Green Maintenance: A Review Of Sustainable Repair Impact On Embodied Carbon Expenditure For Heritage Buildings

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Abstract: Essentially, historical and architectural values of heritage buildings require continuous care and planned maintenance i.e fundamental process of buildings conservation. Subsequently, good maintenance intervention is seen as a tenet of sustainable repair approach for heritage buildings, through the emerging concept and methodology of Green Maintenance model. The emergence of this model entails noble understanding on the cumulative effect of routine maintenance interventions i.e repairs, not only in terms of cost and philosophy, but also from the environmental impact perspective. This paper gives insight on how sustainable repair approach of Green Maintenance stimulates the usage of low carbon materials and reduction of CO₂ emissions in heritage buildings repair. This was expressed based on the quantification of embodied carbon expenditure expended from repair within ‘cradle-to-site’ boundary of Life Cycle Assessment (LCA). This review shows that CO₂ emissions from heritage buildings repair is increasingly become the prime concern. Substantially, sustainable repair approach of Green Maintenance model relays the ‘true’ CO₂ emissions.

Key words: Green Maintenance, Sustainable Repair Approach, Embodied Carbon Expenditure, Heritage Buildings

1. INTRODUCTION

Heritage buildings continue to perform their irreplaceable role as representation of societies past history. Indeed, it also universally recognised with the wealth of esthetical, archeological, architectural, cultural, historic, documentary, social, political, spiritual or symbolic values that become something that is passed down from one generation to another, through the conservation practice (Fieldan and Jokilehto, 1993). Conservation of heritage building is an establish method to preserve a heritage building through maintenance works. It has
been identified that maintenance. It has been identified that maintenance is one of the primary principles for conservation of heritage building (Dun, 2000). It is impossible for heritage building to be free from maintenance (Abdul Hakim, 2002). It was relates to the nature of heritage building that is prone to some avoidable degree of decay and degradation. Therefore, it shows the need of carrying a continuous care and planned maintenance to mitigate the problem (Hamilton and Wan Salleh, 2002). Consequently, it shows the importance of maintenance that seen as part of conservation process that closely related to the value and the nature of heritage building.

However, maintenance work is always associated with the corrective and driven budget. In current practices, whether based on planned or unplanned maintenance, budget becomes the main topic of discussion, which maintenance is carried out based on the allocated budget (Yusof, 2013). It was reported in Property Maintenance Budget Unit, Ministry of Finance in Malaysia (2008) that each year, government has to increase the budget for repair works for building from RM4 billion in 2004 to RM7 billion in 2008. Maintenance work becomes more active in the year of 2007 where government insisted on maintenance management as a new culture for the nation. It consequently caused the increment of a budget for repair work that reaches almost RM9 billion. This also lead to the formation of Manual Total Asset Management (TAM) which more focusing on asset management (operational and maintenance) and facility management (Yusof, 2013). The scenario and series of National Budget shows more attention has been given to the maintenance work specifically when it translated into budgetary forms. It is still vary in the context of maintenance for heritage buildings.

Nonetheless, maintenance of heritage cannot solely emphasised in cost and budgetary perspective. It requires a long term solution where maintenance of heritage building is more complex because of the need to retain it’s value, the difference of the original built materials and technology that required higher cost (Rashid and Ahmad, 2011). However, it must be emphasise that whenever the option presents for repair strategies, preserving an original building element is commonly preferred (Canada’s Historic Place, 2004). Despite the enactment of the National Heritage Act and establishment of the National Heritage Department, by large, heritage buildings in Malaysia still remain in poor condition. Additionally, existing legislations are yet sufficiently addressing the maintenance issue, and somehow this was vaguely described. Non-existence of specific statement, guidelines and references therefore shows the main reason on why immediate actions should be taken (Rashid and Ahmad, 2011). Based on the aforementioned issues, acknowledgement of good maintenance intervention and sustainable repair approach is paramount important to attained good condition of heritage buildings through Green Maintenance concept and methodology.

Conceptually, Green Maintenance promotes good maintenance intervention as a tenet of sustainable repair approach for heritage building. The sustainable repair approach of the model will assists to strengthen the appreciation of heritage building repair i.e. not only minimising of cost or attaining building conservation philosophy, but also mitigating environmental impact (reduction of embodied carbon expenditure or CO$_2$ emissions as well promotes usage of low carbon materials). Significantly, adoption of sustainable repair approach in heritage buildings repair has sustainability benefits, mainly to adhere the significant reduction of carbon emission. Therefore, this paper gives insight on how sustainable repair approach stimulates the usage of low carbon materials and reduction of CO$_2$ emissions in heritage building repair.

