AN OVERVIEW OF DESIGN DEFICIENCES ON BUILDING MAINTENANCE

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Abstract: Building maintenance is seen as a huge activity in the context of the emerging discipline of facilities management. With the rapid development of industry construction, building maintenance has an important role to ensure the long life span of the building. However, the trend in the building industry is still alarming, building defects and/or poor building performance that is attributed to design deficiencies during the design stage, and maintenance is becoming more and more expensive. The purpose of this paper is part of ongoing research; it intends to investigate the causes of building defects at post occupancy stage due to design deficiencies. There are many causes of building failure or defects. This paper only focuses on design deficiencies. Design phase activities involve the architectural and engineering design of the entire project. These decisions will influence all decisions made in subsequent stage and vice versa. Therefore, the design phase was a major source of problems for the subsequent phase if not well manages to specify at the outset of the project. The review indicated that the vast of maintenance problem are due to design deficiencies.

Keywords: Building Maintenance, Building defects, Design Deficiencies

I. INTRODUCTION

Over the course of the building life - cycle, a building construction passes through various phases. The lifecycle building associated with each phase, namely design, construction and post-occupancy stage. Design for building maintenance is an important process since it ensures smooth performance of the life cycle of building with minimum life cycle cost and downtime. Consideration of maintenance during design, construction and post-occupancy stage ensures those maintenance requirements are minimized in the future. This means that the building components can easy to maintain at less expense, in less time and with less effort. Unfortunately, many times building designers often neglect considering a very important aspect which is the possibility to perform future maintenance needs.

The design of a building has a major impact and influence on the operational performance of a building. Maintenance activities are crucial to the overall performance of the life cycle of a building. Design and maintenance are two activities that directly contribute to the quality of construction and performance**.** Conventionally, maintenance and design are frequently treated as two separated activities that have no interrelationship (Arditi and Nawakorawit 1999). The result of the building survey conducted in Hong Kong stated that 40% of maintenance faults were design related, 30% of maintenance problems were construction/installation related and 30% of maintenance problems were related to maintenance management (Lam, 2000). Considerations of maintenance required during the pre-construction phase may lower the operation and maintenance cost of the facility (Helen and Soibelman, 2003). Maintenance planning should start at the design stage of any building project and should

continue throughout the life of that building (Mills, 1980).

A researches by Arditi and Nawakorawit(1999), Rozita (2006), Mills (1980) and Liu (2006) highlights that the issue of building maintenance is important to consider during the design stage to increase the future performance of buildings as maintenance cost in high for building owners throughout the life of that building. Some of these problems could probably be considerably reduced by a more suitable maintainable design. Therefore, it is important to take a suitable approach to design a better building. A numbers of studies have been conducted to find out faults in design that affect building maintenance and will be discussed in the next section.

II. BUILDING MAINTENANCE

Building maintenance is seen as a huge activity in the context of the emerging discipline of facilities management. With the rapid development of industry construction, building maintenance has an important role to ensure the long life span of the building. Normally, the building is assembled with a variety of individual components such as system, subsystems, material, equipment, devices or etc. The building components from the foundation to the roof such as façade, basement, roof, HVAC, electrical or structure, need of regular maintenance. The cleaning, servicing, repair and replacement of building components are a maintenance task carried out during post-occupancy stage to ensure the building function properly and that they retain their value and original appearance.

In general, building maintenance tasks performed either preventive maintenance or corrective maintenance. The definition of these maintenance works given by Cruzan 2009. Preventive maintenance is defined as "*Preventive maintenance is a scheduled program of regular inspections, adjustment, lubrication, or replacement of worn or failing parts in order to maintain an asset's function and efficiency."* Whereas, corrective maintenance tasks carried out after a failure is occurred. There are many literatures that discussed on definition of building maintenance. Most of them have the same concept about maintenance. BS3811; 1984 defined maintenance as "*A combination of any actions carried out to retain an item in, or restore it to, an acceptable condition"*. It highlights the condition of a building is central to the notion of building performance and maintenance input should consider at every stage of building life cycle (Chanter and Swallow 1996). In return for effectively and efficiently maintenance process, the maintenance issue should incorporate in the design stage to achieve ease of maintenance.

Although much work has been done on building maintenance (Horner et al 1997, El-Haram and Horner 2003, Yau 2011, Hassanain 2003, Shohet 2003) but very little research has been done on integrating the maintenance issue during the design stage. According to Liska (1988), building maintenance can be carried out at every stage of building life cycle. The maintainability concept could be making the largest contribution to the total life cycle maintenance impact. Furthermore, the maintainability concept can be used to minimize the maintenance problem and building defects. It is important to consider maintainability concept in order to optimize a maintainable building. Although much work has been done already in building maintenance and the efforts improve the maintainability of the building must continue because of the challenges that the building industry is facing.

