Lime Mortar Composition of Old Fort in Melaka: A Case Study of Bastion Maurits and Bastion Santiago

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Abstract
Historical masonry buildings in the state of Melaka are among the top attractions for tourist. It has attracted peoples from all over the world to come and visit Melaka to appreciate the beauty and value the architectural aspects of the masonry building. Based on this situation, there is a need to properly restore the buildings in order to make it sustain for a longer period of time. Works has been done from to time to restore and preserve the building. However, the works of restoration was not properly done due to the lack of information on the composition of lime mortar used in the development of masonry building. This study aims to identify the accurate composition of lime mortar in order to suggest the best solution in restoring masonry building in the future. Bastion Maurits and Bastion Santiago was chose as the sample of this study. Acid dissolution and sand grading method used in this study to identify the composition of lime mortar from each area chose. The result shows that the ratio of sand to lime in both Bastion Maurits and Bastion Santiago forts are the same. The analysis shows that the ratio is 1:3. Based on the previous studies, it is proved that the mortar with the ratio of 1:3 has better strength compared to the mortar with the higher ratio of lime to sand. In addition to that, the result from sand grading analysis shows that, lime mortar from both forts consists of the same content of material, which are lime, coarse sand, brick dust and egg broken pieces. This study has best identified the content of lime mortar from each of the forts mentioned. The material used in the development of the forts should be taken into consideration for restoration works of historical masonry building. Apart from that, a study on other forts should be done, as it may come out with different kinds of lime mortar content.
Keywords: Lime Mortar, Fort, Conserve, Heritage

1.0 Introduction

Masonry was the earliest construction technique discovered in the world. The early civilization such as Mesopotamia, Egypt and China used masonry technique in constructing temple and shelters. Masonry structures can be seen in most of the earlier century building from all over the world. According to Alex (2017), masonry is one of the oldest styles of construction discovered. Great Wall of China, Holy Kaabah, and pyramids are the kind of building built using masonry technique (Nor Azlinda, Che Sobry & Mohd Nasrun, 2014). This kind of technique was widely used from the beginning of civilization.

Even though masonry was found as the oldest technique in construction, the building that used the technique is still standing over the centuries (Valluzzi, 2016). Most of the historical masonry building especially in Malaysia is still in used. States government has been maintaining the old or historical building for a good purpose. Museum, churches and government offices were placed in the masonry building and it has become as a tourist attraction to most of the states in Malaysia. Melaka for instance, has been maintaining the masonry building as the historical attraction for tourist. The works of conservations and preservations are gradually being done from time to time. This works is being done to extend the life span of the building and to make it sustain for a longer period of time. According to Hasif (2014), conservation is to preserved a building especially historical building for as long as possible and retain it existence to the community.

Conservation is a work to preserve a structure that has been constructed by previous developers. The process of this work is the best way to sustain the heritage values whilst identifying the opportunities to reinforce it for future generations (Historic England, 2015). According to Noorfadhilah & Shamzani (2012), conserving a historical building is to preserved material, identity and aesthetic values of the building. Works must be done properly to gain the objectives of sustaining the historical building. The works of conservations is vital as it is a process to retain the cultural significance, restore and reconstruction of the ruin building (Burra Charter, 1981).

However, most of the heritage building was not being conserved the right way due to unsuitable materials used for the repair works (Kamarul & Lilawati, 2014). The building has become damage and lost of it design originality (Nur Hasyyati, 2016). Improper used of materials that bind the masonry structure was identified as one of the problems faced during the conservation works. According to Rodiah & Zuraini (2010), the used of inappropriate materials in conservation works and lack of technical knowledge and the use of substandard material in repairing old building (S. Johar & A. Ghafar, 2010 & Arya, Boen & Ishiyama, 2014) has impacted major damages to the historical masonry building. Trough observation, cement has been introduced as a binder to most of the mortar that made up the masonry units of the heritage building in Melaka (Nur Hasyyati, 2016). Therefore, there is a need to study the content of lime mortar binder that can be used as the best materials for conservation works for masonry building in Melaka. Lime mortar from masonry building in Melaka was analyzed to determine the composition of it. Two (2) old forts, Bastion Maurits and Bastion Santiago were chose as the sample of this study.

