LIME MORTAR COMPOSITION OF OLD FORT IN MELAKA: A CASE STUDY OF BASTION VICTORIA AND FREDERICK HENDRICK FORT

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ABSTRACT

UNESCO has recognized Melaka as one of the World Heritage City Centre. With its fortifications, Melaka has demonstrates the early history originating from Malay Sultanate to the colonial (Dutch and Portuguese) period. As for the recognition, there was an awareness to conserve the remnants of forts in Melaka. The conservation of the forts should begin with the composition identification of the mortar used to develop it. This study was conducted in order to identify the accurate composition of mortar to be used in the conservation of Bastion Victoria and Frederick Hendrick Fort in Melaka. Acid dissolution test and sand grading were all the methods used in identifying the composition of lime mortar. The result shows that mortar in both forts consists of sand, lime, beach shells, beach sand, lump lime and crushed coral. The analysis of this study shows that the ratio of lime to sand in Bastion Victoria Fort is 1:4 whilst Frederick Hendrick Fort is 1:3. Based on the previous study it has proven that the mortar with the ratio of 1:3 has a better strength compared to the mortar with the ratio of 1:4. As for the analysis of this study, it has shown that mortar in Frederick Hendrick is much better compared to Bastion Victoria Fort. This result can be used as a guideline in conserving mortar in other historical fort.

Keywords: Lime Mortar, Fort, Conserve, Heritage

Introduction

Melaka is one of the states in Malaysia that have been conquered by Portuguese, Dutch and British. According to Syed Zainol (1995), the used of lime mortar in Malaysia can be prove by the masonry buildings, monuments and shop houses that were built before World War II. The heritage fort is one part of the national heritage, which is, should be preserved from time to time for the future generations. The issue of heritage fort nowadays, many of these heritage fort are not properly restored and destroyed due to inappropriate repair materials. Among the issues being experienced by this heritage masonry fort, it should be by using appropriate material in order to extending the life span of the fort. According to Knight (1995), the main purpose of repairing is to restrain the process of decay without damaging into characteristic of fort. The fort become damage and also affect the originality of design, architecture and building materials as well as the history of the heritage fort (Kamarul & Lilawati, 2014). According to Holmes & Wingate (2002) defects can be reduced by using the same mortar for maintenance work. It has to replace by using a similar composition of historic mortar to protect the heritage old fort from damage.

In order to repair the heritage old fort, the condition and characteristic of the historic mortar must be first evaluated. Therefore, two samples have been taken from the heritage fort of Melaka to analyse suitable composition of mortar. In this study, the mortar was analysed by using two type of method: acid dissolution test and sand...
Literature Review

Conservation
The history of architectural conservation is a movement and development to the preservation of ancient structures and momentum. Conservation is not a new thing, but it has been started during the 18th and 19th centuries. According to Burra Charter (1981), conservation is defined as all the processes of looking after a place so as to retain its cultural significance, it includes maintenance to conservation approach such as preservation, restoration, reconstruction and adaptation, and will be commonly a combination of more than one of these. Meanwhile, the Department of National Heritage (2010) defined conservation as a restoration activities of old buildings, monuments and site that was involved with conservation approach. It is not simply as an architectural deliberation, but it is a sustainable management of an economic, social issues and environmental.

Advantages of Conservation
The main advantage of conservation is to conserve the past, present and future of the building and involve it to history, resources available and sustainability. Other than that, it also can preserve the old building regarding to era from damage. Also it can help to extend the life cycle of the building. Conservation should make use of all the disciplines, which can contribute, to the study and safeguarding of a place. The techniques and methods can be practice by following the principles of conservation (Department of National Heritage, 2010).

Principles of Conservation
There are a few of conservation principles need to be followed by conservator. According to Drury & McPherson (2008) the principles of conservation are that historic environment is a shared resource to the public to sustain the values and the originality of the historic building. Other than that Siti Norlizaiha, et al., (2010) stated, the principles of conservation can prolong the age of the building, respecting the quality of the place, emphasizing the authenticity of the original material as well as workmanship, careful research and recording before the disturbance and interfere with the work of building a position in terms of composition and fabric of the building. According to Knight (1995), the way to achieve the objective of conservation is by follow ten principles of conservation such as the purpose of conservation, the need for repair, avoiding unnecessary damage, analysis historic development, analysis the causes of defects, adopting proven techniques, truth to materials, removal of later alteration, restoration of lost features and safeguarding the future.

Conservation concept
The concept of conservation practiced is authenticity in heritage conservation. According to Section 2(1) Government of Malaysia (2006), an authenticity can be considered as one aspect of the process to restore the aesthetic of the historic building. In the context of the conservation of heritage buildings, the most important aspect is ethical rather than aesthetic. Thus in conservation, beauty is not about the building
size and design of the building but it’s about method on how to restore the building and maintain it as the original. Conservation concept was included with the authenticity of the materials, the construction design originality, authenticity of workmanship and authenticity of the setting of the building.