2. GREEN MAINTENANCE: A SUSTAINABLE REPAIR APPROACH FOR HERITAGE BUILDING

“Sustainability” term often recurs in all areas of human activity related to production, management, building methodology and it became a phenomenon (Vitiello, 2012). The Brundtland Report in 1987 defined the term as equilibrium between the satisfaction of the present needs and the maintenance of possibility for future generations to meet their own needs, so proposing a sustainable development that should be able to guarantee good living conditions in the long term. Subsequently, Kyoto conference in 1996 expounded sustainability directly to
building sector due to its relatively close association with environmental impact. The absorption integration of the between sustainable philosophy into with building industry has had adopted new ideas and practices. This includes the recognition of crucial aspect of maintenance that linked to building’s sustainability (Ofori et al., 2000, SPAB, 2013). Significantly, this is parallel with Green Maintenance concept and methodology.

Figure 1 provides an illustration of Green Maintenance concept that parallel with generally accepted model of sustainable development and acting as a tool of measurement to achieve sustainable repair, based on relevant parameters and factors. Forster et al. (2011; 2013) and Kayan (2013) suggested that maintenance intervention for heritage buildings can be assessed based on cost, conformity to building conservation philosophy and environment. These three-factor influences the maintenance for heritage buildings that would potentially considered as the most sustainable repair (Forster et al., 2011 and 2013; Kayan 2013).

![Figure 1: Green Maintenance Conceptual Model](source: Forster et al., (2011 and 2013); Kayan (2013))

It is well accepted that the way of undertaking of any repair project of heritage buildings should underpin by building conservation philosophy, which are based on ethics and principles. This is building conservation philosophy factor. Bell (1997) and Forster (2010) expounded that repair should be undertaken based on ethical and combination of principles include “least intervention, life for like material replacement, honesty and distinguishability, integrity, reversibility, respect for historic and respect for traditional craft skills” will generally contribute to highly defensible, lead to naturally good and well-founded conservation interventions (Bell,1997; Forster, 2010).

The second emerging factor in sustainable repair approach of Green Maintenance is economic factor. The issue of cost associated with the heritage building maintenance consist of the need to retain the heritage value, the difference of the original built materials, technology, the need for specialist surveyors, architects, skilled labour and special materials that required higher cost (Benhamou, 1996; Ahmad, 2000). Most current maintenance being practiced is not considered clearly and systematic where it is very common to see that the failure to identify the damage from early stage will cause the wasted in term of cost. Hypothetically, the maintenance cost decreases with improvement in the physical condition. As building condition improves, maintenance cost decreases sequentially because there is a uniform decrease in annual maintenance cost (Sodangi et al., 2015). It clearly demonstrates that if maintenance works is planned properly and continuously, the cost could be reduced in the longer period of time (Mohd-Isa et al., 2011).
However, comparatively to first emerging factor which is philosophy. It shows that good conservation does not governed by cost factor alone. Hill (1995) highlighted about the reality of many conservation jobs that philosophical approach taken in any repair project is based on “the finances available, and will be affected by current fashions in conservation philosophy”. It is important to realise that good conservation need not always be expensive. Hence, the option of cost merely does not affect much on conservation of heritage buildings. It enables the decision maker to make a rational choice to decide the high quality and longevity of repair project that not only consider about the cost.

Adding complexity to Green Maintenance model is environmental factor. From environmental perspective, existing building generates approximately 40% of total carbon emissions (Levine et al., 2007). It urged that the need to improve their performance to meet the statutory carbon reduction target, in which, heritage buildings have significant contribution to meet the target. In United Kingdom (UK), heritage building is discussed beyond the issue of conservation, which they already championing the building conservation’s sustainability, particularly in the reduction of Carbon Dioxide (CO$_2$) emissions (Godwin, 2012).

