Classification of Factor Affecting External Wall Defects Focusing On Lime Material of Heritage Buildings in Penang, Malaysia

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Abstract
Awareness of the used of compatible and sustainable material in historical building conservation has resulted in the rebirth of lime technology and application. Then again, the knowledge of the preparation and procedure influencing the final quality of lime is still limited and disagreement regarding the conservation treatment still continues to exist among the conservator. The purposed of this paper is to highlight the current deterioration condition and suggests possible treatment focusing to external wall of selected heritage buildings in UNESCO’s George Town Heritage City in the State of Penang, Malaysia. It is agreed within the Malaysian conservation works scenario, lime has been used on most part of the external wall and therefore this smart material will be the focus of the report. The study was conducted based on qualitative method, such as literature review, visual observation and interview. From the pilot survey of 85 historical buildings in Georgetown core zone, it has been found that lime has been used as a major based material for its external wall prime render material. However, the findings determine these external wall has noticeable defect causes by three main factors which are climatic charge, air pollution and maintenance issues. This study however will be focusing on lime material. Therefore, the paper hope to generate understanding on the lime usage to the conservator or for those within the construction industry thus the restoration for external wall can be established within the area.

Keywords: external wall; deterioration; lime treatment; heritage building; building conservation

INTRODUCTION
The city of George Town in Penang Island, Malaysia faces several problems in dealing with the issues of its historic building. Askari (2009) stressed lack of technical knowledge in repairing and maintaining historic building is a major problem because repair and maintenances stage required good conservation understanding and proper analysis of building diagnose. Understanding the building defect is simply a logical way of proceeding from the evident to the causes of defect after which remedies can be prescribed. Hence, it is importance to understand the original material used and the factor and process responsible for deterioration. Talib et.al (2011) mentioned the selection of the suitable repair method and correct material chosen during the building conservation can decreased the defect to occur for the second time in future.

It is interesting to note that lime has been use as building construction and decoration material for decades in Malaysia. Lime is a product of calcium carbonated which commonly takes the form of limestone, as found and quarried in lime stone hill and also can be found in coral, sea shells, and chalk. Conversion to calcium oxide take places and better known as quicklime, when any form of calcium carbonate are burnt at between 850°C and 1300°C. Lime are used in wall (lime mortar, lime plaster, lime wash), floor and roof. Fig. 1 shows the wall breathable concept. Lime allows natural ground moisture to move up the wall and evaporates through lime plaster. Mold (2005) however mentioned if the wall are plaster with cement, the moisture will be block and cause wall damage.

Figure 1. Moisture evaporation; comparing concrete cement and lime plaster

In order to understand the techniques associated with lime, it is necessary to review the lime development chronological as indicated by Muhamed (2002). He also found in his research that the art of using mortar in some form or another is as old as the art of building or as civilization itself. Evidences of the use
of mortar are not only in the early civilization of Europe, Asia or Africa, but also in the ruin of Mexico and Peru of the New World. The remains of work of these ancient artisans are evidence to us of the enduring qualities of lime mortar as well as the skill and knowledge possessed by the user.

The revival of lime mortar application for the repair of historic building has also taken place, due to recognition of an unfavourable properties of Portland cement mortar, including brittleness, high strength and thermal expansion coefficient which twice as large as lime mortars compare to most type of brick and stone. Portland cement have low porosity and large amount of small pores, might hinder water movement in masonry and cause damage due to the accumulation of moisture behind cement layer or to evaporation and deposition of salt in the adjacent stone or brick. Toniolo (2009) mentioned soluble salt such as calcium sulphates and sodium salts might be present in Portland cement mortar, which can leach out over time. However, lime mortar has a low efflorescence potential due to its relatively high chemical purity. It also have the advantage of allowing limited movement within the mortar joints and can undergo autogenously healing due to dissolution and precipitation process, and it’s important that lime mortar being softer and more porous than masonry, and act as a sacrificial substrate water evaporation and decay from soluble salt crystallization.

METHODOLOGIES

The study was conducted based on qualitative method; hence, the data was collected through gathering related literature review, visual observation and interview. Literature review is mainly based from published books, research paper and journals. Type of interview used in this study is un-structure interview and focus group interview. The data gather are based on four main questions, that are:- 1. Type of lime that are used during the conservation project? 2. Method of lime slaking that was use during the conservation? 3. Lime determination of the mixing ratio? 4. What preparation that needed for the wall? 5. What guideline can be used during the restoration?

The duration of data collection was from February 2014 until April 2014. The study area consists of existing historic buildings located within the core zone of the Penang heritage site where survey has been done to collect data on the wall defect. The criteria types of the building ranges from heritage shop houses to colonial buildings. The estimated number of heritage building as sample size is 170 that are 10% of 1700 buildings within the core zone. To eliminate bias factor, simple random sampling is adopted in this study. However, out of the 170 building sampling size, survey was carried out to 85 number of buildings and two number of buildings have been selected for desk study and will act as guide in answering the studies objective. Data collected in the survey is analyses using Glaser and Strauss constant comparative method, and simply summarized in the pie chart form.