**Masonry**

According to Como (2013) masonry is a combination of brick or stone and mortar such as mixture on binder, aggregate and water. Masonry old fort was categorized as a dry wall. According to MacAfee (1997), a dry wall was constructed using stones to balance it without using mortar to bind. Construction of the fort can be proved by discovery of monuments (the old fort) in used a stone as a main material to construct the wall.

**Lime mortar**

Lime mortar can be used as a binder for pointing and rendering (ANCADE). Como (2013) defined lime mortar as a mixture of lime, water, and sand. Balksten (2007) state in his study, lime is produced in a process called the lime cycle; burning, slaking, carbonation. Mitchell (2007) stated building lime is produced by burning a naturally occurring form of calcium carbonate (such as limestone, chalk or sea shells) to form quicklime by driving off carbon dioxide. As referred to ANCADE in Practical Guide to Lime Mortars, the characteristic of lime mortar are good plasticity and workability, lack of shrinkage due to volume stability under variable conditions of humidity, great elasticity, and good resistance to the penetration of rainwater. The characteristic of pure lime mortar as the outer and inner layers in conservation work gives many advantages to the durability of a masonry building.

**Method**

This study was conducted in order to identify the accurate composition of mortar used to build the fort of Bastion Victoria and Frederick Hendrick in Melaka. The result from this study will give a better picture on conservation of each fort. Laboratory works was done in order to analyze composition of mortar in each fort. Acid dissolution and sand grading was the two (2)-laboratory test used in analyzing the composition of mortar.

The simplest method of mortar analysis involves the separation of the aggregate from the binder by dissolving the binder using dilute acids and subsequent chemical analysis to determine the chemical compound present in the mortar (Ngoma, 2009). The carbonate binder can be dissolved from the aggregate by using hydrochloric acid (HCl). The main limitation of technique is that if carbonate aggregate is present in lime mortar then it will be dissolved along with the binder (Ashurst, 1988). The reaction between the lime mortar sample and acid hydrochloric is given as below (refer to Figure 1.0)

According to Leslie & Gibbon (1999), the quantification and initial identification of mortar is carried out by using acid dissolution 10% hydrochloric acid. The analysis result is presented in a simple form. It designed to allow their use in development of a replacement mortar specification. This is to identify about type of binder and ratio between binder: aggregate weight. The analysis and the observation are incorporated
in this result to discuss about the original mortar mix. Besides that, the sieved is provide to give information on aggregate grading and colour. This result presented graphically to show a simple comparison of original sand with aggregate (Leslie & Gibbons, 1999).

**Acid Dissolution**

Acid dissolution test was one of the analyses used to analyze the composition of mortar from the identified forts. Sample of 100 grams of mortar was taken out from the fort to be analyzed. In this test, 100 ml of acid hydrochloric solution and 900 ml of distilled water were used. Based on the test run, Calcium chloride (CaCl$_2$), Carbon dioxide (CO$_2$) and water (H$_2$O) were all the elements produced. The amount of lime mortar was then calculated by weighing the amount of sand left. Below are the figure explaining on the chemical reaction in this test.

\[
\text{CaCO}_3 + 2\text{HCL} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}
\]

**Figure 1:** Chemical Reaction in Acid Dissolution Test

**Sand Grading**

Sand grading procedure was then conducted to categorize the sizes of sand sample obtained from acid dissolution test. The sample was sieved by using sieved machine for ten (10) minutes. The sands were graded by the range of sizes which is 14mm, 10mm, 5mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm, 53μm and <53μm. Every sample from the sieving process was being weighed and recorded. The conditions of the sample were also being examined to determine whether it is a grain of sand or solid sand.

**Result and Discussion**

As shown in the Table 1, the characteristic of mortar in both Bastion Victoria and Frederick Hendrick Forts were identified. A jellylike layer with reddish colour was formed on the surface of specimen after two weeks of acid dissolution test was run. The reddish colour shows that the iron aggregate is present in mortar from both forts. Based on this test, it is found that mortar from Frederick Hendrick Fort has a higher chemical reaction compared to mortar from Bastion Victoria Fort. It is happened due to the differences of lime composition in each mortar. The mortar with a high composition of lime has a high chemical reaction compared to the one with the less composition of lime. The percentage of CO$_2$ released was also indicated in this test. Based on the reaction, it is found that, the released of CO$_2$ from Bastion Victoria mortar is lower compared to Frederick Hendrick mortar. The sample with the highest percentage of CO$_2$ released shows that the mortar has a higher amount of lime compared to the one with the lowest releases of CO$_2$. 
Table 1.0: Acid Dissolution Analysis Result

<table>
<thead>
<tr>
<th>No</th>
<th>Characteristics</th>
<th>The Bastion Victoria</th>
<th>The Frederick Hendrick</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Colour</td>
<td>Reddish</td>
<td>Reddish</td>
</tr>
<tr>
<td>2</td>
<td>Reaction</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>Layer of Jellylike</td>
<td>Exist</td>
<td>Exist</td>
</tr>
<tr>
<td>4</td>
<td>Percentage of CO₂ released</td>
<td>19.3%</td>
<td>24.6%</td>
</tr>
</tbody>
</table>

Sand grading procedure was the second process in this study. It is taken place after the process of acid dissolution test. The sample from the acid dissolution test were graded into 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 Victoria mortar is shown in Figure 2, meanwhile the result of sand grading of Frederick Hendrick mortar is shown in Figure 3.