2.0 Methodology

As mentioned earlier, this study was conducted to identify the definite composition of mortar used to construct the fort of Bastion Maurits and Bastion Santiago in Melaka. Laboratory works were done to analyze the content of each mortar from both forts. Acid dissolution and sand grading test were conducted in this study. This is the best and accurate technique in

identifying lime mortar composition (Middendorf et al., 2000). Both techniques of test were define as follows.

a. Acid Dissolution

Analysis of mortar involves the separation of compound that made it. The quantification and initial identification of mortar is carried out by using acid dissolution 10% hydracloric acid (Leslie & Gibbons, 2000). According to Ngoma (2009), the analysis of mortar involves the separation of mortar sample by dissolving it in a dilute acid. This technique of analysis was used to identify the composition of mortar from both forts. In this test, 100 grams of mortar sample were introduced to 100 ml of acid hydrochloric solution and 900 ml of distilled water. A chemical reaction between all the elements produced Calcium Chloride (CaCl2), Carbon Dioxide (CO2) and water (H2O). Equation (1) explaining the chemical reaction in this test. The amount of lime mortar was then be analyzed by weighing the amount of sand left.

$$CaCO_3 + 2HCL \longrightarrow CaCl_2 + CO_2 + H_2O \quad (1)$$

b. Sand Grading

Sand grading technique was also conducted in this study. The method was organised to categorise the sizes of sand sample gathered from the previous method of test, acid dissolution. The gathered sands were sieved using sieved machine for ten (10) minutes. The sample then is being graded between the range of sizes which is 14mm, 10mm, 5mm, 2.36mm 1.18mm, 600µm, 300µm, 150µm, 53µm and <53µm. The graded sample then was weighed and recorded. The samples' conditioned were examined to determine whether it is a sand or solid sand.

c. Result and Discussion

This study focuses on the composition of lime mortar used in Bastion Maurits and Bastion Santiago Forts. Based on the laboratory test, characters of mortar as well as composition of mortar have been identified. This section discusses the result of analysis for the laboratory test done.

d. Acid Dissolution Analysis

This method of test has been done to identify the characteristics of mortar in both Bastion Maurits and Bastion Santiago Forts. Four (4) types of characteristics were recorded. After two (2) weeks of acid dissolution test, a jellylike layer with reddish colour was formed on the surface of specimen. The form of reddish colour shows that the iron aggregate does exist in mortar from both forts. In addition to this test, it is found that both mortar from Bastion Maurits and Bastion Santiago has a quick chemical reaction. The percentage of carbon dioxide (CO_2) were also analysed from this test. Carbon dioxide (CO_2) was released from the chemical reaction. It was found that the percentage of CO_2 released was slightly the same from the sample of both forts. It is found that the percentage of CO_2 released from Bastion Maurits sample was 27.7% whilst CO_2 from Bastion Santiago sample was 27.1%.

Table 1: Acid Dissolution Analysis Result

No	Characteristics	The Bastion Maurits	The Bastion Santiago
1	Colour	Reddish	Reddish
2	Reaction	High	High
3	Layer of Jellylike	Exist	Exist
4	Percentage of CO_2 released	27.7%	27.1%

e. Sand Grading Analysis

This study has also considered the sand grading analysis. This process has been done right after acid dissolution test. Sample taken from acid dissolution test were graded based on eight (8) range of sizes which was 14mm, 10mm, 5mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm, 53µm and <53µm. The sand grading of Bastion Maurits' mortar is shown in Figure 1, meanwhile the result of sand grading of Bastion Santiago's mortar is shown in Figure 2. Based on the analysis, it was identified that 22% of mortar from Bastion Maurits Fort contained with 5mm of sand size. It is also shown that, this type of sand is the highest percentage from any other type of sands sieved from the mortar of Bastion Maurits. It is believed that this type of sand can increase the strength of a mortar and at the same time help to prevent any cracking that can cause the mortar to break.

