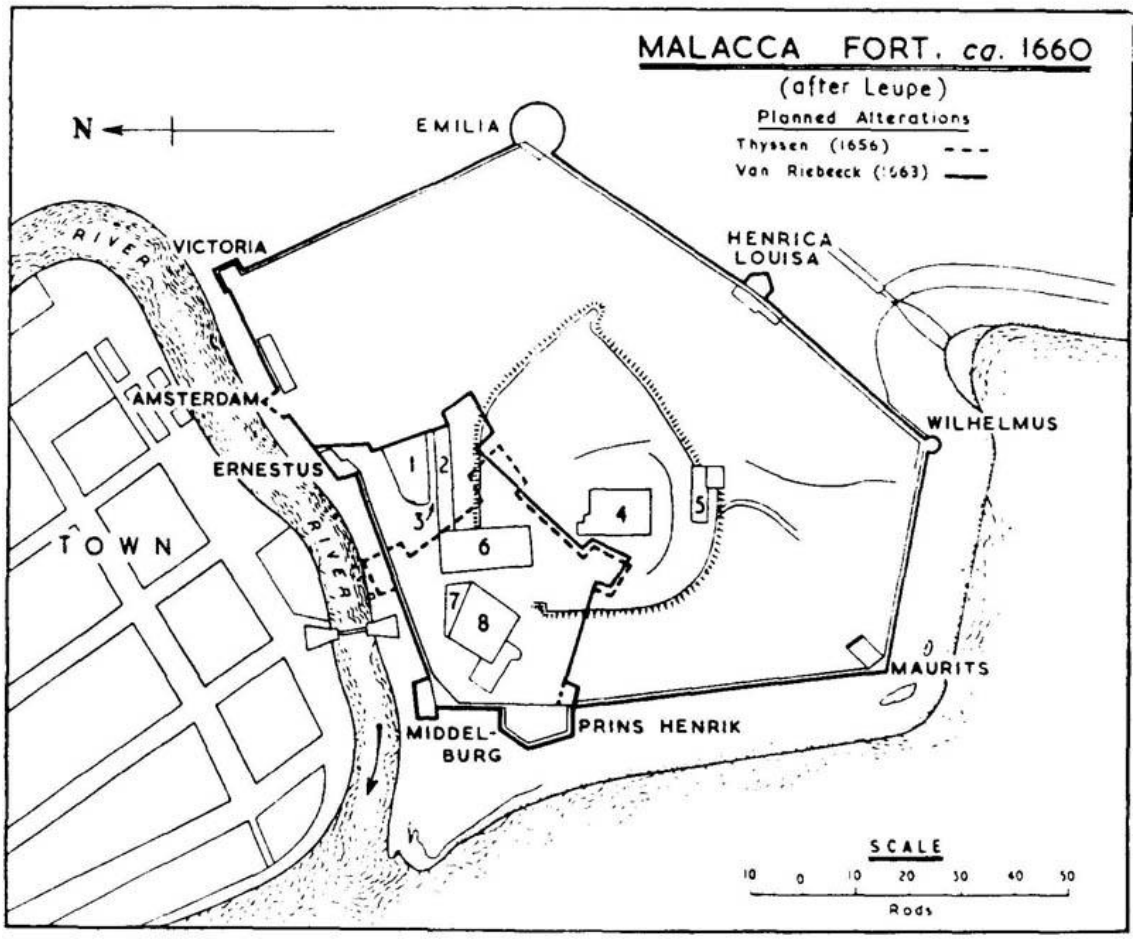


Figure 3.11 Malacca fort. *ca.* 1660 (Referred to the analysis as Plan 4) (Source: Irwin, 1962)

3.2.2.1.5 Map of Malaka, 1735 - 1744

Drawing in Figure 3.12 was drawn by Heydt Johann Wolfgang. He was a German who served VOC (Vereenigde Oost-Indische Compagnie or VOC in Dutch, literally "United East Indian Company"), between 1734 to 1737 in Ceylon (Bosma and Raben 2008). Early in 1737 he left Ceylon for Batavia where he was appointed as an architect and draughtsman to the company. Due to health problem he was permitted to resign in 1740. However, some of his works were still available after his retirement. His last job was as an architect and surveyor with by Grand-duchy of Hohenlohe-Schillingsfurst (De Silva and Beumer 1988).

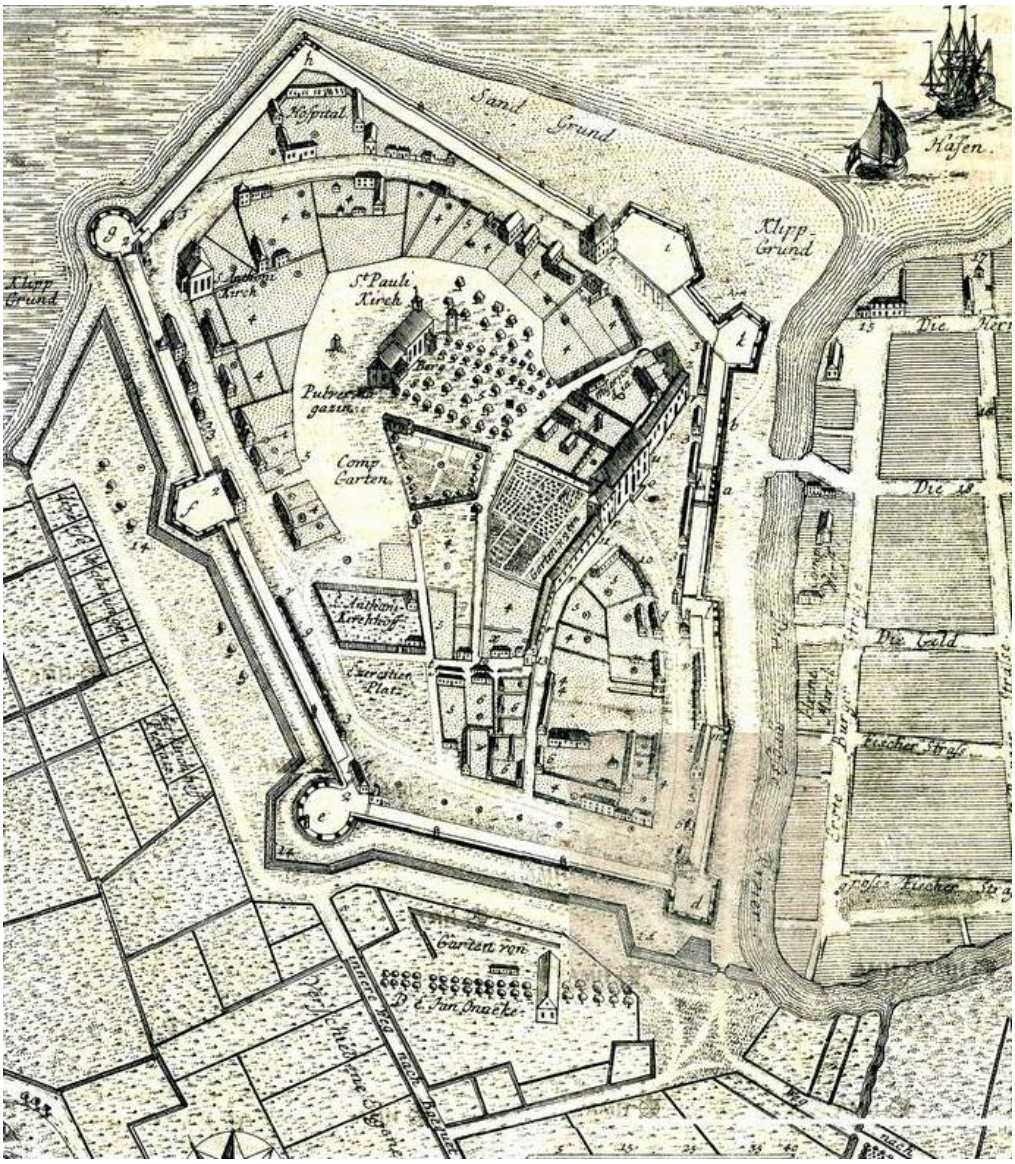


Figure 3.12 Map of Malaka, 1735 – 1744 (Referred to the analysis as Plan 5) (Source: NA,2007)

3.2.2.1.6 Melaka fortress

This plan (Figure 3.13) is produced by the Museum Department of Melaka based on two selected identical plans drawn during the Dutch period in Melaka. The original plan was drawn in 1744 in which the prominent buildings are shown. This map has been used by the department as an official main reference for visitor's information.

Figure 3.13 Melaka fortress (Referred to the analysis as Plan 6) (Source: Museum Department of Melaka)

3.2.2.1.7 Plan of Malacca fortress, ca. 1792

Figure 3.14 is a clearer reproduction of the map entitled "Hoofdplan van de Stad en t Kasteel Malacca," drawn by P. Elias from the information supplied by Engineer-Major C.F Reimer. Reimer is one of the lieutenant-colonels appointed in 1791 to make an examination of the company's fortification and military state (Irwin,1962). Irwin (1962) ascribed this Elias and Reimer's plan to ca. 1792 with complete indication of bastions' name, fortress elements and buildings inside the fortress.

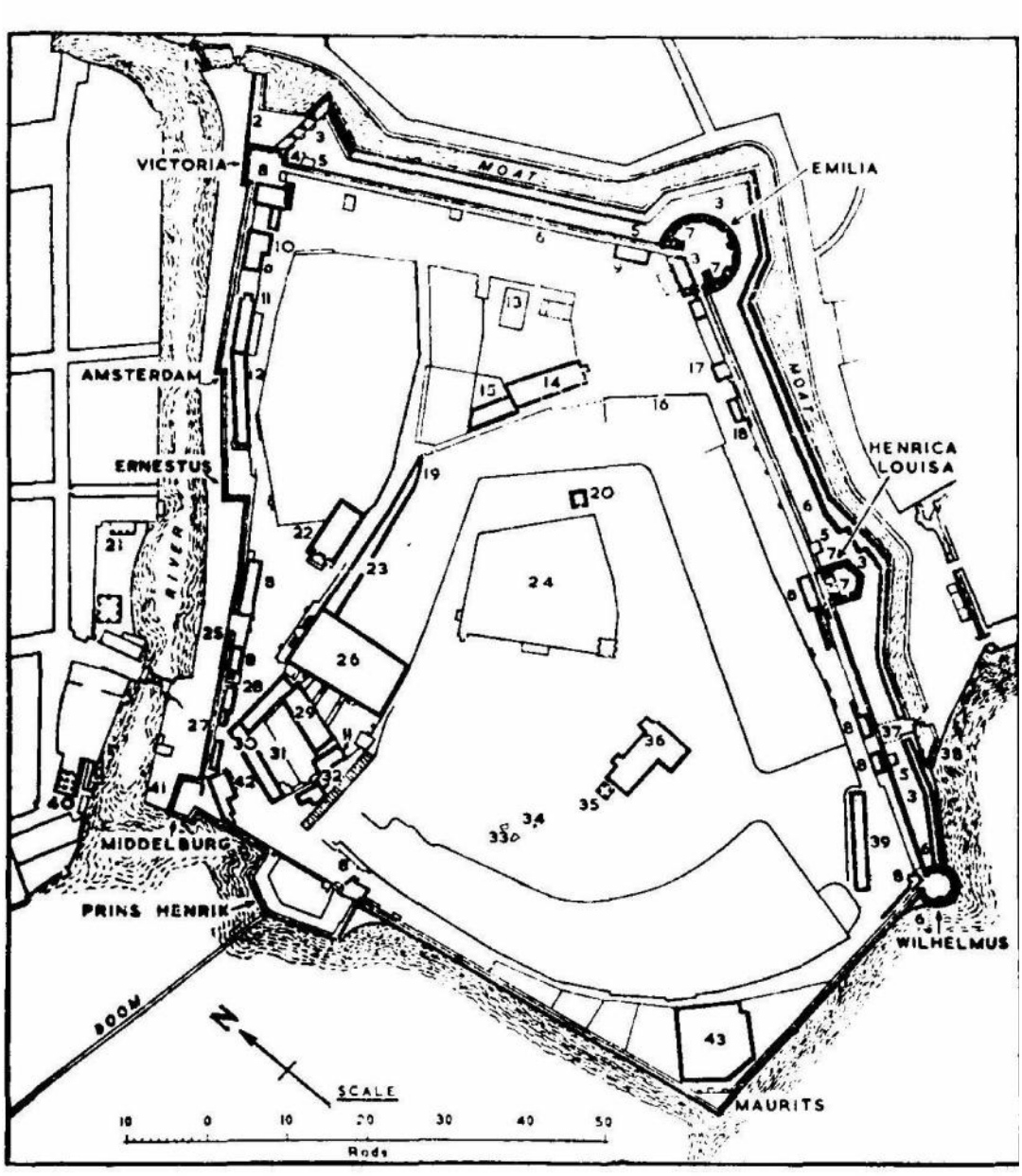


Figure 3.14 Plan of Malacca fortress, circa 1792 - after Reimer and Elias (Referred to the analysis as Plan 7) (Source: Irwin,1962)

3.2.2.1.8 Plan of Dutch fortress at Malacca (Undated)

This drawing in Figure 3.15 is taken from the book of *"A history of Malaya and her neighbours"* by Francis Joseph Moorhead. There is no date given in this drawing (Moorhead 1957).

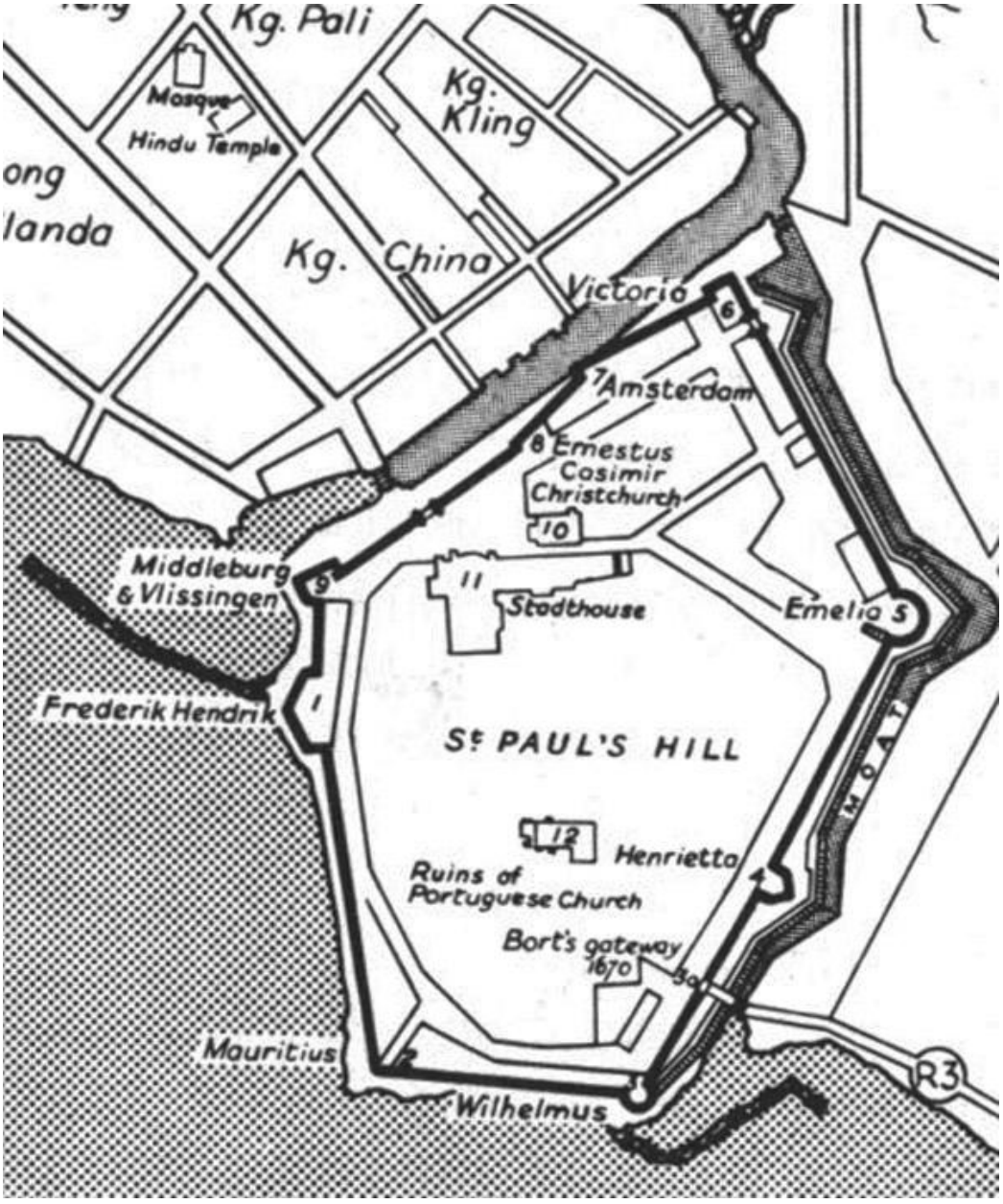


Figure 3.15 Plan of Dutch fortress at Malacca (Referred to the analysis as Plan 8) (Source: Moorhead, 1957)

3.2.2.1.9 Plan de la ville de Malacca, 1764

This drawing in Figure 3.16 dated in 1764 and belongs to Jacques Nicolas bellin (1707-1772). He was a French hydrographer and geographer (Petto 2007). He was a member of the Académie de Marine and of the Royal Society of London. He worked as a hydrographer of France's hydrographic office and throughout his service he had produced a large number of maps. He was listed by Robert de Vaugondy (leading mapmakers in France during the 1700s) as prominent, active and highly respected geographic practitioners (Godlewska 1999).

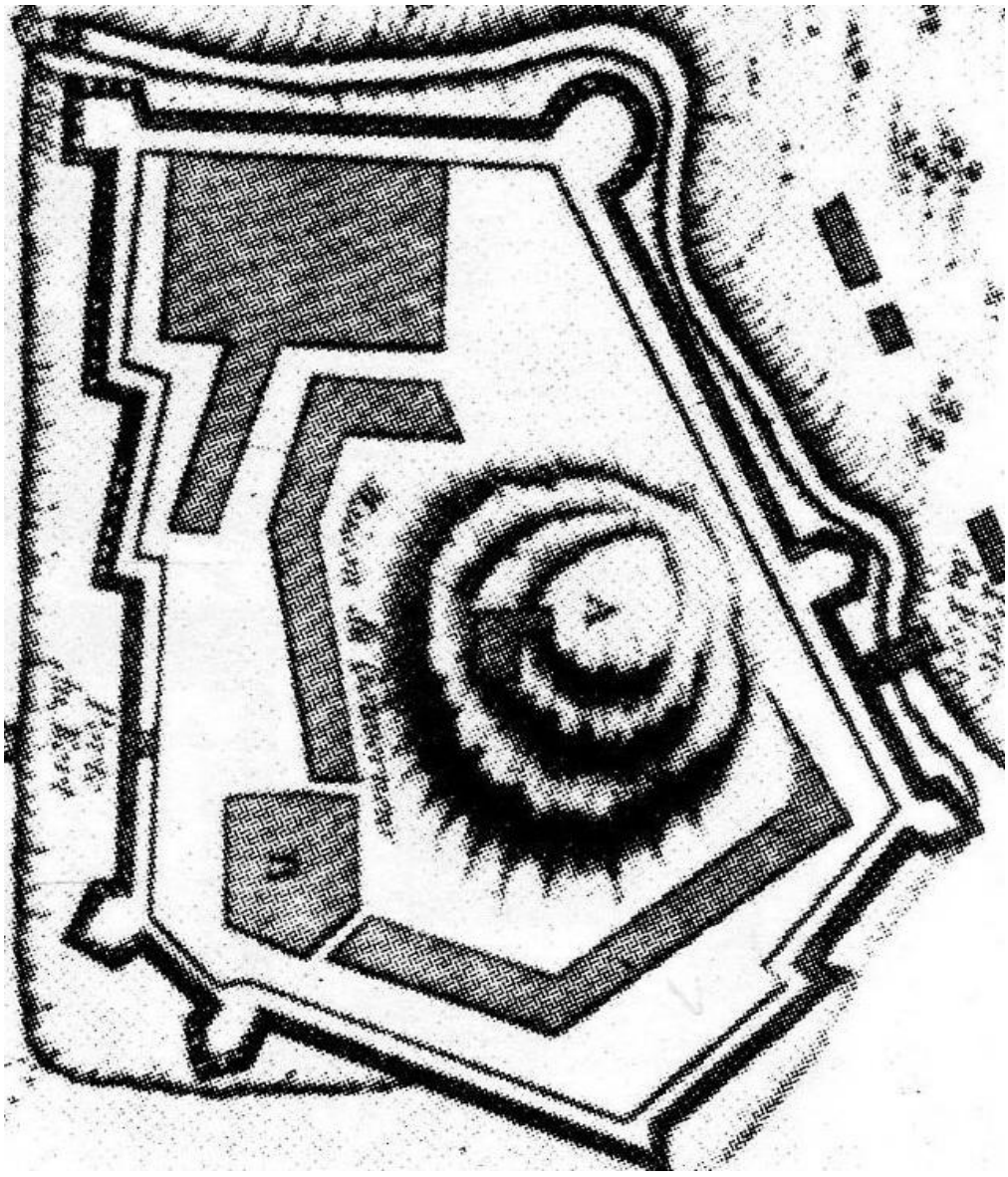


Figure 3.16 Plan de la ville de Malacca (Referred to the analysis as Plan 9) (Source: Pintando, 1990)

3.2.2.1.10 Malacca town: Showing position of old fortifications, 1936

Federated Malay States (FMS) Survey Department produced this map (Figure 3.17) in 1936. The main duty of FMS is to make maps in a theatre of war and as parts of Malaya and adjoining Siam were unmapped it was apparent that a Survey Company should be available in Malaya (I.C. Booth 1945).

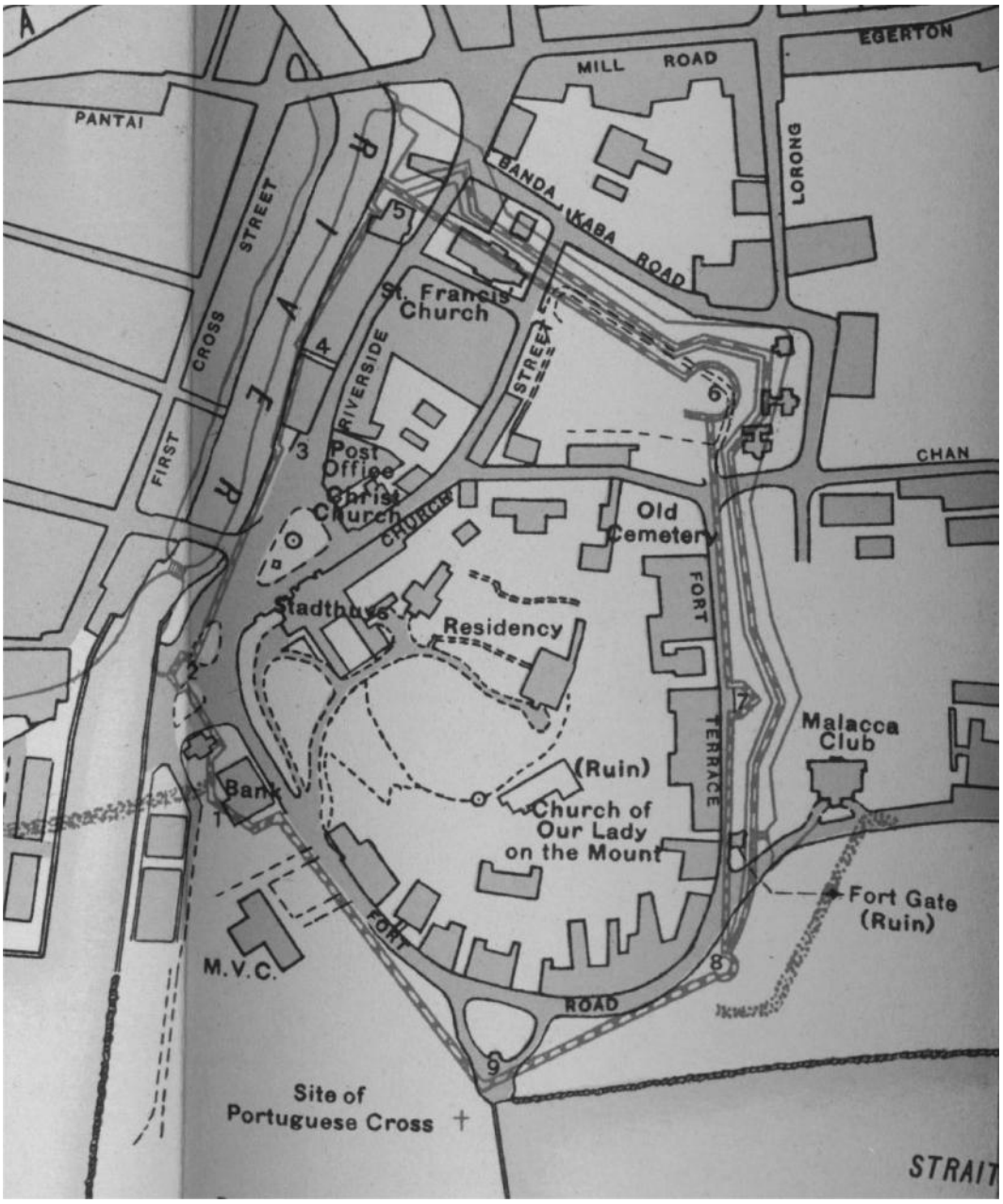


Figure 3.17 Malacca town: Showing position of old fortifications, 1936 (Referred to the analysis as Plan 10) (Source: Malacca Historical Society, 1936)

3.2.2.1.11 Map of the fort at Malakka, 1663

This drawing in Figure 3.18 dated in 1663 is kept in National Archive Netherlands. According to the National Archive, the artist for this drawing is unknown.

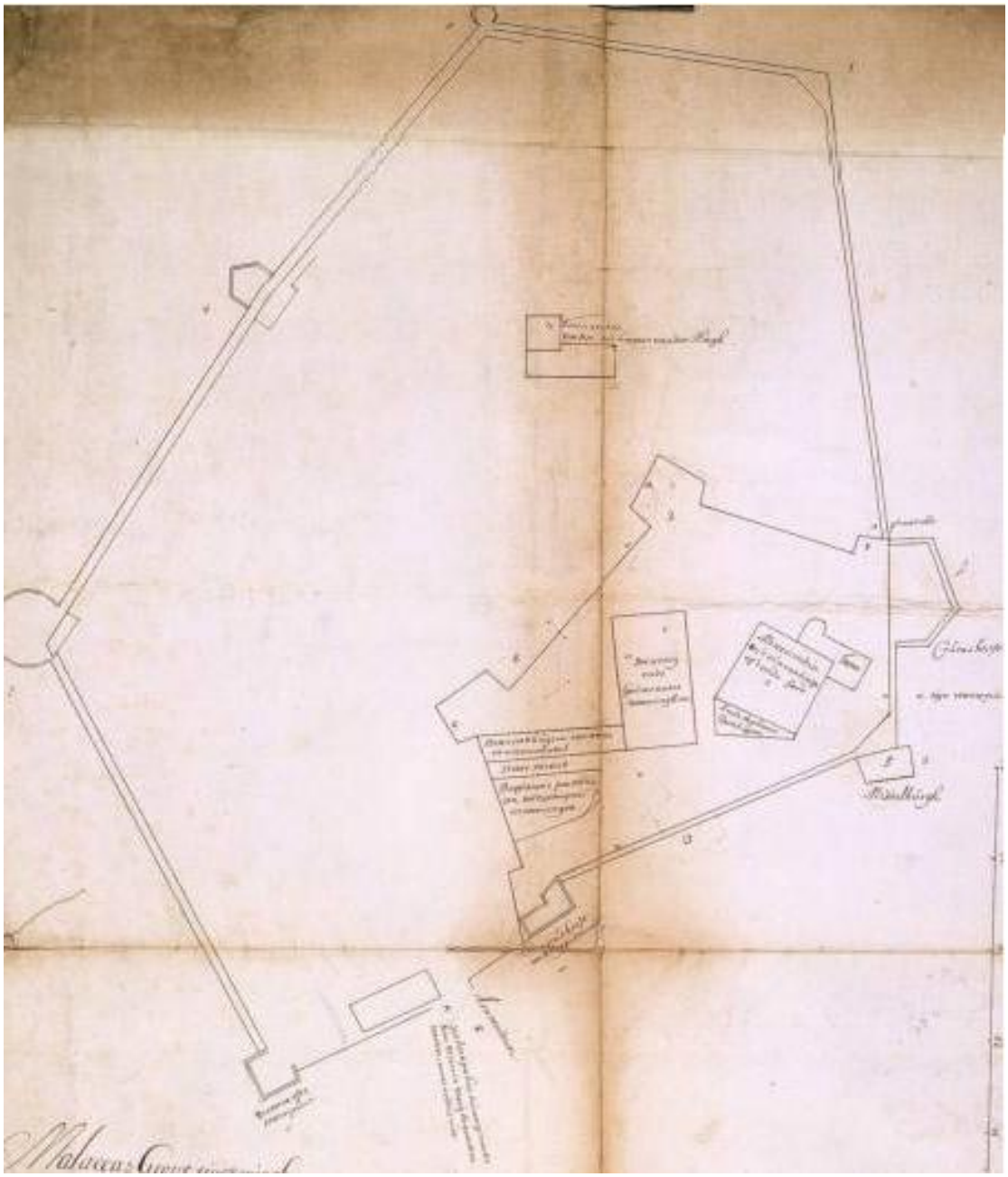


Figure 3.18 Map of the fort at Malakka, 1663 (Referred to the analysis as Plan 11) (Source: NA, 2007)

3.2.2.1.12 Map of the fortress at Malakka circa 1656

The drawing in Figure 3.19 dated circa 1656 is currently kept at the National Archive, Netherlands. Based on the descriptions given this drawing is partially restored, but the edges are frayed and torn. The drawing also exhibits moisture stains. It is recorded that the drawing was brought over from Batavia (Jakarta, Indonesia) (NA 2007).

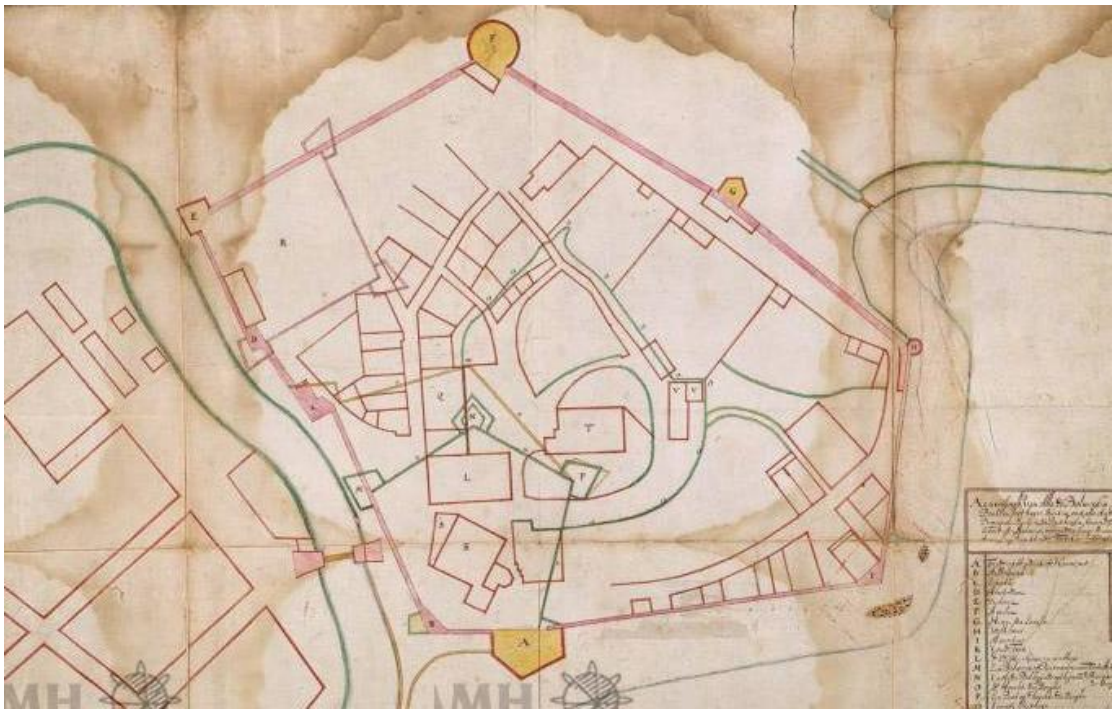
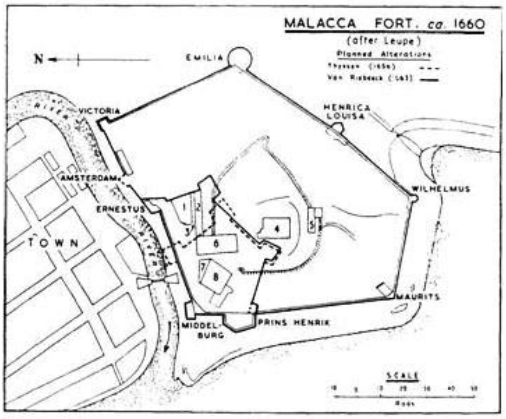


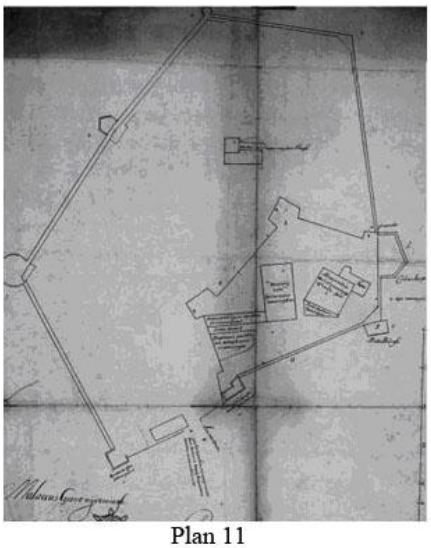
Figure 3.19 Map of the fortress at Malakka circa 1656 (Referred to the analysis as Plan 12) (Source: NA, 2007)

3.2.2.2 Pre-analysis of the selected plans

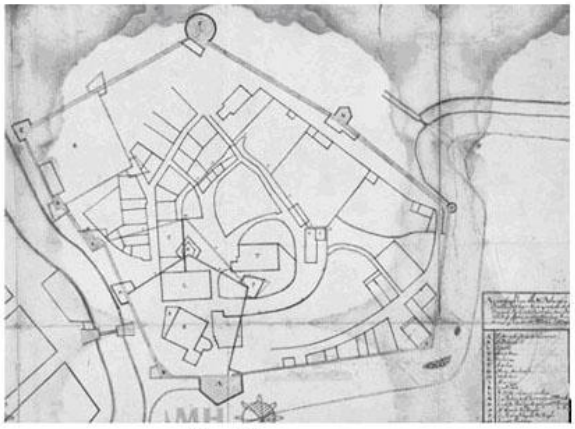
From the twelve selected plans of A Famosa, three of the plans have been identified as dated before Bort's administration (1678). They are the ones as described in Figure 3.11 (Plan 4), Figure 3.18 (Plan 11) and Figure 3.19 (Plan 12).



Plan 4



Plan 11



Plan 12

Figure 3.20 Three selected plans from Figure 3.11 (Plan 4), Figure 3.18 (Plan 11) and Figure 3.19 (Plan 12), before Bort's report 1678.

General observation from these plans shows that the base layout of A Famosa is basically same with the conjectural layout which has been built from the Bort's report. However when compared to other map which is within the Bort's era, it can be clearly seen that some elements which were said to be introduced during Bort's era were not present. These elements are such as moat from the river (Victoria bastion) to the seashore (Wilhelmus bastion), faussie braie and covered way. These elements are

further discussed in later section. According to (Irwin 1962) before Bort's administration (1665-1678) there has been a controversy about reducing the size of A Famosa to cut the maintenance cost. This proposed alteration of A Famosa can be seen in the maps above. However the reduction plan has been abandoned by Bort. Thus there has been no modification on the basic base of A Famosa before or during Bort's era. For this reason it is decided to include these three maps for comparison with the conjectural layout using procrustes analysis in the following section.

3.2.2.3 Data preparation for Procrustes Analysis

From each selected plans, the outermost shape of A Famosa has been extracted and 34 landmarks are identified on each shape. Figure 3.21 gives an example of the extracted outermost A Famosa shape of Figure 3.7 with the 34 identified landmarks. Figure 3.7 is the conjectural layout which has been verified in the previous sections. The landmarks on this figure acts as the reference landmark and the experimental landmark extracted from Plan 1 to 12 are mapped using Procrustes analysis.

To find the best fit that minimise the distance between reference landmark and experimental landmark.The procrustes analysis was run using FindGraph Procrustes analysis software which is available from http://www.uniphiz.com/procrustes-analysis.htm. Once the best fit is found, the average and standard deviation of the distance between reference landmarks and experimental landmarks are calculated.

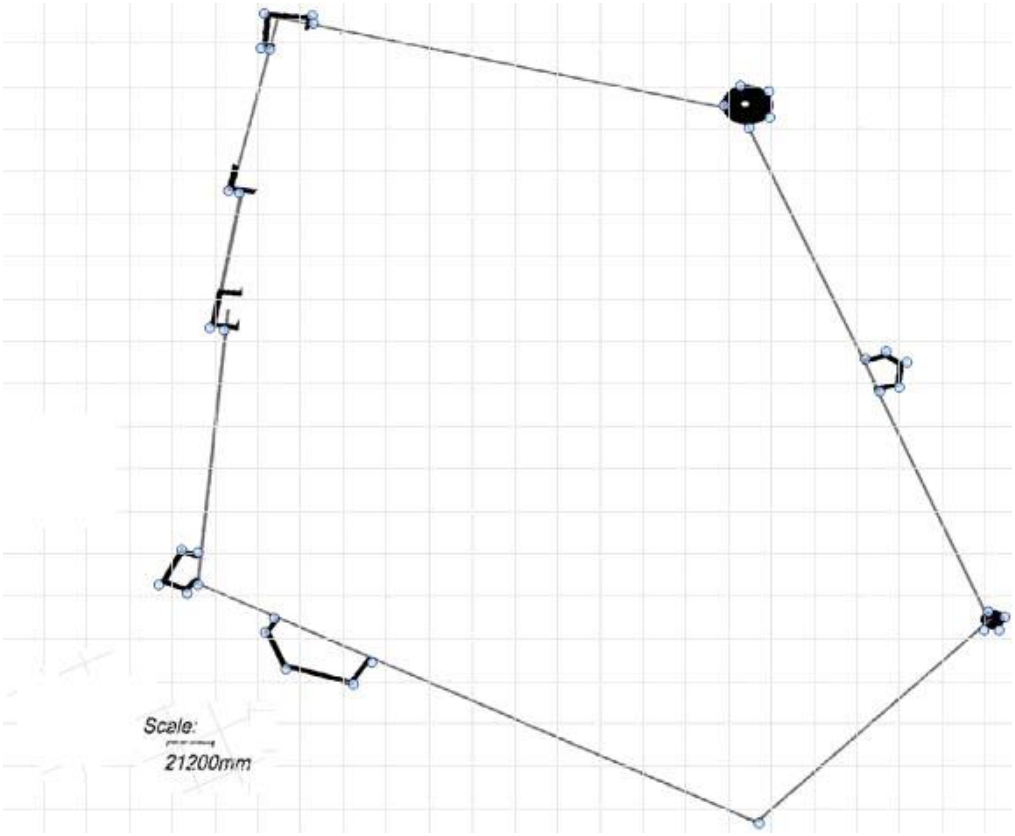


Figure 3.21 The reference landmark: Extracted outermost A Famosa shape of Figure 3.7 with 34 identified landmarks

3.2.2.4 Results and analysis

Figure 3.22 presents the average and standard deviations calculated on the distance between reference landmarks from the conjectural layout (Figure 3.7) to the experimental landmarks extracted from Plan 1 to 12 (Figure 3.8 to 3.19). Based on the result of Figure 3.21, it is shown that Plan 1 (Figure 3.8) and Plan 7 (Figure 3.14) have the minimum average and standard deviation for the distance with the conjectural layout, followed by Plan 3 (Figure 3.10) and Plan 6 (Figure 3.13). Thus it is decided to run further analysis on these 4 plans. Recall that the reference landmarks are based on the outermost shape of A Famosa from Figure 3.7. To further verify the consistency of these plans to the conjectural layout, the innermost shape of A Famosa from Figure 3.7 has been projected into Plan 1 (Figure 3.8), Plan 3 (Figure 3.10), Plan 6 (Figure 3.13) and Plan 7 (Figure 3.14). Table 3.8 presents the result of this projection.