Primarily, Green Maintenance model emphasised on the environmental impact, in the perspective of embodied carbon expenditure. The embodied carbon expenditure become more significant compared to operational emission. It has extensively covered by the regulation and program such as Target Zero Program, Green Building Index and others. As the operational energy efficiency of new buildings is improved, the relative significance of the embodied impacts of construction materials and processes also increases. In recognition of this, significant attention is now being paid to the quantification and reduction of embodied carbon impacts of buildings and construction products (Sansom and Pope, 2012). A report by Junilla (2004) stated that maintenance generates relatively small part of the carbon emissions from a building in a life cycle perspective. It supports the need of further investigation that urged the accurate picture of total emissions for maintenance through embodied carbon expenditure to achieve a sustainable repair.

3. GREEN MAINTENANCE APPROACH ON SUSTAINABLE REPAIR: MAINTENANCE AND EMBODIED CARBON EXPENDITURE

Sustainable repair approach of Green Maintenance highlights the relationship between maintenance and embodied carbon expenditure. Figure 2 represents each maintenance intervention that characterized by its longevity and embodied carbon expenditure. The maintenance interventions were undertaken to maintain the condition of building at the optimal service condition. It clearly shows by Figure 1 that there is a relationship between the numbers of maintenance intervention, longevity of repair and embodied carbon; the more frequent of the maintenance intervention will contribute to higher embodied carbon expenditure (less efficient repair) (Forster et al., 2011 and 2013; Kayan 2013).
Additionally, sustainable repair approach of Green Maintenance also promotes low embodied carbon expenditures expended from repair. In order to attain this, preference is given to the repair technique that has higher longevity of repair and less number of maintenance interventions. Forster et al. (2011) and Kayan (2013) articulate that… “there are three most common types of repairs for natural stone, plastic repair, and pinning and consolidation. Replacement stone technique in repair is considered very durable with a life expectancy of 100 years but the energy used in this process is potentially considerable as a result of quarry, extraction, processing and transportation”

Both Forster et al. (2011) and Kayan (2013) also expounded that… “Plastic repairs (denoting plasticity not the addition of polymers) are surface repair to deteriorated masonry faces, with a life expectancy of about 30 years that highly defensible. Same goes to consolidation and pinning that purposely used as stabilisation technique in which nylon or stainless-steels dowels are inserted into holes drilled into delaminating layers or detached sections of masonry and fixed with modified lime grouts. Comparatively, both of repair technique do not use a great deal of energy compared to the former interventions as their life expectancy may be low” (Forster et al., 2011 and 2013; Kayan 2013).

Based on the above scenarios, it shows that higher longevity repair require less intervention but will consume more energy (in this case is embodied energy representation of CO₂ emissions) over the lifespan of building and vice versa. However, sustainable repair approach of Green Maintenance concept encourages higher longevity, which fewer interventions undertaken. Comparatively, it is relatively clear that replacement stone technique (only require single intervention within arbitrary period of 100 years), compared to three, four and five interventions for plastic repair, re-pointing and consolidation respectively (Forster et al., 2011 and 2013; Kayan 2013).

In addition, the total embodied carbon expenditure expended on repair was influenced by by the functional units of relevant building elements and components. The larger the area (example of wall surface are in meter square) that need to be repaired; the higher number of intervention to be undertaken, the greater the total of embodied carbon expenditure. However, Green Maintenance model also initiate various mechanism to reduce the CO₂ emission which “usage of locally sourced repair materials, engagement of regional companies to undertake repair work and selection low embodied carbon” (Kayan, 2013).

Due to diversity of heritage buildings repair options and techniques, there is also complexity of in terms of repair materials resourcing, manufacturing and transportation processes. These incurred processes in the maintenance (repair) will contribute to embodied carbon expenditure. For instance, in the UK, material sector alone is accountable for 5-6% of total emission, which 70% are associated with manufacturing and 15% are associated transportation of material (Rawlinson and Weight, 2007).
Relatively, laterite stone works for heritage building in Melaka, Malaysia is as the example: “The original material that used to construct the Bastion Middleburg in Melaka during the Portuguese and the Dutch occupation was available locally and is called the laterite stone. Due to the fact that there is a depletion of the source of laterite in Malaysia, the works of Bastion Middleburg was carried out using the stone that was brought in from Prachinburi, Thailand. Moreover, the composition of the laterite stone that is available in Prachinburi was found to be equivalent to the composition that was used to construct the Bastion Middleburg. In fact, the laterite stone of Panchinburi has an additional property whereby the strength of the stone increases in the process of its chemical reaction with the rainwater and the moisture in the air” (Melaka Heritage Department, 2006).