RESULTS AND DISCUSSIONS

To ensure the objective of this study can be achieved, pilot survey are done in George Town Heritage building zone. Pilot survey is use to get a clear understanding related to the current condition of historic building in George Town. Fig. 2 shows the percentage of building condition in George Town, Penang; base on the visual observation of 85 number of buildings. From the observation, 53 percent of the buildings are in fair condition, while 35 percent is in good condition and 12 percent is in dilapidation condition.

External wall are chosen to be evaluated because the building façade gives important impact to the historical district image. From Table 1, nine defects on external wall have been identified. Out of 85 selected historical buildings, 75 number of buildings have staining, 74 buildings have discoloration, 73 buildings have chalking, 57 buildings suffer with peeling paint and 55 buildings have blistering defect, non-structural crack on 46 number of buildings, loosing of lime plaster on 35 number of buildings, erosion of mortar on 10 number of buildings and effloresces on 9 number of buildings.

Hence, it can be identify that the highest number of building suffer with staining defect, discoloration and chalking. The lowest defect occur are erosion of mortar, and effloresce. Plaster is used to protect the brick and to create surface finishes for the wall paint. However the uses of cement plaster on wall will trap moisture inside the wall and after few years the plaster will start to crumble and eventually fall off (Fig. 3). The same thing will happen to the wall when using standard chemical paint that does not allow the wall to breath. From the site observation, some buildings have been identified using incompatible material. The uses of incompatible material will cause deterioration to the wall. Cement renders and
chemical paint has been identified as the factors contributed to wall deterioration.

Table 1. Number of building with external wall defects in George Town, Penang UNESCO World Heritage Site

<table>
<thead>
<tr>
<th>Number of Defect</th>
<th>Peeling Paint</th>
<th>Discoloration</th>
<th>Erosion of Mortar</th>
<th>Non-Structural Crack</th>
<th>Loosening of Lime Plaster</th>
<th>Efflorescence</th>
<th>Chalking</th>
<th>Staining</th>
<th>Blistering</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>74</td>
<td>10</td>
<td>46</td>
<td>35</td>
<td>9</td>
<td>73</td>
<td>75</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Two types of stain found in George Town, Penang; black crust due to air pollution (left) and black stain due to bio-growth (algae) (right)

Table 1. Number of building with external wall defects in George Town, Penang UNESCO World Heritage Site

The combination of discoloration, chalking, staining and peeling paint have been found due to environmental effect. Stain is the discoloration produces by foreign matter that has penetrated into masonry. This is the result from chemical reaction between masonry and the foreign mater. Two type of stains was found from the site observation, bio-growth and black crust due to air pollution as shown in Fig. 4. Most common stain is black layer on the external surface cause by vehicle smoke. However, stain due to bio-growth is cause by moisture. Surface repainting will not solve both of the stain problems. Moreover, a serious stain problem will lead to façade damage such as losing of plaster and erosion of mortar.

Chalking or powdering of the paint surface is causes when resin in paint film is slowly weakening. The amount of chalking can be determine by the formulation of the paint and the amount of ultraviolet light which the paint is exposed as indicated by Weeks (1982). Chalking can be considered as a way for the paint to ‘age’. Discoloration of paintwork was commonly found in several historical buildings. This is also due to the tropical climatic factor in George Town, Penang. Discoloration also happens when the mineral inclusion reacts to water or chemical cleaners.

Furthermore, peeling paint can be resulted of improper surface preparation or due to incompatibility between paint types. As example, the
used of non-breathable paint type on lime plaster surface such as the uses of chemical paint, will causes bad evaporation and the extent moisture that lead to wall deterioration.

On the other hand, paint bulging or blistering is a result from common application error and not likely caused by moisture, but caused by action of ambient heat on paint. When paint is applied during direct sunlight, the top surface will quickly dry and as a result the moisture will trapped beneath the dried paint. When the moisture vaporizes it forces its way through paint film. This problem occur mostly to dark colour paint due to the dark colour absorb more heat than the lighter one.

Repairing the Damage on Heritage Building
From the data collection, the restoration of external wall can be divided into two categories, remedial for mortar and plaster; and surface remedial. In order to make an ideal repair, it is important to choose right material and systematic technique approach to be used.

Four basic phases can be identified to determine the suitable plaster to be used during the restoration. First is the visual analyses and documentation, second experiment study, then evaluation and finally decision making. Visual analyses and documentation are used to determine the location of the defect and cause of defect. Experimental study is composed of two experimental methods (non-destructive and destructive test). Both test is used to remove doubt regarding the determination of damage encountered during the visual analysis.