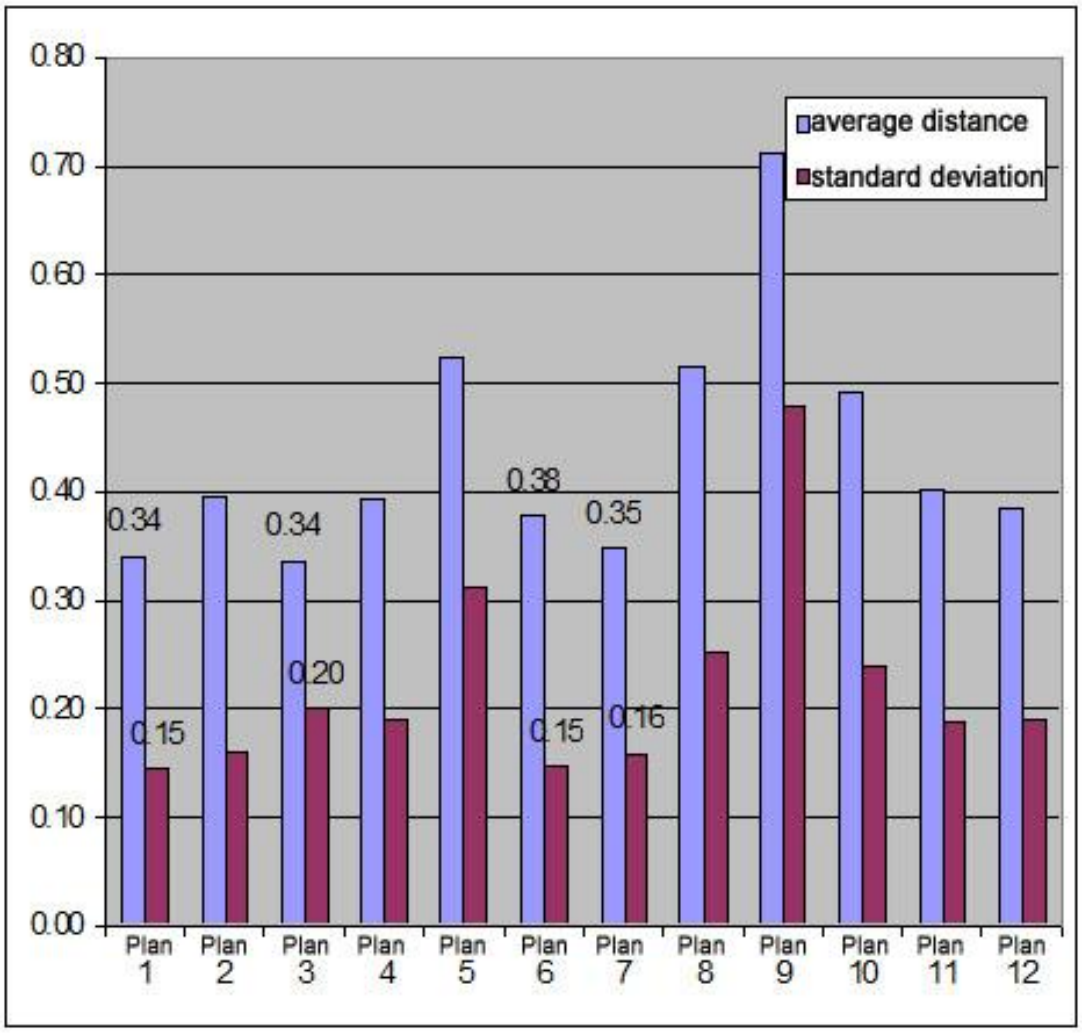
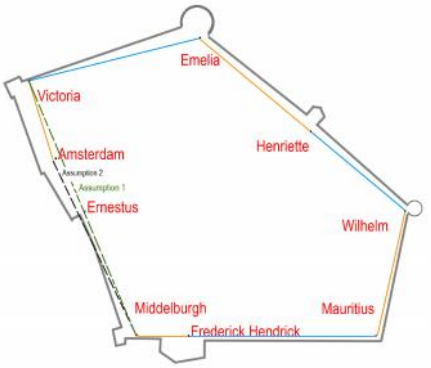
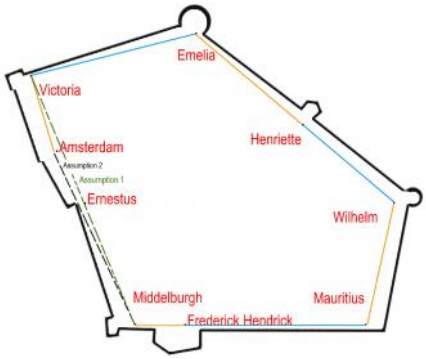
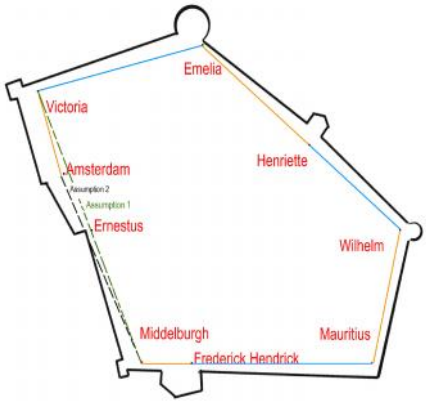
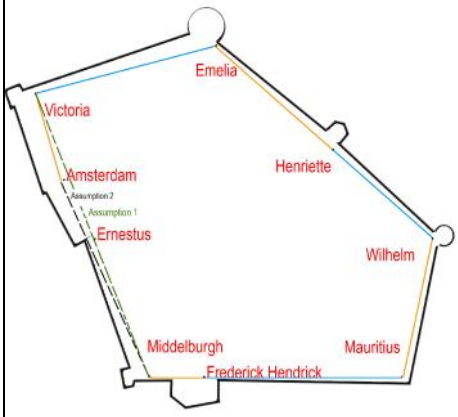


Figure 3.22 Average and standard deviation of the distance between reference landmarks from the conjectural layout (Figure 3.7) to the experimental landmarks extracted from Plan 1 to 12 (Figure 3.8 to 3.19)

From the result in Table 3.9, it is identified that there are 3 innermost polygon angles which clearly indicate some inconsistencies with the outermost line. These angles are identified as angles involving the bastions of Middleburgh, Victoria and Emelia. The reason for these variations might be due to the fact that there has been some modification done during the Dutch era compared to the original during the Portuguese era. In Bort's report (Bort, Bremner et al. 1927), he reported that some modifications were done on the fortress during his time such as the bastion of Victoria was extended to 1/3 of its original size and the addition of Middleburgh bastion, which does not exist during the Portuguese era. Even though there is no modification made to the bastion of Emilia, but since it is linked to the bastion of Victoria, thus

some variation might be observed. Plan 3 and Plan 6 shows further inconsistencies in the angle for Mauritius and Wilhelmus, thus it is decided to discard these maps and use Plan 1 and Plan 7 as the most reliable visual representation of A Famosa.

Table 3.9 Projection of innermost polygon onto Plan 1, 3, 6 and 7

Plan no.	Projected plan	Plan no.	Projected plan
1		6	
3		7	

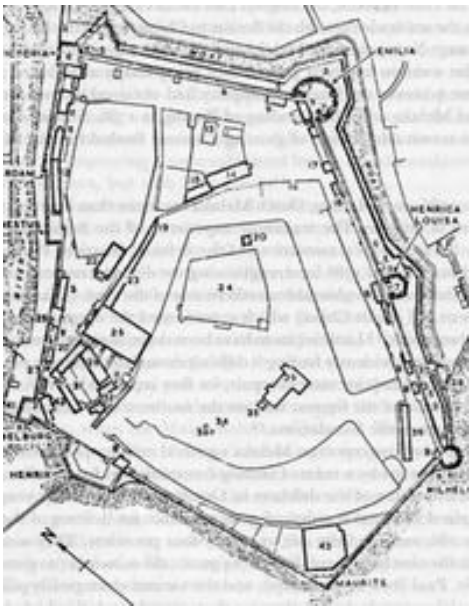
Based on the result from procrustes analysis, it is decided to use Plan 1 and Plan 7 as the main visual reference in the attempt to model this fortress in 3D. Plan 1 and 7 is renamed to Plan A and Plan B accordingly in future reference as shown in Figure 3.22.

The plans in Figure 3.23 are considered the most accurate representation of the A Famosa as reported in the Bort's report based on the findings. However it should be understood that all other collected plans are not necessarily wrong. This is because as stated before that the A Famosa has gone through several changes in its architectural development mostly due to war and the current economic situation. For example after

a war some part of the fortress might need to be repaired or reconstructed. Depending on the severity of the damage and the current economic situation of the occupier, the reconstructions might involve some modification in shapes and materials.

Thus it is assumed that all other collected drawings might be an accurate representation of the A Famosa at the particular period which is not during Bort's administration. It is decided to reconstruct the A Famosa based on Bort's description because it was during his time that A Famosa fortress assumed its final form and this was the structure captured by the British in 1795 (Irwin 1962).

Plan A
Title: Map of the city and fortress at Malakka, 1780 (Source: National Archive, 2008)



Plan B
Title: Plan of Malacca fortress, ca. 1792, (after Reimer and Elias)
(Source: Irwin,1962)

Figure 3.23 Selected plans for visual reference (Source: National Archive, 2008 and Harrison,1986)

To further verify the consistency and reliability of the finding, the conjectural layout in Figure 3.7, Plan A and Plan B have been projected to the current Melaka map taken from Google Earth. On the map, few spots such as Middleburgh bastion and Wilhelmus bastion, discovered from the excavation, St. Paul church, Stadhuys building and the gate of Santiago has been marked. The result is shown on Figure

3.24. From the observation it can be seen that Figure 3.7 gives the most accurate matching with the identified spot. This shows that measurement from Figure 3.7 is the most consistent with the physical evidence.

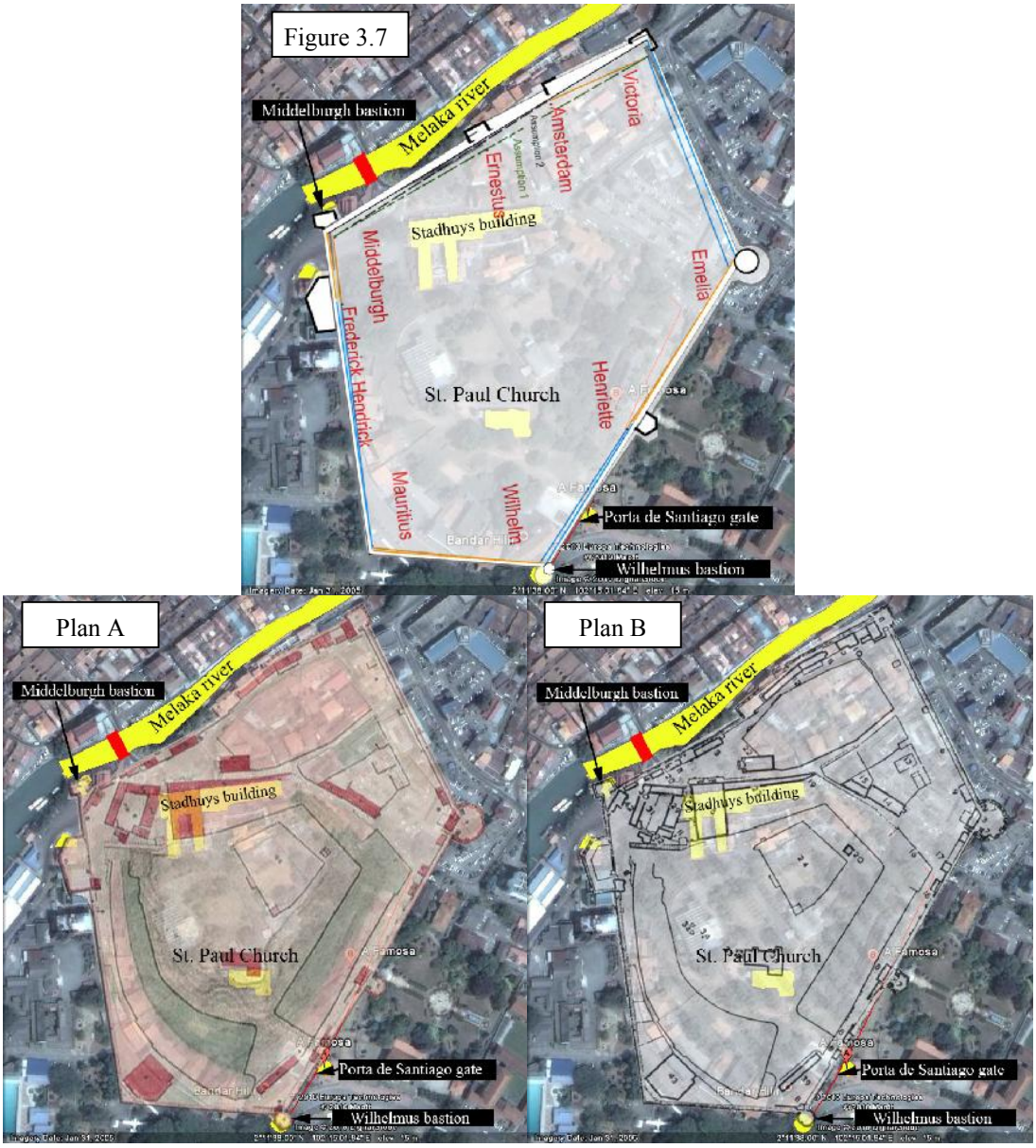


Figure 3.24 Overlay of Figure 3.7, Plan A and Plan B onto Melaka map from Google Earth (Source: Author)

Visual information is very helpful in providing the information which is not given in the textual report such as the bastion actual shape, the fortress layout and other details. However, the visual data, might not give the most accurate information in terms of measurement (Goldthwaite 1980; Lefe`vre 2004). Thus in the next step, it is intended

to compare point to point measurement of the visual data (Figure 3.5, Plan A and Plan B) to the textual data (Bort's report and and Eredia's description).

3.2.3 Comparison of measurement from textual and visual data

3.2.3.1 Comparison of measurement from visual data (Plan A, Plan B and Figure 3.7) to textual data (Bort's report and and Eredia's description)

This step is important to verify the size of the bastions so that it is consistent with the measurement from textual data. One problem for this task is to determine the start and end point for the measurement. The reason for this is because it is not known where is the start and end point for the measurement given by the textual data. Thus to reduce the error resulted from different start and end points, an approach on trial and error measurement has been carried out with several combination of start and end point. Based on the findings, it is come out with the points given Figure 3.25.

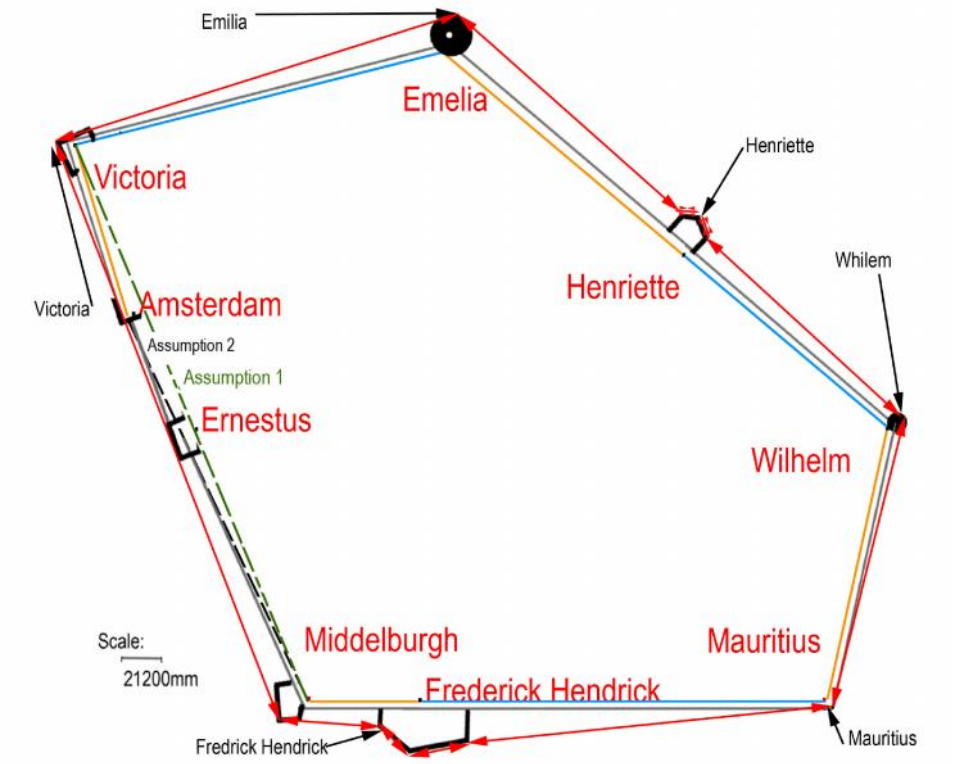


Figure 3.25 Rough point to point measurement (Source: Author)

Another attempt to reduce this problem is to reduce the number of measurement points. This is done by grouping the fortress into 2 groups. Group 1 consists of the part of the fortress which has been modified during the Dutch occupation. This group

consists of the measurement from Frederick Hendrick to the bastion of Emelia. The circumference for this group is denoted as L1. Group 2 consists of the part of the fortress which has not been modified during the Dutch occupation and it consists of the measurement from Emelia to the bastion of Frederick Hendrick. The circumference for this group is denoted as L2.

Two readings are made from each measurement which are:

1. Detailed point to point measurement connecting each landmark in Figure 3.10 (considering every curve and corner)
2. Rough point to point measurement connecting each point as shown in the outermost line in Figure 3.25.

The reason for taking the rough measurement is based on the assumption that measuring device at that time is limited and detail measurement might not be available. This assumption is further supported by the fact that both Bort's report and and Eredia's description does not describe in detail the size of each bastion.

3.2.3.1.1 Results and Analysis

Figure 3.26 presents the comparison of point to point measurement of textual and visual data. Even though it can be seen that the value shows some variation for different sources, in general it can be seen that the variation for Group 2 is small compared to Group 1. This general observation is consistent with the fact that Group 1 consists of the part of the fortress which has been modified during the Dutch occupation and Group 2 consists of the part of the fortress which has not been modified during the Dutch occupation. Analysis of the result of Group 1 shows consistency with the previous finding which are:

1. Eredia's descriptions give the smallest value because other sources are representing the Dutch era, where the fortress has been extended.

2. Measurement given in Bort's report should be bigger because measurement from Plan A and Plan B are bigger and closer to Figure 3.7.

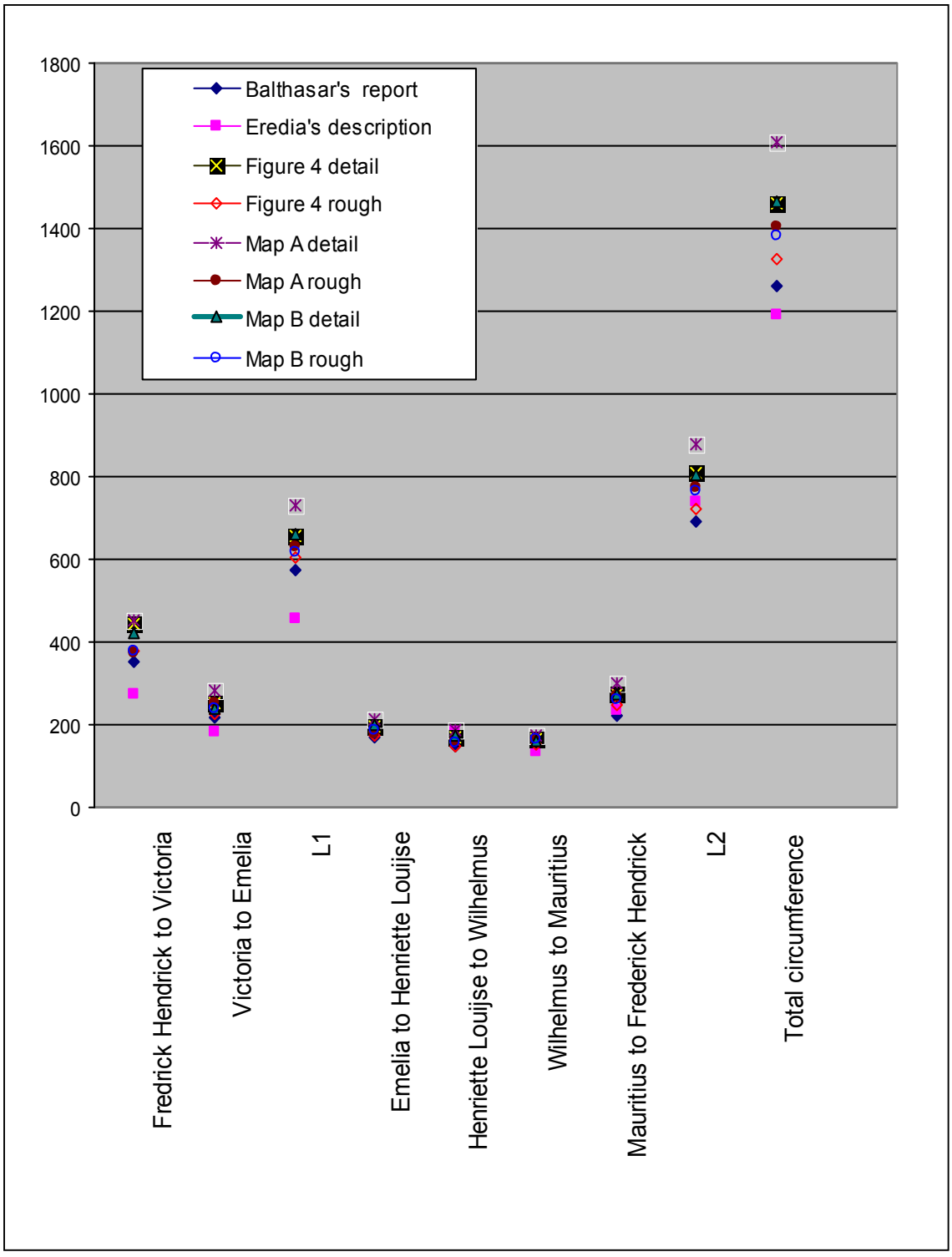


Figure 3.26 Comparison of point to point measurement of different sources (Source: Author)

Another finding shows that the rough measurement of visual data is closer to the value reported in Bort's report compared to detail measurement. One explanation for

this might be referred to (Lefe`vre 2004) which has been discussed in the previous chapter. According to Lefe`vre ,fortifications plans are littered with the numbers and calculations, from the preparatory to the final drawings and in no way resemble the orthographical plans and schematics that engineers trace and employ today.

3.2.3.2 Projection of point to point measurement from Bort's report to Plan A and Plan B)

This step is taken to understand some of the inconsistencies in the measurement reported in Bort's report and support the assumptions that have been made in building our conjectural layout. In this section, firstly each point to point measurement for innermost polygon stated in Table 3.2 is projected to Plan A and Plan B. Then, the angle for each bastion is calculated, followed by the projection of measurement for the outermost line.

3.2.3.2.1 Result and analysis

The result of the projection is shown in Figure 3.27 and Figure 3.28. Observation on the figures has given some interesting findings which explained the inconsistencies highlighted in Figure 3.4:

1) According to the report, the angle for Middleburgh bastion is 133^0.However, based on calculation, the angle should be 113.2^0 (Assumption 1) or 115.5^0 (Assumption 2). Based on the projection, it is found that the angle 133^0 is actually the angle between the wall connecting Fredrik Hendrik bastion to the building situated at the corner of Middleburgh bastion (refer Figure 2.7 and Figure 2.8). The angle connecting the two walls at Middleburgh bastion is calculated to be 113^0 which is very close to the calculated value based on Assumption 1.

2) According to the report, Amsterdam bastion and Ernestus bastion are laid together on a straight line. However, Figure 2.7 and 2.8 shows that this is not accurate because there is a slight bend at the angle of around 165^0 and 170^0 at each bastion respectively. This finding is close to the calculation in based on Assumption 2.

3) In general, the point to point measurement for inner polygon in Bort report stated in Table 3.2 is slightly smaller compared to the measurement in Plan A and Plan B. This is shown as gap in the inner wall in Figure 2.7 and 2.8.

4) As for the angle, other than those discussed in 1) and 2) above, angle for Victoria, Wilhelmus and Mauritius are consistent with Bort's Report stated in Table 3.3. However, the angle for Emelia is found to be slightly smaller. One explanation might be because the point to point measurement from Henriette Louise bastion to Emilia Bastion is longer on both plans compared to in Table 3.2.

5) In general, the point to point measurement in Bort's report stated in Table 3.2 for outermost line is shorter than the actual measurements on Plan A and Plan B. The projection suggest that the measurement might just be rough which supports the findings in the previous section (3.2.3.1.1)

As described in previous chapter, most of the early drawings do not actually represent the plan (Goldthwaite 1980). The drawings had limited utility as practical guides, lacking technical specifications such as scale and jointing stones. From here, it is decided that the textual descriptions might be more accurate in terms of measurement compared to the visual descriptions, thus it will be used as the main reference. This is because as explained previously, drawing technology during that time is limited and merely dependent on the skills of the artists. However the finding from this comparison has verified the conjectural layout that has been produced in Figure 3.7.

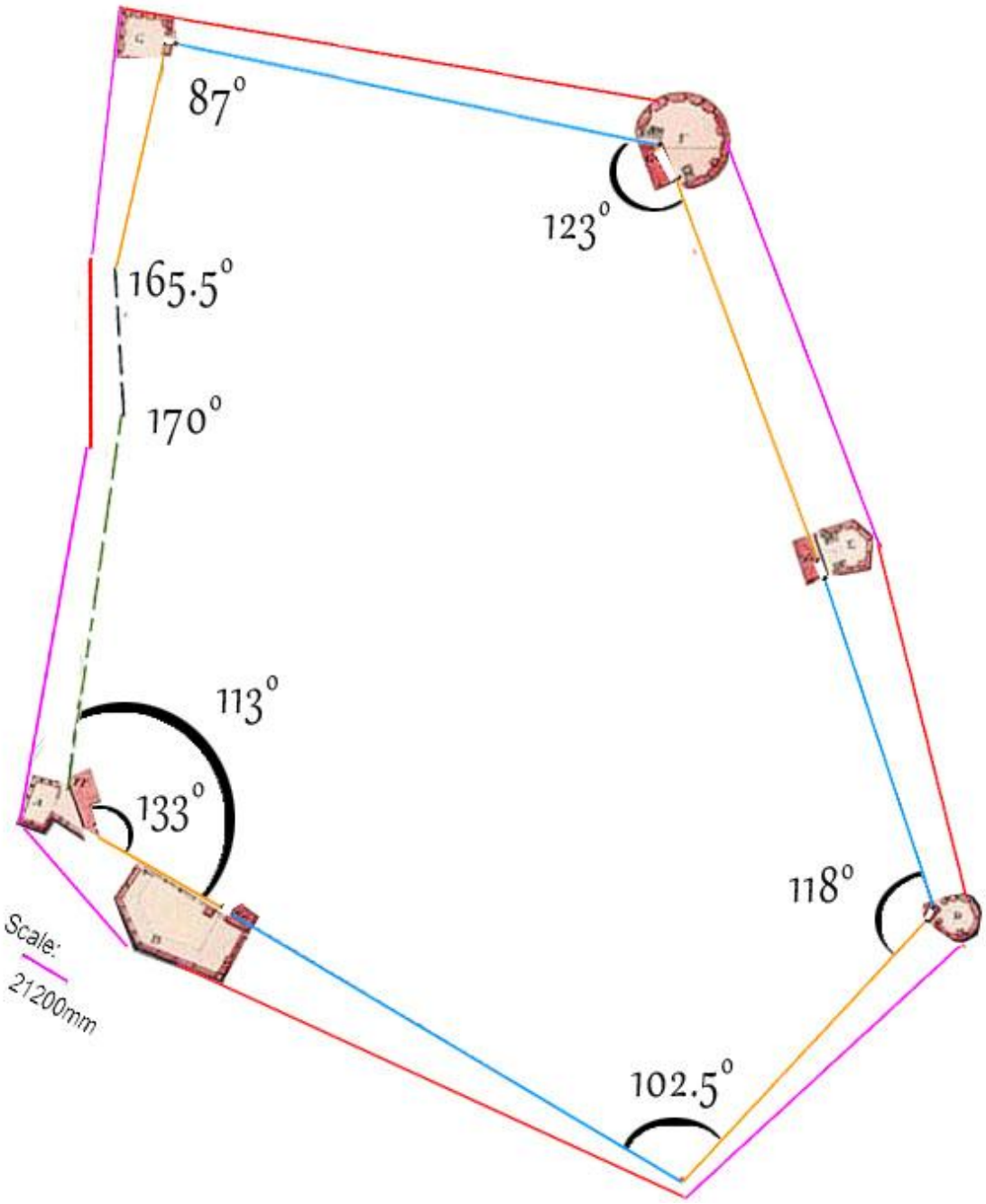


Figure 3.27 Projection of measurement in Table 3.2 to Plan A

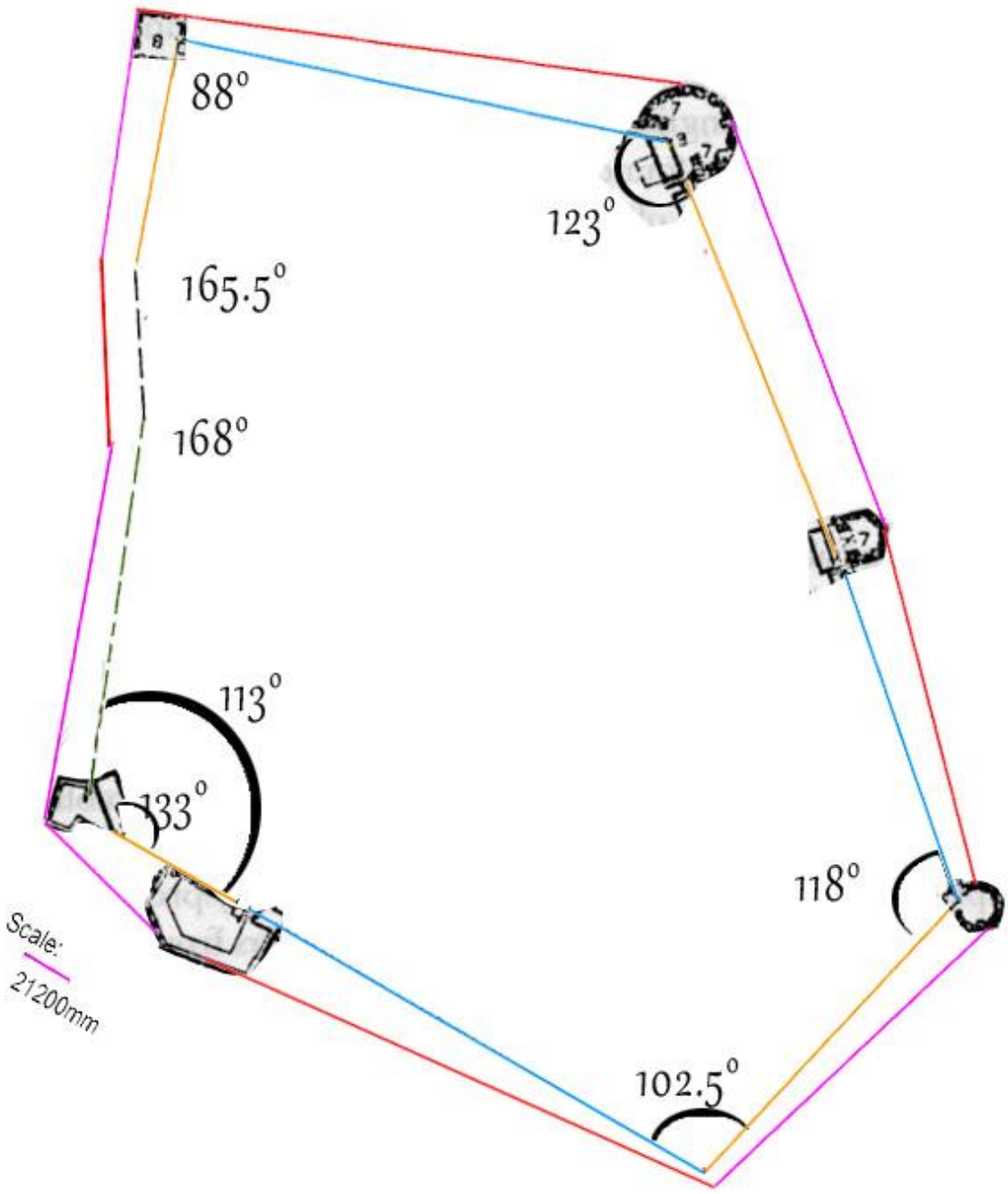


Figure 3.28 Projection of measurement in Table 3.2 to Plan B

3.2.4 Determination of fortress element

Up to this stage, a verifiable conjectural layout of the A Famosa fortress wall has been determined. In order to complete the visualization in 3D model, the elements attached to the wall such as gate, passageway, parapet and bastion need to be included and verified too. The selected plans include some information of the elements on the wall.

To verify these elements, an attempt is made to match the information with those mentioned in Bort's report.

3.2.4.1 Result and analysis

In general, most of the elements mentioned in Bort's report are also mentioned in the plan. However, since the plan is drawn in 2D and mostly presenting the top view, thus not all elements can be included in the plan, such as casemates, height, door and so onrf where some elevation is needed to view these elements. Another important finding from this stage is the location of some elements such as watch tower, stone gates, fausse porte and stone sluice since in Bort's report, he only mentioned a brief estimation of these elements' location.

There are also some elements which were not mentioned in the report but present in the plan such as fausse braie from bastion of Emilia to Wilhelmus, turret, crenel and so on. For these elements, reference to the collected drawings and plans were made and the decision whether to include these elements in the model are made based on the observations and consistency of these elements.

The next figures present the extracted elements available in Bort's report. These elements are discussed in the next descriptions and highlighted in each figure.

3.2.4.1.1 Passageway between bastion Emelia and Victoria

Governor Bort made a passageway (Figure 3.29) between these two bastions along the breastwork. The passageway was built between bastion Emelia and Victoria by reducing the breastwork thickness and its size is 3 feet (Bort, Bremner et al. 1927).

Remark: The passageway is highlighted in the plan.

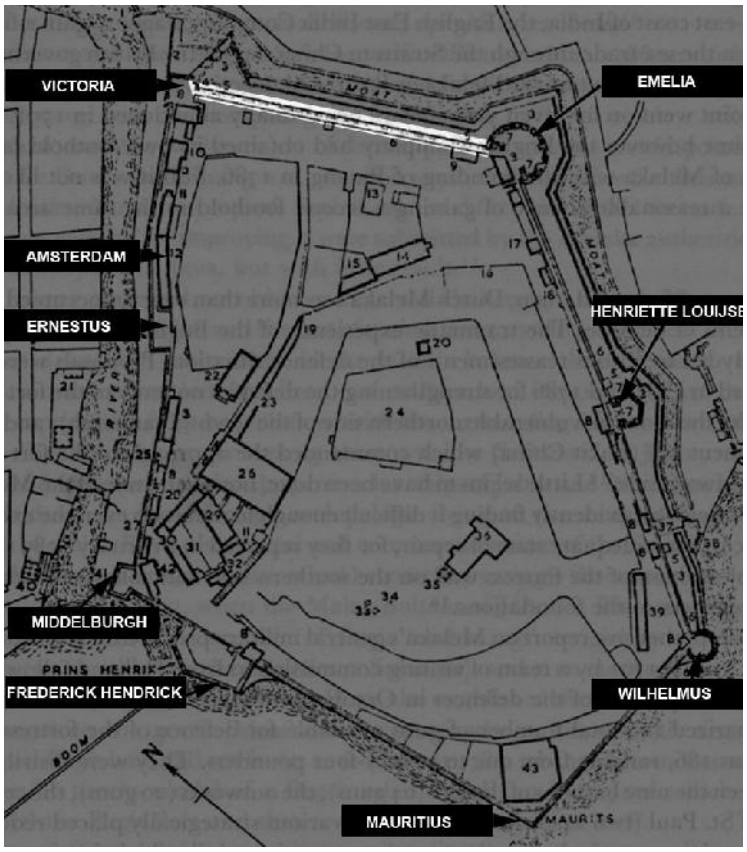


Figure 3.29 Passageway between bastion Emelia and bastion Victoria (Source: Harrison, 1986)

3.2.4.1.2 Passageway from bastion Emelia to Wilhelmus

From bastion Emelia to Wilhelmus, there was a passageway built above on the walls at the side of breastwork. Figure 3.30 highlights this passageway. Bort et al., (1927) explains, "*The fort has also a passage-way above on the walls at the side of the breastwork; it is very broad from the bastion Emelia to Wilhelmus, but thence it gets narrower.*"

Remark: The plan does not clearly show the reduction of passageway thickness towards Wilhelmus.

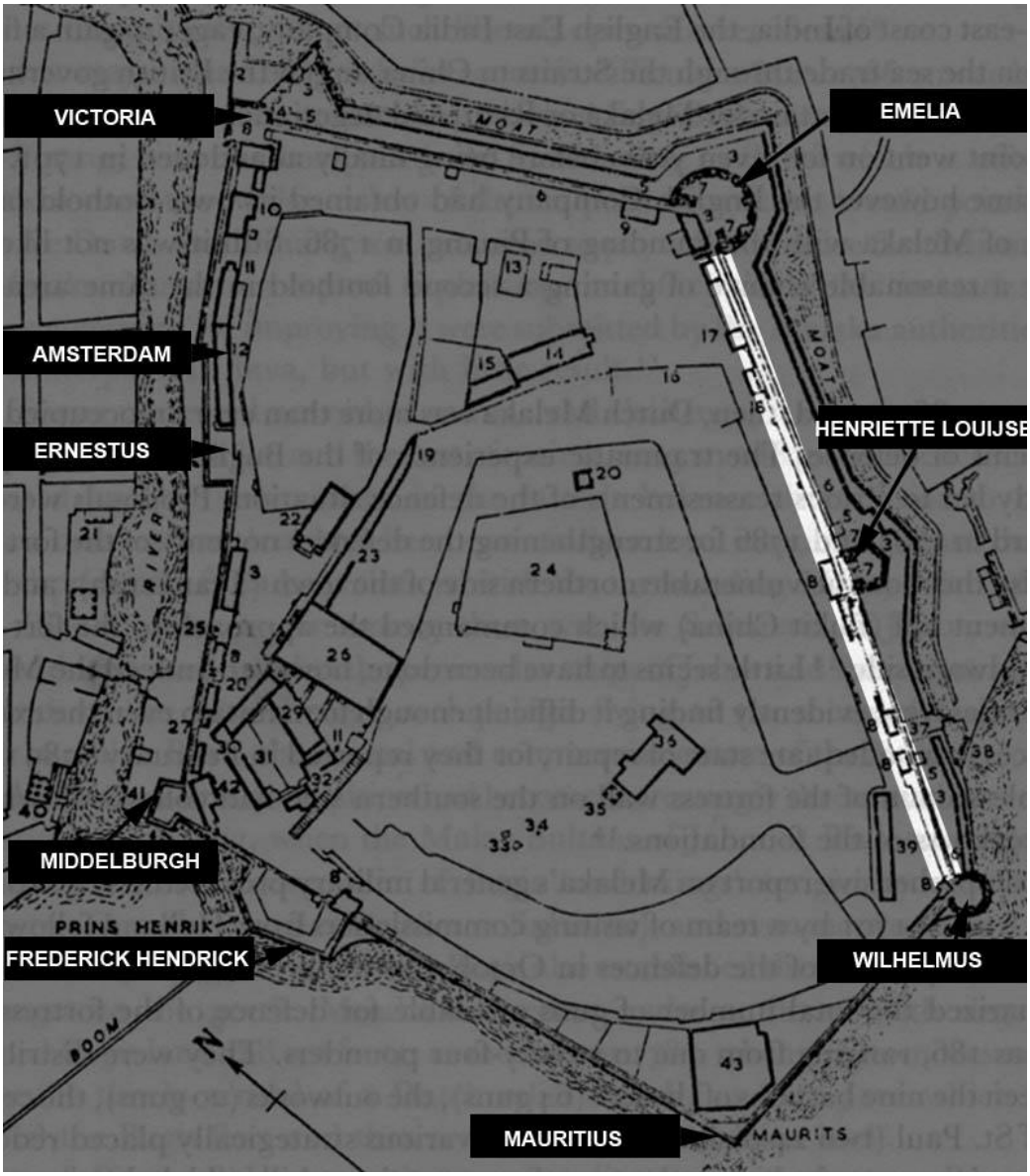


Figure 3.30 Passageway from bastion Emelia to Wilhelmus (Source: Harrison, 1986)

3.2.4.1.3 Watchtower

Governor Bort has rebuilt some of the watchtowers by using stone which previously made of wood. The watchtowers are located next to the stone gates as shown in Figure 3.31 Bort et al., (1927) explains, *"Some wooden watchtowers were also rebuilt in my time in stone, and some guardhouses which were formerly roofed with 'atap' (coconut leaves) I had tiled."*

Remarks: The location of the watch towers was not mentioned in the report. Thus the location shown on the plan was adopted.

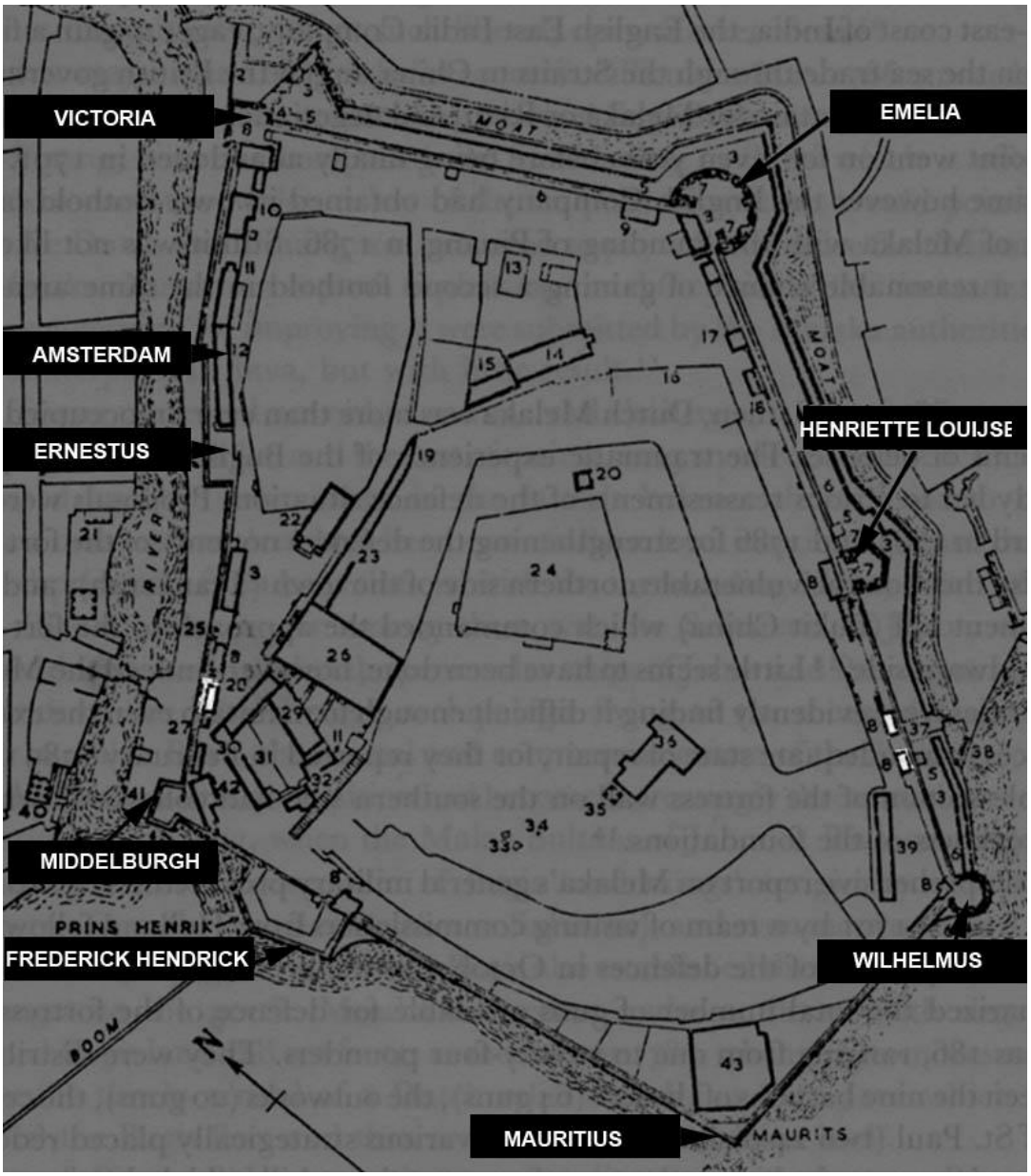


Figure 3.31 Watchtowers (Source: Harrison, 1986)

3.2.4.1.4 Stone gates

In 1669, two stone gates were remade in between bastion Ernestus and Middelburg, another one was between bastion Wilhelmus and Henriette Louijse. Both gates as shown in Figure 3.32 have curvature and double doors with wicket. The previous gates were old and in bad condition. On both side of the gates Bort built two stairs come down from the upper wall. There are also two stone guard houses on both sides.

Remarks: One of the gates referred here is the St Paul gate which is still available.

Both gates were present in the plan at the location consistence with the report.