III. BUILDING DEFECTS

Building problems can be classified as defects or failure. The definition of failure first advancedby Leonards (1982) has been adopted by Technical Council on Forensic Engineering of the American Society of Civil Engineers (Citied from Feld and Carper, 1997); "*Failure is an unacceptable difference between expected and observed performance*." According to Kaminetzky (1991), which defined failure as:"*Omission of occurrence or performance; lack of success; nonperformance; insufficiency; loss of strength; and cessation of proper functioning or performance*." Watt 1999 view building defects as "failing or shortcoming in the function, performance, statutory or user requirement of a building, and might manifest itself within structure, fabric, services or other facilities of the affected building ".

The causes of building defects or failure are classified in three categories, poor design, specification, construction and maintenance management. In this paper, the researcher will only focus on design deficiences. Design phase activities involve the architectural and engineering design of the entire project. Design decision is one of aspect consider for achieving quality of building. Specific information and knowledge of building deficiency before finalizing their design are required for designers to help prevent defects. These lacks of

information will always be problematic for designers. In additional, the architects seldom refer to standards and codes developed by engineers. Consequently, similar defects are continued to be repeated in every new building. (Chong and Low, 2006).

IV. DESIGN-RELATED BUILDING MAINTENANCE PROBLEM

In the context of the design deficiencies highlighted earlier, the study considered the problems resulted from design deficiencies that the facility manager had to face during post-occupancy as design-related problems. The following definition of the design-related problems has been adopted.

"Problems that are occurring during post-occupancy stage but originated during the design process."

There are various types of design-related problems that can be found during post-occupancy stage. Details of the design-related problems are described as below;

Poor material selection

The building material is widely used in building construction. The building material is an important driver of life cycle of a building and could help prevent maintenance works (Marsh, 1970). High performance building materials provide greater strength, durability and resistance to external elements and can also reduce maintenance costs. In most cases the first building material decisions are generally made during the early stages of the design . Poor material selection is a frequent cause of ineffective maintenance (Chong and Low 2005 , Al-Hammad et al 1997, Peacock 1986, Gibson 1970, Ishak et al. 2007, Watt 1999, CheAni et al. 2007, Wordsmoth 2001 and Miles & Syagga 198. For example, Graham (1979) stated that, architects and developer has been used new materials and methods which have not been properly test and inadequate research in use. As a result, a vast of problem emerged to future maintenance. These building defects could be reduced by considering the availability of accurate and appropriate material during the design stage (Che-Ani et al .2009, Chew and Tan 2003, Chew et al. 2004 , Chew et al. 2006).

Access

All building elements and the components should be readily provisions for access and coverage for easy accessibility to make the maintenance processes efficient and may greatly reduce maintenance cost. Building defects will occur due to failure to allow for ease of maintenance access (Watt 1999, AL-Hammad 1997, Seeley 1987, Gibson 1970). The building design should consider accessibility and provision working space for maintenance staff can access any part of building to be repaired damages (Miles and Syagga, 1987, Al-hammad1997, Seeley 1987, Watt1999, Gibson 1970, De Silva 2011, Feldman 1975, Lam 2000, Harrison 1995).

Lack of detail

Miles and SYagga (1987) stated that the detailing problem occurred due to the designer usually left the detail of their work to the unqualified draughtmen's. As a result, many maintenance problems are occurring. Good detailing is an integral role in the whole design life cycle and designer should properly check working drawing before they are issued. In order that, design error can identify and corrected before the next phase. Andi and Minato (2003) highlighted that effect of faulty design on building defects or inadequate information, unawareness, wrong assumption and lack of knowledge and organizational and motivational factor.

According to Calders (1997) stated that inadequate designs and poor specification words have contributed to the low quality construction. Unsatisfactory detailing and the specification of incorrect selection of building material and component is a major complaint (Miles and Syagga, 1987). Peacock (1986) and Gilder (1989) also stated that unsatisfactory detailing will cause maintenance problems.

Poor communication

Poor communications among participants in the building phase are often leaded to faults (Che-Ani 2009, Gibson 1979, Wordsworth 2000,). Ishak (2007) also stated that communication gap caused building maintenance. The design, construction supervision and management of the building are involving a vast number of team members. Communication design is usually described as nonverbal and oral, which imply that exchange and flow of information and ideas from the design stage to the next stage. So that, it is a very important designer, contractors/construction manager and owner do properly communicate their requirement and expectations each other to achieve effective outcomes.

Facility managers should carry out their day-to-day roles managing and operating existing space for the life of the building after designers and engineers completed the building. In many cases, facility manager does not integrate early in the design

process to understand how the building was designed to operate and designers also seldom seek advice from the facility manager about problem in design. Consequently, poor design decisions continue to be repeated in every new building (Andi and Minato 2003 and Zubairu 2001). As a result, buildings frequently do not function as anticipated by the designers. According to Mohammed and Hassanain (2010), highlighted that the involvement of facilities manager in the design stage could reduce the building maintenance problem at the post occupancy stage.