![Figure 2: Sand Grading Result of Bastion Victoria Mortar](image1)

![Figure 3: Sand Grading Result of Frederick Hendrick Mortar](image2)
Based on the Table 2, the sample shows that the characteristics of sand in mortar from both forts are reddish in colour. The texture of sands is rough, angular in shape and has an uneven surface. Both samples were identified as beach sand. The sand in mortar from Bastion Victoria Fort found as well graded, however the sand in mortar of Frederick Hendrick were identified as coarse graded. As shown in Figure 1.0, the highest percentage aggregate found in Bastion Victoria mortar is 33.5% weighted 600µm. This sand grading is important in the lime mortar bonding as it can fill up the spaces between the aggregate in the lime mortar. The sand in the range size of 5mm which is 1% of the sample is the most course sand in the mixture. It is able to increase the strength of the mortar and at the same time it also able to stop crack that can cause the mortar to break. The highest contents of aggregate in 600µm can be prove that the lime mortar have a porosity. It can help the lime mortar hardening by carbonation. The carbonation process in lime mortar is a physical chemical process when calcium hydroxide (Ca (OH)\(_2\)) reacts with carbon dioxide (CO\(_2\)). It also can help the lime mortar evaporation in atmosphere faster. According to this analysis, it found that the sample is well-graded and a normal composition. Therefore, it became a good lime mortar as a binder to the building.

However, based on Figure 1.0 it is found that the highest contents of aggregate in The Frederick Hendrick are 19%. The highest aggregate is 10mm in size. The analysis result also shown that the percentage is in a range of sizes between <53µm to 14mm. According to this analysis, it shows the result that the sample is coarse graded in it composition. Therefore, it became a good lime concrete as a binder to the building. The lime concrete is a mixed between lime, coarse sand, brick dust and eggs broken pieces in a position dry.

<table>
<thead>
<tr>
<th>No</th>
<th>Characteristics</th>
<th>The Bastion Victoria</th>
<th>The Frederick Hendrick</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Colour</td>
<td>Reddish</td>
<td>Reddish</td>
</tr>
<tr>
<td>2</td>
<td>Texture</td>
<td>Rough, angular shape, Uneven surface.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Type of Sand</td>
<td>Beach Sand</td>
<td>Beach Sand</td>
</tr>
<tr>
<td>4</td>
<td>Sand Graded</td>
<td>Well-graded</td>
<td>Coarse Graded</td>
</tr>
</tbody>
</table>

In this study, the ratio of sand: lime is also analyzed to find out the composition of the lime contained in the samples. The result of this analysis is presented in Table 3. The ratio of lime to sand in Bastion Victoria’s mortar is 1:4, whilst the ratio of mortar in Frederick Hendrick is found to be 1:3. This is to prove that lime mortar is 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 1:4 because it has less sand but more lime. In this case it is proven that mortar in Frederick Hendrick have a better strength compare to Bastion Victoria Fort.
Table 3: Ratio of Sand to Lime

<table>
<thead>
<tr>
<th>Location</th>
<th>Sample (g)</th>
<th>Sand (g)</th>
<th>Lime (g)</th>
<th>Ratio of Sand: Lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Bastion Victoria</td>
<td>100</td>
<td>80.96</td>
<td>19.31</td>
<td>1:4</td>
</tr>
<tr>
<td>The Frederick Hendrick</td>
<td>100</td>
<td>75.4</td>
<td>24.6</td>
<td>1:3</td>
</tr>
</tbody>
</table>

Conclusion
This study has found that mortar from both Bastion Victoria and Frederick Hendrick Forts consist of beach sand, additive materials such as lime, beach shells, beach sand, lump lime and crushed coral. The findings of shells and beach sand in the mortar can be proven that the materials used were from the beach. It was also proof that the location of this case study was near by the beach. This study was also found that there was a different in ratio for both forts. It found that Bastion Victoria Fort has more content of sand compare to Frederick Hendrick Fort. It also proved that Frederick Hendrick’s mortar has a better strength compared to Bastion Victoria’s mortar. The result from this study has given the accurate composition of lime mortar that can be used in repairing the historic masonry. As for that, it is suggested that, this kind of ratio should be consider in conservation works for the old forts in Melaka specifically and to other forts in Malaysia generally.

References


