CIVIL ENGINEERING AND ARCHITECTURAL BUILDING FEATURES DISPARITY AND PRESERVATION OF STRUCTURAL AND FABRICS INTEGRITY IN HERITAGE BUILDING: A REVIEW

Siti Nor Fatimah Zuraidi¹, Zainal Abidin Akasah² and Mohammad Ashraf Abdul Rahman³

¹,²,³ Universiti Tun Hussein Onn Malaysia, Johor, Malaysia

¹timi-gee@yahoo.com, ²zainal59@uthm.edu.my, ³ashrafr@uthm.edu.my

ABSTRACT: This paper will present a review of the literature pertinent to the life-cycle preservation, operation, and maintenance aspects of buildings features disparity are rarely considered at the initial design and construction stages. This is due to the facts that mainly in the disconnections within built facilities life-cycle, from their initial creation processes, through use to obsolescence. There is also a dearth of knowledge of the specific impact of upstream design and construction decisions and choices on the downstream preservation, operation, and maintenance of building structures and fabrics. Hence, in order to bridge this knowledge gap and forge a connection between design and life-cycle use and maintenance of buildings, this study aims to identify design defect which affect building maintenance and to identify the systematic framework for selecting a suitable maintenance strategy for each individual item in a building. The investigation for this study will be undertaken in two phases. The first phase involved a literature search on the identification of some of the relative defect factors in design stage that affect maintenance. The second phase involved gathering data through site visits, interviews and discussions with owners, architectural/engineering firms and contractors. The scope of this research will be limited to civil and architectural defects in building design that affect maintenance only in the Museum Adat Istiadat Melayu Kelantan (Muzium Islam). It will be observed that the different of structural and fabrics integrity of these buildings to their different defect styles and features. This finding will underscores the importance of designing architectural features of buildings with their operation, maintainability, and life-cycle preservation in mind, if structural and fabrics integrity must be maintained, and a greater sustainability achieved, while restoration ringgit are saved.

Keywords: construction, architectural, building, maintenance, life-cycle, preservation, defects

1. INTRODUCTION

Malaysia is a fast developing country and new building are being erected every to accommodate the needs of public and private sectors. Many building construction projects have been built due to the demand of both the public and private sectors. In order to meet the high demand of both the public and private sectors in new building constructions in a short space of time, it is anticipated that many defects will arise especially during design and construction phase. This will inevitably resulting in high maintenance costs. Maintenance costs of a building during their functional lifetime could easily surpass the initial outlay of a new building. Therefore it's important to consider maintenance aspects at the very outset of the life cycle of a building because decisions made at planning, design and construction stages have a large effect on the maintenance costs and works incur later in the life cycle of a building. Aged building doesn't necessary have to be associated with high maintenance cost as a new building with numerous defects from faulty design and construction could easily equal or surpass the maintenance cost of an aged building (Ahmad Ramly et al, 2007).

Under normal condition all building begins to deteriorate the moment after they are constructed, and of course maintenance is needed. One research conducted in United Kingdom revealed about 20% of the average annual expenditure on repairs in building arises from defects (Sadi Assaf et al, 1996). As consequences if the number of defects could be reduce it would reduce the maintenance expenditures.
It is obvious that the need of maintenance is very important and needed for all sectors including properties sectors. Regard to the highly cost of maintenance it is important to study maintenance problem so that an effective maintenance can be carried out.

Maintenance is defined as the required processes and services undertaken to preserve, protect, enhance and care for the university buildings’ fabrics and services after completion, in accordance with the prevailing standards to enable the building and services to serve their intended functions throughout their entire life span without drastically upsetting their basic features and uses (Lateef, 2010).

Building maintenance is defined as "work undertaken in order to keep, restore or improve every part of a building, its services and surrounds, to a currently accepted standard, and to sustain the utility and value of the building". The objectives of building maintenance are therefore (Alner, 1990):

a. To ensure that the buildings and their associated services are in a safe condition;

b. To ensure that the buildings are fit for use;

c. To ensure that the condition of the building meets all statutory requirements;

d. To carry out the maintenance work necessary to maintain the value of the physical assets of the building stock; and

e. To carry out the work necessary to maintain the quality of the building.