Poor Ventilation design

Ventilation in building is an essential to supplying an adequate amount of oxygen and replaces the carbon dioxide produced in the space as well as to remove any undesirable odours and contaminants. Natural ventilation in buildings is an important issue in heating, ventilation and air conditioning (HVAC) system design. Poor operation of the ventilation system building causes ineffective removal of polluted indoor air and increase of maintenance cost during operation of building.

Poor ventilation design in the building also leaded to more maintenance (Ishak et al, 2007). Buildings with poor ventilation design can be better understood in the context of human morphology. Windows, exhausts and ventilation ducts and air passages are ventilation components in buildings. These ventilation components used as respiratory organs and passages for buildings. Chong and Low (2006) state dthat humid air caused many problems such as moisture condensation and staining. Proper ventilation can also help control air humidity. A designer plays a fundamental role in the control of the indoor temperature of a building. In order to improve building maintenance, ventilation decision taken rapidly in the early stage of design can have a large impact on the performance of the finished building.

Poor structural design

The design quality of any building and the subsequent of its occupants safety depend on the long-term structural performance of the building's components. It is estimated that in the UK, up to 2,500 million was spent to repair and maintenance works in repairing structurally damaged residential buildings. One of the reasons for the occurrence of structural defects is inadequate design (Page and Murray1996, Chong and Low 2005, BRE 1991). Olusola and Akintayo (2009), identified that type, proportion, grading and quality of aggregate and overloading and deviation from standard specification in use, as contributing failure of structural elements in buildings. Consideration of all these factors during the design and construction stage could help to minimize building defect rate and as well as maintenance cost in future.

Poor Geotechnical design

There is an important designer do some sort of geotechnical test when a designer chooses an area of land to build on. Improper soil analysis can be very damaging to buildings. For instance, the building affected by differential expansive soil settlement due to instability expansive soil will shrink and swell wet it dries and wet. Such problems will be cracks in the walls, garage floor, pavement and etc. Such defect can be prevented with better geotechnical design (Chong and Low 2005)

Ignoring environmental issue

Ignoring environmental issue in design stage were caused maintenance problem (Al-Hammad, 1997, Che-Ani, 2009, Chong and Low 2006, Silva 2011, Ramly 2006, Ishak et al 2007, Assaf et al. 1996, Seeley 1987). A building designed in localities where environments conditions are adverse presents challenge to the designer. Weather condition is different in every country with different temperatures and this condition is also contributing to high maintenance cost. Sustainability is an important issue in building design. Che –Ani et al, 2009, said that absence of sustainability considerations in the design phase will cause maintenance problems in post-occupancy stage and highlight the correlation between these two variables of building; higher the quality of sustainability design lower the maintenance and lower the quality of sustainable design higher the maintenance.

Lack of standardization (peacock)

In another study, Peacock (1986) mentioned that it is crucial that standardization be discussed early with the designers to easier and less costly to maintain the facility. For example, that the designer must be concerned with the availability maintenance equipment in the market when a designer designs the building (Al-Hammad, 1997).

Biological agent

Most buildings are not designed in ways that effectively reduce facility managers' risk of exposure to biological threats. Biological agents are naturally occurring such as fungal, molds, bacteria and that are

introduced into a building unintentionally or by natural processes. Ignoring such factors caused an increase of maintenance expenditure in the construction industry (Al-Hammad 1997). Michael Mair (2008), showed that some general building attack scenarios associated with biological agents into a mechanically ventilated building. One of that is indoor release of a biological agent directly into an HVAC system from within the building and distributed throughout. It is essential that proper attention on biological factors needs should be given during the design phase.

Looking at the various design faults that have been highlighted, it can be seen that design fault are a major source of building defects. Problems such as lack of consideration to accessibility need, choice of material and poor communication among the parties are common problems in most of the building. It is estimated that in the USA, up to 50 percent of the construction budget was spent to repair and maintenance works in buildings (Lee, 1996). As a consequence if the number of design and construction defects could be reduced, it would reduce the maintenance expenditures (Gibson 1979, Peacock 1986, Liska 1988 and Lee 1987).

CONCLUSION

From the literature reviews above, it shows that inadequate input of maintenance at the design stage results in lot of building maintenance problems especially during the post occupancy stage. The variability of the problems indicates that methodology that seeks to approach the integrating maintenance issues with design to minimize the design related problem during post-occupancy stage remains sorely lacking. For this reason, good method will always be important for integrating maintenance with design. It will become a useful reference for architects and design engineers to incorporate crucial maintenance issue during design phase to ensure a successful implementation of design for maintenance concept.

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