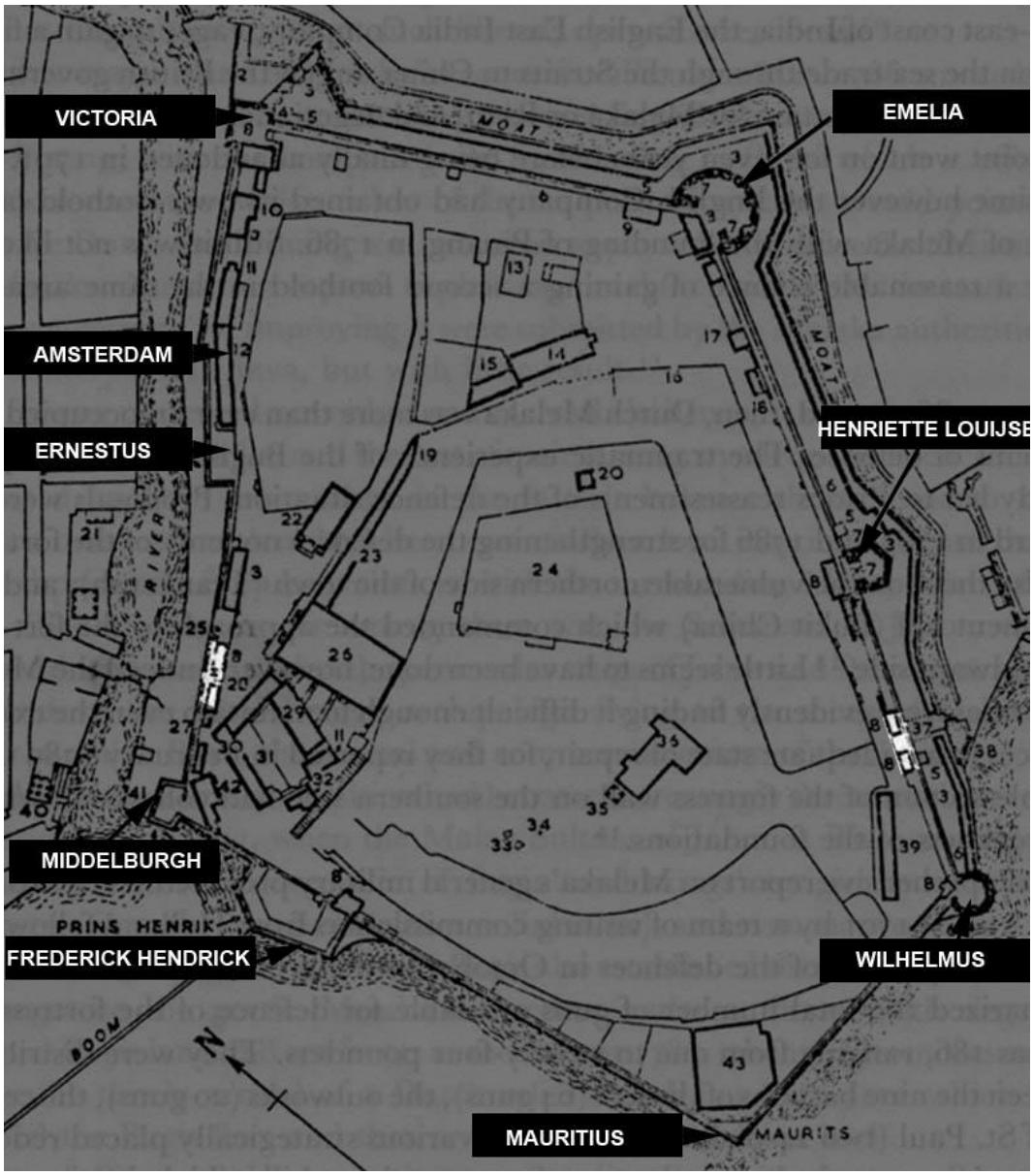


Figure 3.32 Stone gates (Source: Harrison, 1986)

3.2.4.1.5 Old gates

The old gates belong to the Portuguese and when Bort arrived in Melaka, they were in bad condition. In addition Bort et al., (1927) explains, "*The gate on the land side close to the bastion Wilhelmus I found blocked and the other on the river side, which consisted merely of a single door, had been much reduced in size rind is now opened only in the morning to put out the refuse tubs and when the ships have to be unloaded and loaded."* Locations of these gates can be seen in Figure 3.33.

Remarks: Both gates are highlighted in the plan.

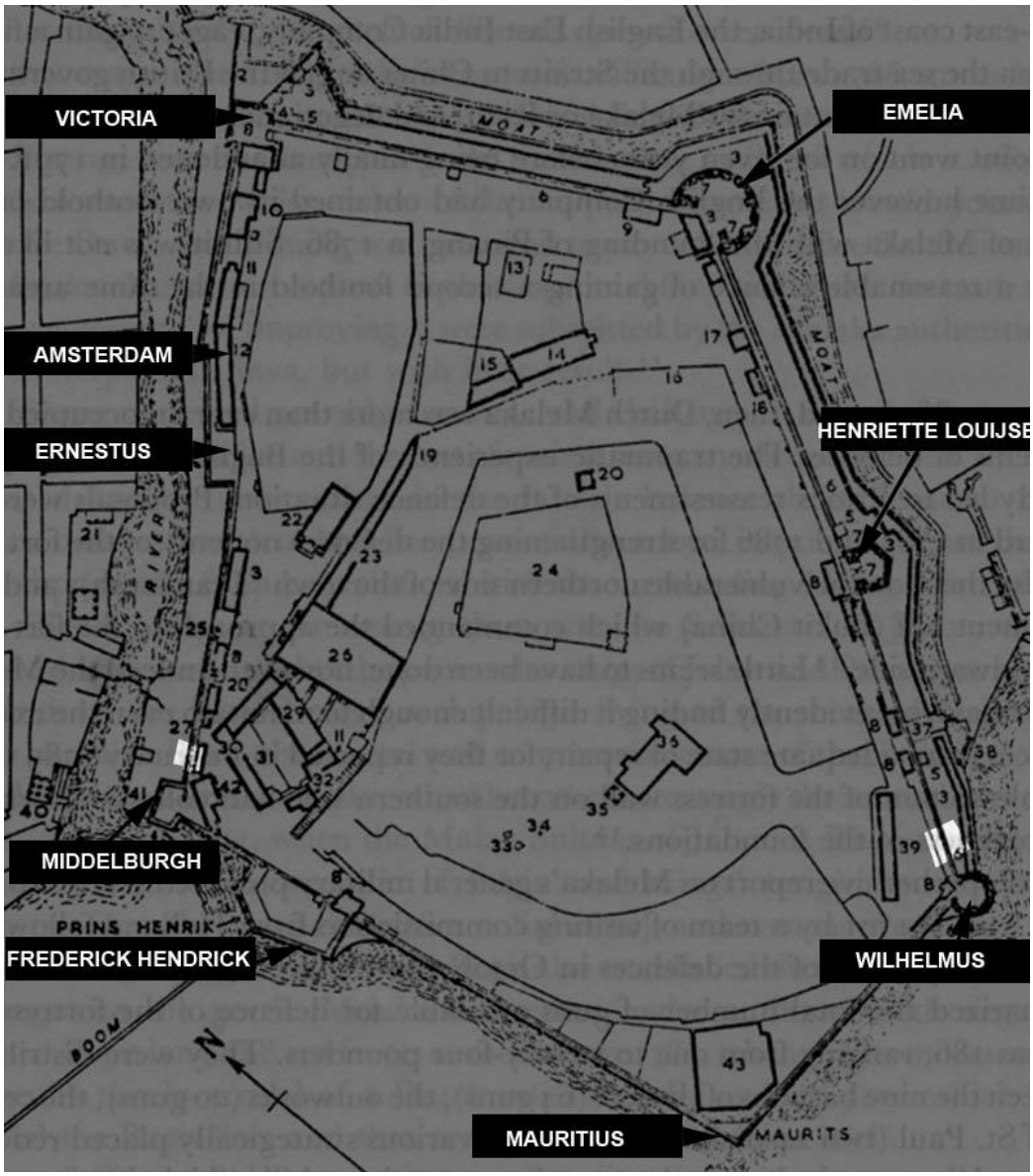


Figure 3.33 Old gates (Source: Harrison, 1986)

3.2.4.1.6 Moat

According to Bort et al., (1927), *"A moat has also been dug here from the river to the seashore and a ravelin placed on the outer side of the bastion Victoria for the greater protection of the same and also to give command thence towards Emelia. The aforesaid moat 183.5 rods long, 2-4 rods wide and 12 feet deep (Rhenish measure) including the square in front of the face of Victoria. This moat was begun in 1673 and completed in 1674, that is, when the French were in India with a fleet and, in conjunction with the I.inglish, were making fierce war on our State."* Figure 3.34 shows the moat at the fortress.

Remarks: The moat presents in the plan.

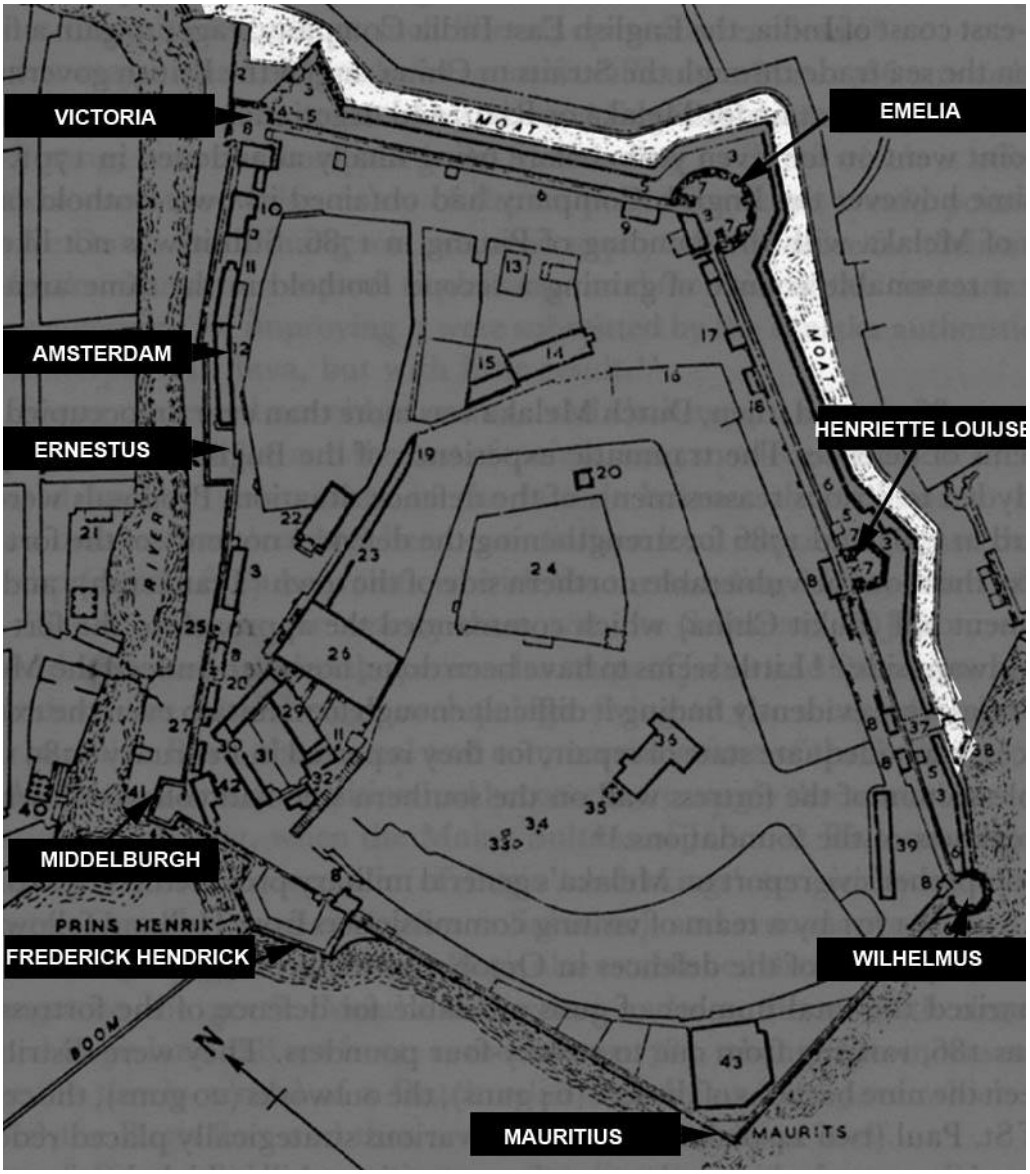


Figure 3.34 Moat (Source: Harrison, 1986)

3.2.4.1.7 Fausse braie

Bort had added faussie braie (Figure 3.35) on the inner side of the moat along Victoria bastion up to Wilhelmus bastion. This is done to strengthen the wall which is believed to be the weakest because it is not filled with the earth inside. Bort et al., (1927) adds, "*Behind this fausse braie between the bastions towards the wall, there is a space of 24 feet forming a covered way from which and from the ravelin the moat can be defended over the fausse braie, and the passage of the enemy can be obstructed with less danger. From the point Henriette Louise past the land gate to the bastion Wilhelmus there is also an earthen breastwork on the side of the moat."*

Remarks: In the plan, the fausse braie is from bastion of Victoria to Wilhelsmus and this is consistent in almost all collected plan.

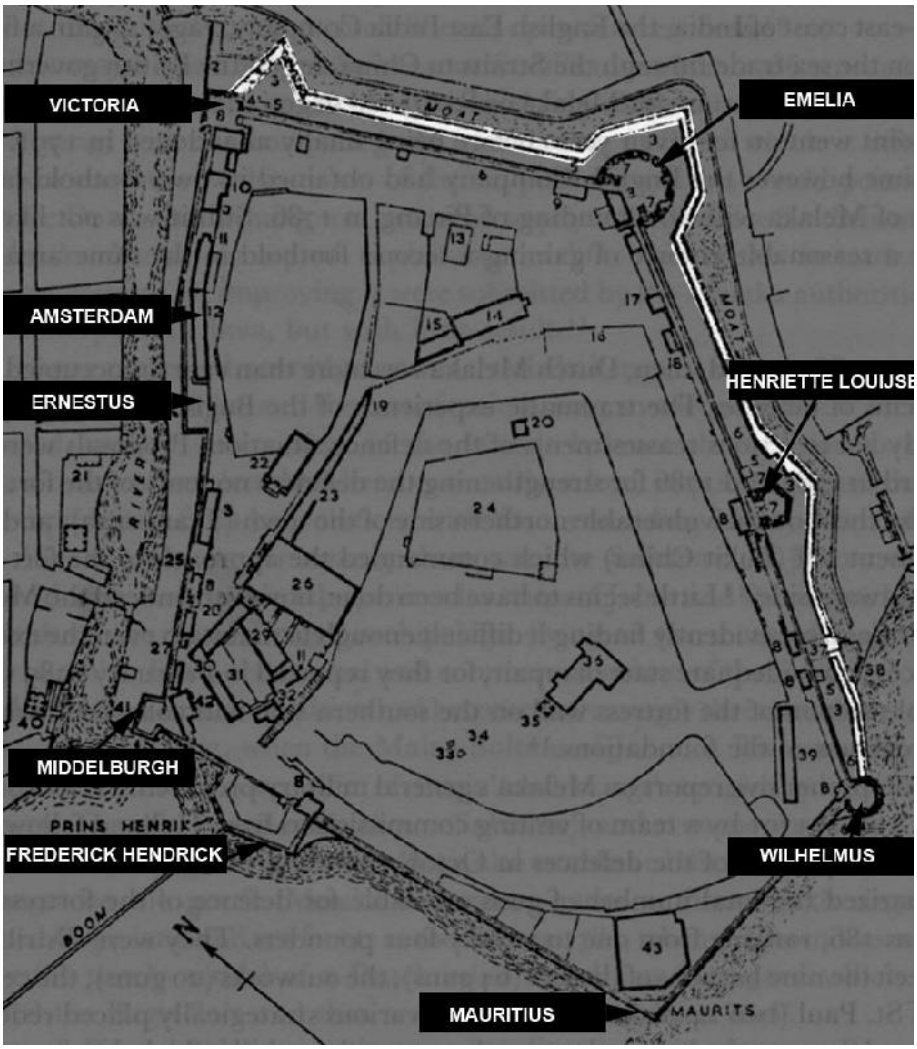


Figure 3.35 Fausse braie (Source: Harrison, 1986)

3.2.4.1.8 Fausse braie watch towers

There are four fausse braie watch towers as shown in Figure 3.36 which are located next to Porta de Santiago gate, Henriette Louijse bastion, Emelia bastion and Victoria bastion. Bort did not mention about these watch towers in his report but in section 3.2.2.1.9 (Plan of Malacca fortress, ca. 1792) the plan legends indicated the location of these watch towers in the plan.

Remarks: Shown in the plan.

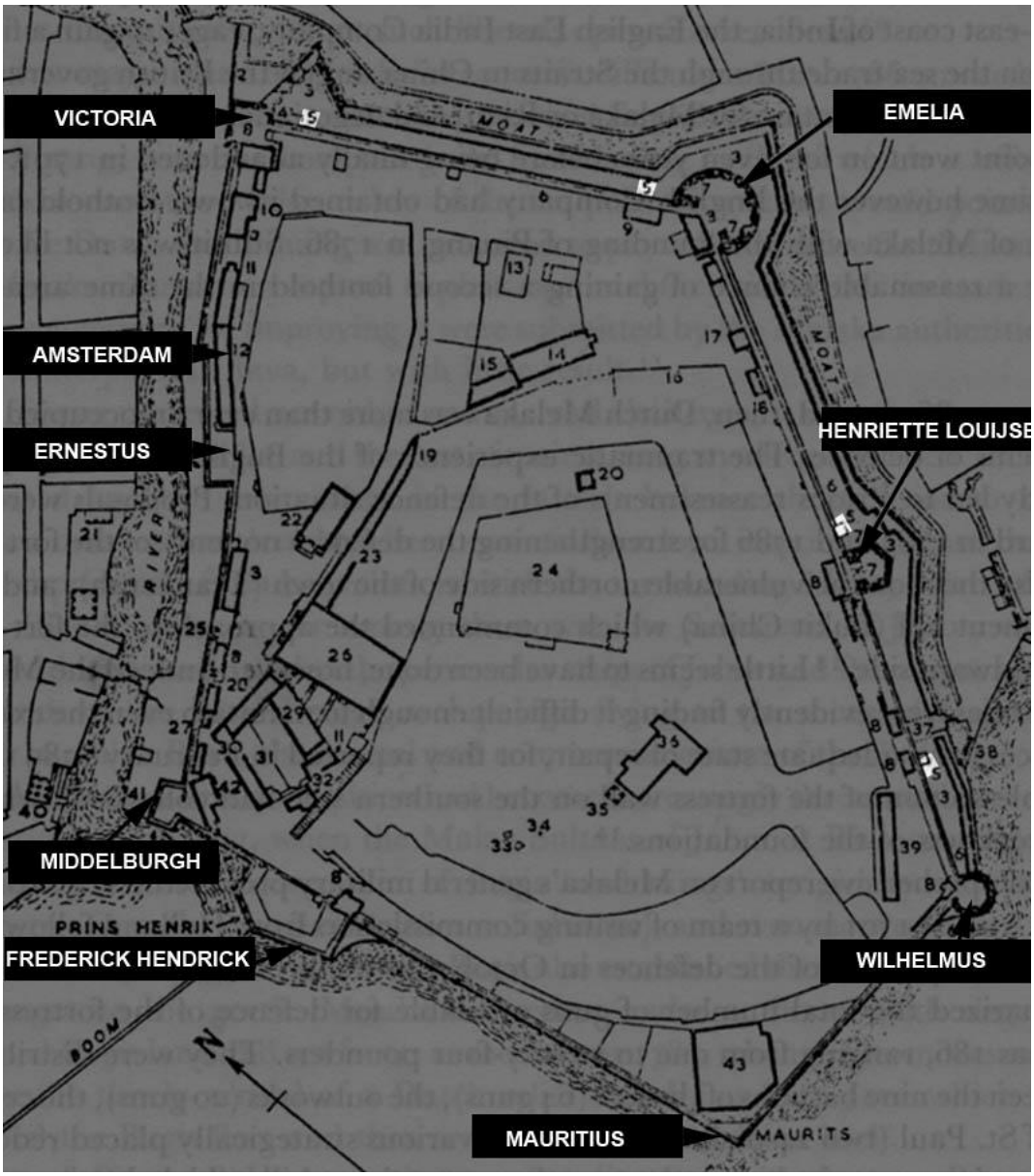


Figure 3.36 Fausse braie watch towers (Source: Harrison, 1986)

3.2.4.1.9 Fausse braie gate

Only one fausse braie gate found next to Victoria bastion, however by looking at the plan this fausse braie also can be accessed through Porta de Santiago entrance. This is shown in Figure 3.37. The location of this gate is clearly indicated in section 3.2.2.1.9 (Plan of Malacca fortress, ca. 1792).

Remarks: Shown in the plan.

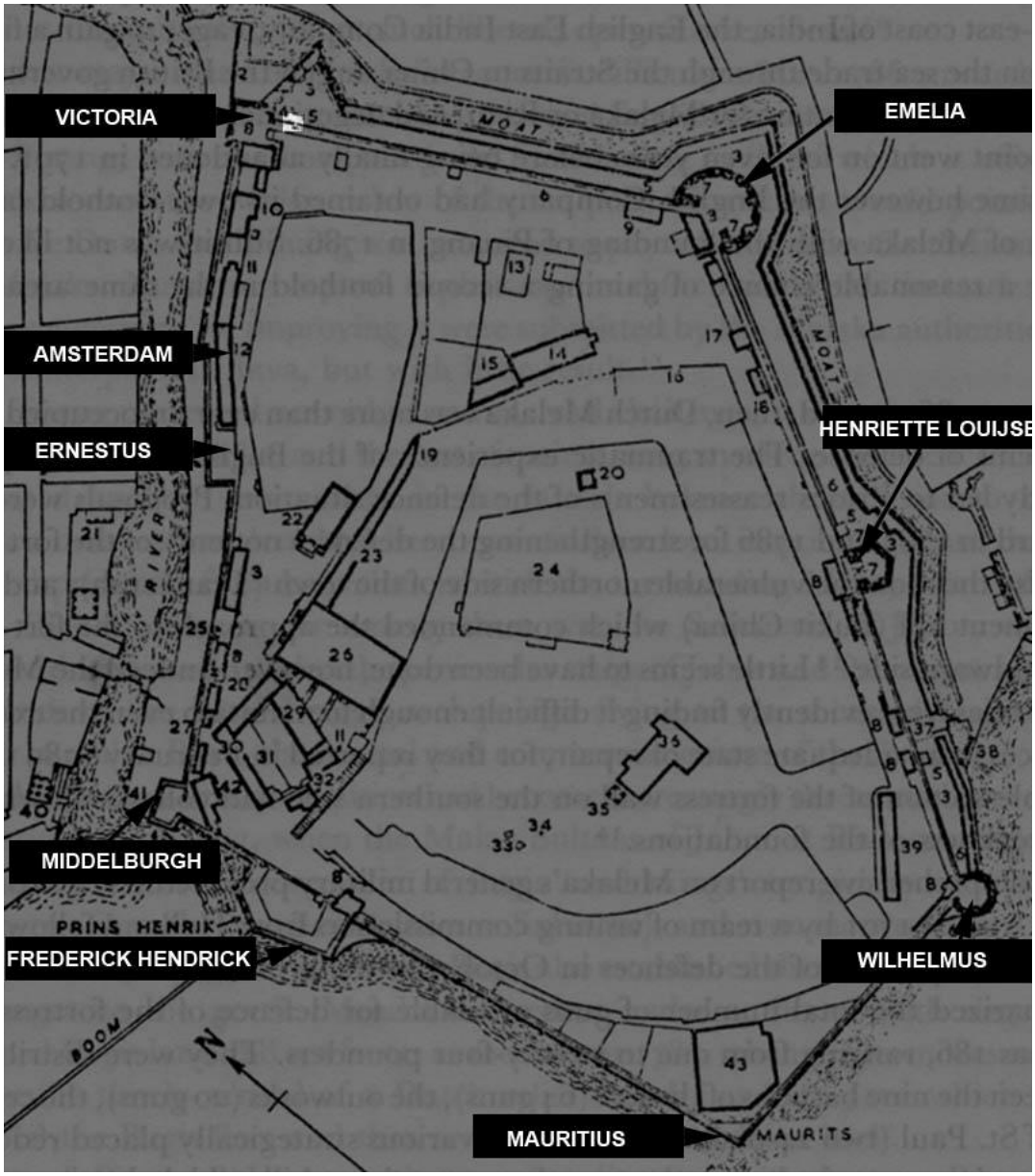


Figure 3.37 Fausse braie gate (Source: Harrison, 1986)

3.2.4.1.10 Covered way

Behind this fausse braie between the bastions towards the wall, there is a space of 24 feet forming a covered way from which and from the ravelin the moat can be defended over the fausse braie and the passage of the enemy can be obstructed with less danger (Bort, Bremner et al. 1927). Figure 3.38 shows this covered way between the walls Victoria to Wilhelmus and fausse braie.

Remarks: Shown in the plan.

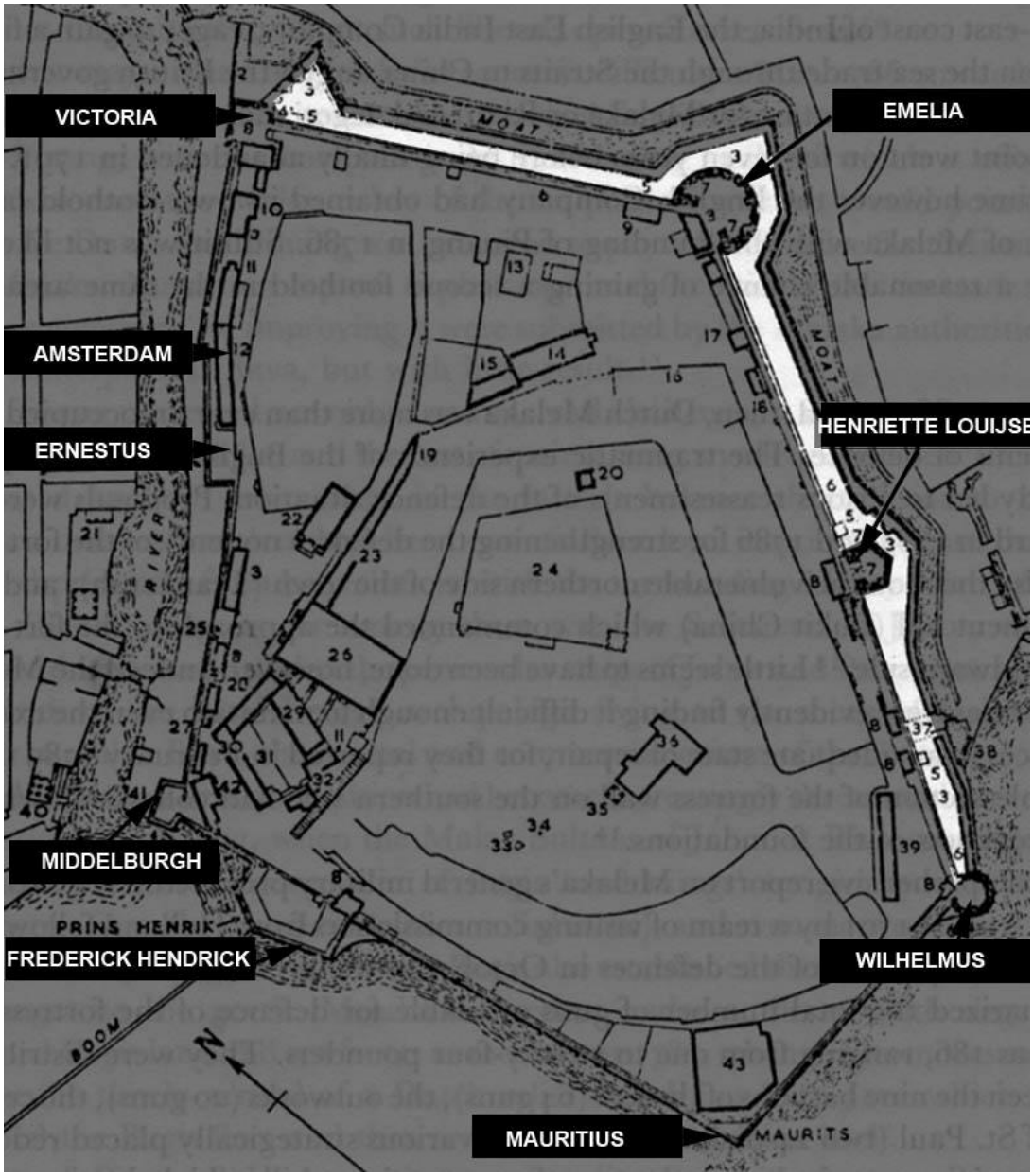


Figure 3.38 Covered way (Source: Harrison, 1986)

3.2.4.1.11 Casemates

In A Famosa there are only two bastions that have casemates namely Henriette Louijse and Emelia. These casemates were not mentioned in Bort's report however by referring to the legends in section 3.2.2.1.9 (Plan of Malacca fortress, ca. 1792), it clearly indicates the location of these casemates. Figure 3.39 shows the location of these casemates.

Remarks: Shown in the plan.

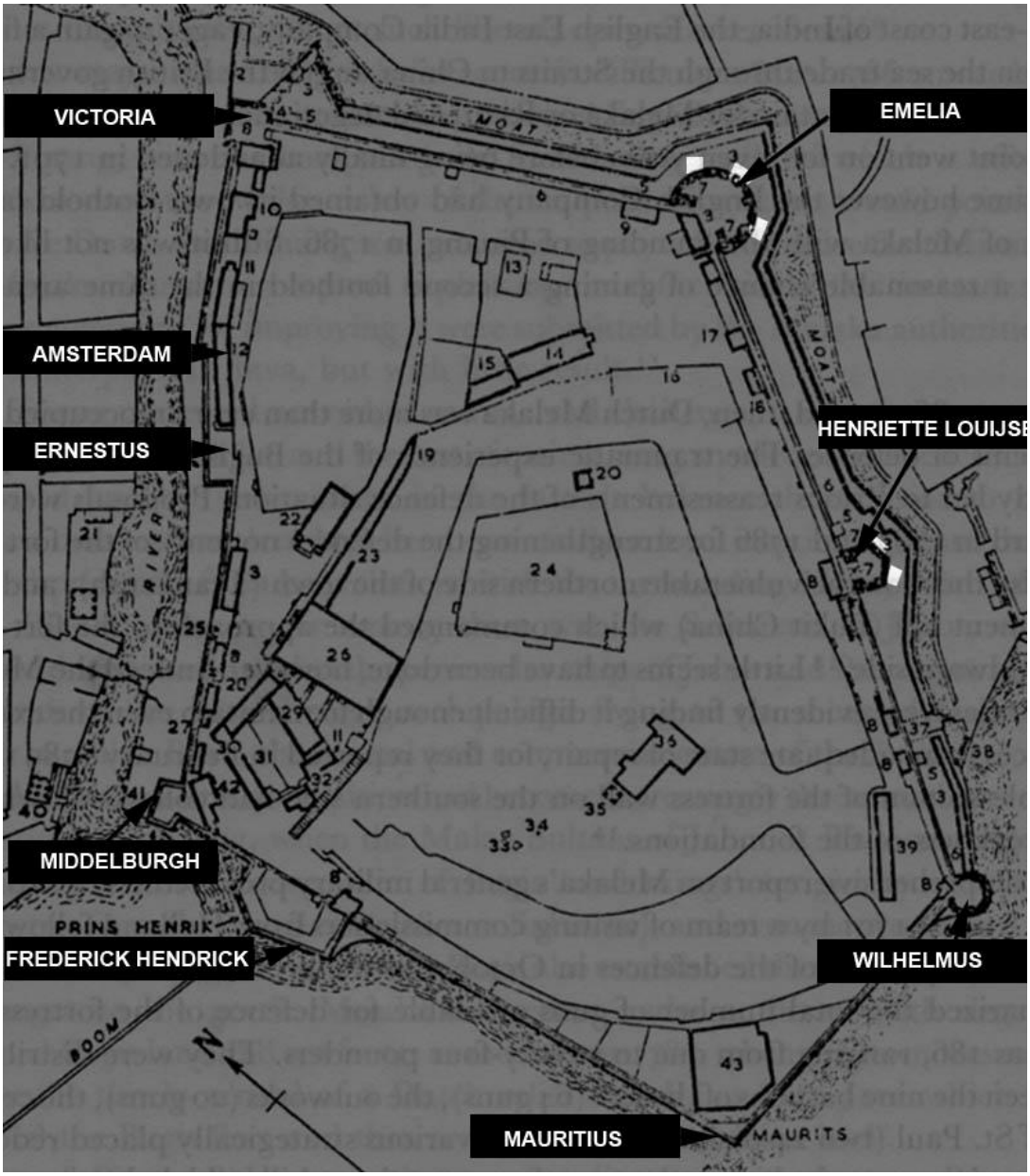


Figure 3.39 Casemates (Source: Harrison, 1986)

3.2.4.1.12 Fausse porte

Bort et al., (1927) explains, "*At the bastion Victoria there is a fausse porte giving access through the wall to the ravelin, fausse braie, covered way and moat; it is at present always kept shut and need not be opened except in time of necessity."* The location of the fausse porte is indicated in Figure 3.40.

Remarks: Shown in the plan.

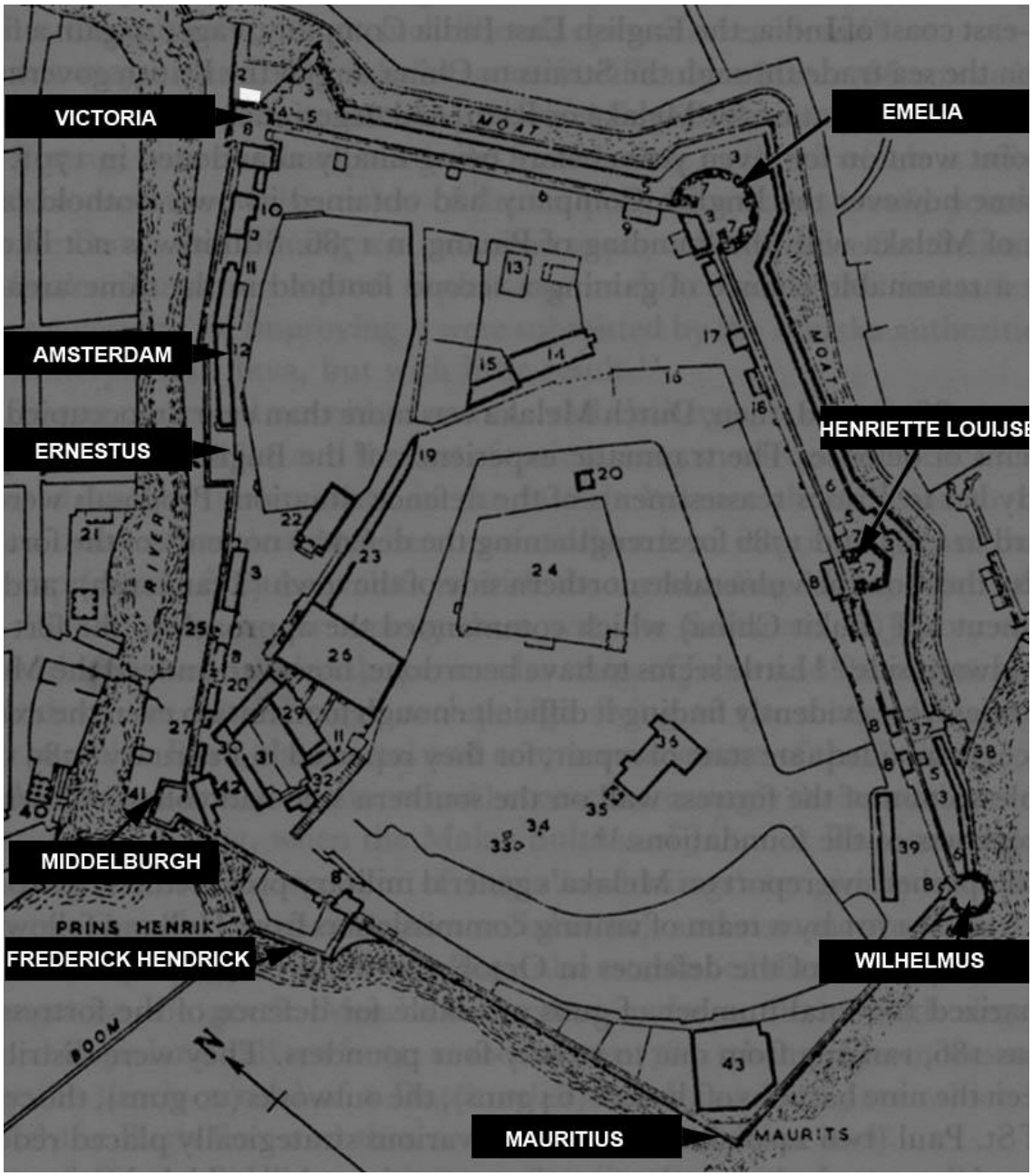


Figure 3.40 Fausse porte (Source: Harrison, 1986)

3.2.4.1.13 Arsenal

Bort et al., (1927) describes, *"Within the fortress, between the bastions Victoria and Ernestus there is a convenient arsenal, built in my time out of an old but strong bit of the Portuguese defenses against the wall. It has a flat roof, where it should be possible to place guns for the defense of that part of the wall at need and to bombard the northern suburb*."

Remarks: Not clearly shown in the plan.

3.2.4.1.14 Stone sluice

The moat was equipped with two stone sluices (Figure 3.41), the one on the river, the other on the sea-side, by means of which the water can be controlled to let in and out. In the report Bort et al., (1927) explains the benefits of having this stone sluices, "*Fresh and salt water fish come into and are preserved in it, yielding already some profit, although not much, from the annual farming, but it is evident that in time the profit will increase with the multiplication of the fish."*

Remarks: Shown in the plan.

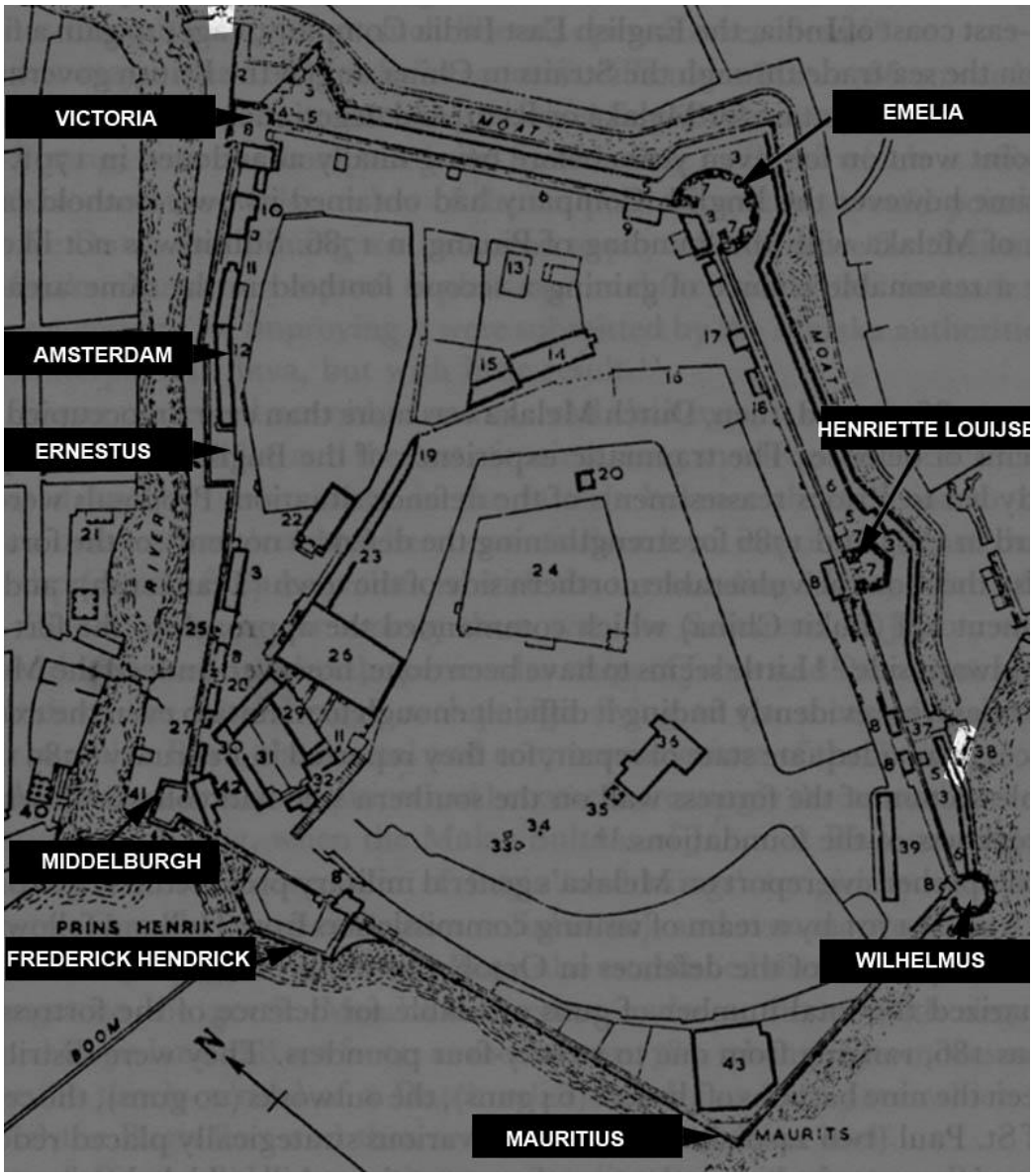


Figure 3.41 Stone sluices (Source: Harrison, 1986)

3.2.4.1.15 Drawbridge

A Famosa has two drawbridges, one on the river,the other on the sea-side, opposite the stone gate between Henriette Louise and Wilhelmus aforesaid as shown in Figure 3.42. According to Bort et al., (1927), "*Over it there are two drawbridges, one on the river, the other on the sea-side, opposite the stone gate between Henriette Louise and Wilhelmus aforesaid. By this latter drawbridge the southern suburb, and by the one over the river (close to its entrance near the other gate) the northern suburb joined to the fort and have access to each other. These bridges, which also were made during my governorship, must be continually kept up, to the end that they do not fall into ruin and perish."*

Remarks: Shown in the plan.

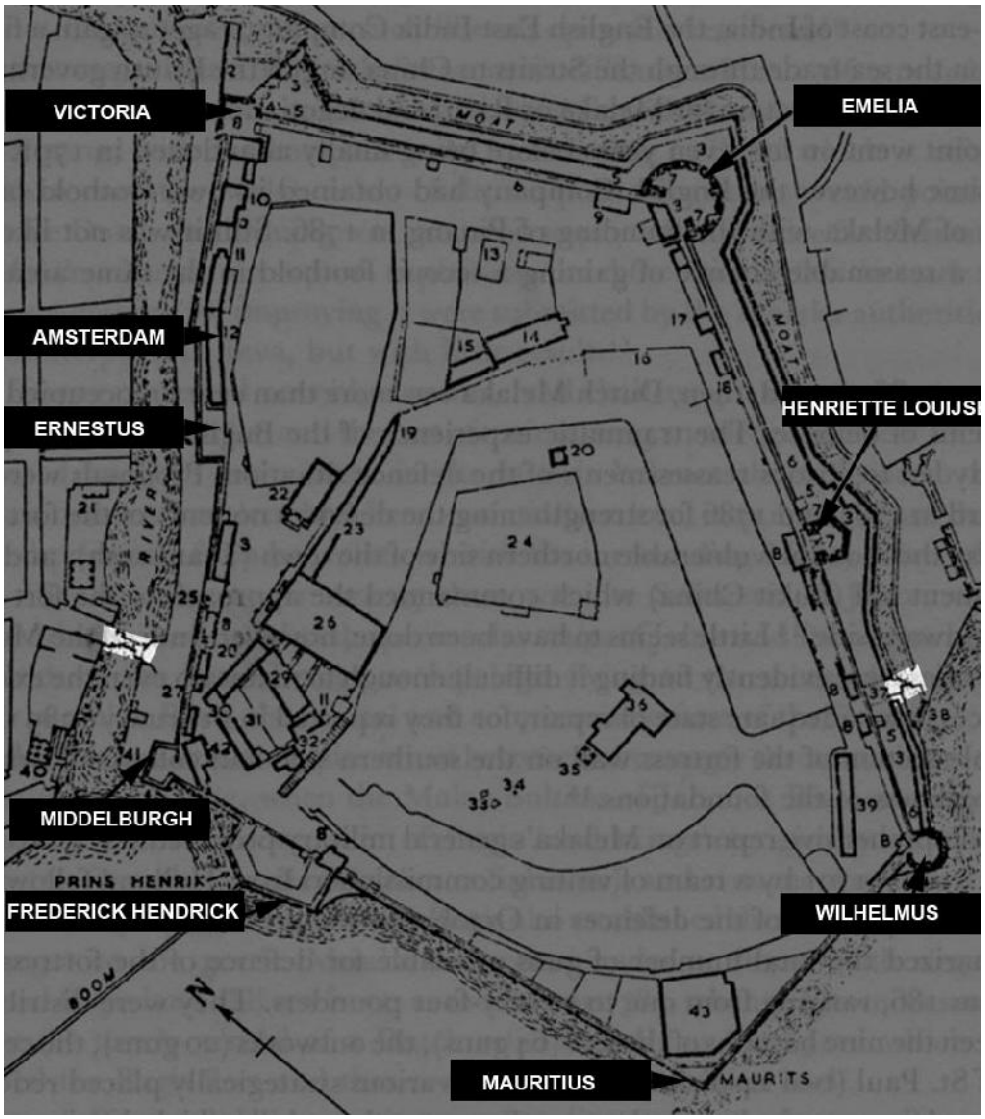


Figure 3.42 Drawbridges (Source: Harrison, 1986)

3.2.4.1.16 Vaulted cellar

Vaulted cellars can be found at bastion Frederick Hendrick, Emelia and Ernestus.