1.1 Problem Statement

The Malaysia is a rich developing country with huge capital resources. It is developing very fast in every area including building construction. Public and private sectors have initiated the need for large and complex construction projects. Meeting the high demand of both parties in a short time, it is expected that many errors and defects have occurred during the design and construction stages which will result later in high maintenance costs. Building maintenance is a major activity in most countries.

The researcher believes that the neglect of building maintenance in Malaysia is serious that intervention at national level must be done. Since maintenance problems in building facilities are heavily attributed to many factors, whereby the most important ones are design limitations and construction knowledge, owners must be made aware that insufficient funding of design and construction will impact future maintenance capabilities. Owners will continually be challenged to meet greater demand for improved maintenance standard with less staff, less capital and in less time than ever before if nothing is to be done (Chong, 2004).

Problems in buildings can be broadly categorized as defects or deterioration. Defects arise due to errors or omission or negligence by the designers or contractors. Deterioration on the other hand, is the natural process which is unavoidable, although maybe minimized by exercising care in design, material selection and proper construction method. A research by Gibson (1979) found that while most building defects are associated with the structure, others are associated with unsightly patterns of soiling of the elevations and lack of accessibility to services. Whereas, for a building not more than 25 years old, Ranson (1981) showed that design faults and specifications comes the second after the wear and tear factor.

Accordingly, any reduction in resources applied to building maintenance will have a visible effect on the national economy. The easiest way to cut maintenance costs is to stop doing maintenance. This approach is simple, but the long-term results are usually very costly. Thus, the goal of the new approach is to carry out as little maintenance as possible as infrequently as possible while at the same time preserving the availability of the services facilities, the building elements and the whole building. In other words, maintenance should be carried out only when necessary to ensure the continued, safe and profitable use of the building at acceptable levels of satisfaction or when there is the possibility of extending the useful life of the elements of the building.

1.2 Objective of Study

The relative objectives to achieve the aim of study are as follows:

a. To identify design defect which affect building maintenance.

b. To identify the systematic framework for selecting a suitable maintenance strategy for each individual item in a building.
1.3 Scope of Study
The scope of this study will be limited to civil engineering and architectural building features associated with certain faults and defects, and by implication, impact preservation of buildings' structural and fabrics integrity design that affect maintenance. The Museum Adat Istiadat Melayu Kelantan (Muzium Islam) will be investigated to illustrate the problem related in this study.

2. LITERATURE REVIEW
A research by Arditi and Nawakorawit (1999) has shown that design plays a major role in determining the condition of buildings after completion, especially in the aspects of defects and maintenance. Indirectly, design influences the performance and physical characteristics of the building and its durability to stand against environmental elements, noise and social interferences such as graffiti and vandalism. Therefore, the link between design and maintenance should not only be seen from the point of increasing number of repair works or cost involve, but it needs to consider also the impact of a design on structure and materials installed as well as the life cycle for each of the components or elements of the building.

Arditi and Nawakorawit (1999) have listed 22 sources of the major maintenance related complaints on building defects that designers and property owners each, reported receiving from clients. The complaints are categorized in 5 groups:

a. Safety
b. Design quality
c. Maintenance
d. User comfort
e. Building services

Results from the survey show that complaints on user comfort become the clients" number one concern followed by maintenance. Design quality category was almost not in their list as most clients (and designers themselves) believe building design and building operation/maintenance are entirely separated and both building owners and designers did not consider serious enough.

Assaf et al 1996 identified 11 major groups of faults; they are, the defects in civil design, architectural defects in design, design defects in maintenance practicality and adequacy, defects due to consultant firm administration and staff, defects due to construction drawings, defects due to construction inspections, defects due to civil construction, defects due to contractor administration, defects due to construction equipment, defects due to construction materials and defects due to specifications.

Through literatures, the author had identified six dominant variables that are associated with the decision making of building cost. The variables are:

a. Existing building condition
The existing conditions of buildings were assessed through several ways. One of the easiest methods is by using visual survey. The exterior of each building structure was viewed from the ground level and all important information would be documented and some areas of deterioration are noted through annotated sketches and plans.

b. Building age
Age of building provides important indication on level of maintenance service required. The important elements that need to be considered in allocation of maintenance resources is the building’s age. In order to know the future image of building, building manager needs to offer right service so that the building has competitive advantage (Lateef, 2010). Services given must meet expectation in response to time, delivery schedules and within the agreed performance indicator.