The example above shows the depletion of the sources and similarity of composition of material in maintenance forces the need to import the material from other country. The CO₂ is the most important by-product in the manufacture of building materials, manufacture, transportation of building materials that mainly contribute from the usage fossil fuels. In Malaysia, the buildings account for about 20% of the production of carbon emission that comes in third after transportation which about 27% and industries 21% (Kilbert, 2002). It obviously shows that carbon emission from maintenance process will take place in the every percentage of carbon emission statistic in Malaysia.

Similarly, the need for other material also contributes to carbon expenditure; lime, sand, white cement and reinforced concrete. For the example of the laterite stone works for heritage building in Melaka, Malaysia; “The mortar sealant composition for Middleburg Bastion was prepared using lime, sand and white cement. Moreover, the reinforced concrete is being use for differentiating the original and the new materials for Middleburg Bastion work. Next, sand is also being used that will functions as an absorptive material to prevent dampness on the floor surface before layer it with laterite stone” (Melaka Heritage Department, 2006).

Based on the statement above, the additional material that needs to be use will produce the carbon emission such as concrete and cement especially in the production. “Reinforced concrete has problem which the production that comes from constituent materials, the fuel and process used to manufactured, the strength class of the concrete and the resulting mix composition, the level of steel reinforcement, transports impact. It production contributes 5% of CO2 and China’s booming construction industry producing 3% alone. The rule of thumb is that for every tonne of cement you make, one tonne of CO2 is produced. However it has good building material” (Crow, 2008).

From the above scenario, it clearly pointed out some examples of maintenance work in Malaysia that relatively contributes to significant carbon emission throughout the process. In broader sense, in order to meet the carbon emission reduction and to get the accurate picture of emission from maintenance, it is necessary to consider the cumulative impacts from maintenance process through quantification of embodied carbon. To quantify the embodied carbon expenditure, the Life Cycle Assessment (LCA) is a technique to assess the environmental impacts specifically embodied carbon data (Anderson, 2012). The Scottish Buildings Standards Agency (SBSA, 2007) adopted a mechanism to evaluate the release of embodied carbon (CO₂ emissions) within ‘cradle-to-grave’ boundary of LCA. However, for many construction products, there is lack of data on the impacts after they have left the factory gate. Consequently, many embodied carbon assessment are currently limited to ‘cradle-to-gate’ studies in LCA boundary.

Similarly to the previous work has been done in order to evaluate carbon expenditure within the cradle-to-site boundary using (P-LCA) for stone masonry wall historic masonry buildings. By using this methodology, comprehensive calculation could be done includes all the aspect in maintenance such as maintenance intervention and other variable that may include total area repaired area (m²), longevity of repair, resourcing and geographical location, technological development, mode of transportation, quality of initial work and specification (Kayan, 2013).

Rather than all aspects of maintenance stated above, the calculation of carbon expenditure is also being tailored to Environmental Maintenance Impact (EMI) in selecting the most efficient repair technique, either single or combination of technique in selected maintenance periods. As a result, it would provide the data of impact in repair that will guide for the selection of maintenance options and
mechanism that minimize the carbon emission (CO2). The fully consideration of tripartite model in Green maintenance will gives and allows the rational appraisal of maintenance option for heritage buildings, with the consideration of cost, philosophy and environmental.

4. CONCLUSIONS

Maintenance underpins heritage buildings conservation. It may prolong their lifespan by stave off decay. Hence, sustainable repair approach of Green Maintenance concept and methodology provides the good understanding on cumulative effect of maintenance intervention upon embodied carbon expenditure. This is mainly interlaid between the three main parameters: cost, philosophy and also environmental. Also, this paper highlighted that the quantification of embodied carbon expenditure expended from repair within ‘cradle-to-site’ boundary of Life Cycle Assessment (LCA) is immensely significant in heritage buildings conservation. The sustainable repair approach of Green Maintenance stimulates the usage of low carbon materials and reduction of CO₂ emissions in heritage buildings repair, is highly influenced by number of maintenance intervention, longevity and other variable such as resourcing and geographical location, technological development, mode of transportation, quality of initial work and specification. Increasingly, Green Maintenance model also provide novelty in terms of mechanism to reduce the embodied carbon expenditure from repair; usage of locally sourced repair materials, engagement of regional companies to undertake repair work, and selection low embodied carbon. This will relays the ‘true’ CO₂-emissions mitigation through sustainable repair approach as well providing good maintenance options for decision maker.

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