The powder-cellar is under the bastion Wilhelmus.

Bort et al., (1927) explains, "*Fredrick Hendrick, Ernestus and Emelia have spacious, convenient, vaulted cellars for gunpowder; moreover in time of need ammunition can be stored and kept dry under Victoria and Wilhelmus so as to have it ready to hand for use. The powder-cellar under the bastion Wilhelmus I had cleared of the soil with which it was filial and made fit again for its purpose."*

Remarks: Not clearly shown in the plan.

3.2.4.1.17 Guardhouse

Originally built of '*atap'* and changed to tiles. According to section 3.2.2.1.9 (Plan of Malacca fortress, ca. 1792), there are four guardhouses (Figure 3.43) and they are attached to the gateways of custom and Porta de Santiago. There are two more guardhouses based on the detailed explanation from Bort et al., (1927), *"At the new gates there are stone stairs by which to mount to and come down from the upper wall and they have on both sides convenient stone guardhouses and cookhouses. Moreover I have had two more guardhouses made, one at the bastion Fredrick Mendrick and the other at Victoria, which had great need of them."*

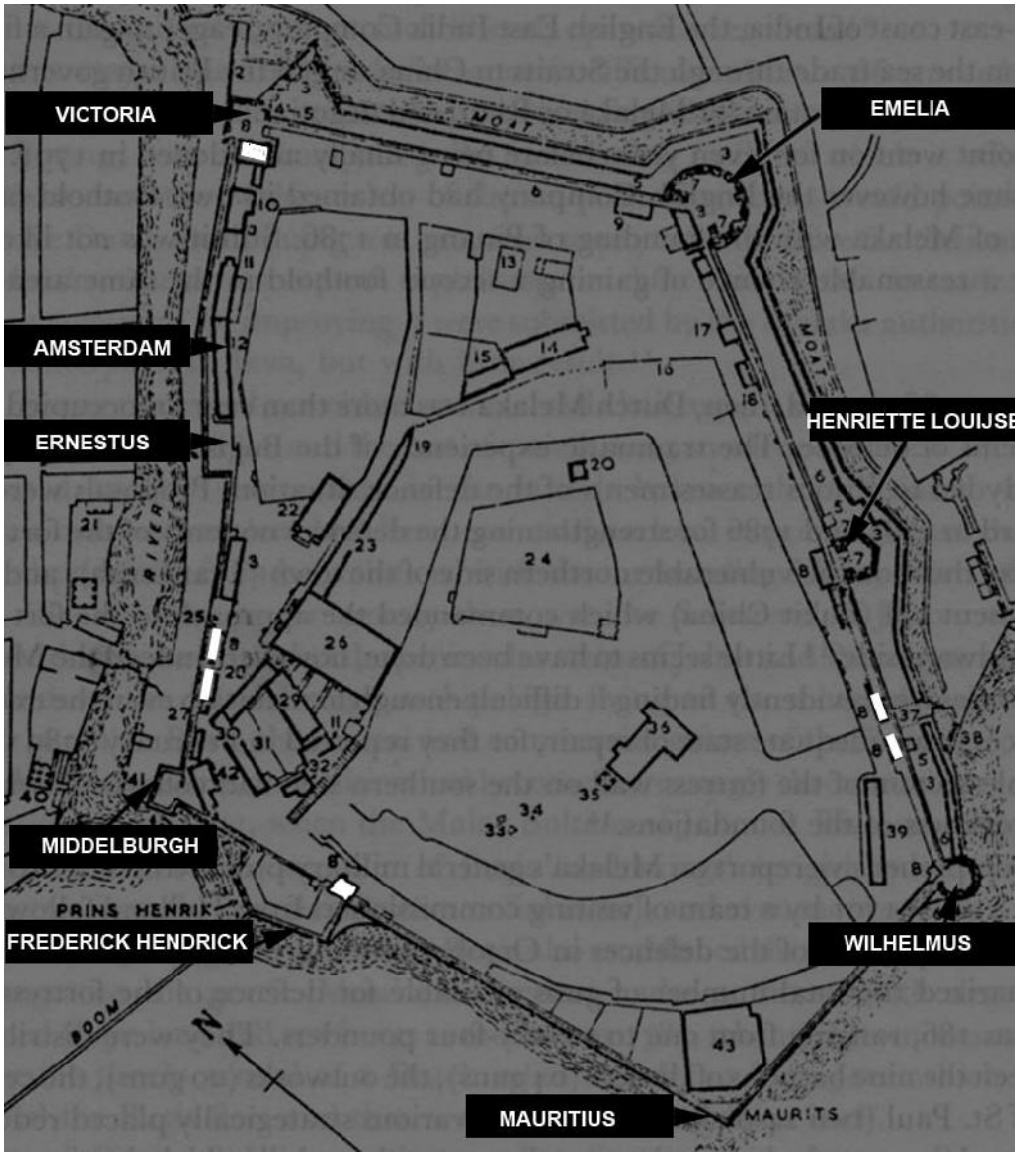


Figure 3.43 Guardhouses (Source: Harrison, 1986)

3.2.4.1.18 Stairs

Both sides of the guardhouses have stairs connecting upper wall to the ground. This has been explained in section 3.2.4.1.17. In Figure 3.44 the stairs are marked in white.

Remarks: Not clearly shown in the plan but the location is known based on the guardhouses.

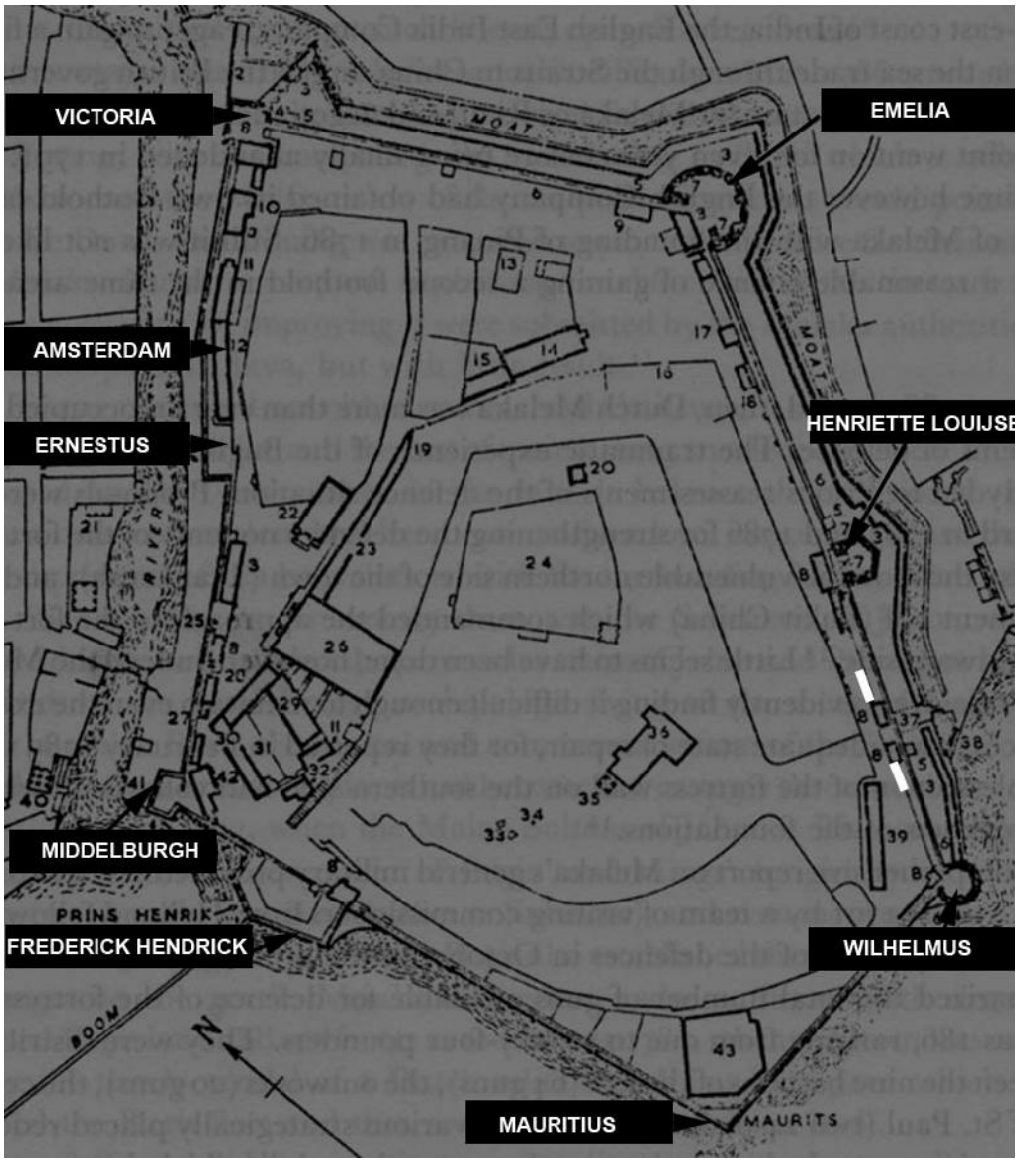


Figure 3.44 Stairs marked in white (Source: Harrison, 1986)

3.2.5 The height

To proceed with the 3D modelling process, it is crucial to know the height of the fortress walls. Unfortunately to obtain the height data for this fortress is very difficult due to no evidence in form of visual explaining about the height. All of the visual materials only provide plan and map of the A Famosa fortress. Throughout this

research there is no elevation drawings found and to project the height for this fortress, it totally relies on the textual descriptions. The only reliable information about the height can be obtained from Bort's report.

Bort's report gives two height information; walls and bastions. For wall's height, Bort divided it into two categories which are landside and seaside. This can be seen in Table 3.10. Unfortunately this height information is very general because there is no indication of the starting point and ending point. This requires the given wall's height to be closely matched with the confirmed height unit for instance the bastion's height. Additionally, in the research fieldtrip, it is found that most of the wall's heights are inconsistent, it depends on the topology of the site and design rationale. Figure 3.45 and 3.46 show the different heights for Aguada fortress and Galle fortress. It is also noticed that most of the heights for the bastion are higher than the common walls. Below are the extractions of the wall's height from the Bort's report which have been converted into metric unit.

Table 3.10 Conversion of the height from the Bort's report

Location	**Height (metre)**
Seaside:	5.9, 8 and 8.8
Landside:	5.9, 6.7, 7, 7.7 and 8
Bastion	
Fredrick Hendrick	7.3
Mauritius	8.5
Wilhelmus	8.9
Henriette Louijse	6.8
Emelia	8.3
Victoria	8.6
Amsterdam	6.8
Ernestus	7.3
Middelburgh	5.7
On the wall between Middelburgh and Frederick Hendrick	5.9

Figure 3.45 Different heights for Aguada fortress (Source: Author)

Figure 3.46 Bastion wall is normally higher than other walls, Galle fortress (Source: Author)

From the given height data, it is projected to the reference map of the A Famosa fortress (Figure 3.47). Four categories; seaside and landside, confirmed and unconfirmed heights are distinguished by four colour codes.

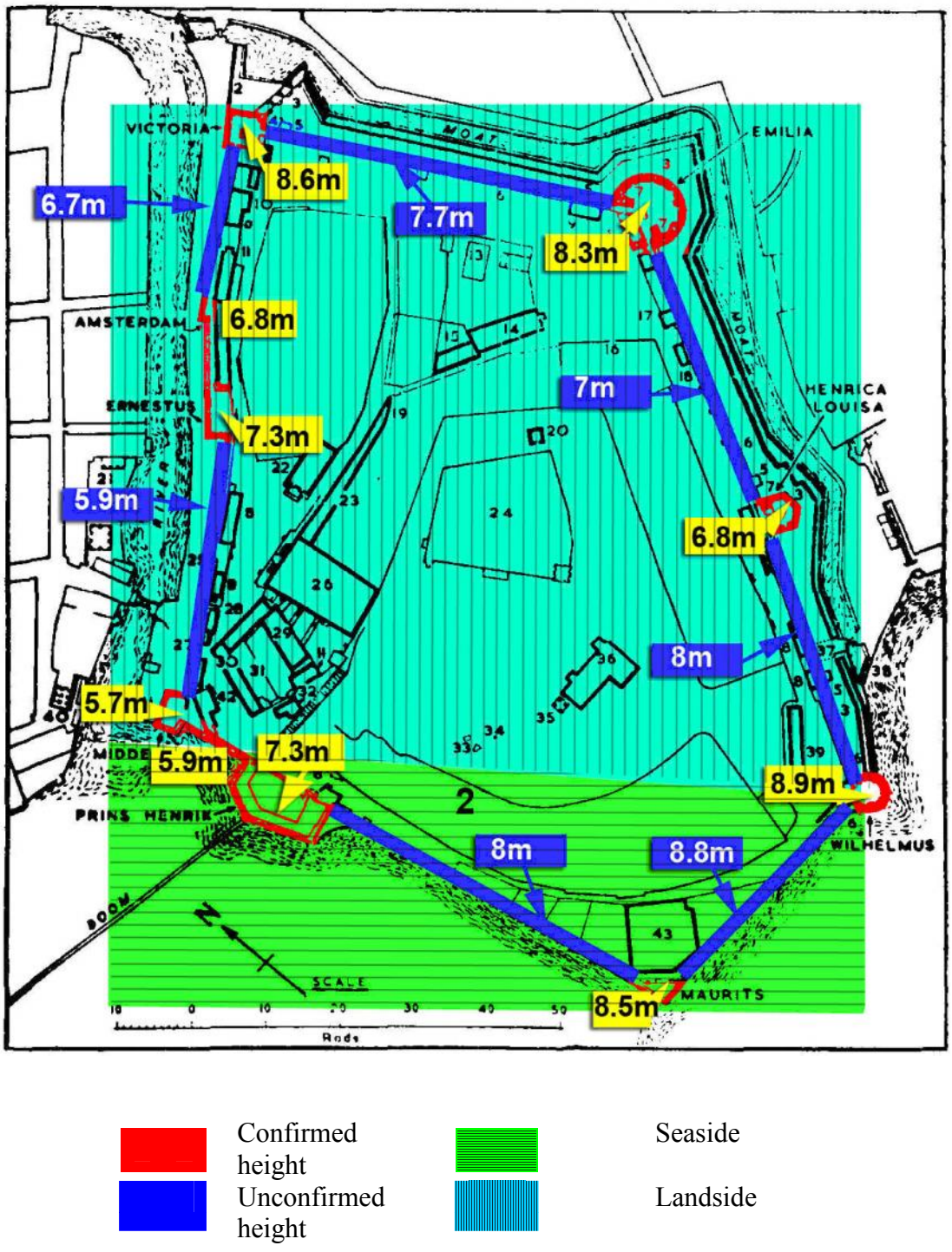


Figure 3.47 Indication of the walls height in metre (Source: Harrison, 1986)

Based on the seaside categories, the wall's height between Middelburgh and Frederick Hendrick bastion is matched with the height from Table 3.10. The remaining wall's heights are given based on the nearest unit between two bastions. To obtain exact

wall's height is impossible except if they are given in form of elevation drawings or complete textual descriptions. As for the A Famosa fortress, the information is partially complete because some of the height areas are not indicated. To have a clear visual about the height, next chapter will provide the pre-visualisation of these findings.

3.3 Summary

In this chapter, it focuses on the verification of available data of the A Famosa fortress which are to be used as a reference in reconstructing 3D model. The overall process involved is summarised in Figure 3.48.

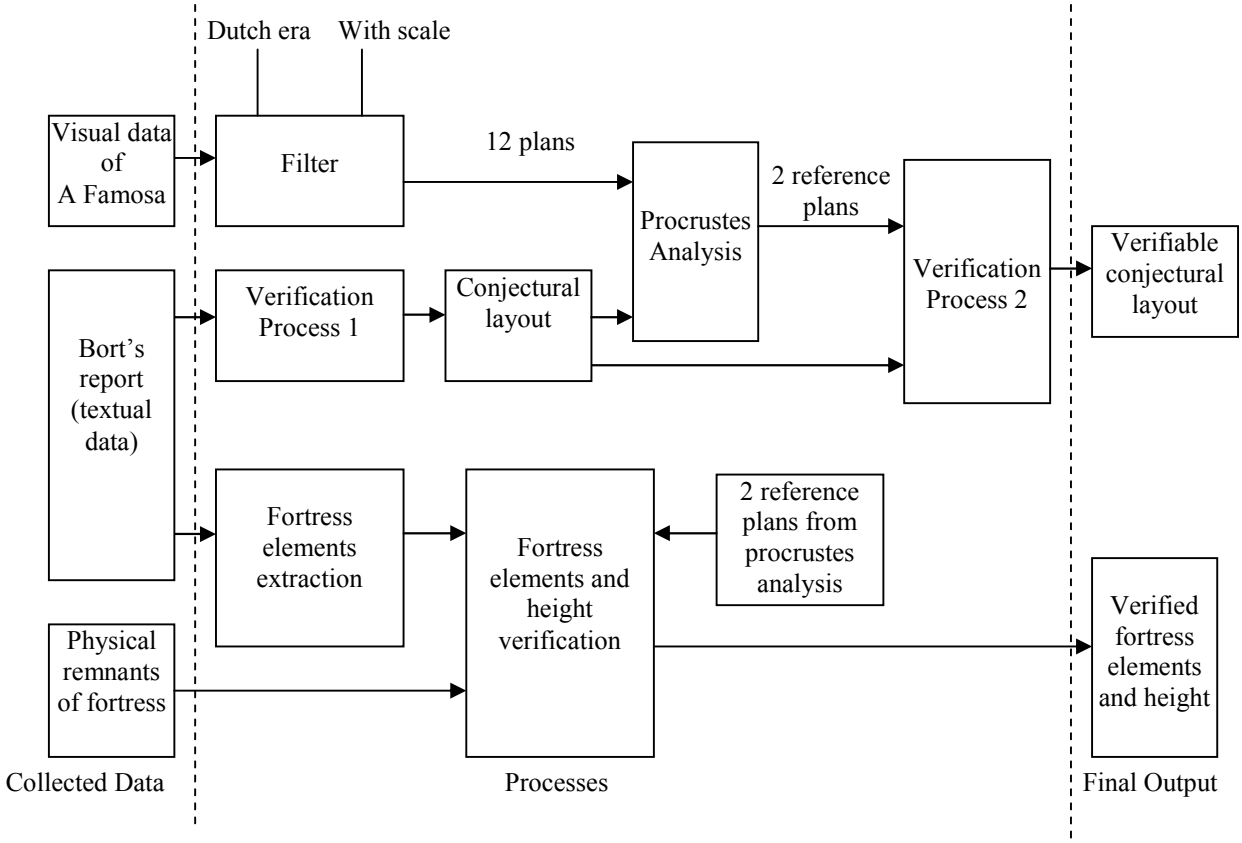


Figure 3.48 Summary of the data verification process (Source: Author)

In tracing the A Famosa fortress, the collected data is categorised into three categories which are textual descriptions, visual data and physical data. The fortress layout determination approach was started by verifying textual data from Bort's report and

translating it into a conjectural layout. Then this conjectural layout was matched through the selected visual data using procrustes analysis to find the best map that match textual descriptions. As a result from this approach two reference plans have been identified.

The next step was to conduct detail comparison on the measurement from conjectural layout (resulted from textual data verification) and the reference plans (resulting from procrustes analysis). The output of this process is a verifiable conjectural layout of A Famosa.

Other than the fortress layout determination, this chapter also identified and verified the elements and height of the A Famosa fortress. This verification process matched and compared data extracted from Bort's report, reference plans selected from procrustes analysis and available physical remnant of the fortress. The outputs of this process are the verified fortress elements and height. It should be noted that the outputs from this chapter are limited to plan and text representation. In the next chapter, approaches to transform these representations to 3D visualization will be discussed.

Chapter 4

REBUILDING THE A FAMOSA

This chapter discusses about the approaches which have been adopted to model the conjectural layout of the A Famosa fortress found in chapter three. Firstly this chapter will study about the similar digital reconstruction projects which can be used as a reference and guidelines for this research. Secondly, the collected data particularly textual and 2D data will be transformed into sketches as visual reference. Finally all of the findings will be used for 3D modelling process, this includes other related approaches such as texturing, lighting and rendering. Final rendered images will be presented at the end of this chapter.

4.1 Digital reconstruction projects: A study on selected projects

In order to model the A Famosa fortress in 3D model, a brief study on selected projects which have same similar issues with it will be discussed. Three projects have been selected namely *Michelsberg synagogue*, *The Jewish Quarter in Regensburg* and *Reconstruction of the old main church in Curitiba, Brazil*. These three heritages are

no longer available today and the researchers have put some effort in preserving them into 3D models. Aspects such as background of the project, challenges, purpose, output and solutions will be discussed in this section. These three projects involve with the use of art history, architectural heritage and computer visualisation technology. The reasons for choosing these projects are to extract the similarities, analyse the methods used and the findings from the study will be used as guidelines and comparison with A Famosa fortress.

4.1.1 Michelsberg synagogue, Wiesbaden

Michelsberg synagogue was built in 1869 by a local architect, Philipp Hoffmann. This synagogue was a symbol of success and self-confidence of the Jewish community at that time. Unfortunately in 1938, this synagogue was destroyed by the German Nazis and it was totally demolished in 1939. This can be seen in Figure 4.1. The digital reconstruction of the destroyed synagogue began in 1998 by a group of interior design students from Wiesbaden University. There were two phases of reconstruction involved in this project. It began with the exterior part in November 1998 and followed by the interior part in November 1999 (Hemsley, Cappellini et al. 2005). The output of this project is in 3D computer animated film. The purpose of this project is to preserve and reconstruct the lost Jewish heritage in digital medium specifically 3D computer animation. This project has caught the interest of scholars, heritage experts and archaeologists (Krebs and Brück 2004). The output of this project has been used as teaching tools and theoretical content.

According to the team, all of the construction plans and drawings are completely lost (Krebs and Brück 2004). Figure 4.2 shows the site of this synagogue in 1995. The team has gathered all of the information by collecting photographs from the townspeople and helped by historical institutions and archives. Some of the evidences are scattered abroad and the site itself has no remnants at all. With the existing data, it is still not sufficient particularly to model the interior part. One of the most important evidences has been found at the Jewish Museum in Paris and other evidences have been obtained from the synagogue architect's family.

Figure 4.1 Wiesbaden synagogue in 1939 (Source: (Krebs and Brück 2004)

Figure 4.2 The site of synagogue in 1995 (Source: (Krebs and Brück 2004)

Some of the drawings are available in water colour presentation and this is useful for texture colour mapping in 3D animation process. The team also collected the evidence from similar buildings such as Berlin synagogue which was built in the same era.

Other than that, personal collections and consultation with the local Jewish community had also helped the entire project. With the available data, geometrical studies have been conducted to understand the building's proportion. This is followed by a comparison with the photograph analysis which enables the team to determine the scales and measurements. The building is divided into separate segments and each student focuses on each part.

The completed 3D parts are combined to make a single 3D model and followed by texture mapping process. Both interior and exterior parts are given an intensive concentration to achieve a realistic output. Figure 4.3 shows the rendering outputs of this project. Finally, a storyboard and camera tracks are prepared for animation purpose. This is enhanced with lighting and atmospheric effect. The rendered footage is edited during the post production process and the entire duration of this animation film is ten minutes.

Figure 4.3 The rendering output of the exterior and interior of the Wiesbaden synagogue 1939 (Source: (Krebs and Brück 2004))

4.1.2 The Jewish Quarter in Regensburg

The Jewish quarter in Regensburg is the earliest settlement in Germany (Landman and Cohen 1969; Hemsley, Cappellini et al. 2005). It is first mentioned a document dating from ca. 1000 A.D. It existed from the 9th century to 1519 and the Jews lived there for over 500 years largely free of persecution and pogroms, and left their mark on the history of Regensburg (Krebs and Brück 2004). This quarter comprised on 39 houses, administration buildings and synagogue. Figure 4.4 shows the excavation progress of the synagogue in the Jewish quarter. In the 15th century, due to tension between Jews and Christians and the death of Emperor Maximilian I, the Jews had been expelled from Regensburg by the town council.

Figure 4.4 The gothic synagogue in the Regensburg's Jewish quarter (Source: (Krebs and Brück 2004)

In 1995 during the underground construction on the Neupfarrplatz, the crew discovered old cellars and foundations (Insoll 1999). The archaeologists has been informed about this and an excavation has been done. Since the site had to be closed, an idea to preserve the history of Neupfarrplatz in digital medium has come into mind. The authority proposed to transform this history into a virtual reconstruction

and to present this visualisation in the museum. Interior Design Department of University of Applied Science, Wiesbaden took full responsibility to realise this project with the collaboration of other bodies such as institutions, university institutes and other research agencies from Prague and Vienna. The entire project is supported by the city of Regensberg and Bavarian Monument Protection Office.

This project involves with several part of 3D reconstruction such as interior and exterior of Jewish houses, old streets and gothic synagogue. Materials such as reference of the similar synagogues, archives and publications have been extensively referred as the foundation of 3D reconstruction. To model these in 3D models, analysis of the images have been carried out and the team was also helped by the scholars and curators. Using 3D CAD system all the two dimensional data are then transformed into 3D model. The samples of the outputs are shown in Figure 4.5.

Figure 4.5 3D models of the quarters (left) and the interior part of synagogue (right) (Source: (Krebs and Brück 2004)

4.1.3 The Old Main Church of Curitiba, Brazil

The digital reconstruction of the old main church of Curitiba in Brazil was carried out by Jose Manoel Kozan for the postgraduate master study. It involves interpretative process, historical research and digital reconstruction. This old heritage was demolished in 1875 and the only surviving evidence for this was two photographs taken in 1870. This material had gone through rectification process before it can be continued with 3D reconstruction process. Other supporting documents also came

from sources like old paintings, drawings, maps and comparison with the similar buildings.

Figure 4.6 shows the water colour painting of the church in 1827 by Jean-Baptiste Debret. This research utilises the method of 'single image' photogrammetry technique to restore geometric data of the destroyed heritage. This technique allows retrieving unique source of information from a single image. This has been proven by other project carried out by Bräuer in reconstructing Kommandantur in Berlin (Bräuer-Burchardt 2001).

Figure 4.6 Water colour painting of the church by Jean-Baptiste Debret in 1827 (Kozan 2004)

Historically before this church was built, the community used an old chapel. Since its condition was very terrible, it has been replaced with a new church in 1714. The church has been used for prayer, devotion and debates by local council. Tracing supporting data for this church is very challenging due to several reasons such as scattered information in several places and uncertainty of the location due to no proper excavation has been done.

According to the researcher, before the demolition of the church, all of the religious artifacts had been removed. One of the most important artifacts here is the tower clock which had been used as dimension comparison to generate the scaled image of

the church. To start the virtual reconstruction, the researcher had referred to this clock which is still available in the church of Ordem today.

Figure 4.7 shows the position of this old clock marked with number 1, and the clock at the Ordem church today. Beside that, the researcher also carried out analysis of the historical visual documents, textual descriptions, getting information from local historians on the subject matter, discussion with the experts and evaluation of the heritage virtual reconstruction.

Figure 4.7 Position of the clock in the main photograph (above) and the same clock at Ordem church today (right and below) (Kozan 2004)

Since the excavation data did not determine the location of the church, methods such as aerial photogrammetry and overlaying techniques had been used to relocate its

exact location. To analyse the photograph in Figure 4.8, the researcher used geometric and photographic rules, data elaboration process through photogrammetric technique, geometrical rectification process, edge detection and 3D modelling process. The final result of this reconstruction process can be seen in Figure 4.10. Finally the researcher also categorised the level of uncertainty in the building parts by adding colour code the image.

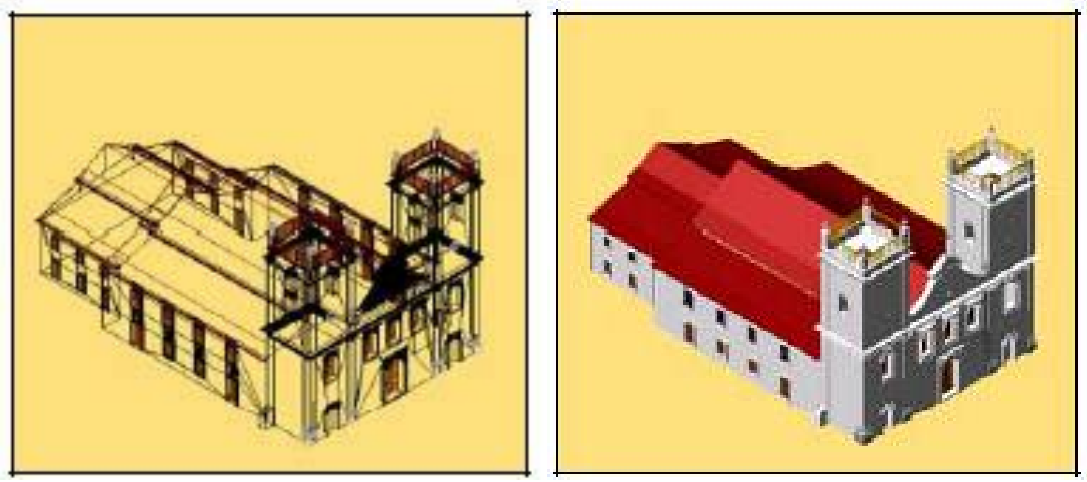


Figure 4.8 Final result of the reconstructed church (Kozan 2004)

4.2 Comparison of the case studies with A Famosa fortress

In general, the main similarities between A Famosa reconstruction and the three case studies are very limited resources and minimal physical remains of the building available. However in term of available data, Lost Jewish Heritage and The Old Main Church of Curitiba have some advantages over the A Famosa and Jewish Quarter in Regensburg since the buildings were still available until 19th century. Thus, they have more reliable evidence such as photographs of the original buildings as compared to man made painting. The architectural drawings produced in this era are also more accurate and advance compared to the previous era. In case of A Famosa and Jewish Quarter in Regensburg, extensive data verification has to be done due to very old, inconsistent record and insufficient reliable data. Comparisons of the elements in case studies are listed in Table 4.1.

Table 4.1 Comparison of the elements in case studies

Project / Elements	Lost Jewish Heritage	Jewish Quarter in Regensburg	The Old Main Church of Curitiba, Brazil	A Famosa
Building's year	1869-1938	9th century - 1519	1714-1875	1511-1807
Project's Year	1998	1998	2004	2007
Conservation	No	No	No	Partial
Who	University of Applied Sciences, Germany	University of Applied Sciences, Germany, research agencies and other institutions	Master thesis by Jose Manoel Kozan	Strathclyde University and Multimedia Univ.
Purpose	To preserve and reconstruct in digital medium (3D)	To preserve and reconstruct in digital medium (3D)	To preserve and reconstruct in digital medium (3D)	To preserve and reconstruct in digital medium (3D)
Available physical remains	No physical remains at all. The site has been converted into a highway	No physical remains except some foundations from the excavation	No physical remains except tower clock	Only a gate and some bastions from excavation data
Available data	Some old photographs and water colour drawings Historian records	Limited drawings and excavation data Copperplate engravings	Photos of the original building, old paintings, drawings and maps, similar buildings	Old report, inconsistent drawings with old measurement units, similar fortresses
Method	Traditional 3D modeling process based on available data No data verification involved	Traditional 3D modeling process based on available data Data analysis and interpretation done by curators	Single image photogrammetry based on tower clock and photos	Traditional 3D modeling process based on available data. Conducted extensive data verification process on available data
Output	3D computer animated film	3D presentation in video, CD and picture	3D model and rendered images	3D model and rendered images
Applications	Presented to public and won some awards for the film	Presented in the museum for public	Education and research purpose	Potential application for education and tourism in Malaysia

Based on the findings it is decided to use traditional 3D modeling technique to reconstruct A Famosa. To accomplish this modelling process, 3D Studio Max has been chosen for the entire process of 3D visualisation such as polygonal modelling,

texturing, lighting and rendering. The following section describes the two main stages involved in this 3D modelling process.

4.2.1 Modelling of fortress elements in 3D

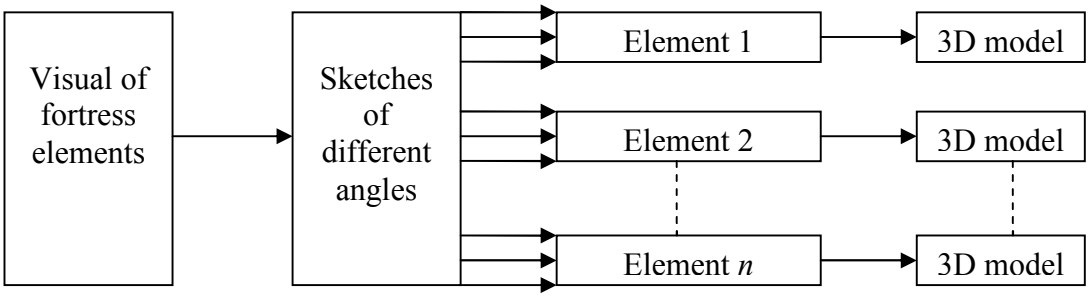


Figure 4.9 The process of modelling fortress elements (Source: Author)

Figure 4.9 shows the process involved in modelling the fortress element. To proceed with this approach, Plan A in Figure 4.10 is divided into several sections. For each section, three sketches were made presenting perspective view, internal wall view and external wall view. The sketches have been drawn based on the findings which have been gathered from section 2.4 of Chapter 2. Initially the sketches are made based on define and match approach from the observation during the site visits to the existing Dutch and Portuguese fortresses as discussed in the case studies. In addition, textual descriptions from Bort's report and definition from fortress architecture books and encyclopaedia, especially for the rare terms such as *ravelin* and *fausse-braie* have also been used to support the missing details.

These sketches are then presented to three identified persons who have been the main figures in the excavation and reconstruction of Middelburgh bastion on site (refer appendix for expert biography) for evaluation and verification. Based on the feedback received, necessary modification and adjustment are made. This pre-visualisation process is very important before commencing with 3D modelling stage. This is to ensure that only finalised elements of the fortress will be modelled in 3D model. The final sketches based on divisions of Figure 4.10 are shown in the following figures. Based on these sketches the modelling of fortress elements in 3D were done accordingly.

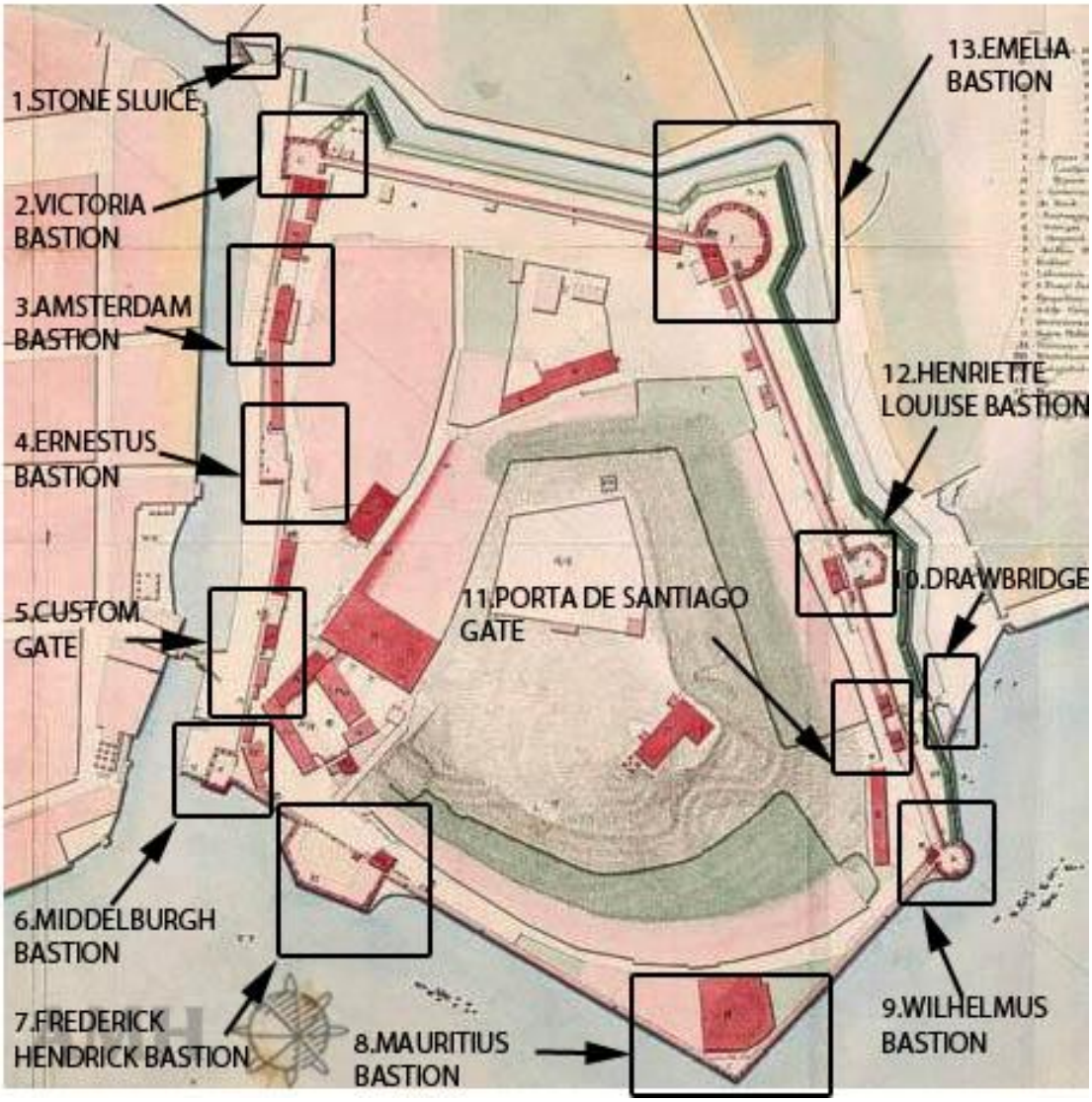


Figure 4.10 Sections of the drawing transformed into sketches (Source: NA,2007)

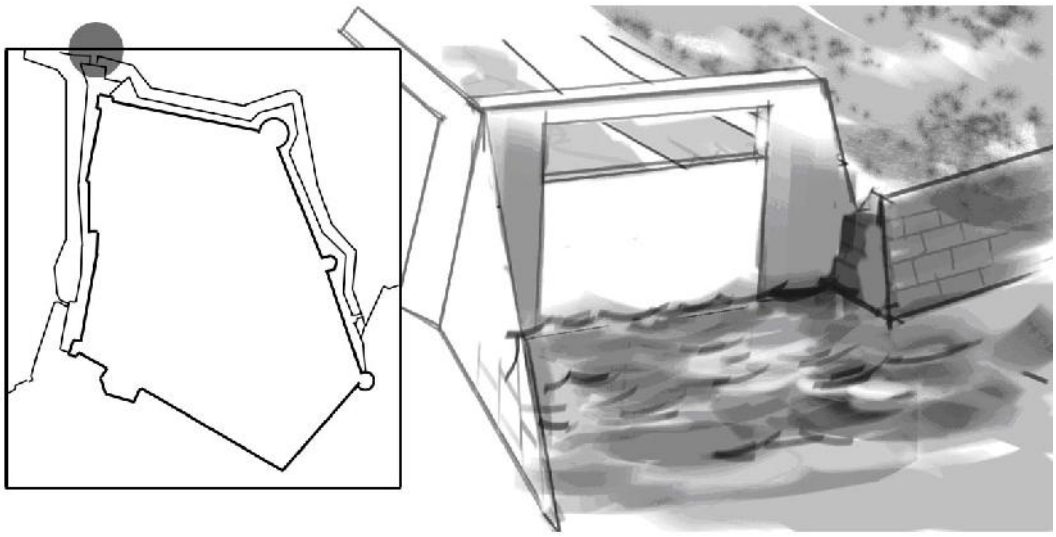


Figure 4.11 1: Stone sluice (Source: Author)

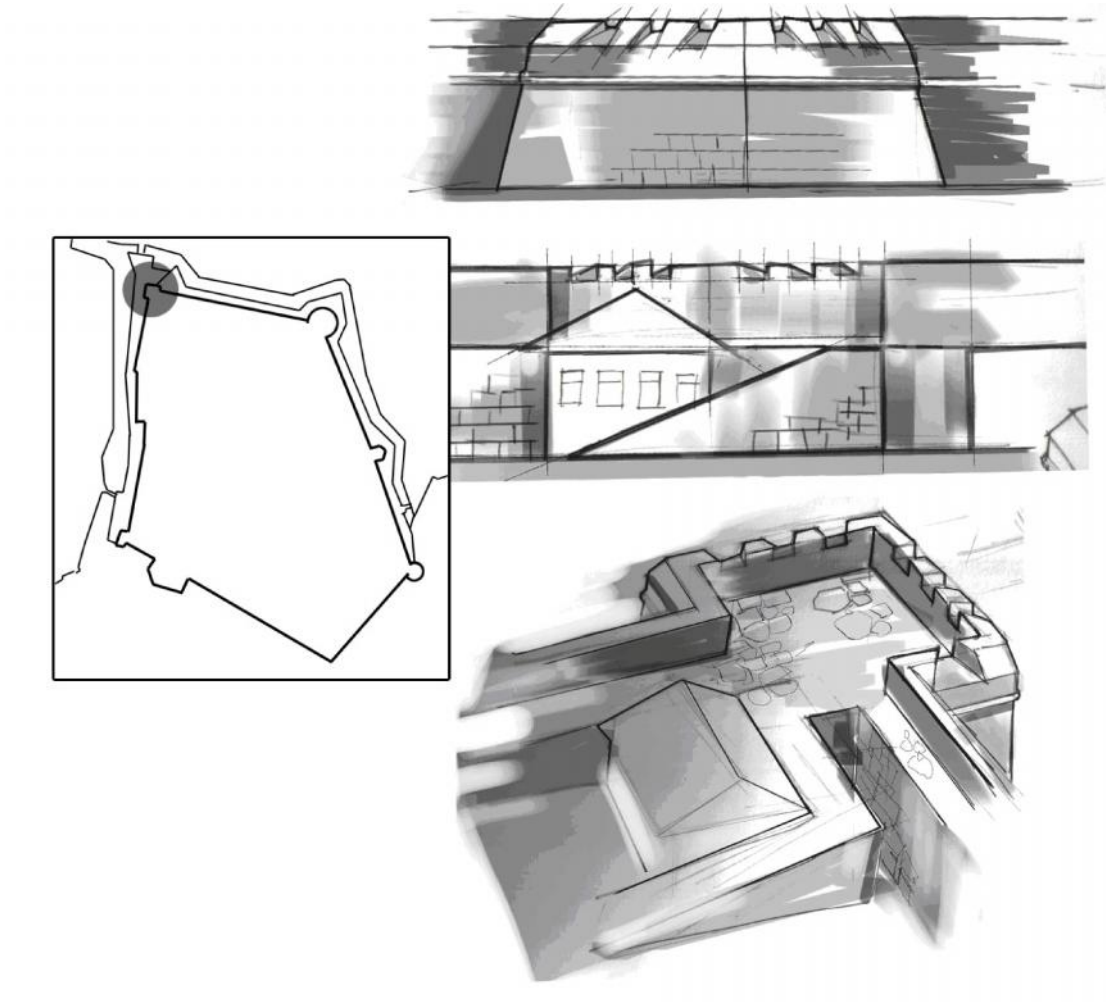


Figure 4.12 2: Victoria bastion (Source: Author)