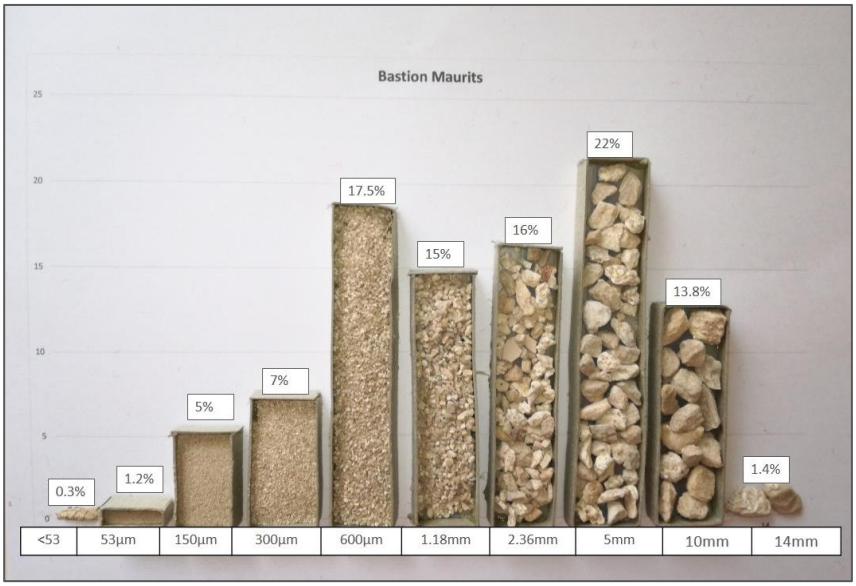

Figure 1: Sand Grading Result of Bastion Maurits

Figure 2 shows the sand grading analysis for Bastion Santiago Fort. Based on the analysis, it was found that 25% of the mortar from Bastion Santiago Fort consists with 1.18 mm of sand size. It is also believed that, this type of sand can can increase the strength of a mortar and at the same time help to prevent any cracking that can cause the mortar to break.

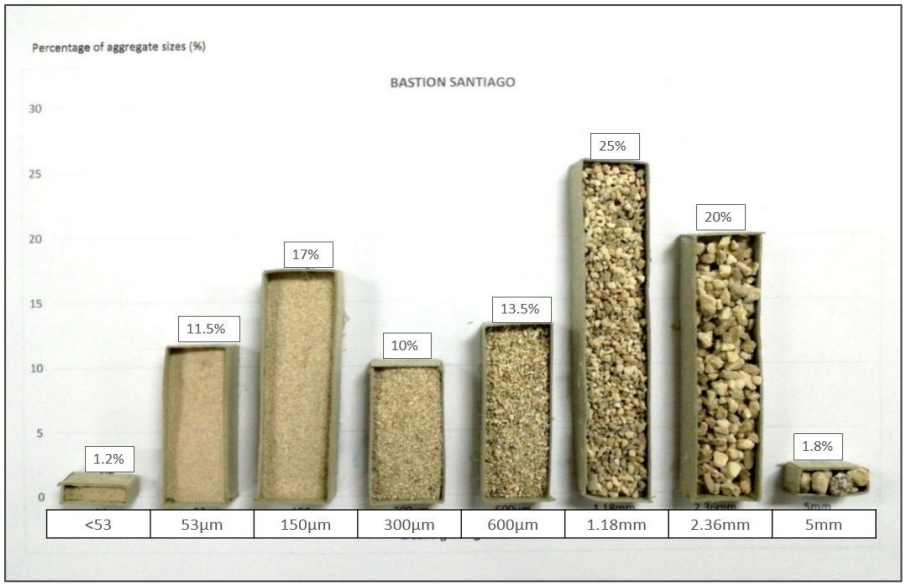

Figure 2: Sand Grading Result of Bastion Santiago

Apart from that, the analysis of sand grading has also identified the characteristics of the sand from each fort. The sands from both forts were identified has the same characteristics. The characteristics of sand from both forts are shown in Table 2. It was found that, sands from both forts are red in colour. The texture of the sand is identified to be rough, angular in shape and has uneven surface. The sand type was also identified as beach sand and coarse graded sand.

Table 2: Sand Grading Analysis Result

No	Characteristics	The Bastion Maurits	The Bastion Santiago
1	Colour	Reddish	Reddish
2	Texture	Rough, angular shape, Uneven surface.	
3	Sand Type	Beach Sand	Beach Sand
4	Sand Grade	Coarse Graded	Coarse Graded

In this study, the ratio of sand: lime was also calculated to find out the composition of the lime contained in the samples from both Bastion Maurits and Bastion Santiago Forts. The result of the calculation is presented in Table 3. The ratio of lime to sand in Bastion Maurits' mortar and Bastion Santiago's mortar is found to be in the ratio of 1:3. This is to prove that lime mortar from both forts are hard and stick firmly to the wall of the Fort. It can be prove that the wall of ratio 1:3 is better and have more strength compare to any other ratio of lime mortar because it has less sand but more lime.

Table 3: Ratio of Sand to Lime

Location	Sample (g)	Sand (g)	Lime (g)	Ratio of Sand: Lime
The Bastion Maurits	100	72.35	27.65	1:3
The Bastion Santiago	100	72.9	27.1	1:3

3.0 Conclusion

This study has found that mortar from both Bastion Maurits and Bastion Santiago Forts consist of sands with different sizes. It is believe that the main material used was from beaches. This study has also found that the ratio of sand to lime from both forts is the same. The result from this study has given the accurate composition of lime mortar that can be used in repairing the historic masonry. The ratio of sand to lime should be consider in conversation works in Melaka and to other forts in Malaysia, generally.

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