Non-destructive testing method such as X-ray Fluorescence Spectrometer (XRF) is used to determine the composition of the material within the old material. Result from the test will determine the main material present in the old plaster and the ratio for the mixture. Having identified the material breakdown, thus mock up plaster need to be applied according to the conservator suggestion. Finding from the George Town World Heritage Incorporate (GTWHI), 2012 report have indicated the introduction of three layers of lime plaster with ratio of 3:1 (sand and lime) being used. Additional material also can be added into the mixture to increase the plaster durability. The addition material can be either brick dust pozzolan or meta kaolin pozzolan.

Furthermore, lime preparation can be done in two ways; first the use of ready mix lime putty or power quicklime. It has been confirmed that several building conservation project used powder quick lime that have been slaked to form lime putty. To elaborate, a slaking process is done in large pond of water (lime pit) and powder type quick lime is poured into the water (Fig. 5).

Figure 5. Preparing lime slaking

Site preparation is one of crucial factor when applying the lime plaster to brick wall. The wall needs to be free from any debris and any source of running water. Since building construction is a wet process, wall that will be received lime plaster need to be wet in order to help the bonding between plaster and wall. Yahya (2002) suggested shade need to be provided during the external application to protect it from strong heat.

It is a good practice to apply three coats of lime plaster with a total of 25 mm thickness consist of base coat, render coat and finished coat. All coats will have the same mixing ratio (3:1) between sand and lime. Base coat will have 6-10 mm thick and to be let to dry for two days before applying the next render coat. Base coat surface need to be rough surface for the next coat to bond. Thickness for render coat is 6-8 mm, and finishing coat is about 3-4 mm. Fig. 6 shows a mock up sample on site.

Figure 6. Mock up sample on lime plastering and preparing clean surface for lime work.

Surface Treatments
Paint serves as the first sacrificial layer of protective protection against weather and deterioration. Lime base paint are commonly being chose as paint material for historic building because lime are vapour permeable, which mean it allow moisture to escape from the walls. This help to control condensation damp within the building and maintain the hydrostatic pressure.

From the study, most of heritage building in George Town, Penang used pigment type lime wash. Lime wash in George Town area is made by adding lime putty, water and color pigment. Lime wash also has been used in wood surface of the building. For the wood surface addictive material such as acidic
calcium was used to make the paint last longer. Mold (2005) point out that the applications of lime wash depend upon the quality of the surface. Surface treatment or cosmetic surface treatment, for heritage wall in George Town usually involve with scrubbing off old paint.

Lime wash is applied in two thin layers; the first layer is a mixture of lime and water. While the second layer is a mixture between lime, water and 10% pigment color. There are four historic colours in George Town, Penang (white, indigo blue, ochre yellow and green). To ensure the paint surface does not chalk and having even coverage of color, it is necessary to lay at least three to five layers of unpigment lime wash and addition of two more layers for pigment colour.

However, when dealing with improper material embedded to the historic building, especially the uses of cement; first, determine the ratio mix of the cement, if the lime to cement ratio less than 1:1, it is advisable to knock out the cement area. Then again, hacking off of the cement area will bring much of the fabric away with it. Therefore, it is important to ensure that only the defected area is being hack-off. For the use of non-lime paint, the paint needs to be carefully scrap manually. This is due to the use of sandblaster, it will damage the surface of the underlying masonry. However, the use of water jet would be most practicable.

For the rake out joint that expose brickwork up until approximately twice the width of the joint, it is wisely to take out the old mortar and brush out thoroughly before spraying down until well wetted. For optimum result, after the surface is dry; the inside of the joint need to be wet before applying the mortar.

CONCLUSIONS
From the result of the visual finding, it can be concluded that the external factor affecting historical buildings in George Town, Penang are due to climatic change, air pollution and lack of maintenance practices. Climate is the act of atmospheric event such as rainfall, temperature, air pressure and humidity. Due to the tropical climatic condition, Penang has heavy rainfall and warm sunshine all year round. Therefore the external part of the building tends to weather rapidly. Furthermore, the discoloration of external wall is also cause by the solar effect factor.

Air pollution due to vehicular traffic also play one of the main factors of historical buildings rapidly in deterioration condition. During the visual observation, several buildings have had the blacking effect problem. According to Toniolo, (2009) black carbonaceous particle also known as black crust is originated from smoke pollution from vehicle and human activity, causes the soiling of facade by deposition of black carbonaceous particle. Most buildings located facing or positioned near the main road have black carbonaceous particle. Lastly, lack of having scheduled maintenance practices is another factor impacting the deterioration of George Town heritage buildings. Building maintenance team play importance role in preventing defects. Poor maintenances knowledge among the construction industry players or practitioners in dealing with the defect also contributed to the deterioration factor. To sum up, it can be concluded that to get effective and smart remedial conservation construction materials, one must understand the deterioration factors and the character of the material used. This is due to each defect has its own character and the produce of the right remedial material can eliminate the defect from reoccurring hence saves the financial aspect.

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