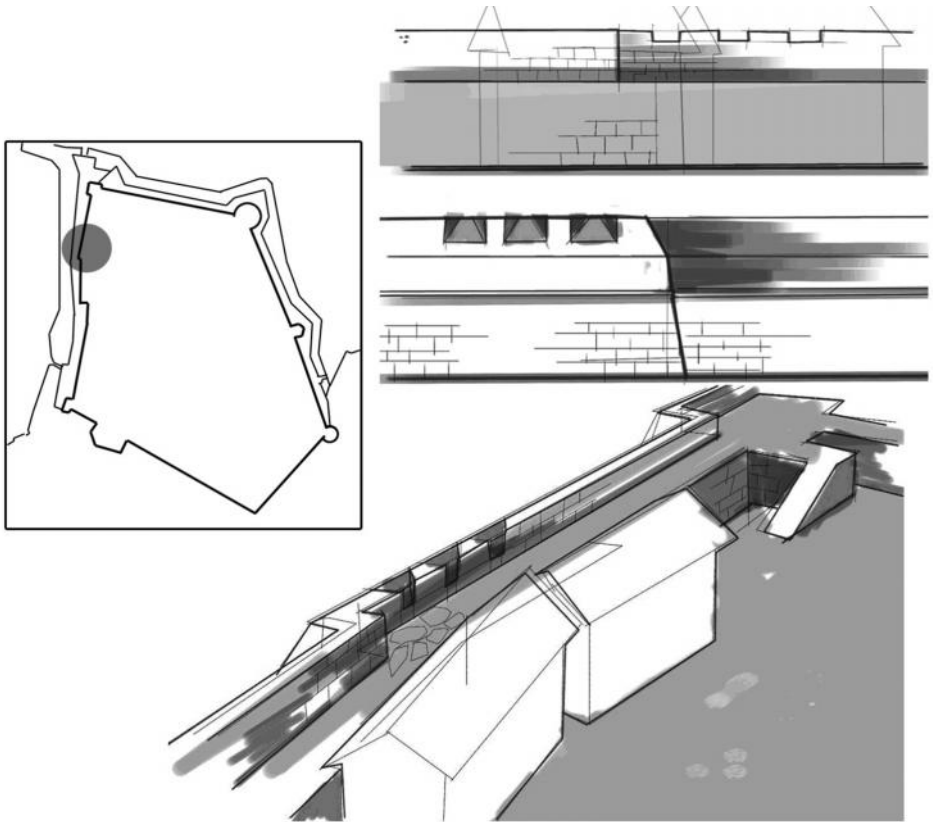


Figure 4.13 3: Amsterdam bastion (Source: Author)

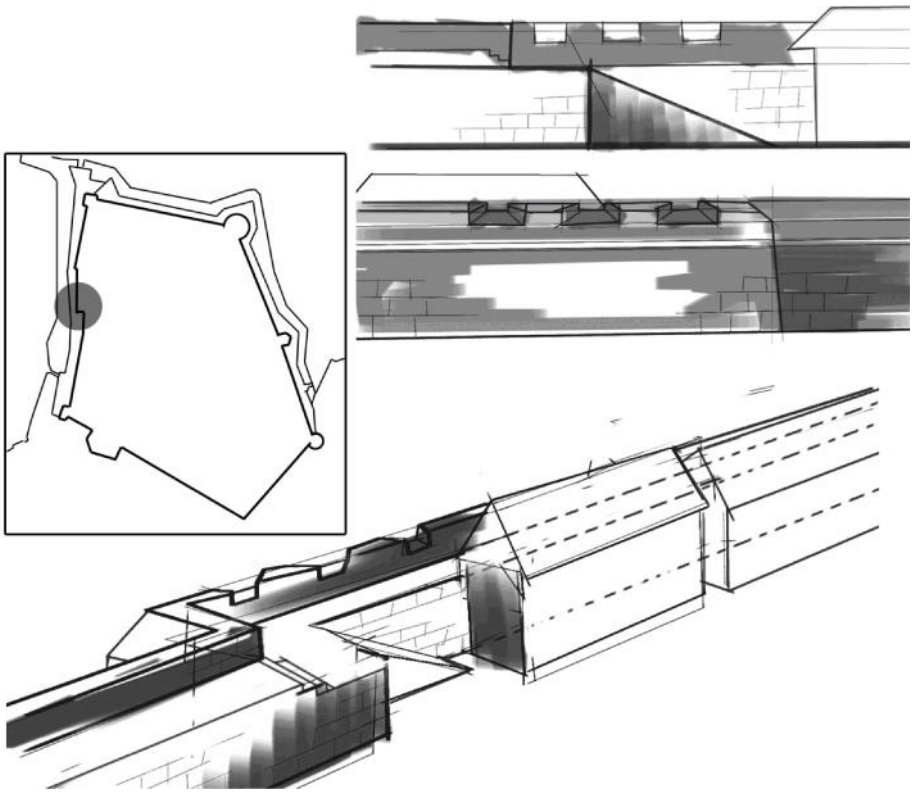


Figure 4.14 4: Ernestus bastion (Source: Author)

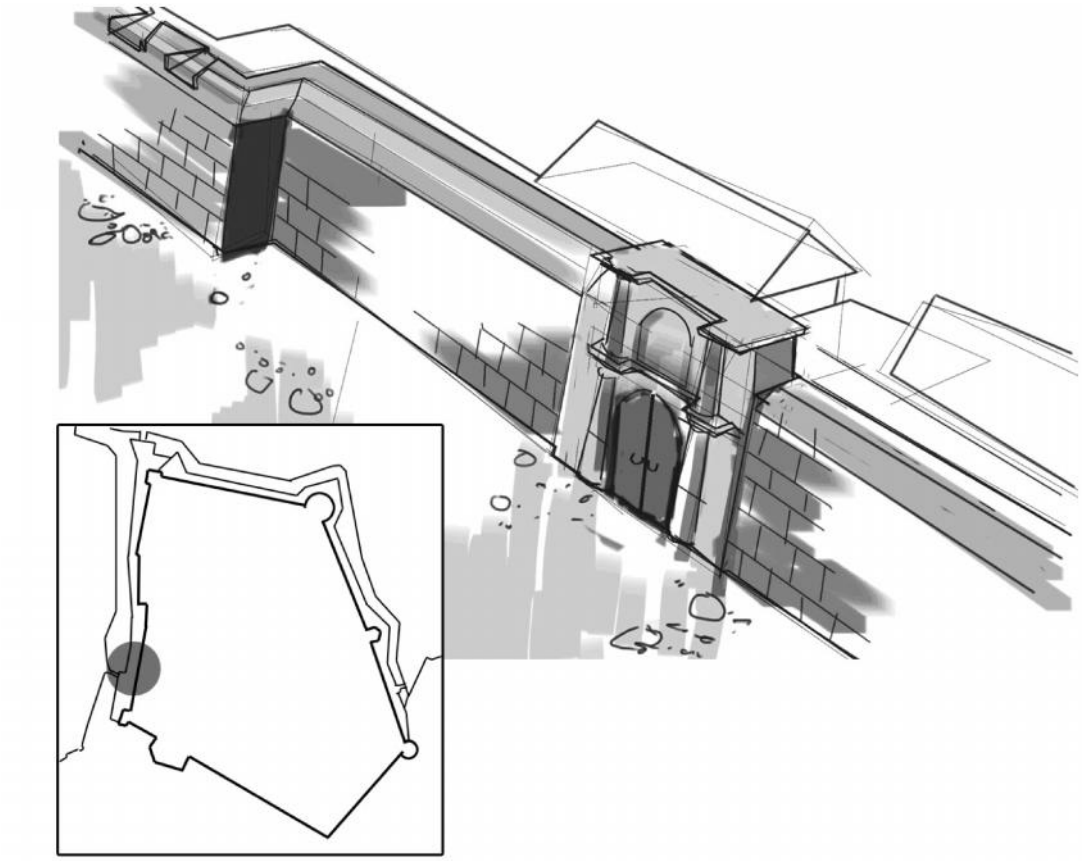


Figure 4.15 5: Custom gate (Source: Author)

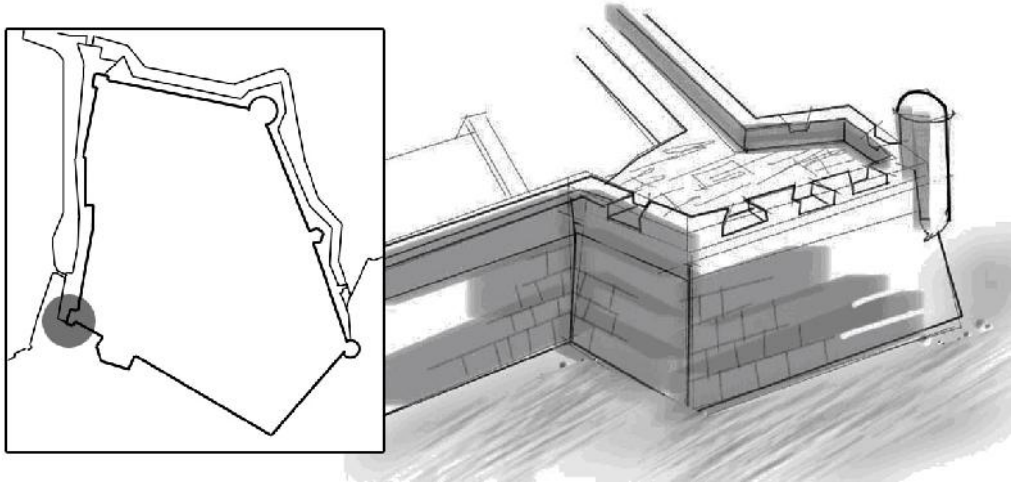


Figure 4.16 6: Middelburgh bastion (Source: Author)

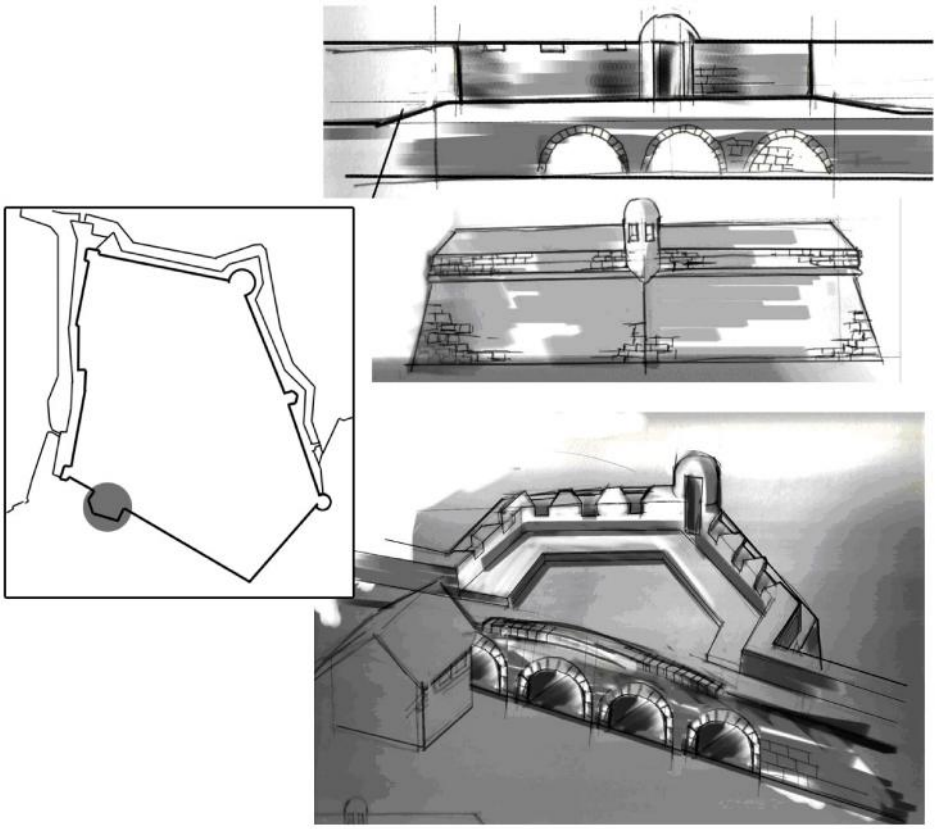


Figure 4.17 7: Frederick Hendrick bastion (Source: Author)

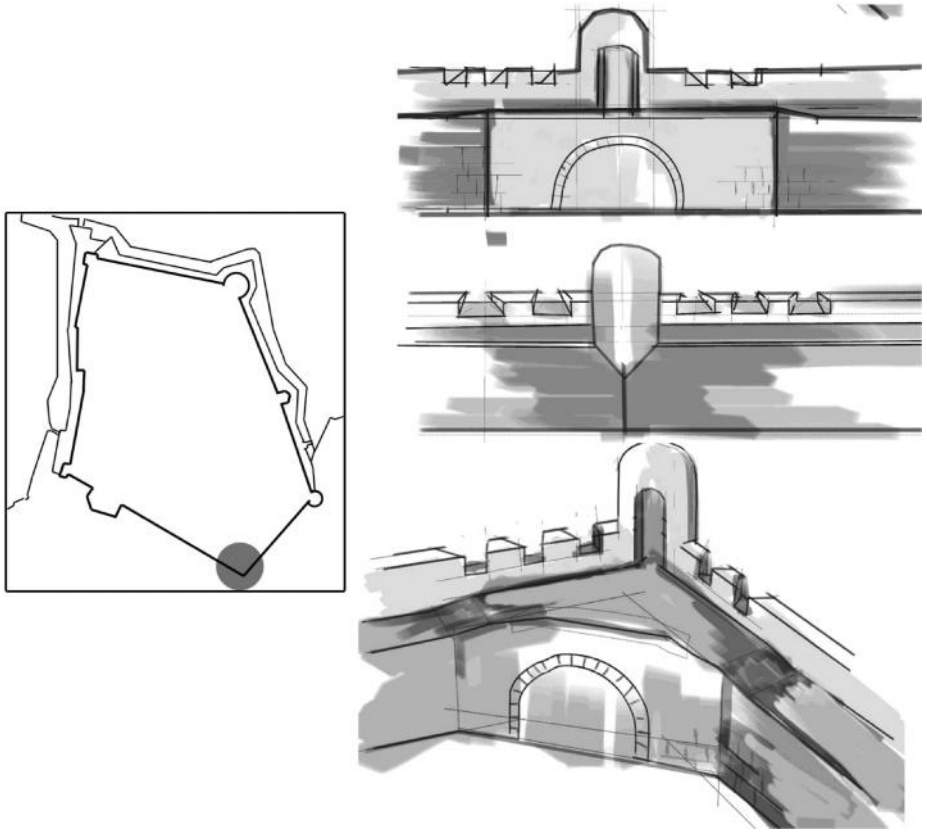


Figure 4.18 8: Mauritius bastion (Source: Author)

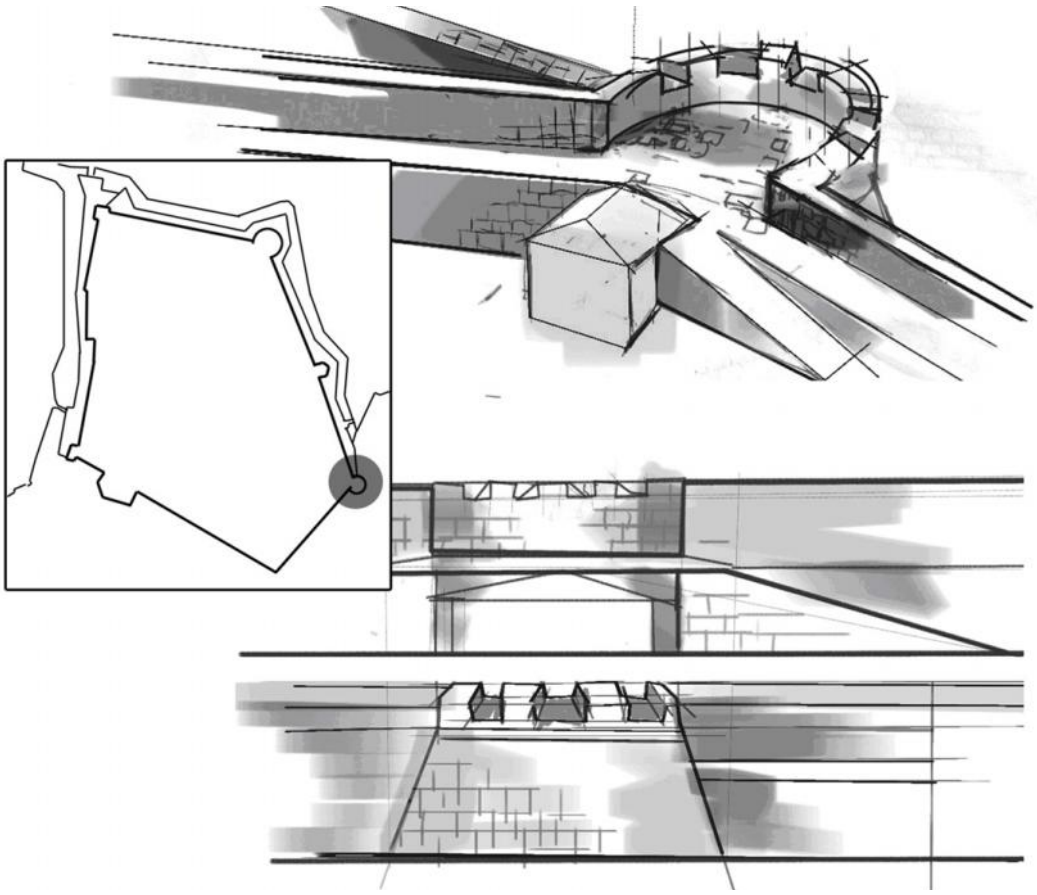


Figure 4.19 9: Wilhelmus bastion (Source: Author)

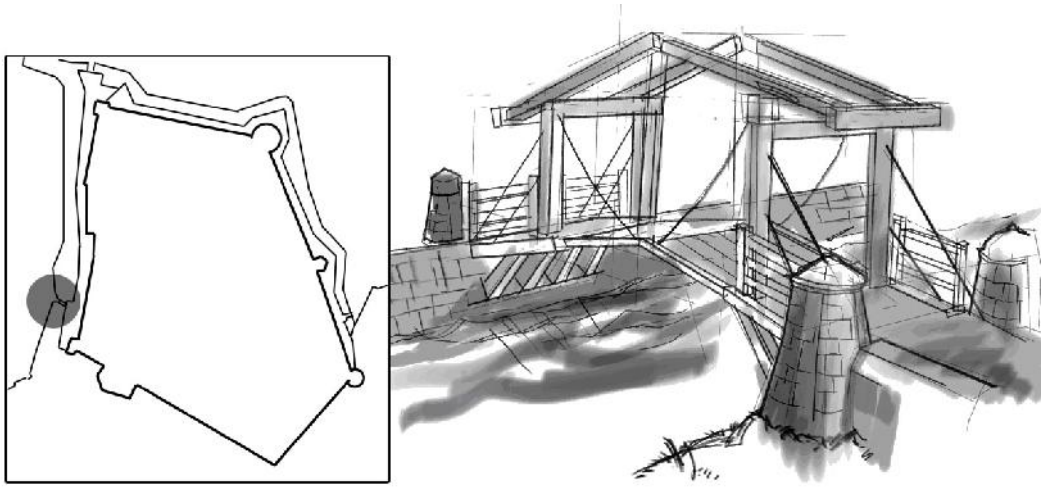


Figure 4.20 10: Drawbridge (Source: Author)

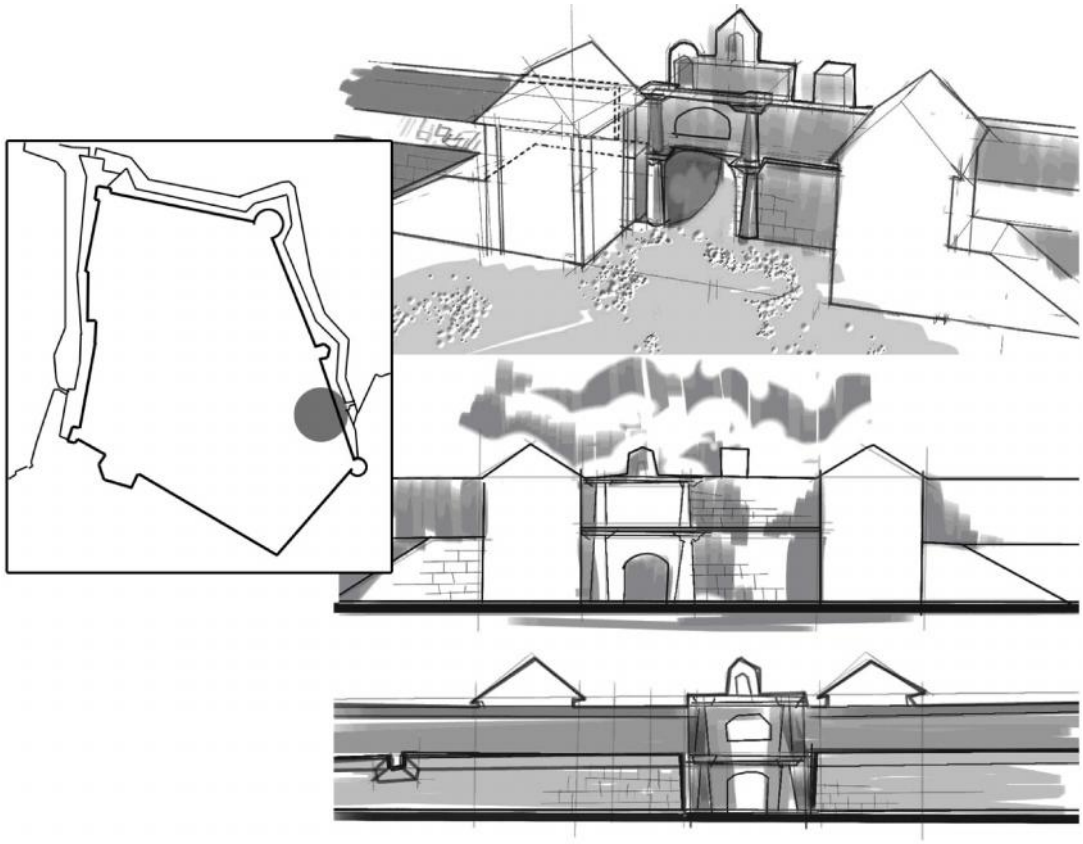


Figure 4.21 11: Porta de Santiago (Source: Author)

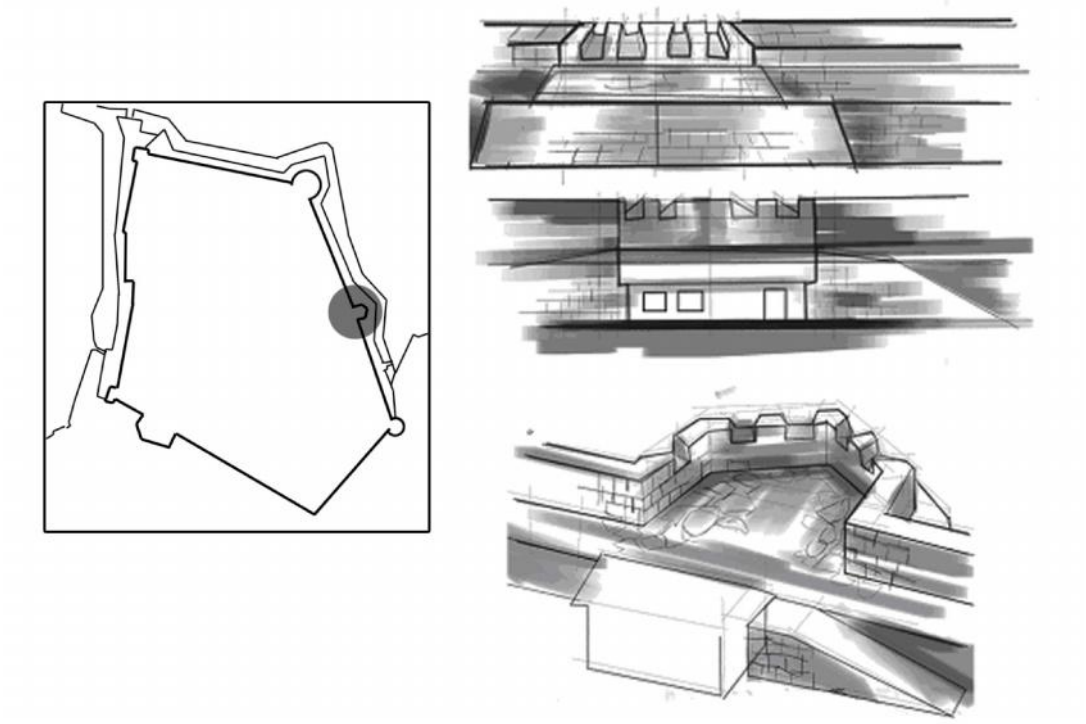


Figure 4.22 12:Henriette Louijse bastion (Source: Author)

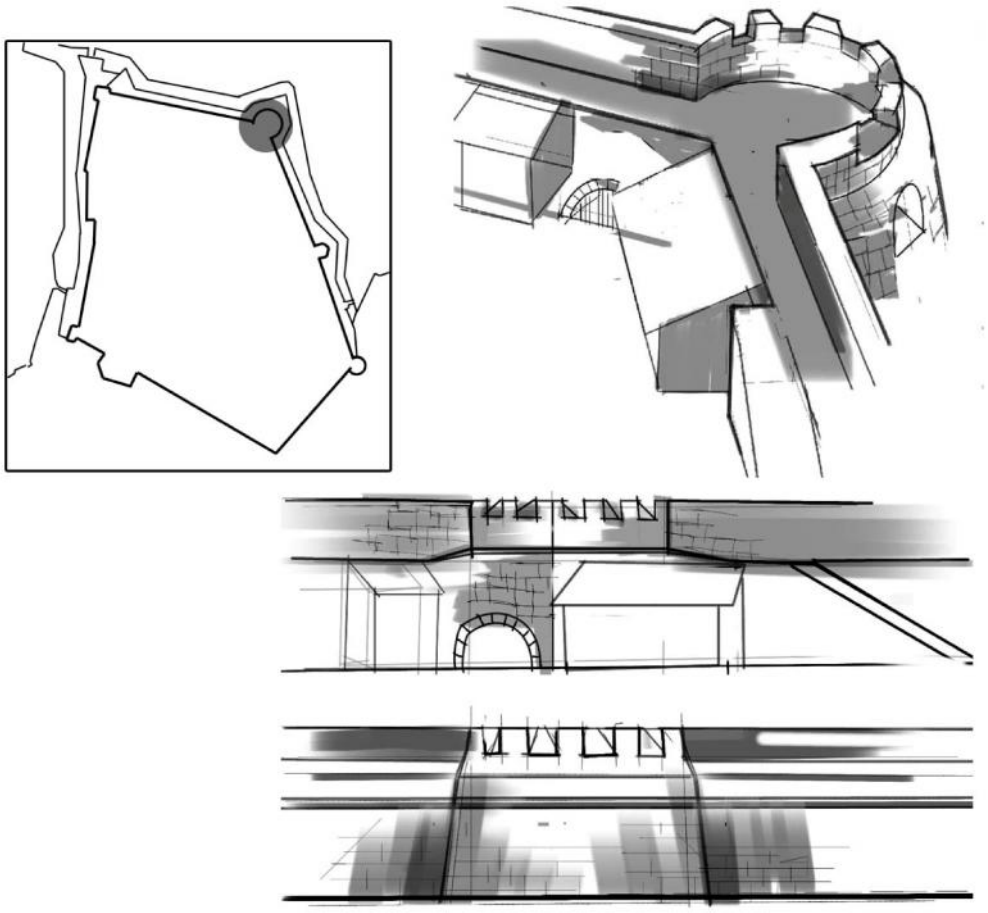


Figure 4.23 13: Emelia bastion (Source: Author)

4.2.2 Modelling of fortress wall in 3D

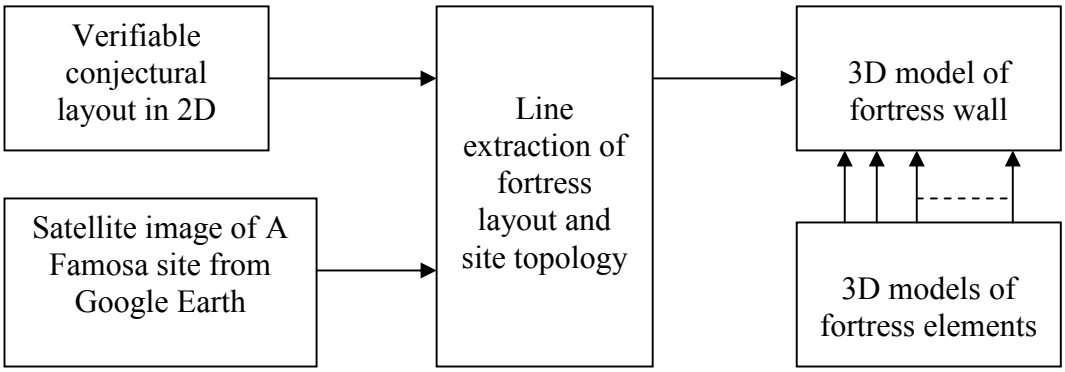


Figure 4.24 Modelling the fortress wall (Source: Author)

Figure 4.24 shows the process of modelling the fortress wall. To start the modelling process, the verified conjectural layout has been mapped onto the satellite image from Google Earth as shown in Figure 4.25. This is to match the location of the layout with the existing topology and mark the location of surviving existing building from the Portuguese and the Dutch era such as St. Paul church and Stadhuys. The information is then exported to line as shown in Figure 4.26 to be used in 3D application.

Figure 4.25 Overlay of conjectural layout of the A Famosa onto Google Earth satellite image (Source: Author)

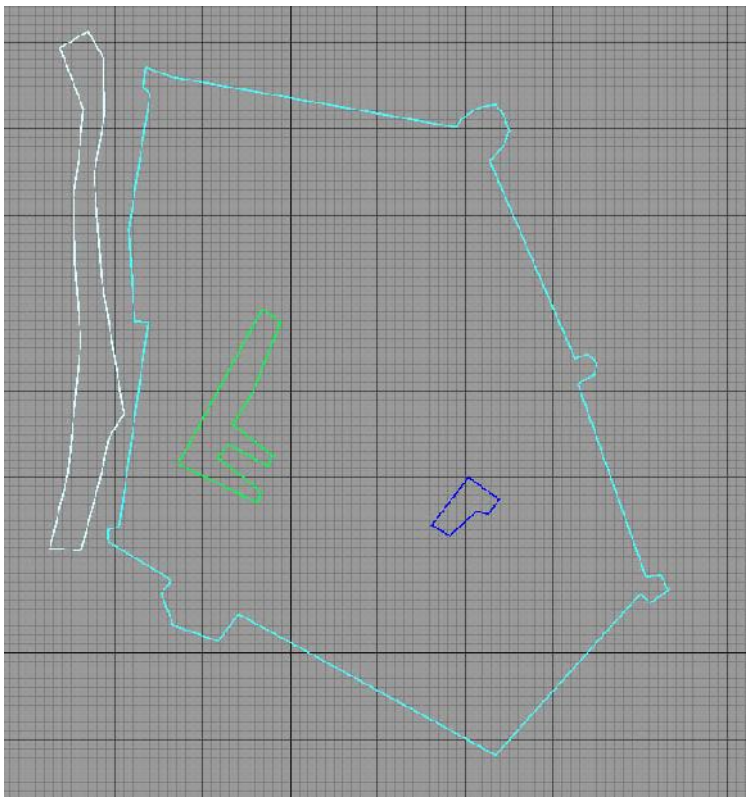


Figure 4.26 Extracted line from Figure 4.25 (Source: Author)

Figure 4.26 has been used as the base for the modelling process which started with the modelling of the fortress site topology. This involves modelling the river, the seaside of the fortress and the land. After that the fortress line is extruded to become the wall and the 3D model of the fortress elements such as bastion, gates, walls, ramps and passageway are then included. Since the fortress elements are modelled individually, hence any further details development and amendment can be done separately. Polygonal modelling has been fully used to model the entire 3D model.

To complete the 3D visualisation of this fortress, a mock up building models have been included inside the fortress. These buildings are not part of this research scope, however have been added for illustration purpose only. Figure 4.27 and 4.28 show the top view and the perspective view of the 3D model of A Famosa respectively.

Figure 4.27 Top view of the 3D model of A Famosa in 3D Studio Max (Source: Author)

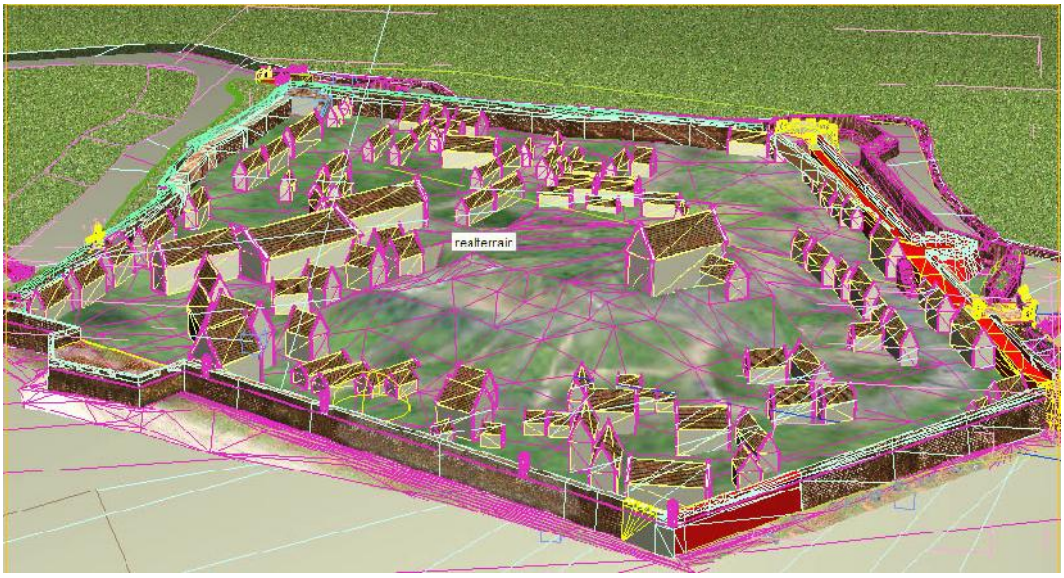


Figure 4.28 Perspective view of the 3D model of A Famosa in 3D Studio Max (Source: Author)

4.3 Completing the visualisation process

4.3.1 Texturing

Once the modelling process completed, textures are mapped onto polygonal surfaces. To control textures (Figure 4.29) individually, each elements are divided into several polygonal surfaces. Each polygonal surface has specific texture. To avoid repetitive textures and to create realistic look, textures have been created with various tones, patterns and styles. All of these textures are collected during the research fieldtrip to Sri Lanka and India. Manipulation of these textures is done in Adobe Photoshop. Final textured model is shown in Figure 4.30.

Figure 4.29 Samples of two different textures for walls (Source: Author)

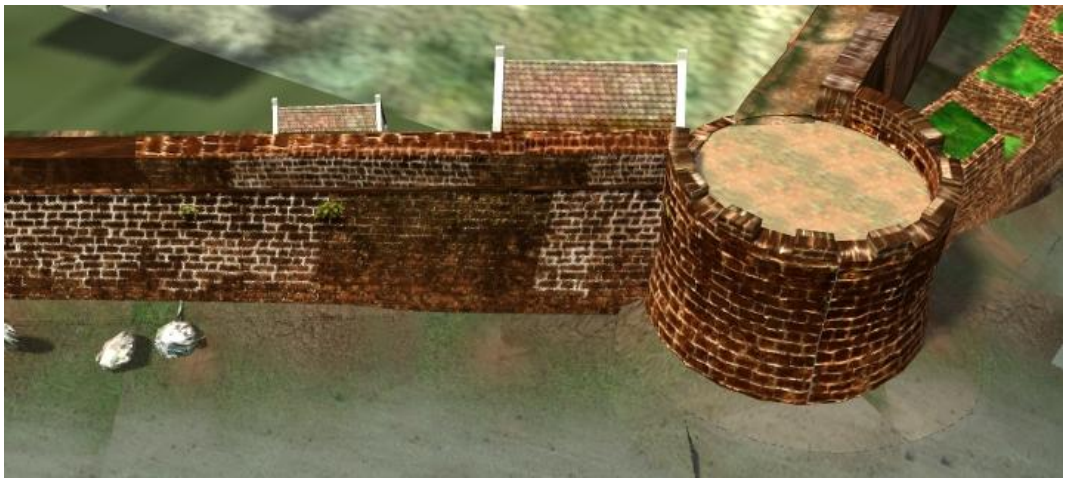


Figure 4.30 3D model with the texture applied (Source: Author)

4.3.2 Lighting and rendering

To create a complete output of 3D model, final approaches such lighting and rendering must be applied. With the advancement of lighting and rendering technology today, photorealistic rendering output can easily be achieved by using minimal 3D lights. This method is known as physical based lighting. It mimics the real lighting based on the real world. In this case two lights have been used known as Skylight and spotlight light as shown in Figure 4.31. To accomplish this, rendering method known as Mental Ray has been used. It uses global illumination approach to create a photorealistic output. Besides realistic lighting output it also produces a very soft shadow. This combination has given a very promising result to any projects that require realistic rendering output.

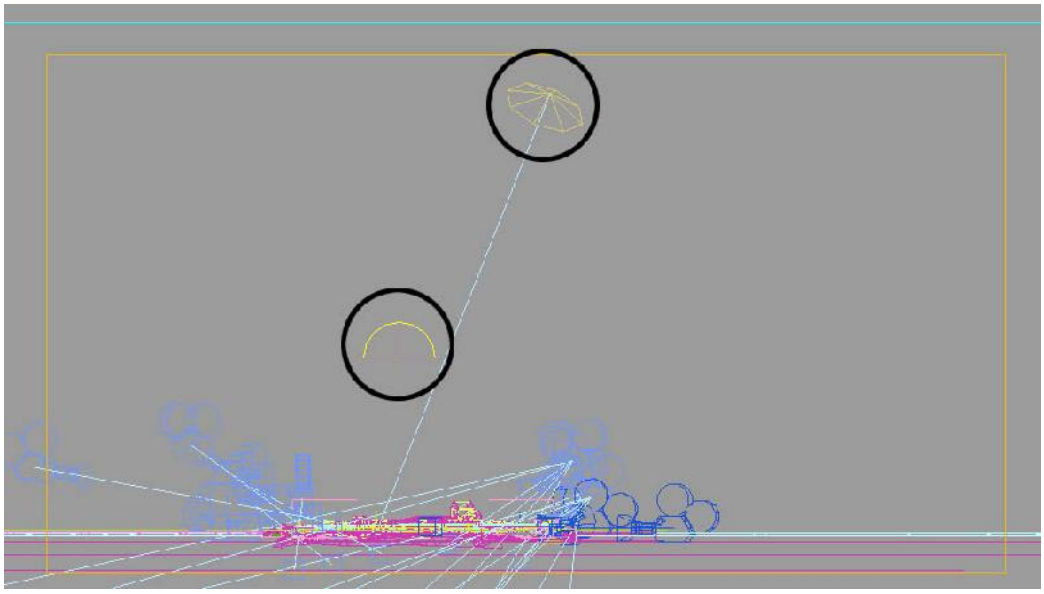


Figure 4.31 Skylight and spot light in final 3D scene (Source: Author)

Final rendering outputs are based on the framings of the 3D camera. Generally these framings are positioned in most significant locations such as bastions, gates, walls and overall look of the fortress.

4.4 Results and analysis

In general this section is divided into two parts:

i- Comparisons of the rendered images with the existing visual evidences such as selected plans for verification, drawings, paintings, reconstructed Middelburgh bastion and existing evidence such as Porta de Santiago gate.

ii- Rendered images of the significant locations in the fortress including interior and exterior parts.

4.4.1 Comparison of 3D images and 2D images

The idea of comparing these images is to match the best look of the existing evidences with the reconstructed 3D model of the fortress. It is hoped that by doing this, the accuracy of the depicted fortress is close to the real one. Comparison of the selected plans with the 3D reconstructed plan can be seen in Figure 4.32.

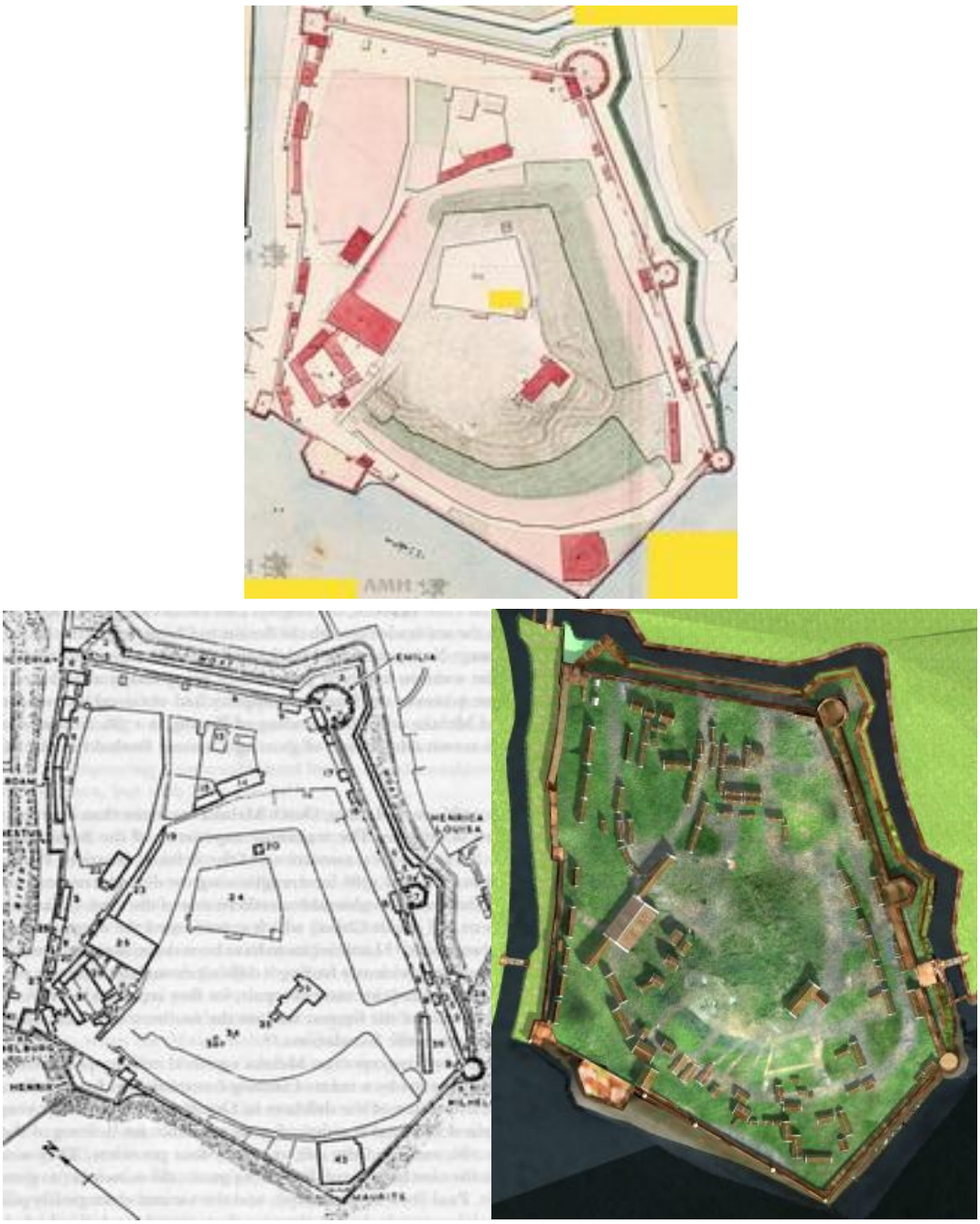


Figure 4.32 Comparison of the selected plans with the 3D reconstructed plan. From above 'Map of the city and fortress at Malacca, 1780' (Source: NA, 2008), below left ' Plan of Malacca fortress, ca. 1792, (after Reimer and Elias)' (Source: Harrison,1986) and below right '3D reconstructed plan' (Source: Author).