c. Complaint received regarding building performance
Inefficient maintenance works could invite complaints by the building users. Users are normally looking for a comfortable space in a building. This includes well functions of building equipments, clean environment, and safe. If buildings do not fulfil the user’s needs, complaints with regards to maintenance performance would be made by the users.
d. **Client's request**

Client refers to the owner of a building. The client is the one who provides maintenance finance and a project brief in the early stage of maintenance works. Quality of client's brief would influence the building performance. The key successful of design is rests much with the clients besides others such as a good budget.

e. **Availability of funding**

A most trying constraint from the design point of view is the budget allocation. That most important factor contributing to successful maintenance work was a sufficient budget allocated for a project. The project fund must be sufficient to ensure the maintenance works could run smoothly (Gibson, 1979).

f. **Safety and health requirements**

Safety and health are command factors influenced in the decision making of maintenance works (Lee, 2009). This is because building maintenance works can lead a risk to maintenance personnel and building users. It is the responsibility of building stakeholders particularly the manager to ensure that health and safety assessments and safety work procedure are documented.

2.1 **Building Maintenance**

Building maintenance is a major activity in most countries. Any reduction in resources applied to building maintenance will have a visible effect on the economy. Few years ago, a rapid growth of housing construction clearly appears as a part of the country development. The number of modern houses increases and more houses are being constructed. As a result, more maintenance work is required in order to cope with this type of construction.

In maintaining a building, there are usually several strategic options available to management, and many alternative decisions to be considered. There is, for example, the possibility of reducing the demand for maintenance by addressing the actual cause of failure and identifying its consequences. For instance, it may be necessary to decide whether to repair or replace an item, and whether to carry out periodic maintenance at fixed intervals or simply to respond to the requests of the users. Thus, building maintenance can be divided into three strategies:

a. **Corrective**

Corrective maintenance is the simplest type of maintenance strategy, where an element in a building is used until it breaks down. It covers all activities, including replacement or repair of an element that has failed to a point at which it cannot perform its required function. Corrective maintenance is sometimes referred to as failure-based or unplanned maintenance.

b. **Preventive**

Preventive maintenance was introduced to overcome the disadvantages of corrective maintenance, by reducing the probability of occurrence of failure and avoiding sudden failure. This strategy is referred to as time-based maintenance, planned maintenance or cyclic maintenance. Preventive maintenance tasks are performed in accordance with a predetermined plan at regular, fixed intervals, which may be based for example on operating time. Such a strategy is frequently applied to external or internal paint work.

c. **Condition-based**

Condition-based maintenance is defined as: “Maintenance carried out in response to a significant deterioration in a unit as indicated by a change in monitored parameter of the unit condition or performance” (Kelly and Harris, 1978). The condition-based maintenance concept recognizes that a change in condition and/or performance of an item is the principal reason for carrying out maintenance. Thus, the optimal time to perform maintenance is determined from a condition survey used to determine the actual state of each constituent item in a building.
2.2 Building Defect

Defects within new buildings are areas of non-compliance with the Building Code of Practice and published acceptable tolerances and standards. Older buildings, or buildings out of warranty period, may not comply with these standards but must be judged against the standard at the time of construction or refurbishment. Building maintenance can be broadly as the application of scientific principles to the care and preservation of building assets. A building, product or application can become defective through age and lack of maintenance and professional advice should be obtained to ensure that replacement or works undertaken are using materials and current systems of application that are appropriate to the building. Examples of building defects are where structural settlement cracks are occurring to brickwork, excessive structural sagging to a roof, ill-fitting windows and doors, leaking showers and sagging ceilings. Building maintenance is therefore concerned with the technical requirements of investigating and diagnosing faults to assess condition; with the organizational needs to specify, select, implement and supervise remedial works and with the management operations to plan, preventive and corrective programmers (Rozita Aris, 2006).

2.2.1 Failure of buildings

Buildings may fail for a number of reasons. Figure 1 shows a breakdown of the most common reasons for this.

![Figure 1. Breakdown of the most common reasons (Ahmad, 2006).](image)

2.2.1.1 Faulty Design

Faults in building design place a heavy burden on the building for rest of its life and there is no compensation for it. In such situations, the responsibility falls on the shoulders of the designer in that they must think carefully with full concentration and consideration towards completion of their design project. Explaining the link between maintenance and building design, suggests that four sectors of building design should be considered and regarded as important if one is to avoid the need for unplanned maintenance at the post-occupation stage (Ramly, 2006). These sectors are:

a. The main fabric which includes walls, floors, roofs, doors and windows;
b. Internal finishes which includes ceiling and wall finishes as well as floors;
c. Special design features such as decorative elements for the doors, windows, glass, air vents and special brick and stone work;
d. The fourth and the last sector is cleaning and house keeping of all building components.