4.4.2 Still images of 3D model

Rendering of the fortress 3D model is categorized into two parts; comparisons with the existing evidences and painting and rendering of the significant parts of the fortress.

4.4.3 Comparison with the existing evidences and painting

Figure 4.33 shows the 3D rendering of Middelburgh bastion which has been referred to the reconstructed Middelburgh bastion in Melaka today.

Figure 4.33 Middelburgh bastion in 3D (above), Picture of Middelburgh bastion(below) (Source: Author)

Porta de Santiago gate is the only main remnant of this fortress. This gate is used as the main reference for reconstructing the remaining parts of the fortress. Figure 4.34 shows the present gate and 3D reconstructed gate.

Figure 4.34 Porta de Santiago gate : picture (left), 3D (right)(Source: Author)

Another element which is very difficult to visualise is Faussebraie. From the analysed plans of the A Famosa fortress, Faussebraie has been illustrated clearly in the drawings. Unfortunately to visualise this in 3D model is very challenging due to no existing evidence available. From the field trip to Galle fortress in Sri Lanka, it is found that this fortress still has its Faussebraie. Figure 4.35 shows the Faussebraie at Galle fortress and the rendered image of Henriette Louijse bastion with the Faussebraie. With data from the old A Famosa drawings and existing visual reference from the field trip, this 3D model of the Faussebraie has successfully been reconstructed.

Figure 4.35 Fausse-braie at Galle fort in Sri Lanka (above) being used as a reference for modelling Fausse-braie at A Famosa fort (below)(Source: Author)

In final comparison, two drawings of the fortress have been selected for reference of 3D rendering from the sea view (Figure 4.36). Although the drawings are not consistent, the main idea is to compare and to get an idea how it looks from long distance.

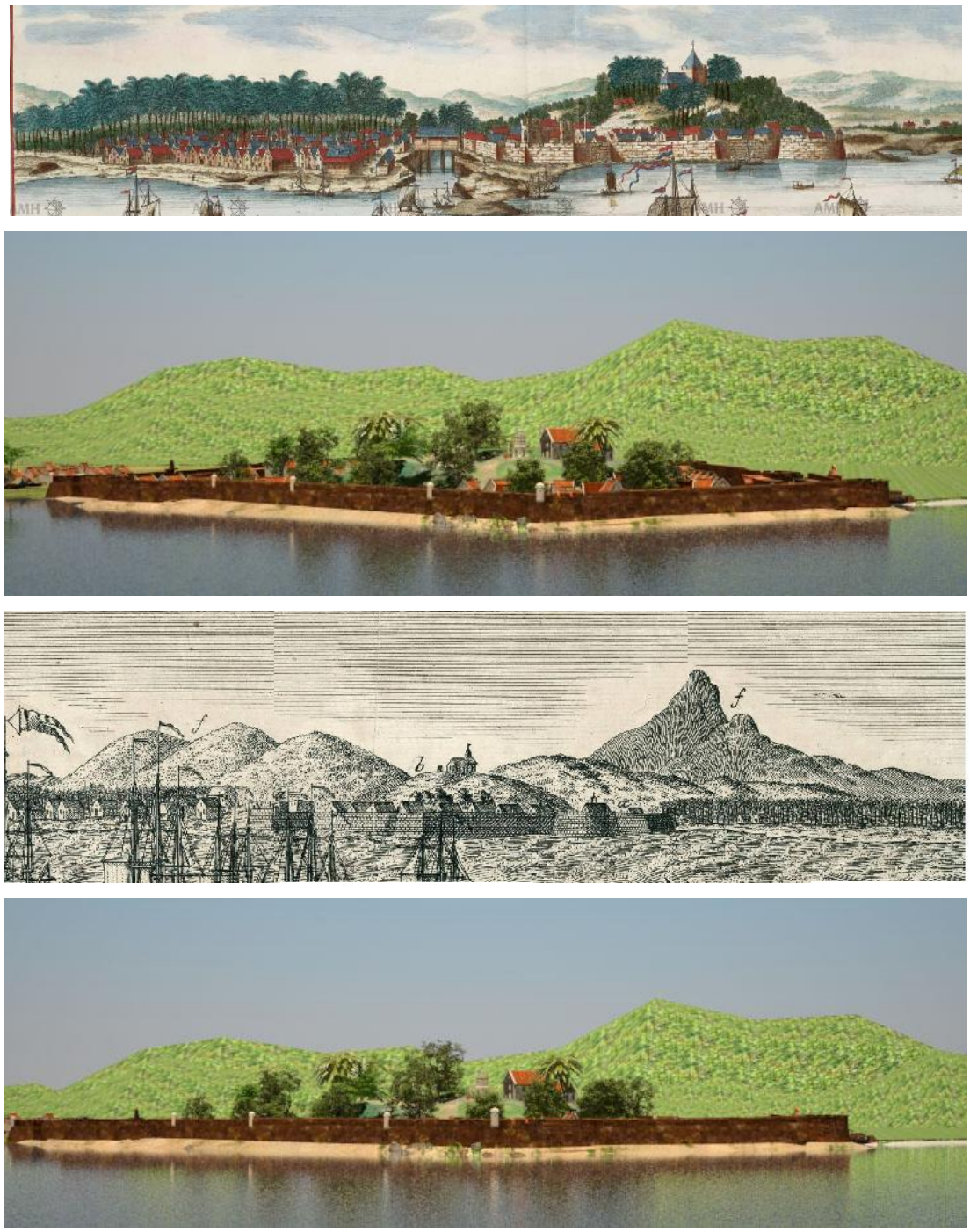


Figure 4.36 Rendering from the sea point of view based on existing drawings (Source: Author)

The drawings show the historical topographic view of the fortress from artist's perception. In this comparison, 3D model of the A Famosa has been rendered from a view as identical as possible to each topographical view. It is noticeable that the hill within the fortress is slightly lower compared to two drawings. This is based on

present hill height in |Melaka today. The hilly background for these two drawings are different from each other, hence for 3D model, it is placed for illustration and context purpose with the environment only. It is very difficult to project exactly based on the drawings due to different perspective vanishing points have been used by the artists.

4.4.4 3D rendering of the fortress elements

This section presents the selected 3D rendering of the fortress based on important elements such as bastions, walls and gates. These images will give a better idea about the look of these elements in 3D visualization medium. The images rendered here are still open for future development, suggestions and amendments. Architectural details are based on previous findings and comparison with other fortresses.

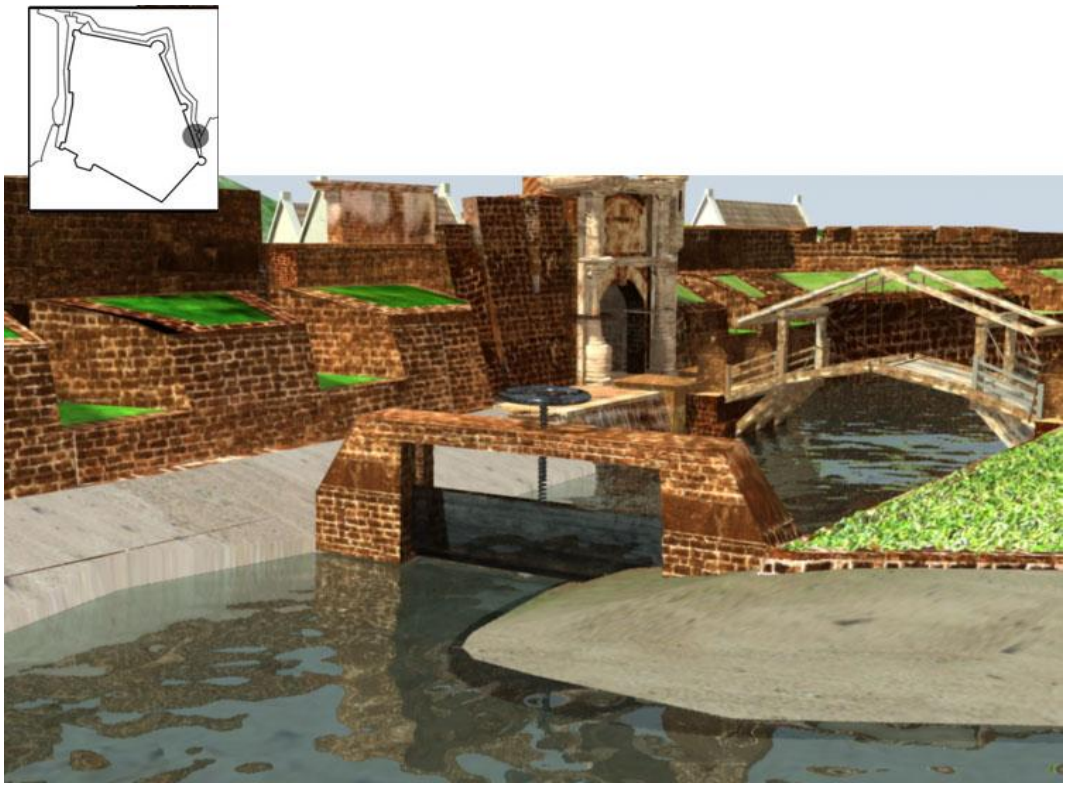


Figure 4.37 Stone sluice (Source: Author)

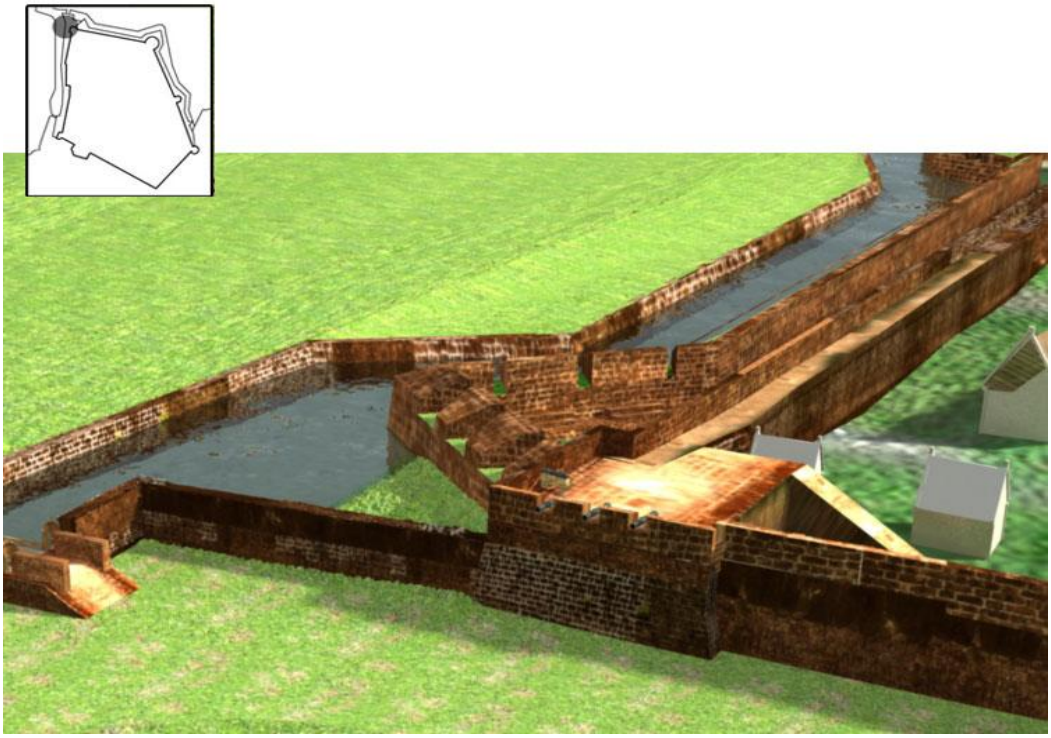


Figure 4.38 Victoria bastion (Source: Author)

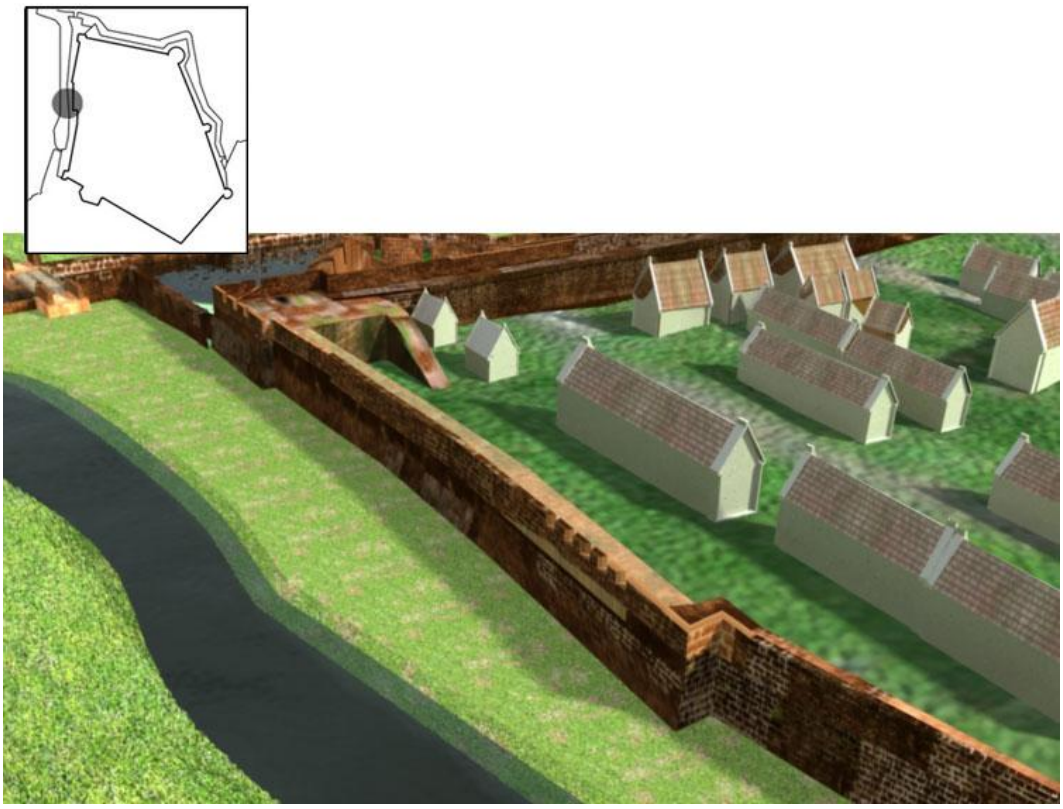


Figure 4.39 Ernestus bastion (Source: Author)

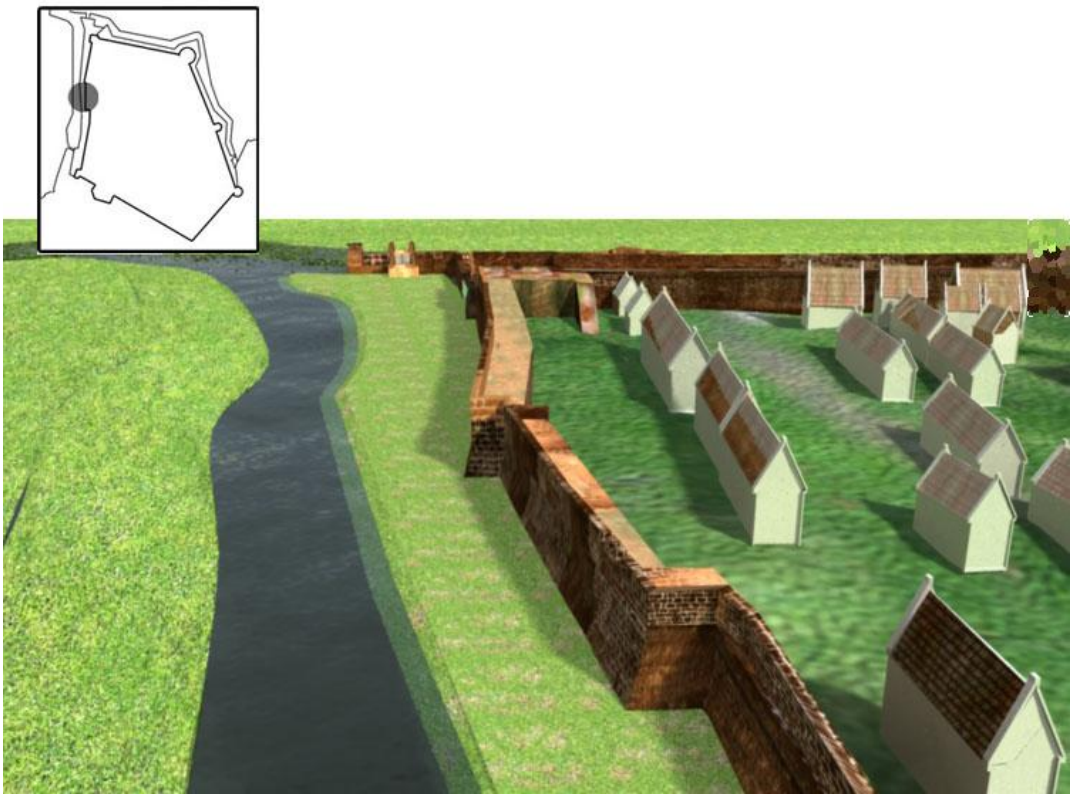


Figure 4.40 Amsterdam bastion (Source: Author)

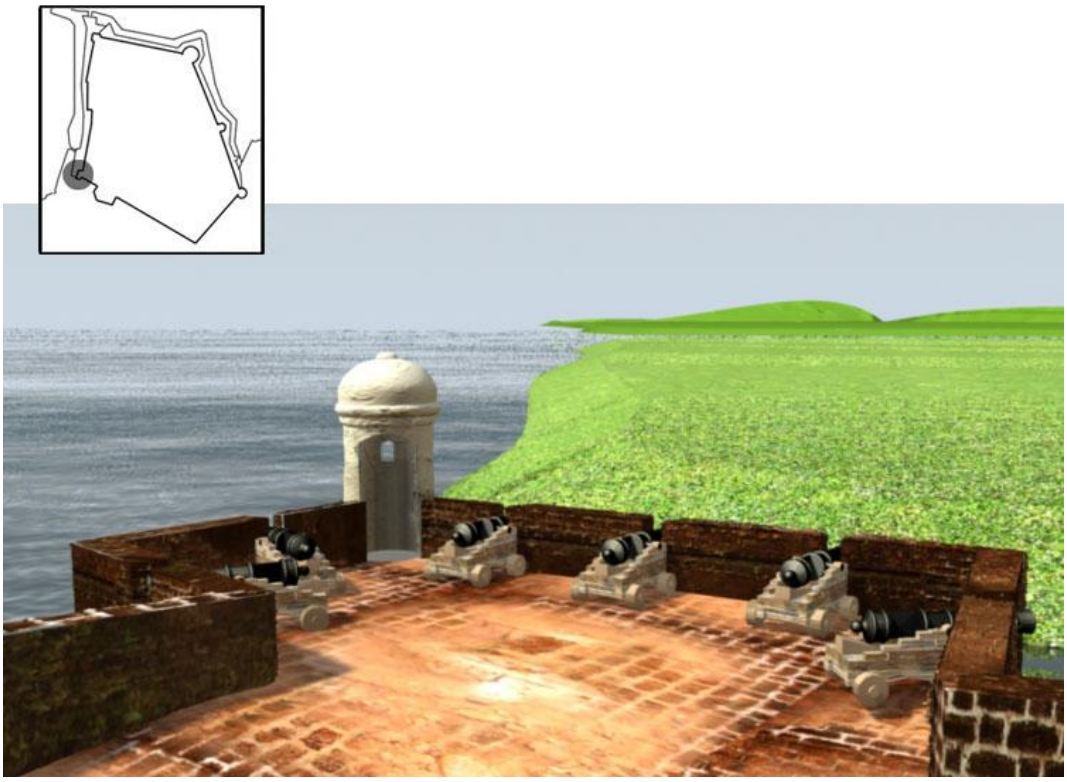


Figure 4.41 Middelburgh bastion (Source: Author)

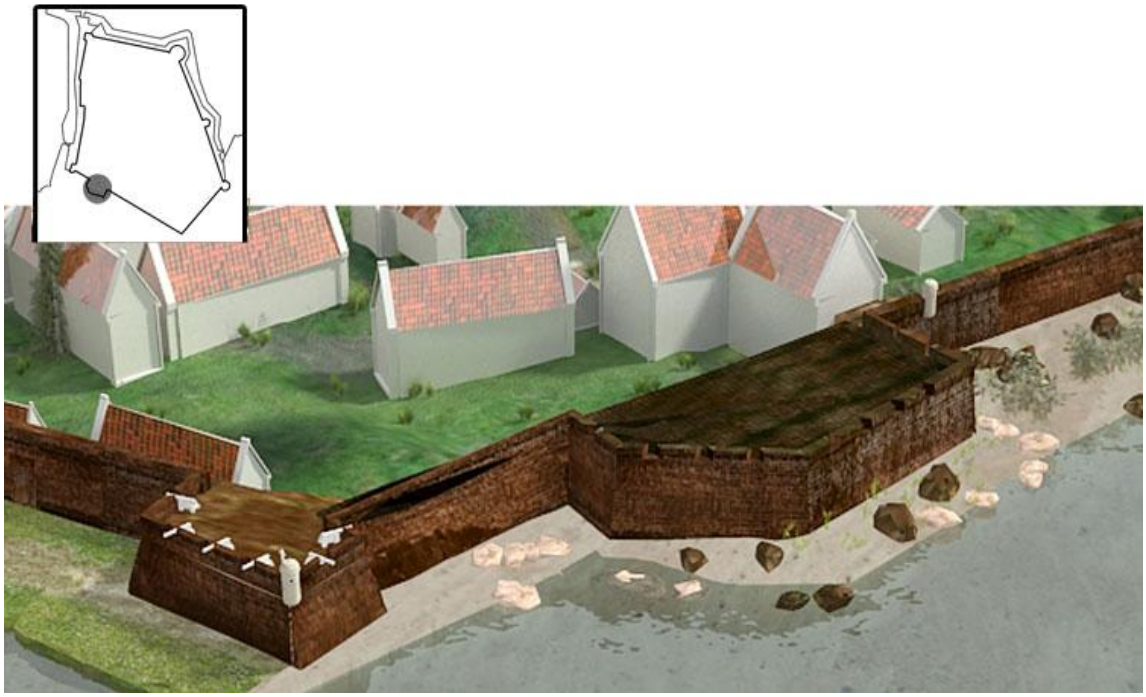


Figure 4.42 Frederick Hendrick bastion (Source: Author)

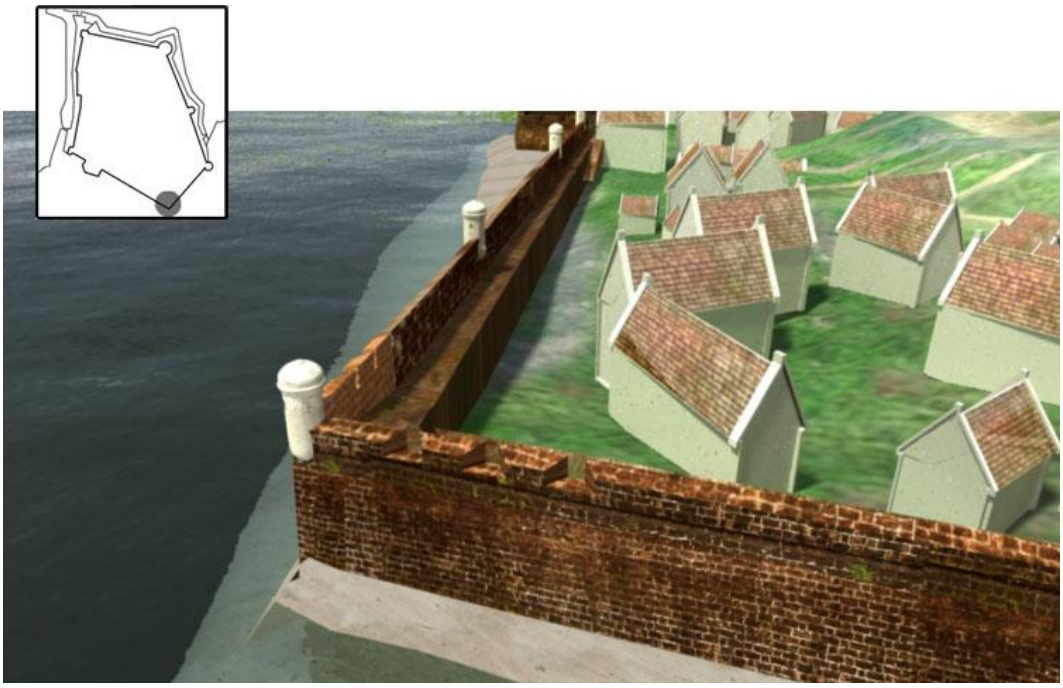


Figure 4.43 Mauritius bastion (Source: Author)

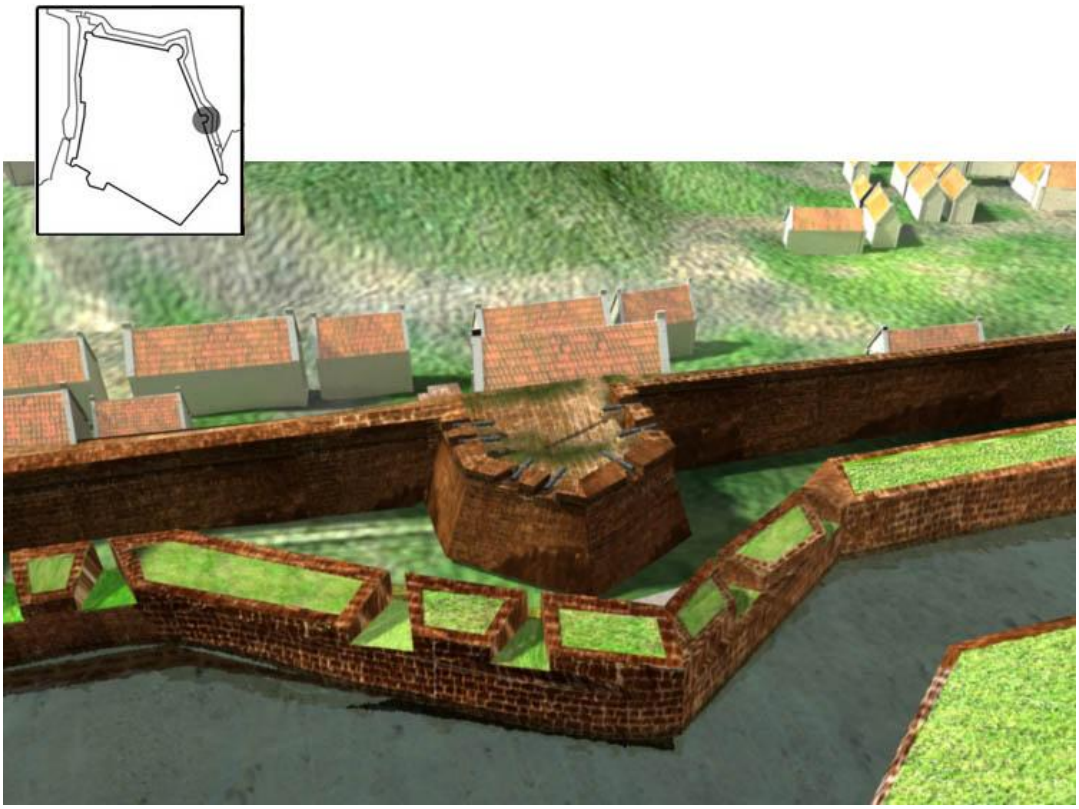


Figure 4.44 Henriette Louijse bastion (Source: Author)

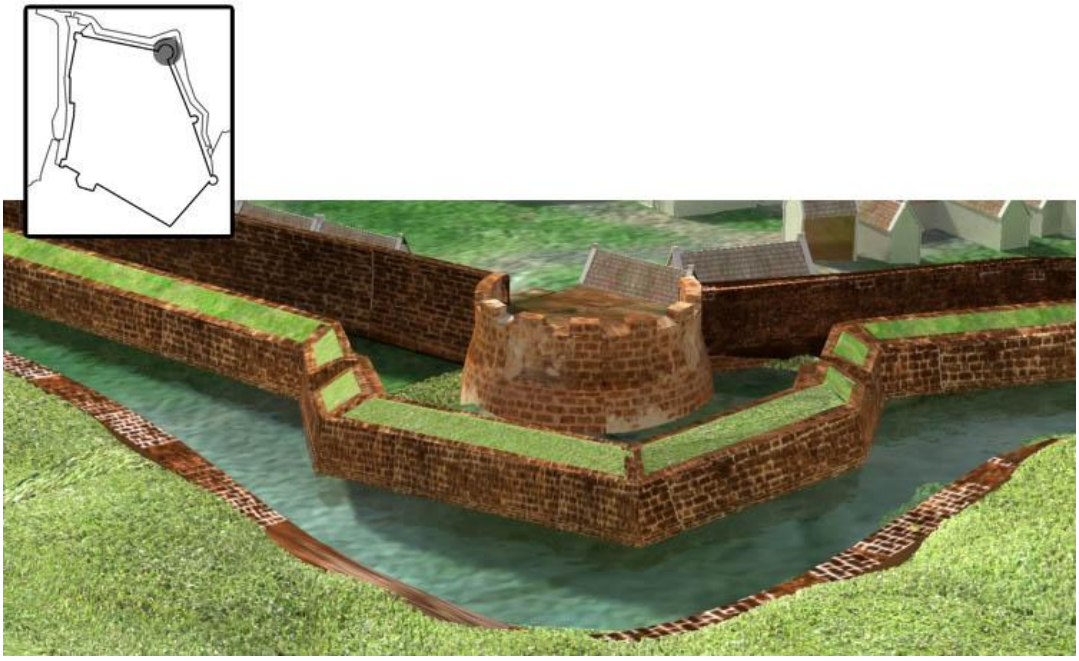


Figure 4.45 Emelia bastion (Source: Author)

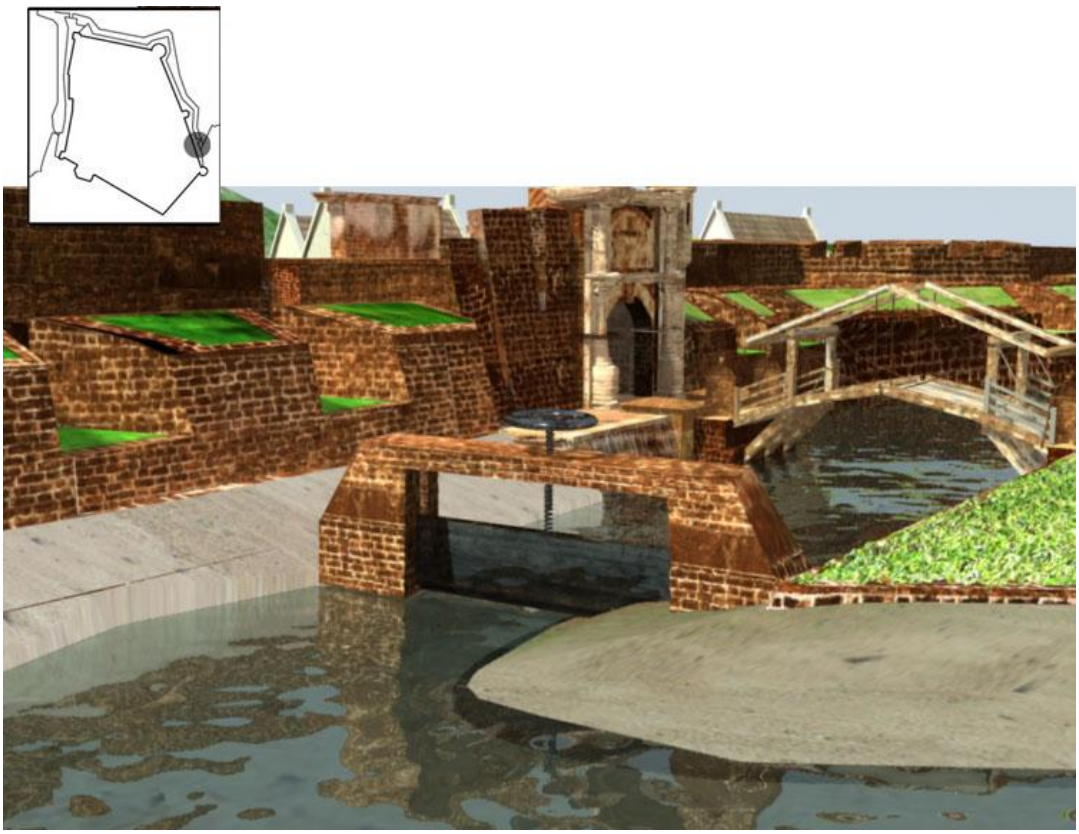


Figure 4.46 Drawbridge at Porta de Santiago gate (Source: Author)

4.5 Summary

This chapter begins with a study on three digital reconstruction projects which have similar issues and situation with the A Famosa fortress. Several aspects have been considered such as availability of the subject matter, project objectives, methodoloy adopted and solutions. These reconstruction projects are Michelsberg synagogue, The Jewish Quarter in Regensburg and Reconstruction of the old main church in Curitiba, Brazil. The summary from these projects is used as a guideline and this has significantly contributed for reconstructing 3D model of the A Famosa. It is found that each project has its own research flow, uniqueness and solutions.

From here all of the collected data are transformed into sketches for visual reference before commencing with the 3D modelling stage. This pre-visualisation stage is very crucial to avoid any unnecessary adjustment during 3D modelling process. Besides 2D data and textual description, this pre-visualisation stage is supported by visual reference from research field trip. Important elements such as bastions, gates and

walls are extracted from the finalized reference plan of the A Famosa fortress. These extractions allow more detailed pre-visualisation and architectural study can be done. The result demonstrates a set of pre-visualised sketches are prepared for comparison and reference of 3D modelling stage.

3D Studio Max has been used for the entire visualisation process from modelling, texturing, lighting and rendering. The visualisation process started by mapping the verified conjectural layout onto satellite image from Google Earth. This is to ensure it matches with the existing remnants and topology. Finally it has been exported as line and being used as a foundation of 3D modelling process. This includes the modelling of the river, the seaside and the land. The details of the fortress elements such as bastions, gates, walls, ramps and passageway have been added accordingly. The entire modelling process uses polygonal modelling technique. To create a context with the surrounding, mock up buildings have been added.

The next stage is texture mapping which fully utilises textures from the field trip study to the related fortresses. By using existing fortress textures allows achieving a realistic rendering output. The final stage in 3D visualisation process is lighting and rendering. Using physical based lighting allows the final result looks realistic compared to standard rendering. Global illumination rendering has been applied by using Mental ray renderer in 3D Studio Max. Framing of the rendered scenes has been done by adding several cameras focusing on each element.

Final rendered images have been presented based on comparison with the existing evidences and significant fortress elements. The entire 3D model reflects the fortress in 1678 as described in Bort's report. The fortress remained in this final form until its destruction by the English in 1807. The representation of this fortress in Plan A dated around 1780 and Plan B dated around 1792 is consistent with this model. For more realistic rendering outputs, it is undeniable that the entire scene is still lack supporting element such as trees, houses and additional architectural details. Since the 3D reconstruction only focuses on the fortress, other additional details can be added in future development for more advanced realistic outputs. The next chapter will discuss

about the evaluation to gauge respondents' knowledge on the A Famosa fortress and its significance.

Chapter 5

EVALUATION

The aim of this evaluation is to gauge respondents' knowledge on A Famosa particularly before and after watching the 3D model and to identify the importance of digital preservation of A Famosa in 3D. The result would justify the importance of further development of the 3D model applications to be used in fields such as education, research and tourism in Malaysia.

5.1 Experimental set up

The evaluation has adopted objective and subjective assessment and was conducted in two higher educational (HE) institutions namely Multimedia University and Darul Iman University in Malaysia. The questions in this survey have been designed with the assumption that the respondent at least have heard about A Famosa previously so that some indication on knowledge gain can be made. Since historical subject pertaining to A Famosa has been taught as part of Malaysia curriculum thus, it is decided that the respondents from HE institutions in Malaysia will fit into the criteria, A total of 50 respondents have participated in the evaluation. 30 respondents were from Multimedia University and the remaining 20 were from Darul Iman University.

The evaluation was divided into 2 sections. Each evaluation session took 1 hour of presentation and evaluation. During the first section, a brief introduction on the project was presented to the respondents and followed by a pre-questionnaire to get some information on the respondents' initial knowledge of A Famosa and their initial opinion on the importance of A Famosa as a historical relic.

In the second section, a video presentation showing a brief history of A Famosa and the complete fortress in 3D model was presented to the respondents. This was followed by a post questionnaire to identify if there is any increase interest or knowledge on A Famosa compared to the previous questionnaire answers and also to get the respondents' opinions and suggestions on the project. The workflow of the survey is illustrated in Figure 5.1. A snapshot of the video presentation on A Famosa in 3D model is shown in Figure 5.2.

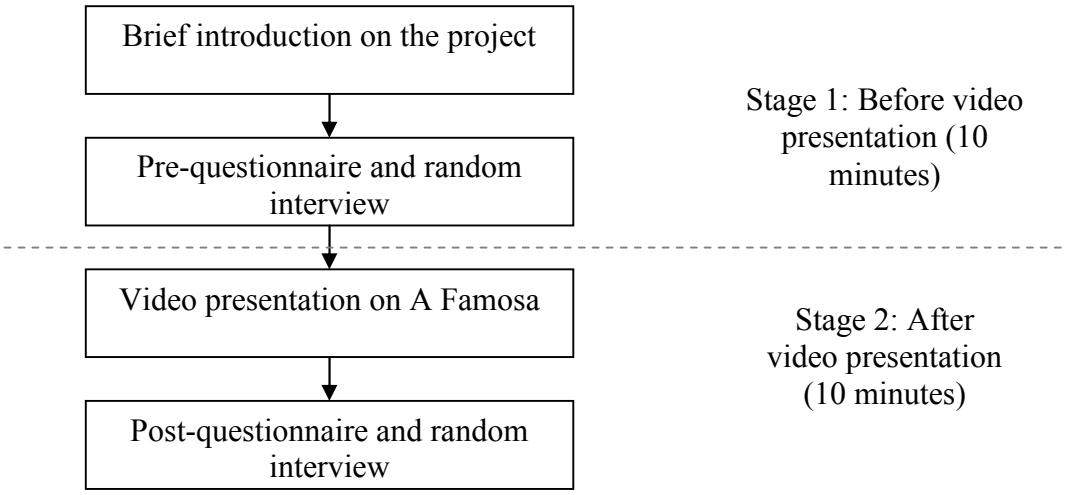


Figure 5.1 Workflow of the evaluation (Source: Author)

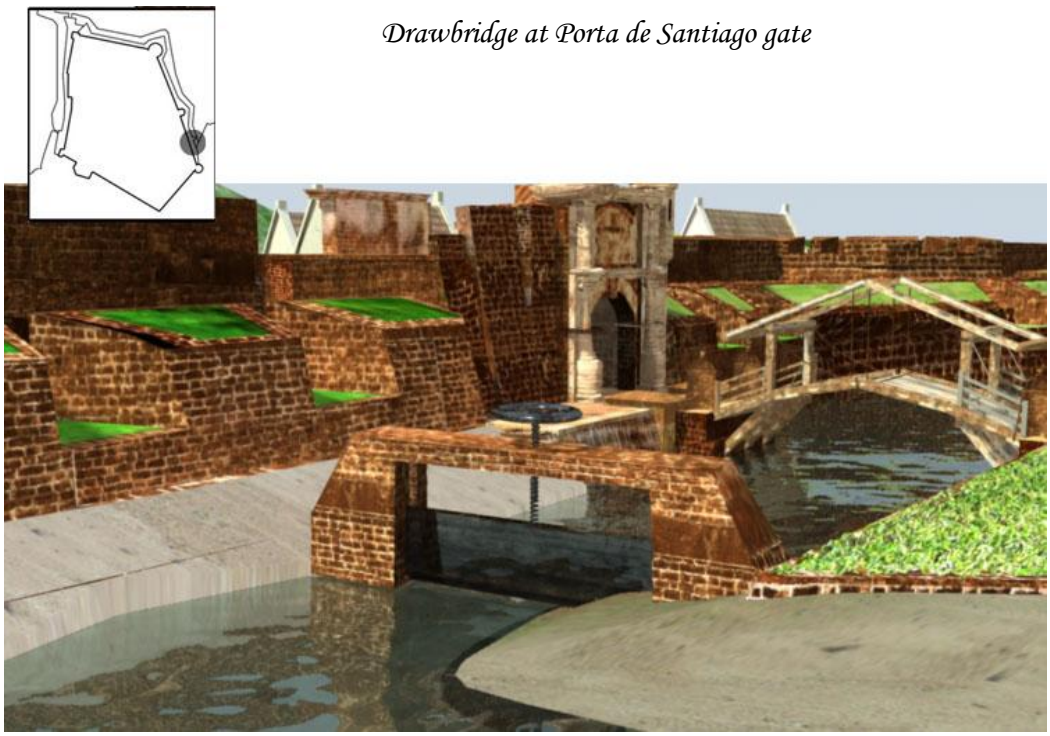


Figure 5.2 A snapshot of the video presentation of A Famosa in 3D (Source: Author)

Initially, the evaluation is conducted manually by visiting selected academic institutions in Malaysia. The advantage of this approach is that beside the response from the survey, some interviews can also be conducted to get further response pertaining to the survey questions. However, to get more global response an online web survey using the same format has also being set up.

5.2 Result and Analysis

In the first part of the survey, it explored the background of the respondents. This information is important to ensure the reliability of the survey result. Since most of the survey is conducted at selected academic institutions in Malaysia, majority of the respondent (88%) consists of students. Another reason for choosing the respondents from academic line is because it is intended to explore the possibilities of applying the 3D model in education. Another group of the respondents came from general (4%) and academic (8%). This result is shown in Figure 5.3 and the bar chart in Figure 5.4

shows the distribution between local Malaysian and non-Malaysian for each category. In general 86% are local people and 14% are foreigners.