This study identified deterioration in these sectors that resulted from design faults, which subsequently imposed a heavy financial burden on the occupier or owner. Based on the outline of causes derived
from the work of the implication of design fault on maintenance in building has resulted from the following (Gibson, 1979):

a. The consequence of thermal movement;
b. The consequence of inefficient detailing;
c. The consequence of improper material selection; and
d. The consequence of poor design for access for maintenance measures.

Faulty design decisions are the most common faults which may be grouped as follows: failure to follow well-established design criteria in the choice of structural system and selection of materials; ignorance of the basic physical properties of the materials; use of new materials or innovative forms of construction which have not been properly tested for use; misjudgement of climatic conditions under which the material has to perform; and poor communication between different members of the design and construction teams (Lee, 1987).

In most of the literature reviewed by Boyle (2003), Ramly (2006), Reason (1990), Melchers (1989) and Porteous (1992) the words “fault,” “failure” and “defect” were used interchangeably to describe imperfections in constructed buildings. A building defect or fault may be considered to be a failing or shortcoming in the function, performance, statutory or user requirements of a building, and manifests itself within the structure, fabric, services or other facilities of the elected building (Watt, 1999). The term “defect” or “fault” is preferred in this paper, but not in the sense of the building or components failing to full intended functions (Allen, 1971).

Building faults, failures or defects are emotive terms and mean various things to deferent people, but always suggest that the client involved has had an unsatisfactory solution (Campbell, 2001). The vast majority of building faults and failures are not dramatic collapses, but far less newsworthy structural or mechanical problems and issues of serviceability such as minor cracking and water ingress (Holtham, 2001). Other significant factors included inadequate design information and poor site practices. The detailed results of the research, summarized in Building Research Establishment (Building Research Establishment, 1988) provide a useful attribution of fault to particular building elements (see Table 1). Another research, conducted by the BRE Advisory Service and based on its database of building defects (Watt, 1999), identified the ten main types of defect shown in Table 2.

Table 1. Building elements and fault attribution

<table>
<thead>
<tr>
<th>S/No</th>
<th>Building element</th>
<th>Fault attribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>External walls</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Roofs</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>Windows and doors</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>Floors</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>Services</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Sub-structure</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Internal partitions</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Separating walls</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Stairs</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Planning and layout</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>General and external works</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Adapted from Watt (1999).
Table 2. Main defect types

<table>
<thead>
<tr>
<th>S/No</th>
<th>Defect types</th>
<th>Magnitude (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rain penetration</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Condensation</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Cracking</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>Detachment</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Entrapped water</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Sound transmission</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Rising damp</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>Floor (not involving moisture)</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Indoor air quality/ventilation</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Appearance/discoloration/surface defects</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Other</td>
<td>8</td>
</tr>
</tbody>
</table>

*Note: Adapted from Watt (1999).*

2.2.1.2 Faulty construction

Faulty construction is one of the most common causes of early deterioration. Common construction faults include inadequate compaction and failure to position the reinforcement so that it has adequate concrete cover. Under almost any exposure conditions these faults will eventually reduce the service life of the structure as a result of reinforcement rusting after the concrete has become carbonated, (Seeley, 1987).

Faulty construction accounts for many building failures and this can be linked to the above. If a new system has not been specified or used previously, then the builder will have no experience of this system and may build it incorrectly. Sometimes lack of suitably qualified supervision can lead to this problem, as can the lack of testing that is carried out during construction work, such as concrete tests. An example of using systems that have not been used before creating this problem is that of the use of precast concrete structural frames. During the 1950s, in order to increase the amount of housing the development of high-rise blocks of flats became endemic.

2.2.1.3 Faulty maintenance

Faulty maintenance accounts for a similar number of building failures, and this can be broken down into two parts: maintenance that has been carried out incorrectly, or more commonly where no maintenance has been carried out during the life of the building. A large section of this book is dedicated to building maintenance, and how it can lead to the improved performance of buildings over their lifespan. If the procedures specified in this book are adopted then this figure should be reduced. However, maintaining buildings costs money, and therefore although building maintenance can be planned and specified correctly, if the funding available is not adequate this will ultimately lead to building failure (Ahmad, 2006).

2.2.1.4 Faulty materials

Faulty materials account for fewer, but still substantial, amounts of building failures, and the reasons for this are to a certain extent the same as for faulty design. We cannot test all materials for 60 years before they are used for construction, and we cannot test all materials in conjunction with all of the materials that they may potentially come into contact with. However, as a general rule, materials that are manufactured in factories will be of better quality than materials manufactured on site (in situ). More prefabrication should reduce this problem, but it can be argued that prefabrication reduces design flair and flexibility (Ahmad, 2006).

2.2.1.5 Faulty use

Faulty use accounts for some building failures, and this generally occurs where the building is not being used for the purpose for which it was designed. For example, occupiers may wish to create more space and therefore knock down walls without the advice of the designer, which can have major implications and possibly cause a collapse (Ahmad, 2006).
3. METHODOLOGY

To achieve the objectives of this research, the following steps were carried out:

a. A literature search was made on the factors that affect maintenance.

b. Site visit, interviews and discussions with owners, designers and contractors. They helped to get the data and to know the design and construction factors that affect maintenance.

c. From the preliminary interviews and the literature review, a questionnaire was formulated.

d. A pilot study was performed before distribute the final questionnaire draft to the respondents. This pilot study was served to:
   i. Test the adequacy of the questions and review the adequacy of provided space for each question.
   ii. Estimate the time needed to fill out the questionnaire.
   iii. Review the more possible answers and increase the lists of choices.

e. Then questionnaire was distributed by post, hand or email to the concerned respondents (evaluators).

f. The questionnaire was collected but the uncompleted questionnaire will exclude.

g. Examining the questionnaire collected from evaluators and obtaining the weighted overall factors affecting building maintenance. The flow chart shows the methodology for the research.

The investigation for this study will be undertaken in two phases. The first phase will involved a literature search on the identification of some of the relative certain faults and defects, and by implication, impact preservation of buildings’ structural and fabrics integrity in design stage that affects maintenance. The second phase will involved gathering data through site visits, interviews and discussions with owners, architectural/engineering firms (A/Es) and contractors.

3.1 Research population / sample

In this study, a questionnaire will be distributed to owners of the building, A/Es and contractors to facilitate input in a more standardized manner and will be design later.

3.2 Proposed data collection method

The interviews will be conducted with the questionnaire form highly supported by visual photographs and illustrations. Site survey will be conducted after each interview for further detailed investigations.

The questionnaire will be divided into three main sections under the categories of certain faults and defects, and by implication, impact preservation of buildings’ structural and fabrics integrity. In the all sections of the questionnaires, the respondents will be asked to select the relevant answer from the choices provided. Figure 2 show the methodology flow chart.
3.3 Data analysis

The collected data will be analyzed quantitatively using the severity index. The aim of formula is to determine the ranking of parameters or factors given for each answer of the questions. For every question there are five parameters that should be used by the respondents as an option to answer the questionnaire. The five options given are extremely affect, strongly affect, moderately affect, slightly affect and does not affect responses.

The severity index is computed by the following equation (Al-Hazmi, 1987):

\[ I = \left[ \frac{\sum (a_i \times X_i)}{3} \right] \times 100\% \quad (1) \]

Where:
- \( I \) = Severity index
- \( a_i \) = Constant, expressing the weight given to \( i \)th response, \( i = 1,2,3,4 \)
- \( X_i \) = Frequency of the \( i \)th response given as a percentage of the total responses for each defect
- \( i \) = Response category index where \( i = 1,2,3,4 \)

The severity indexes for all design defects and the groups of defects were calculated using the above formula (1). These indexes were ranked for owners, contractors and A/Es.
4. EXPECTED OUTCOMES

It is expected that the result will show an importance of selection and design features of buildings with their operation, and maintainability. A suggestion of guideline model will be developed and used by conservation contractors related to structural and fabrics integrity in order to maintain and sustain while restoration costs are saved.

5. CONCLUSIONS

For the conclusion, the objective of this study can be achieved if all questionnaire are done accordingly to its proper procedures and hopefully at the end of this study few designs will be indentified and a feed back to upstream creation stages of the building, in order to achieve downstream less defective buildings and better preservation through their life-cycle.

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