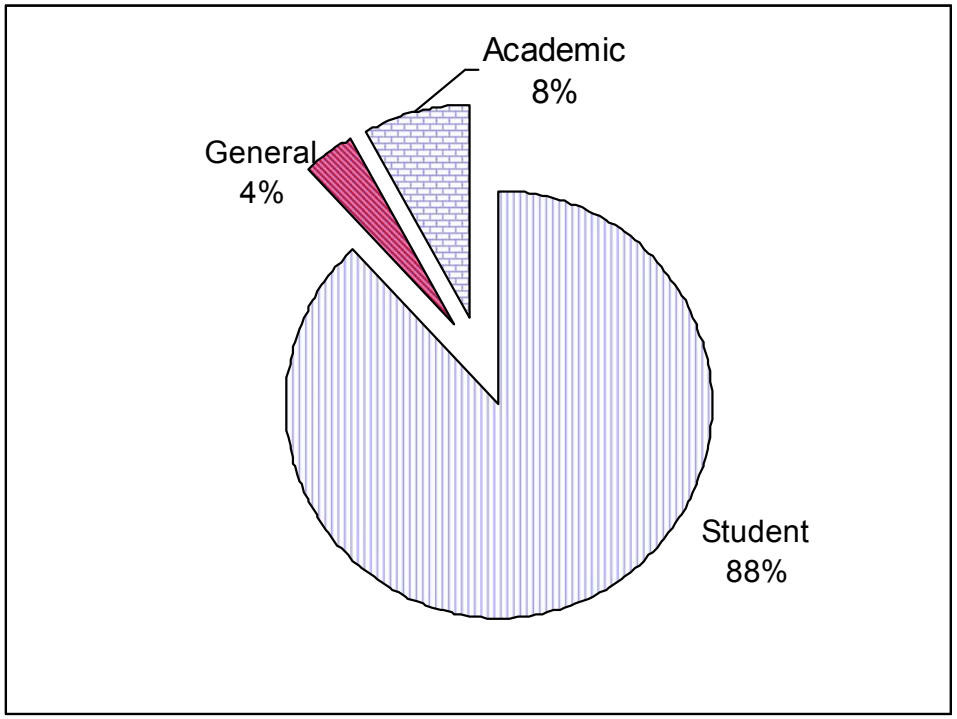


Figure 5.3 Pie chart showing the background of the respondents in percentage

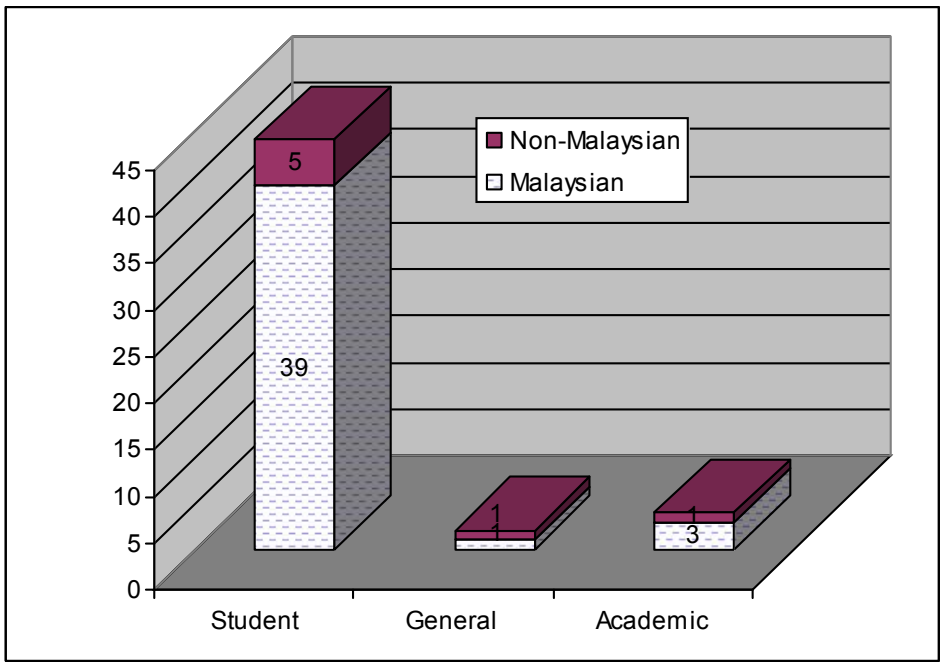


Figure 5.4 Bar chart showing the actual figures of the pie chart above

The results of the survey are discussed in 5 points, namely:

i- Knowledge on the history of Melaka and A Famosa

ii- The importance of A Famosa as a historical relic

iii- Suitable method for preservation: physical or 3D

iv- Feedback on the 3D model of Famosa presentation

v- Suggestion for future improvement of 3D model

The first 3 points are gathered from pre-questionnaire answers and the remaining two are from the post-questionnaire answers.

5.2.1 Knowledge on the history of Melaka and A Famosa

When asked about the knowledge on the history of Melaka and A Famosa, 44% of the respondents have brief knowledge about A Famosa, 48% have a moderate knowledge and only 8% of the respondents knew thoroughly about the history. The result is shown in Figure 5.5. Further interviews with the respondents showed that the basic knowledge was gained from the history subject taught at school. The respondents who had better knowledge of A Famosa usually gained it from visiting the A Famosa site and some because they live in Melaka. Those who claim to have thorough knowledge are actually historians or directly involved in the conservation project.

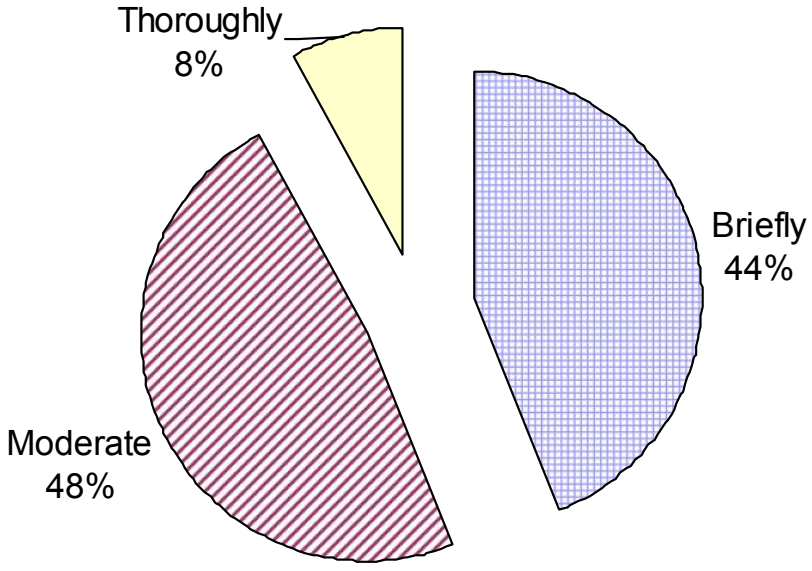


Figure 5.5 Pie Chart showing the respondents knowledge on the history of Melaka

Figure 5.6 shows among the 50 respondents, 66% of the respondents had experienced being to the A Famosa site in Melaka while the remaining 34% had no experience at all. The main reason for not being able to visit A Famosa is mainly due to the geographical factor such as living far from the site. The advantages of having the chance to visit the site are the opportunity to look at the remnants of the fortress and have some idea on the topology of the fortress site. Detail information on the fortress is also given at the fortress site such as the complete plan of the original fortress and some background history. Thus, the experience of being at the fortress site provided better understanding of how the fortress might actually looked like rather than just looking at the pictures of the fortress. This in turn will increase ones appreciation towards the heritage.

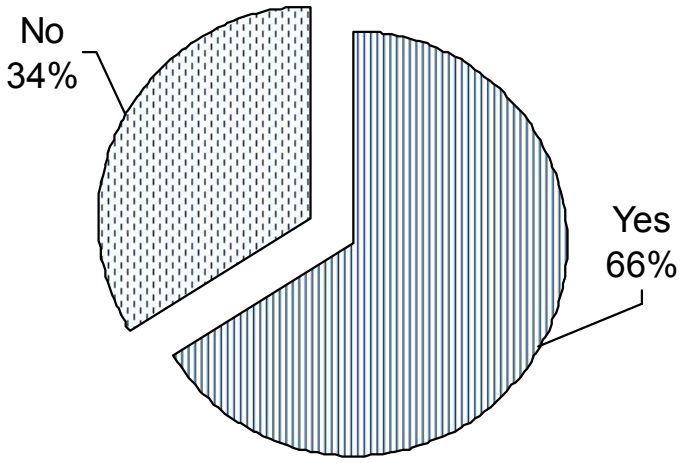


Figure 5.6 Pie Chart showing the respondents' experience to the A Famosa site in Melaka

5.2.2 The importance of A Famosa as a historical relic

Figure 5.7 shows the response on the importance of A Famosa as a historical relic. Although majority of the respondent (66%) strongly agreed that A Famosa is an important historical relic, around 26% doubted about it and 8% felt that it is not very important. Further interviews with these 2 groups indicated that their response is due to the lack of knowledge on the history of A Famosa. Some of them have viewed A Famosa as just a gate as presented by the Santiago gate thus they failed to recognise the importance of this relic.

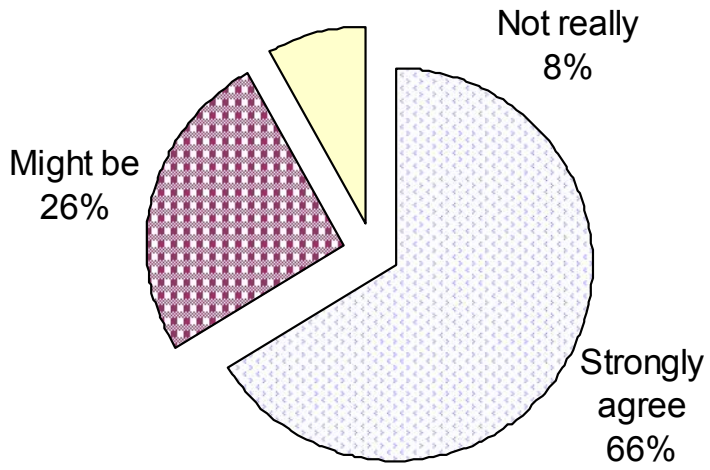


Figure 5.7 Pie Chart showing the respondents opinion on the importance of A Famosa as a historical relic

5.2.3 Suitable method for preservation: Physical reconstruction or 3D model

About 60% of the respondents think that A Famosa fortress should be physically preserved to its original state for historical purpose, even though it might be very expensive and involve a lot of reconstruction work at the original site. However, 28% think that other alternative such as digital preservation in 3D model should be considered taking into account the cost and feasibility factors of rebuilding the fortress to its original form. Another 12% failed to see the importance of preserving this fortress in any form. This finding is shown in Figure 5.8.

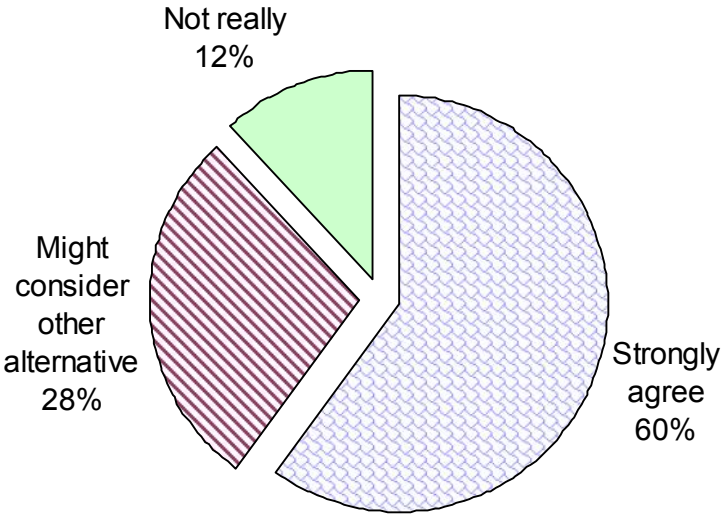


Figure 5.8 Pie Chart showing the respondents opinion on the importance of physical reconstruction of A Famosa

5.2.4 Feedback on the 3D model of Famosa presentation

When asked about the first impression after watching the 3D model of A Famosa presentation, 36% of the respondents said that they were impressed, 30% felt that the presentation was knowledgeable, 24% said the video made them appreciate the fortress more, 4% felt proud and 6% have other mixed feelings such as surprised and undefined. Generally, respondents felt impressed because they have never thought that the A Famosa is as grand as shown in the presentation. Some respondents felt more knowledgeable because the presentation gave them information on the fortress architecture and the history of A Famosa. The presentation also has made some of the respondents felt appreciative about A Famosa as an important historical heritage. The feeling of appreciation has also led some respondents to feel proud of having this historical heritage in their own country and being part of the nations. The result is shown in Figure 5.9.

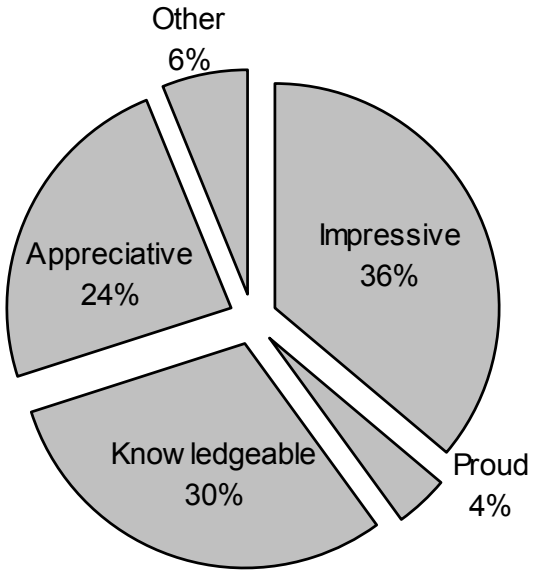


Figure 5.9 Pie Chart showing the respondents first impression after watching the 3D model of A Famosa presentation

Figure 5.10 shows significance increase on the respondent's perception on the importance of A Famosa as a historical relic after viewing the presentation as compared to the earlier result shown in Figure 5.6. This finding has shown that presenting the complete fortress in 3D model can give the viewer a clearer idea on the A Famosa fortress and in return improve their knowledge and appreciation on the historical heritage.

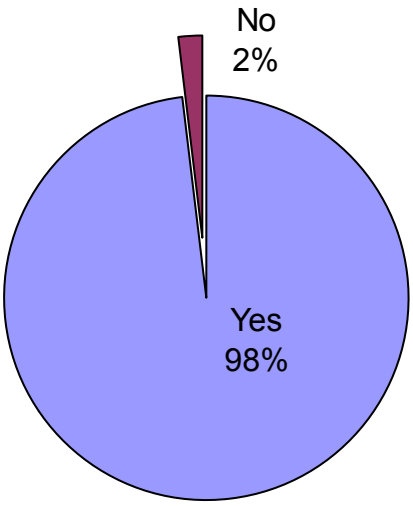


Figure 5.10 Pie Chart showing the respondents opinion on the importance of A Famosa as a historical relic after watching the 3D model of A Famosa presentation

5.2.5 Future improvement

Overall the survey received good feedbacks and several suggestions have been suggested by the respondents to make the presentation more interesting for future improvement:

i- To include more interactivity in the presentation such as the ability to have virtual tour around the fortress.

ii- To make the content more interesting by adding 3D characters, plants and more realistic environment for more effective impact to the audience particularly in creating realistic experience.

iii- To use more advance application such as Virtual Reality (VR) and 3D game engine.

5.3 Summary

In this chapter, we discussed the stages involved in the digital preservation of A Famosa Fortress in Malaysia. A survey has been conducted to gauge respondents' feedback on this attempt and find out their opinion on the importance of preserving this historical relic. In general, the findings have shown that people would appreciate

the importance of a historical relic when they are more knowledgeable of the subject matter.

Even though many would think that physical preservation would be the most appropriate to experience the history, but after looking at the output of this project the respondents agreed that preserving in 3D not only can overcome the economic and feasibility problem of physical reconstruction, but also has overcome the need to travel to a certain location in order to appreciate a particular relic. A significant increase on the importance of A Famosa as a historical heritage can be seen in the respondent's feedback after watching the 3D model of this fortress which implied that digital preservation can increase knowledge and people's interest on a particular historical heritage.

For future improvement of the model, the respondents suggested to expand the contents development of this research into more practical application such as virtual reality (VR) and virtual walkthrough using game engine. It is intended to explore on the use of VR technology to help quantitatively and qualitatively expand, deepen and enhance the architectural educational experience through its functions as an instrument of historic learning, animation, and reconstruction of past architectural and urban planning legacies.

Chapter 6

CONCLUSION AND FUTURE WORK

In this final chapter, the summaries of findings and results from the research are presented. The research objectives accomplishment are summarised in section 6.1, section 6.2 describes the overall conclusion and finally section 6.3 presents potential future development from this research.

6.1 Summary of research objective accomplishments

The objectives of this research as stated in section 1.3 are:

1. To study the historical development and architectural background of the fortress.
2. To collect, analyse and verify authoritative documents pertaining to this fortress and come out with a verifiable conjectural layout.
3. To reconstruct the fortress in 3D model based on verified data.
4. To evaluate the potential of using the developed 3D model in various fields such as education, research and tourism industry.

From the conducted research, the followings are the findings that correspond to the research objectives:

6.1.1 The historical development and architectural background of the fortress

The study shows that the A Famosa fortress has undergone four stages of historical development. It began with a single building with a tower when it fell into the Portuguese hands, then followed by an extension of the walls by the Portuguese. This was followed by the Dutch occupation and finally destroyed by the British. From this development, three elements have formed the basis of the research- visual information, textual descriptions and physical remnants. Visual information from the Dutch surveys have been used for verification as they are accurately scaled drawings. An official report known as Bort's Report was used for extracting data from textual descriptions.

For physical remnants, a gate known as Porta de Santiago and the newly reconstructed Middelburgh bastion have been referred to. This was supported by a field trip survey to the fortresses at Aguada in India, Galle in Sri Lanka and Rotterdam in Indonesia which shows that the A Famosa shares some similarities such as elements, architecture style and functions. These three elements are core foundations for data analysis to build this fortress in 3D model.

6.1.2 Data collection, analysis and verification of the fortress authoritative documents

This objective has been achieved by analysing and verifying the collected data from the Dutch scaled drawings and data extraction from the report. The textual data measurement has been standardised into a standard metric unit due to various old measurement units have been used in the drawings. This standard measurement has been translated into a conjectural layout. A statistical procrustes analysis method has been used to evaluate the selected drawings. Output from the conjectural layout has been matched with drawings from the procrustes analysis method.

This method has successfully identified two reference plans for 3D modelling process. These reference plans were matched with the satellite image of the fortress site. As a

conclusion several important points have been learnt from this process. Firstly, having a right and standard conversion measurement unit is very important particularly in a project that involves old drawings. Secondly, having multiple verification stages are very important to obtain an accurate result and finally, comparison of the results are very essential to establish a final result for reference.

6.1.3 Reconstruction of the fortress in 3D model based on verified data

The process of reconstructing the fortress in 3D model was totally based on verified data. To understand the issues in 3D reconstruction process, case studies on *Michelsberg synagogue*, *The Jewish Quarter in Regensburg* and *Reconstruction of the old main church in Curitiba, Brazil* have been referred to. Having a reference from previous projects is very important and helpful in giving a better understanding about the process significance, issues and solutions. 3D modelling process of the A Famosa started with visual sketches. This process has proven its effectiveness by reducing error during the 3D modelling process. Any changes and amendments are made in the drawings instead of 3D model. The actual 3D modelling process started by combining verifiable conjectural layout in 2D with satellite image of A Famosa site from Google Earth.

6.1.4 Potential of using the developed 3D model in various fields such as education, research and tourism industry

The fourth objective was achieved through human evaluation and the result was very promising. From the conducted evaluation, it proves that this method has shown a significant improvement in term of respondents' knowledge and appreciation towards historical heritage. The evaluation shows that the use of 3D model has proven its effectiveness in depicting the damaged fortress for education and research purpose.

6.2 Conclusions

This thesis makes a number of significant and original contributions in the area of architectural heritage and history particularly in 3D virtual heritage. There are a number of 3D virtual heritage projects which have been studied which make use of photogrammetry, laser scanning and hybrid method but most of these projects depend

on existing objects which are well documented and still exist. Some of the projects also have good reference sources such as photographs and satellite images. This is totally different from the A Famosa fortress sources.

The A Famosa fortress is an isolated case and a special case of 3D virtual heritage reconstruction. Throughout this research it has been very difficult to find similar cases to the A Famosa which has little remains, ambiguous drawings and textual descriptions. Furthermore the age of fortress is more than 200 years. The fortress details are solely extracted from the mentioned sources. Producing a conjectural layout from the main sources and verified through procrustes analysis method has given an established foundation. This method is suitable for digital preservation of the damaged buildings which have minimal physical remnants, remaining authoritative documents for analysis and similar buildings reference within the same scope.

Another significant input is expert interpretation which have been obtained through discussion and research consultation. Additionally, the field trip visit also has given a better idea about the fortress architecture and design. The main principle contribution is the 3D model of the A Famosa fortress which has opened a new dimension in its historical timeline. The research survey shows that the 3D model has given a significant impact to the respondents knowledge, perspective and better idea about this fortress.

6.3 Future work

It is hoped that the findings of this research will encourage and lead to more research to be done in related field particularly the heritage that shares the same fortune with A Famosa fortress. The key findings of this research have led the following ideas for future work. The framework developed in this research would be useful to apply in any cases that have similar issues with the A Famosa fortress. The methodologies implemented here can be adjusted based on case basis and suitability of the project. It is targeted for digital preservation projects like historical heritage and architecture.

The 3D model developed here is not a definitive answer for this research and its development should be continuous. With the new discoveries of this subject matter in the future, an effort should be made to modify and improve this model from time to time for more established output. It is suggested that other researchers also should attempt and implement other research methods that might have potential to establish this 3D model.

With the availability of advanced technologies for use in historical documentation and digital preservation, a wide range of possibilities for future work are available. The power of mobile computing and communication technology can benefit this field. For instance the use of smart phone with global positioning system (GPS) allows the integration of heritage navigation through an interactive application. This research also looks at the potential of integrating the fortress 3D model in Google Earth as one of the approaches in promoting heritage tourism. The use of the internet is borderless and can be a good medium for global promotion.

Hopefully there will be an effort in utilising this 3D model for future development which would benefit fields such as education, history, tourism and architecture. This research looks into potential technological developments such as virtual reality, interactive multimedia, web 3D, augmented reality and games that promise to be useful to the fields mentioned before.

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APPENDICES

APPENDIX 1

Research papers published in completion of this research

2010

Mohamad Izani, Alan Bridges, Aishah Razak, Barnabas Calder, and Michael Grant. 2010. Digital preservation of a famosa fortress in malaysia. *In Proceedings of the second workshop on eHeritage and digital art preservation* (eHeritage '10). ACM, New York, NY, USA, 7-12.

M. Izani, A. Bridges, P. Grant, A. Razak, and A. Rafi. 2010. 3D modelling of the A Famosa fortress in Melaka, Malaysia. In *Proceedings of the Third international conference on Digital heritage* (EuroMed'10), Marinos Ioannides, Dieter Fellner, Andreas Georgopoulos, and Diofantos G. Hadjimitsis (Eds.). Springer-Verlag, Berlin, Heidelberg, 373-380.

2009

M.Izani, A.Bridges & A.Razak,3D Modelling Of A Famosa Fortress, Malaysia Based on Comparison of Textual and Visual Data, *In proceeding of 6th International Conference Computer Graphics, Imaging and Visualization* (CGIV 09),Tianjin, China, 11 - 14 August 2009, 491 - 496

M.Izani, A.Bridges & A.Razak,Determination of the plan of the A Famosa Fortress, Malaysia, *In Proceeding of International Conference on Computing and Informatics* (ICOCI09),24-25 June 2009, Kuala Lumpur, Malaysia, 292-297.

M. Izani,A. Bridges & A. Razak, Using procrustes analysis to determine verifiable conjectural layout of A Famosa fortress, Malaysia, *In proceeding of International Conference on Software Technology and Engineering* (ICSTE 2009), Chennai, India, July 2009, 291-295

2008

M.Izani, A.Bridges & A.Razak,The digital archaeological reconstruction of the A Famosa Fortress, Malaysia, *In proceeding of International Conference on Virtual Systems and MultiMedia* (VSMM 2008), 20th - 25th October 2008,Limassol, Cyprus, 209-214

APPENDIX 2

Questionnaire

1- Respondent background?
A-Student B-General C-Academic

2-Are you from Malaysia?
A-Yes B-No

3-Have you been to the A Famosa site in Melaka?
A-Yes B-No

4-Do you know the history of A Famosa?
A-briefly B-moderate C-thoroughly

5-Do you have any idea of how the complete fortress might look like?
A-briefly B-moderate C-thoroughly

6-Do you think that A Famosa is an important historical relic?
A-strongly agree B-might be C-not really

7-Do you think it should be preserved to its original state for historical purpose, even though it might be very expensive and involve a lot of reconstruction work at the original site?
A-strongly agree
B-might consider other alternative (digital preservation)
C-not really

8-Do you think that preserving in 3D is a better alternative?
A-strongly agree B-might be C-not really

9-Have you come accross any attempt to model the fortress in 3D before?
A-Yes Give detail_____
_____
B-No

10-What do you think after watching the video of A Famosa in 3D?
A-Impressive B-Proud C-Knowledgeable D-Appreciative
E-Other (Please Specify):_____

12-Do you think that you have gained some knowledge on the A Famosa fortress?
A-Yes B-No

13-Has this video changed your perception about the importance of A Famosa in the history of Melaka.

A-Yes Give detail_____
B-No Give detail_____

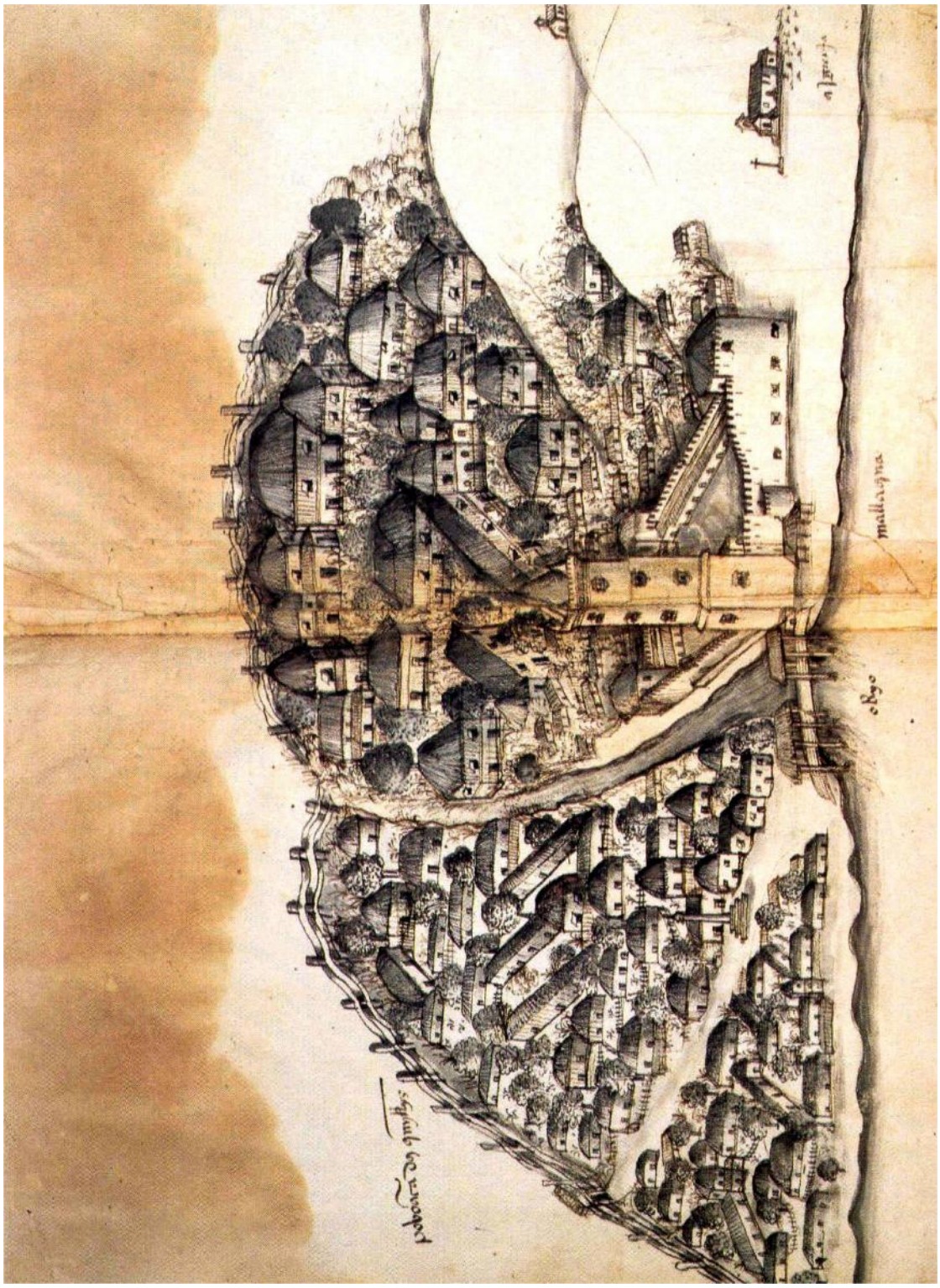
14-Do you have any suggestion on how to improve this model for education and tourism purposes?

_____
_____

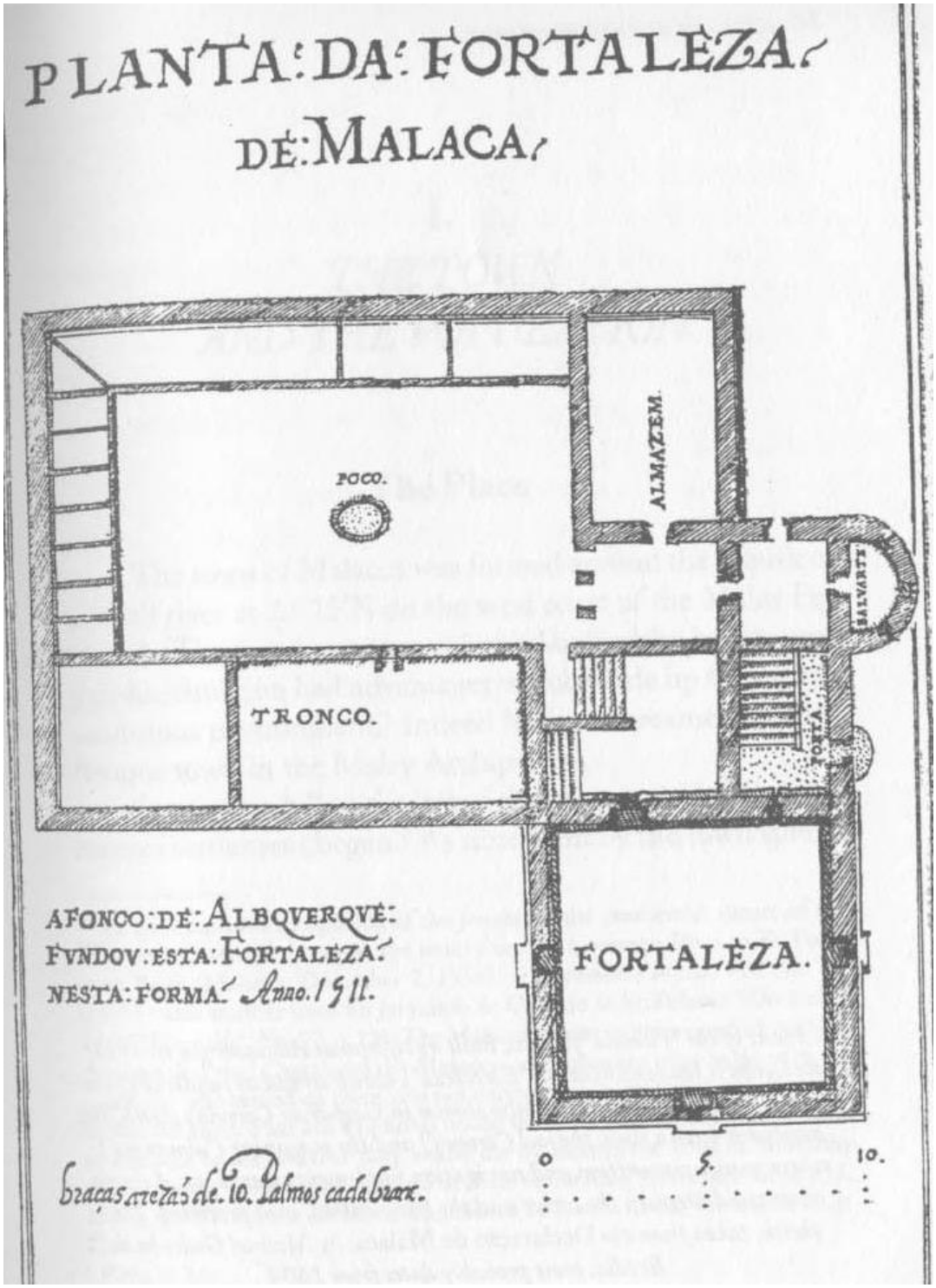
APPENDIX 3

Collection of A Famosa images used in this research in high resolution.

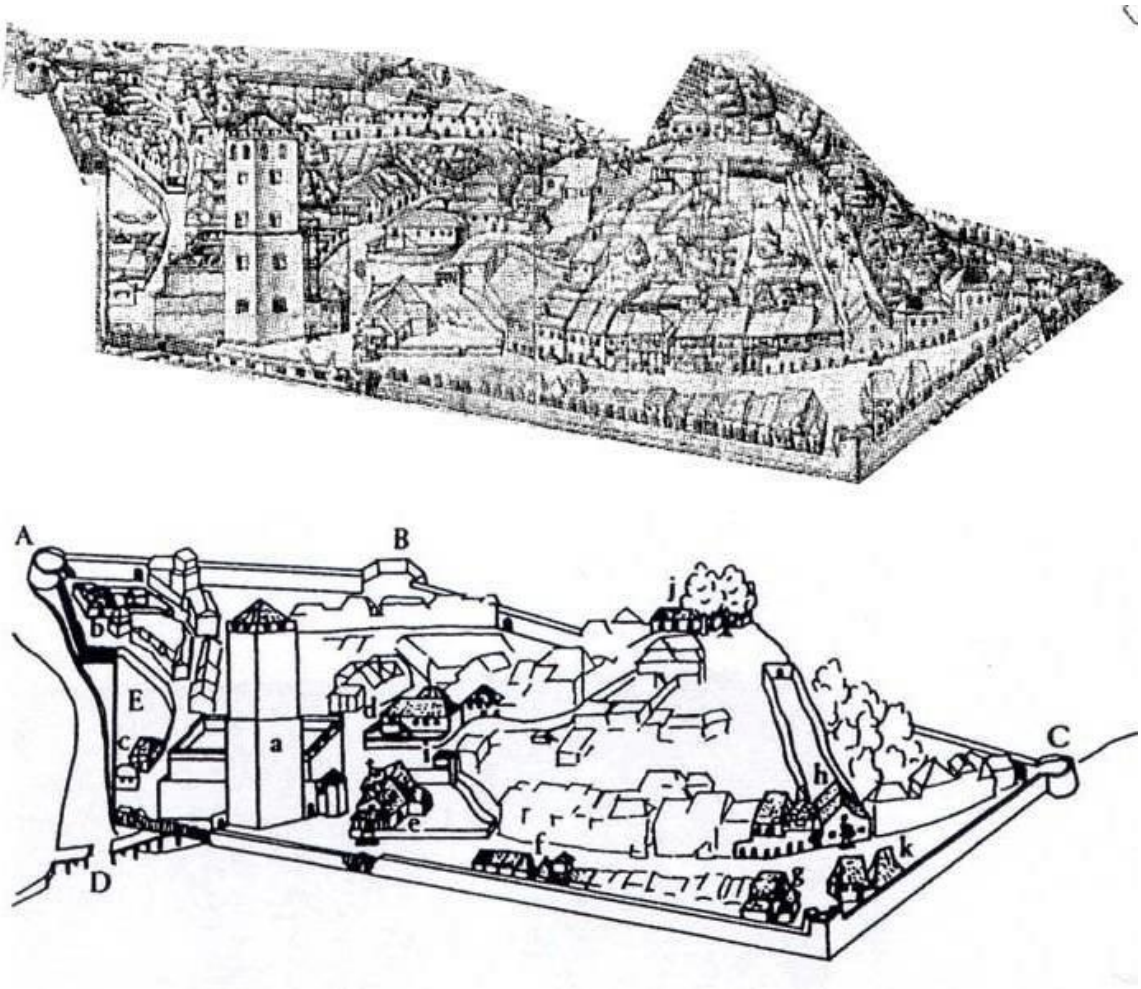
1. Fortaleza de Melaka, drawing by Gaspar Correia, 1527, in his manuscript works, "Lendas da India" (Source: Thomaz, 1991)



2. *Plan of the Malaca fortress*, built by Afonso de Albuquerque in 1511. The sketch, taken from the *Declaracao de Malaca*, by Manuel Godinho de Eredia, most probably dated from 1604. (Source: Thomaz, 1991)

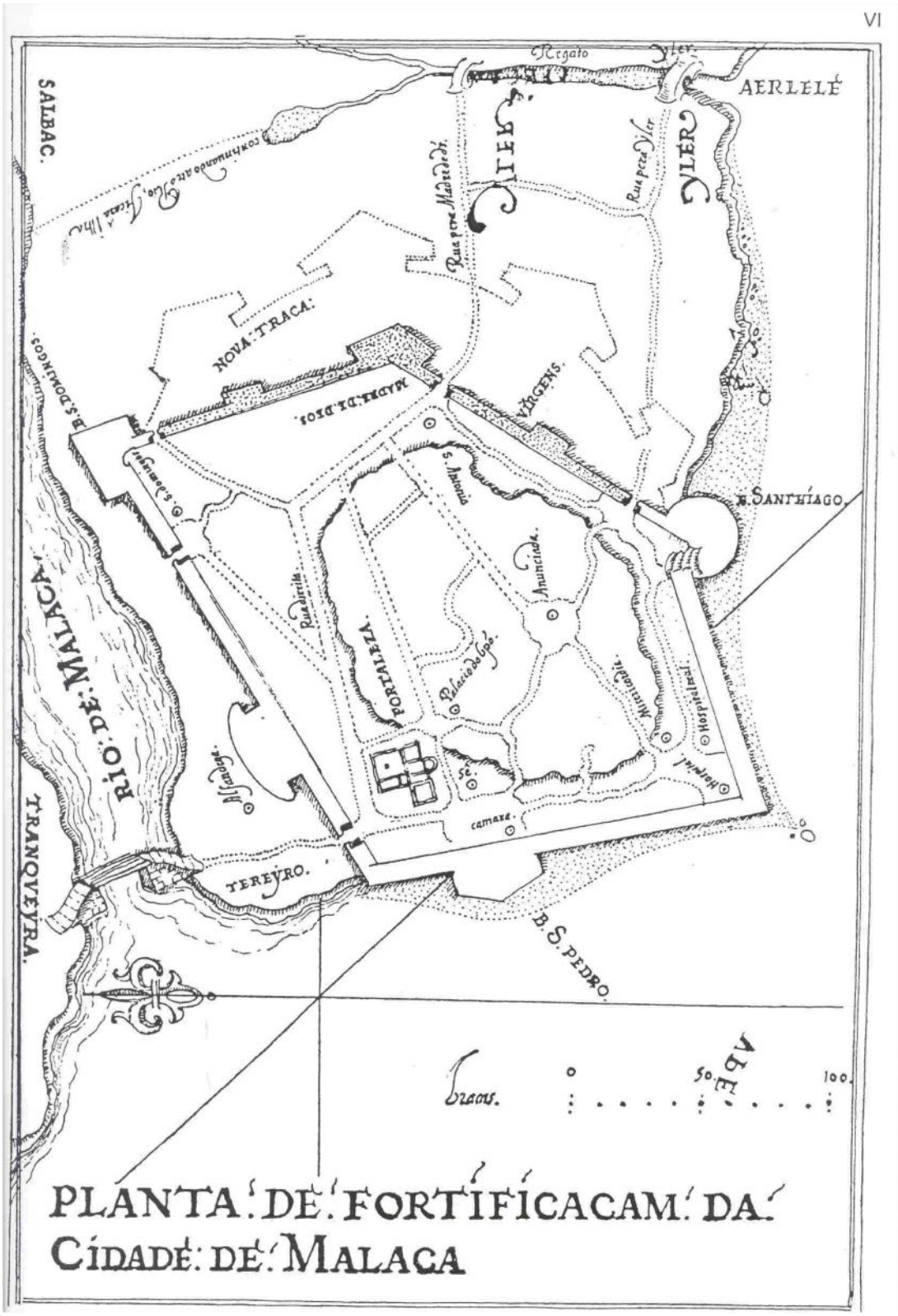


3. Upper image: Anonymous Portuguese drawing of the Melaka fortress, dated 1568. The original is kept at the Biblioteca Nacional, Rio de Janeiro, Brazil (Correa 1858-66) Lower Image: Sketch of the original image indicating the main buildings of Potuguese in Melaka. (Source: Manguin, 1999)

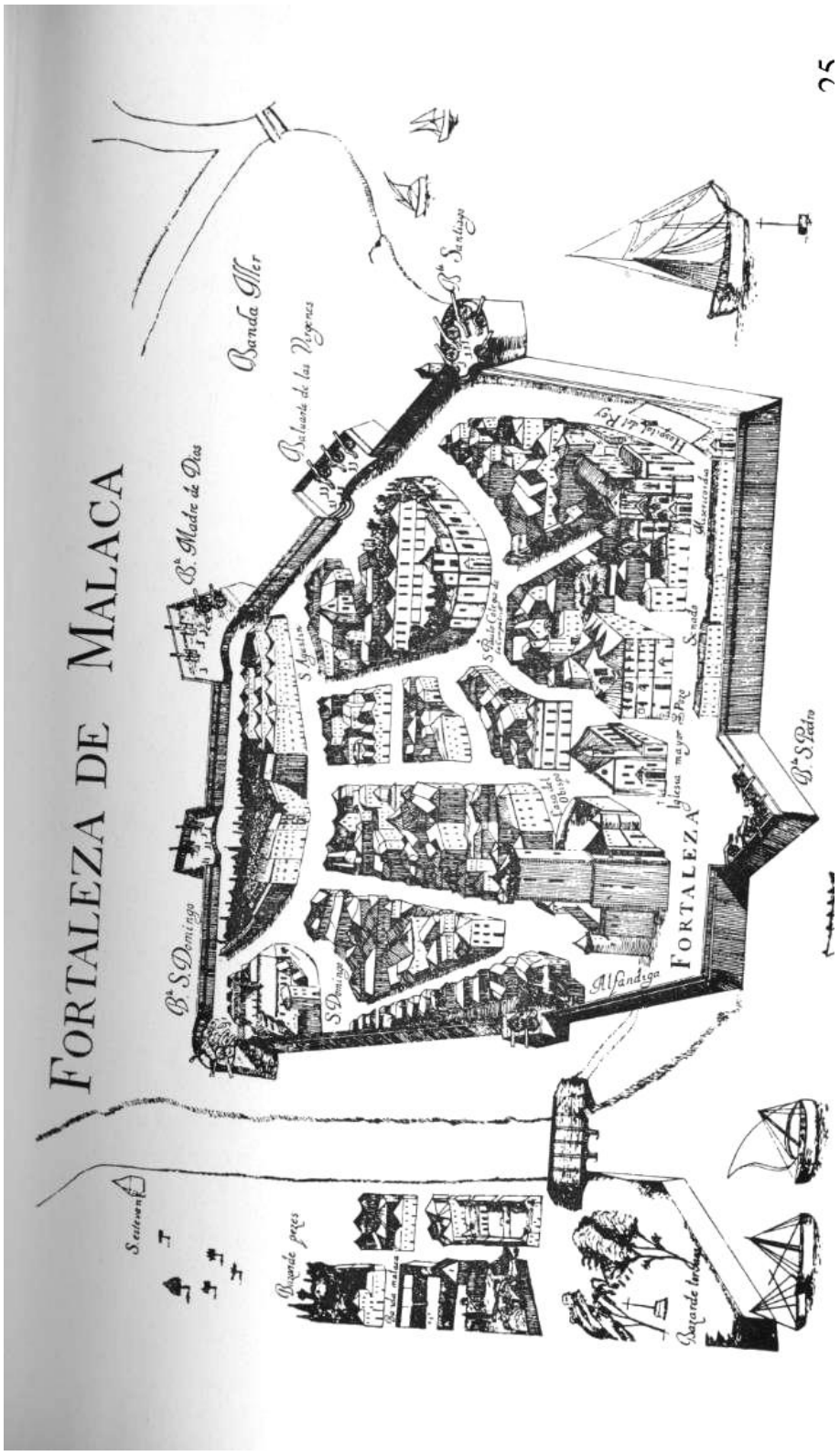


A São Domingos bastion
B Madre de Deos bastion
C São Tiago bastion and neighbouring gate [The Onze Mil Virgens bastion is hidden by Melaka Hill]
D Bridge over the Melaka River
E Riverside slip (*ribeira*)
a *A Famosa* fortress
b São Domingos Church and Convent
c Customs House (*alfândega*)
d Bishop's Palace
e N.S. da Asumpção Cathedral
f Municipal Council and prison (*câmara* and *aljube*)
g Pauper Hospital
h *Misericórdia* (Church and seat of the Confraternity of Mercy)
i Bell tower
j Church of N.S. da Anunciada and Jesuit College
k Royal Hospital

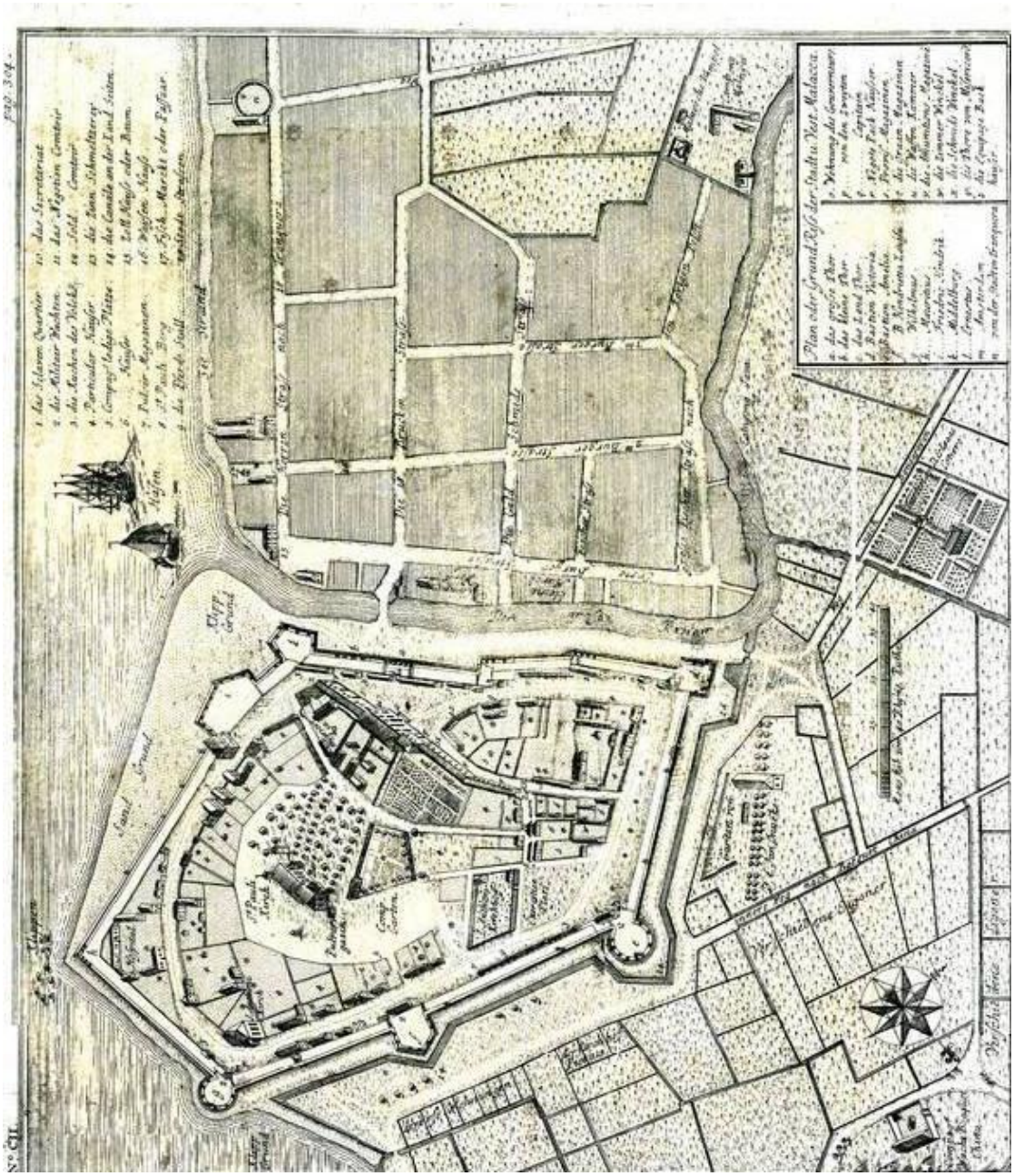
4.Eridia's drawings (1604) of the fortress of Melaka (Source: Godinho, 1977)



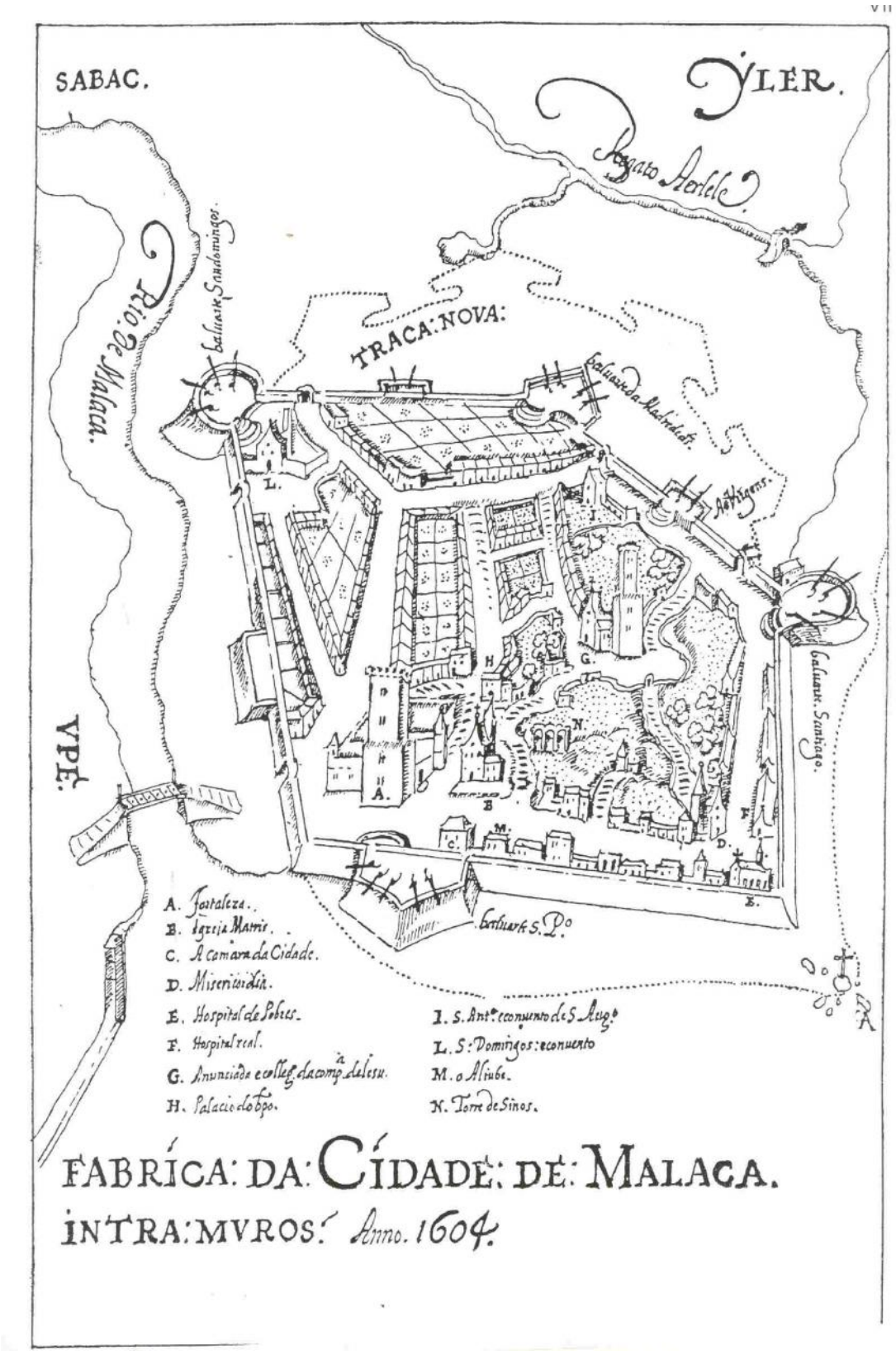
5. Sousa's drawing on Melaka, 1660's (Source: http://www.nationaalarchief.nl)



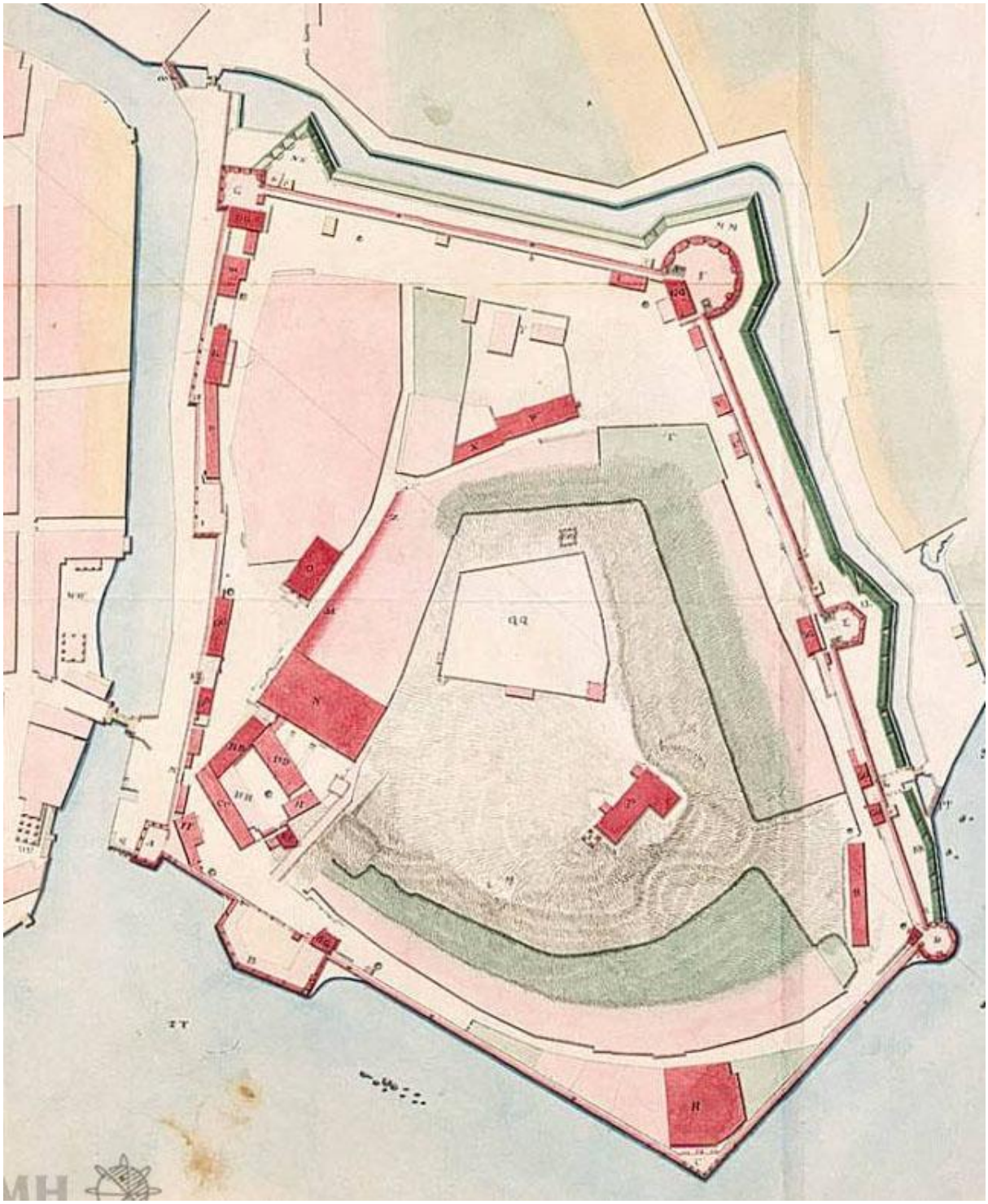
6. The Dutch drawing of Melaka, Copperplate printing of Plan oder Grund Riss der Stadt u. Vest. Malacca by Helydt, Johaan Wolfgang,1735-1744 (Source: http://www.nationaalarchief.nl)



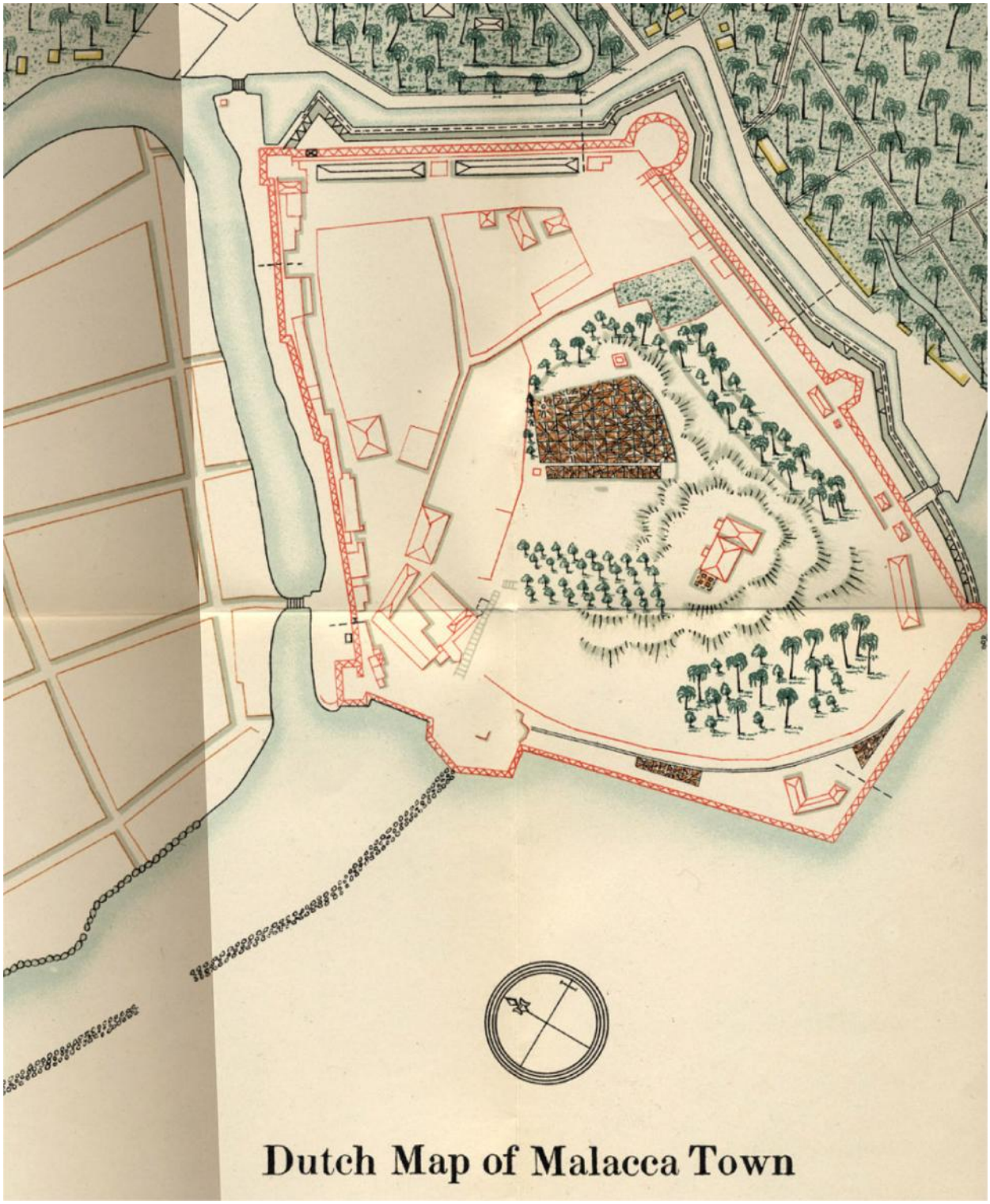
7. The location of Portuguese tower known as the keep according to Godinho Eredia, 1604 (Source: Godinho,1997)



8. Map of the city and fortress at Melaka ca. 1780 by P.Elias (Source: http://www.nationaalarchief.nl)

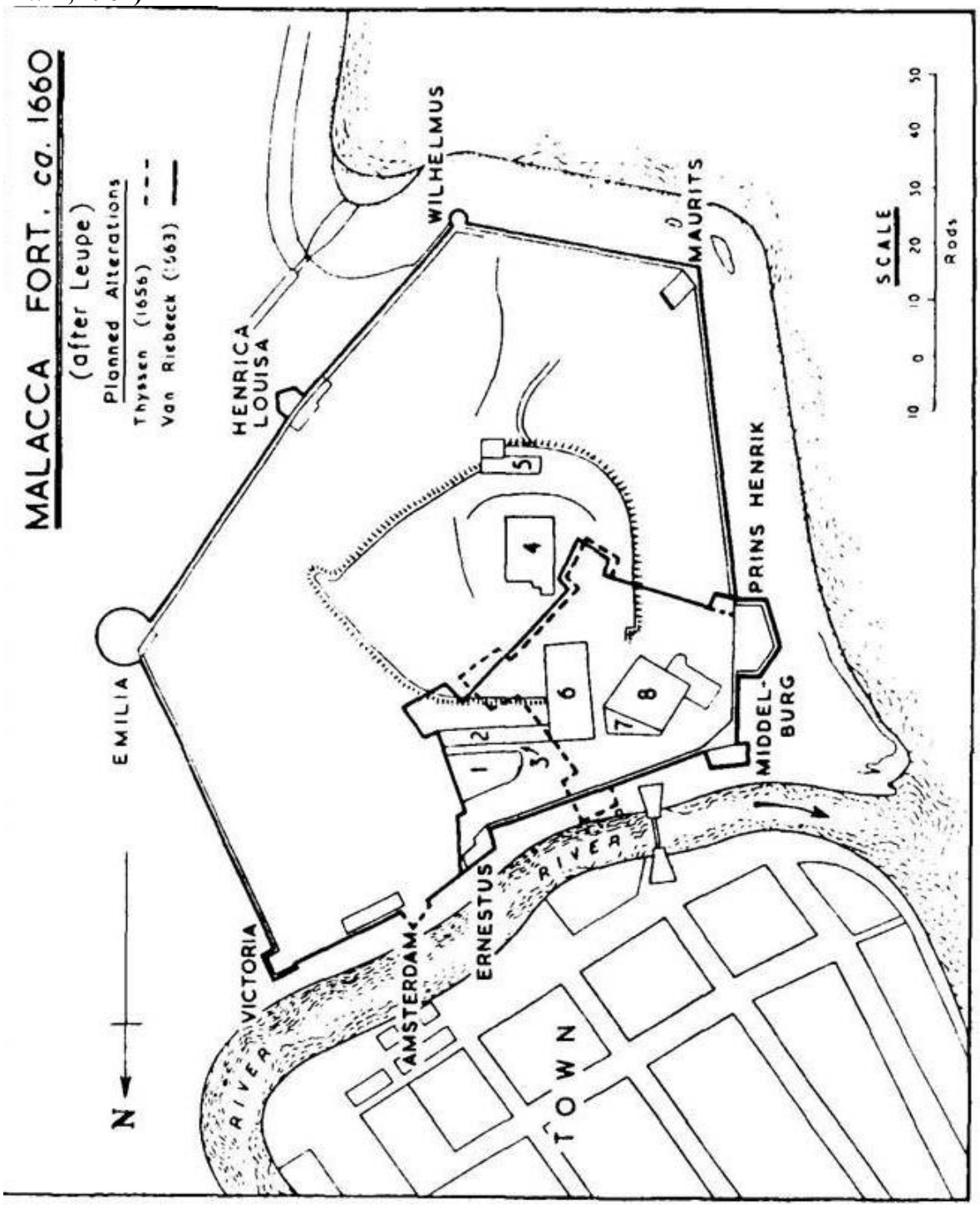


9. Dutch map of Melaka town, 1824 (Source: MCC,1924)

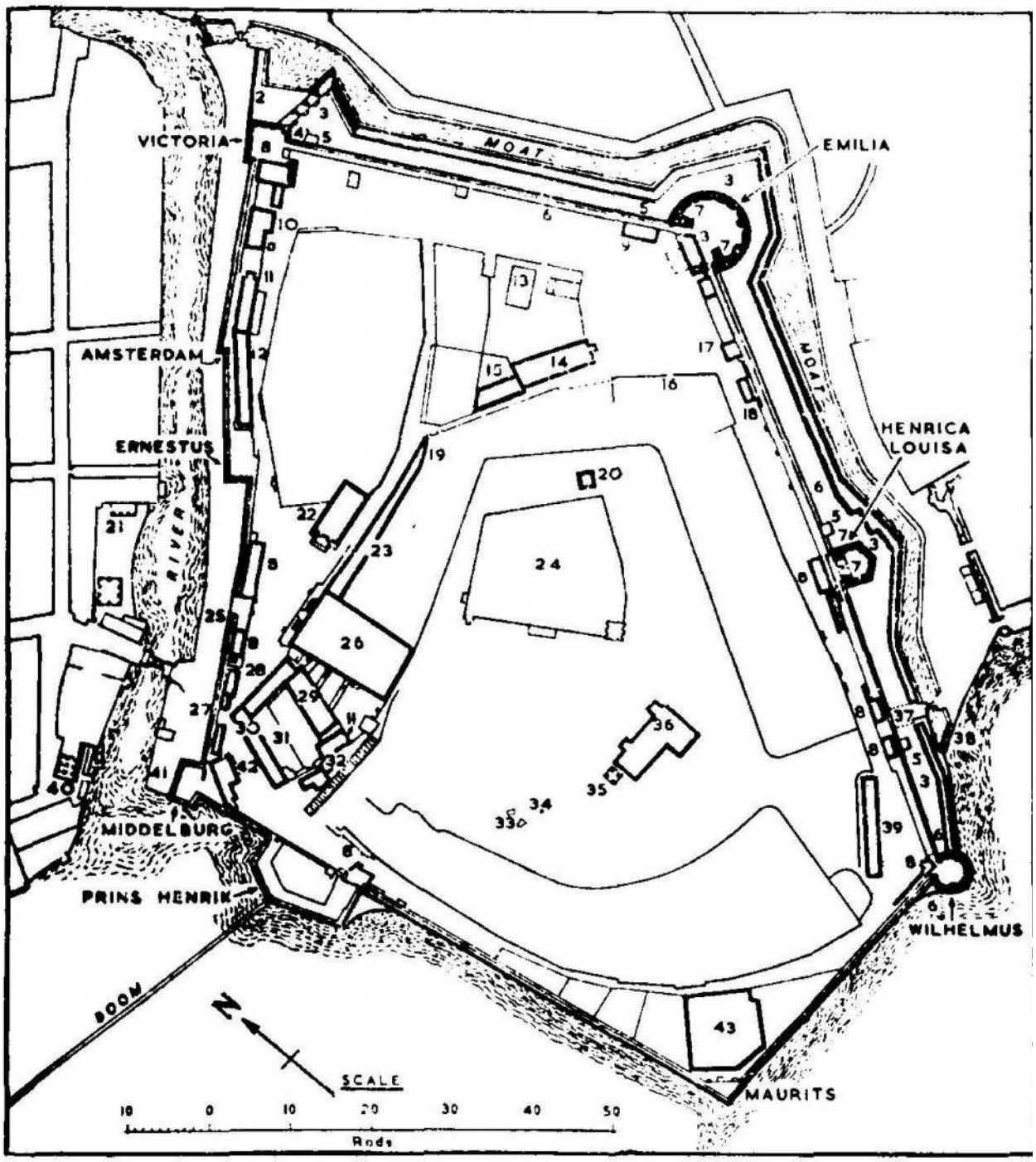


10. Map of Melaka and environs, before AD 1800 (Source: http://www. nationaalarchief. nl)

11. A clearer reproduction of Malacca Fort circa 1660 –after Leupe, image showing two reduction plans proposed by Thyssen and Van Riebeeck (Source: Irwin, 1962)

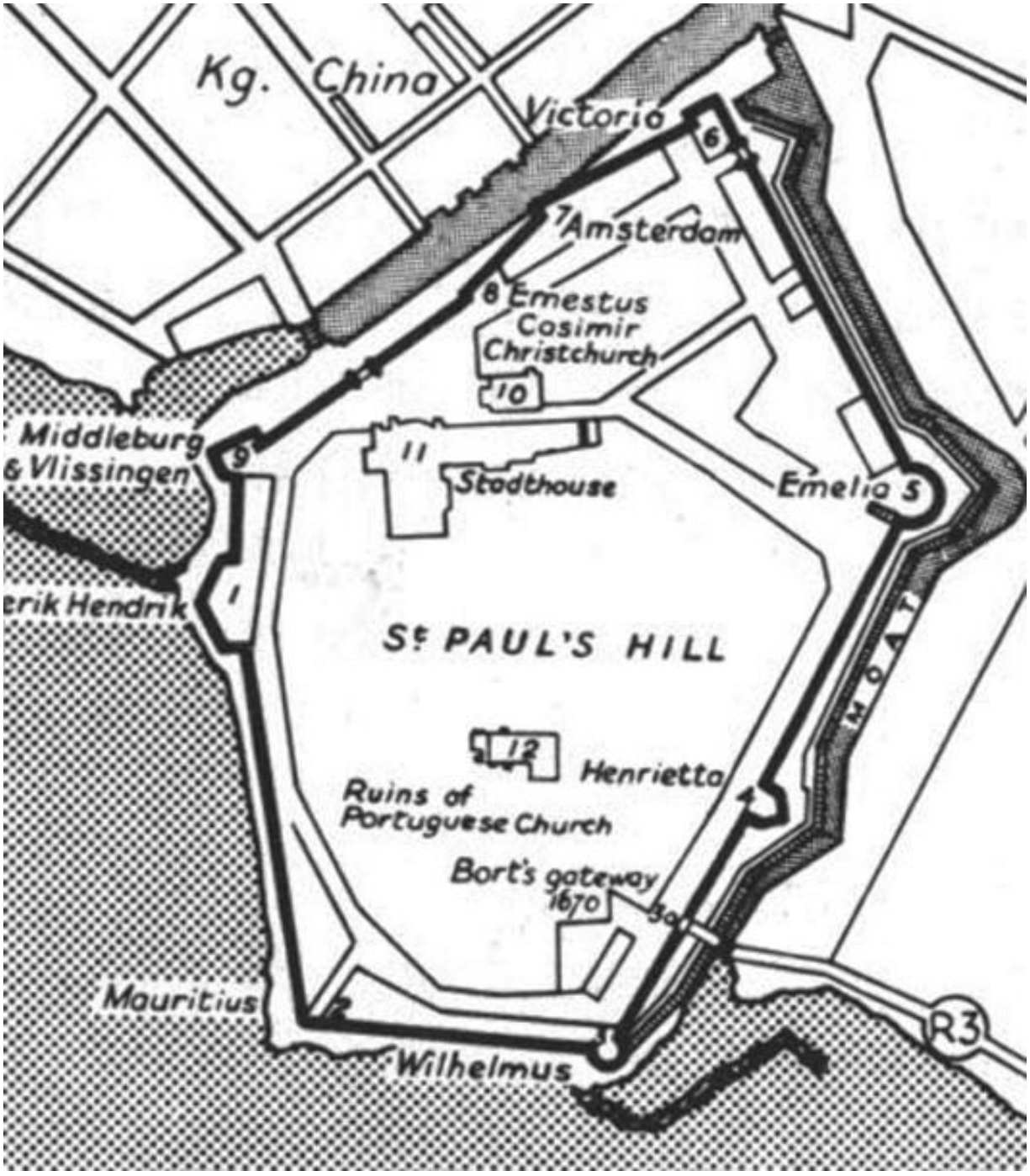


12. Plan of Malacca fortress, ca. 1792: A clearer reproduction of the original image entitled "Hoofdplan van de Stad en t Kasteel Malacca," after Reimer and Elias with complete indication of bastions' name, fortress elements and buildings inside the fortress (Source: Irwin,1962).

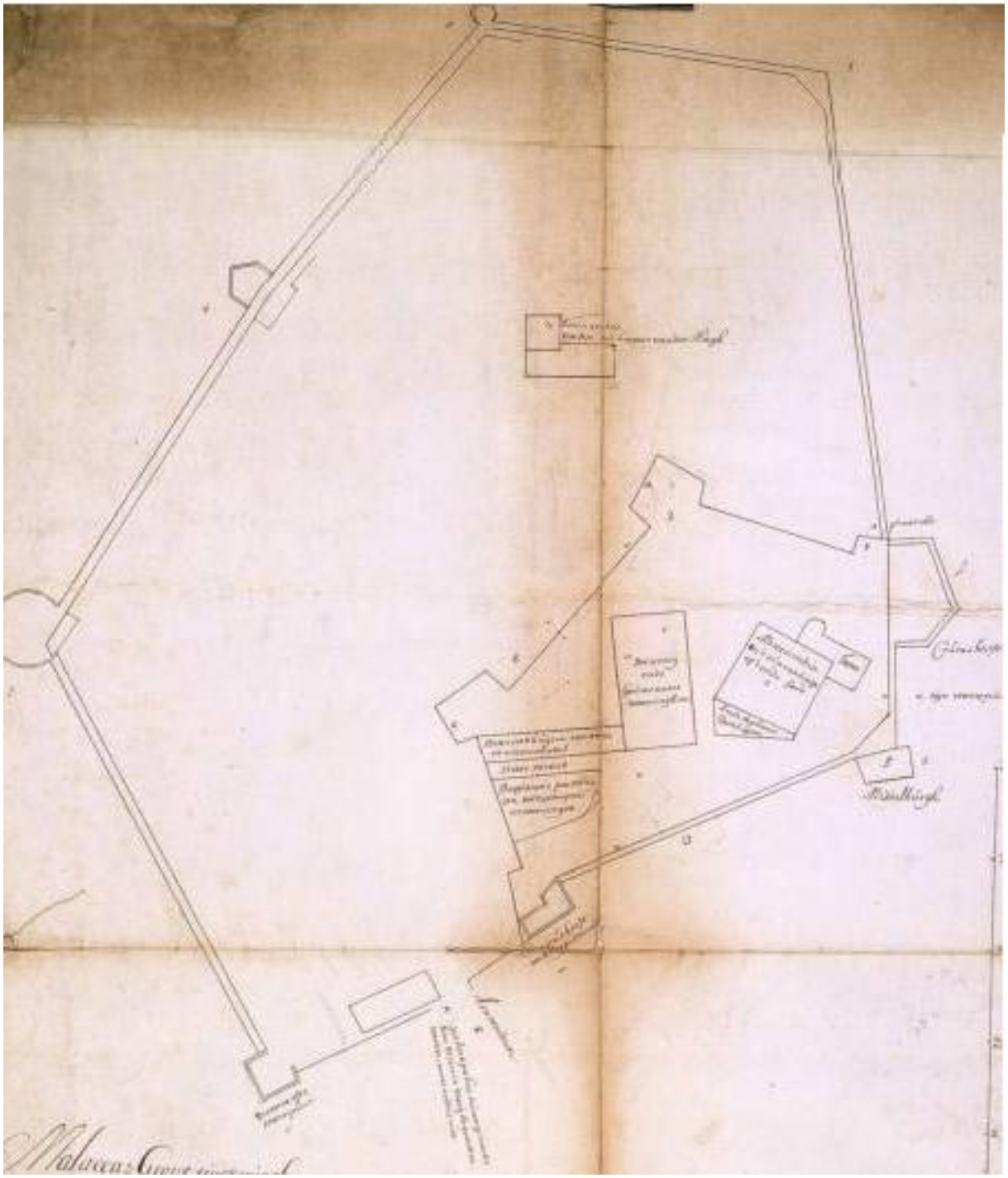


13. Melaka Fortress: A reproduction of the original Dutch plan drawn in 1744 in which the prominent buildings are shown. This map has been used by the department as an official main reference for visitor's information (Source: Museum Department of Melaka).

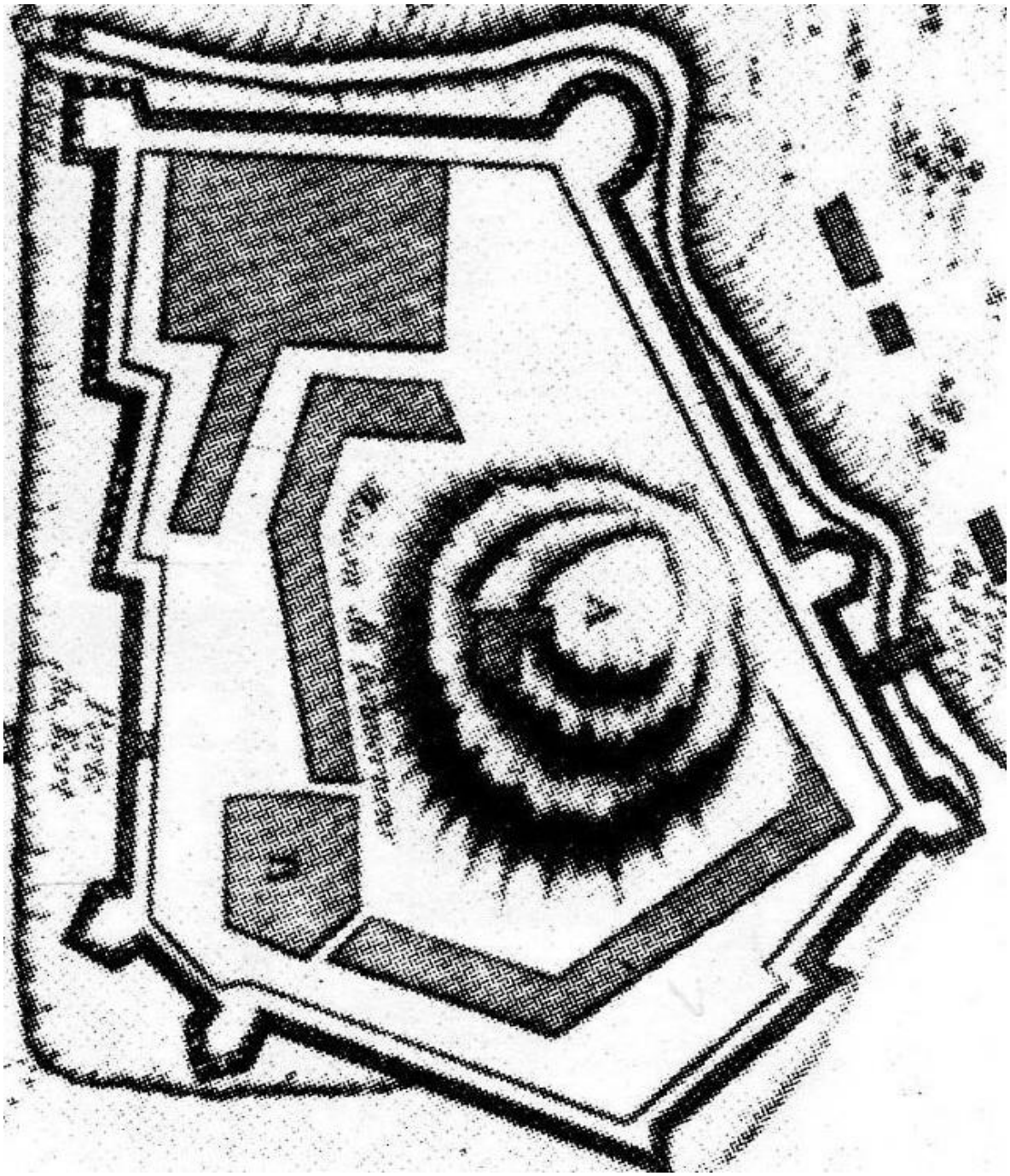
14. Plan of Dutch fortress at Malacca (Undated) (Source: Moorhead 1957)



15. Map of the fort at Malakka, 1663 (Source: http://www.nationaalarchief.nl)



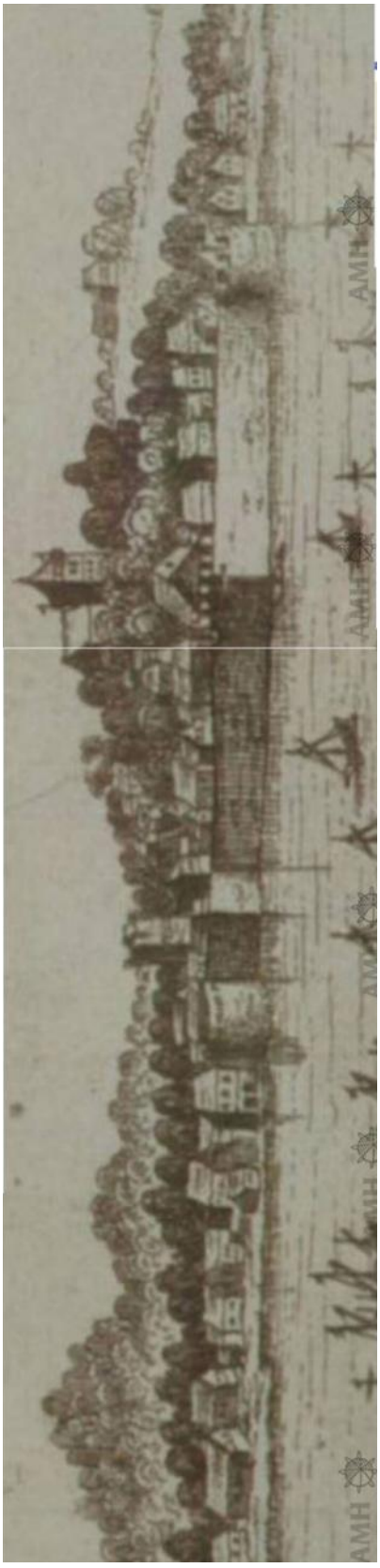
16. Plan de la ville de Malacca, 1764 (Source: Pintando, 1990)



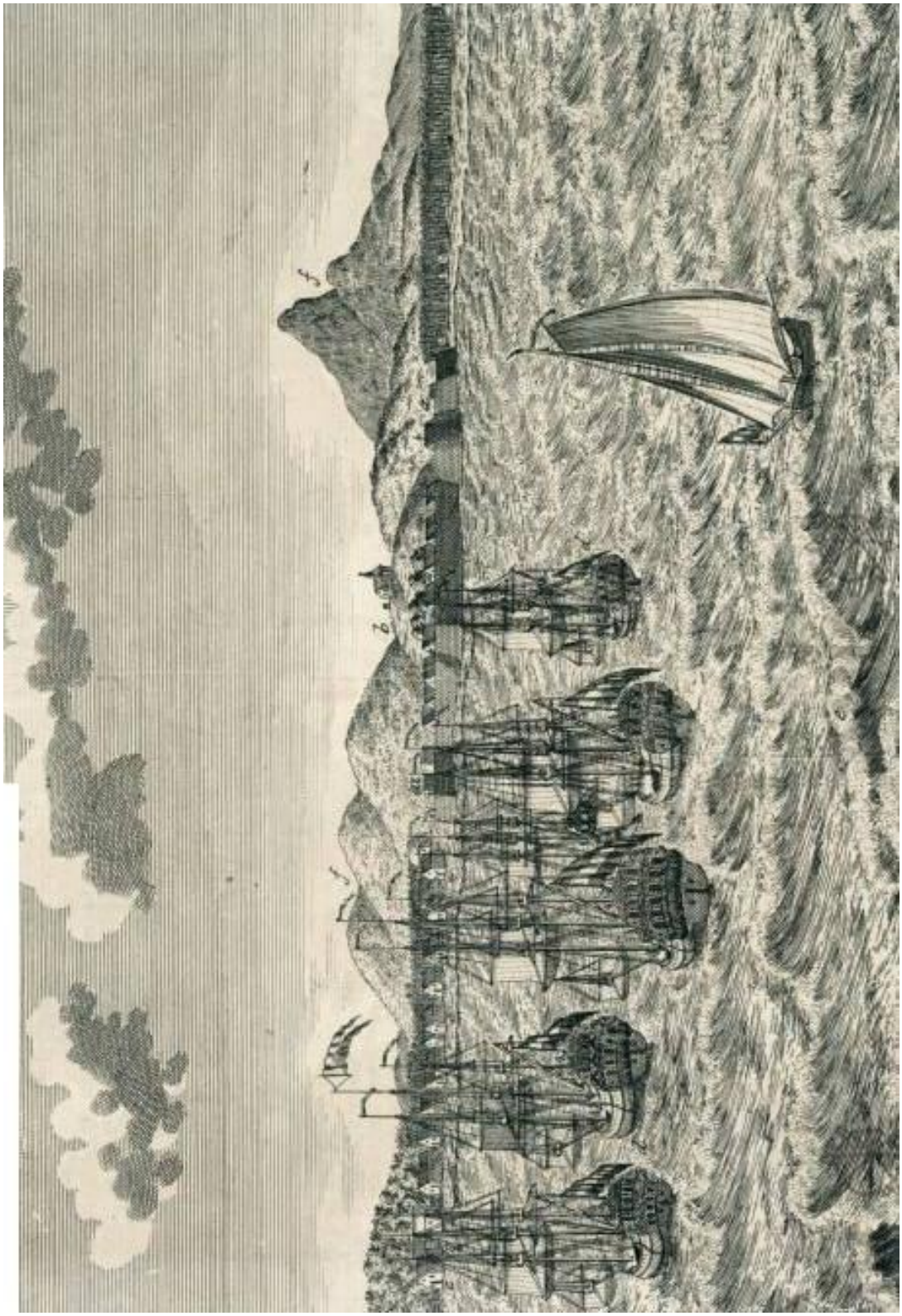
17. Map of the fortress at Melaka ca. 1656 (Source: http://www.nationaalarchief.nl)

18. View of Melaka in 1665-1668 by Johannes Vingboons (Source: http://www.nationaalarchief.nl)

19. 1606 View of Melaka by unknown artist (Source: http://www.nationaalarchief.nl)



20. View of the Malacca peninsula in 1735 - 1744 by Heydt, Johann Wolfgang (Source: http://www.nationaalarchief.nl)



21. Map of the city of Melaka ca. 1665 by Johannes Vingboons (Source: http://www.nationaalarchief.nl)