

CATEGORISATION AND CAUSES OF BUILDING DESIGN DEFECT: A CASE STUDY ON PUBLIC BUILDING HOSPITAL

Mastura Jaafara*, Nur Liyana Othmana

aDepartment of Quantity Surveying, School of Housing, Building & Planning, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia *Correspondence author: masturaj@usm.my

ABSTRACT

Hospital is a complex building which involves a diverse range of people, equipment and systems. The building maintainability aspect has always been neglected at the design stage of project development; on the other hand issues related to maintainability may affect the performance of hospital building and incurred unnecessary cost. Some of the defect could be eliminated with proper attention and consideration during the design stage. The aim of the study is to identify the category and causes of building defects of public hospital. Hospital Sultanah Bahiyah, Alor Setar has been selected as a case study. Data collection has been conducted based on secondary reports produced by the hospital services outsourcing company maintenance. The building defect were categorised based on three items that are enclosure, settings and fittings. Each defect will be discussed in detail in the paper. The study provides a significant contribution to the knowledge on public hospital defect in Malaysia.

Keywords: Building Design Defect, Hospital Building, Design and Build and Maintainability

1.0 INTRODUCTION

Design process is known as a central process in building development project. Design process has to go through few stages as indicated by Formoso et al. (1998), there are seven steps which include inception and feasibility, outline design, scheme design, design for legal requirements, detail design, production monitoring, and feedback from operation. During the design process, architect also needs to gather all requirements that consist of legal provision and regulations, local authorities brief, client brief, economy, aesthetic value, technology and creativity (Øyen, 2000). Each design decision will promote the building quality (Chong and Low, 2006) and determine the building performance. Maintainability also known as inherent design characteristic (Her and Russell, 2002). The consideration of maintainability at design stage is very important to ensure the efficiency of building functionality and performance (Silva et al., 2004) and help in reducing downtime and improve safety (Fitzgerald, 2001). Considering design process is very imperative because it worth 80% of construction cost and it has possibility to eliminate the problems earlier before construction starts (Hamzah et al., 2011). Design and Build (D&B) procurement has different design approach. The D&B procurement is a fasttrack construction system with single point responsibility on the contractor. The contractor will be in charge for design, construction and handover unlike conventional system. In D&B, the architect needs to design based on contractor's agreement and the contractor holds responsibility to make a building design's decision.

The term „public hospital“ refers to a health care provider facility that has been established under the state or territory legislation as a hospital or as a freestanding day procedure

unit(Commonwealth of Australia, 2009). Public hospitals provide hospital services at free of charge to all eligible patients and play an important role in health care safety by providing care for patients who may have limited access to care elsewhere (Commonwealth of Australia, 2009;Fraze et al., 2008). From the aspect of building functionality, hospitals are complex organisations, with many essential services delivered. Public hospitals are very special places with large numbers of diversity of committed such as high quality clinicians, registrars in training, medical students, nursing and allied health staff care (Zajac, 2003). All buildings will experience the occurrence of building defects. There are myriad causes of building defects such as weather or climate, workmanship, design, materials selection, materials selection and etc (Chew, 2005; Ahzahar et al., 2011). According to Low and Chong (2004), design plays an important factor of defect in building. Previous studies relate to building defects with design faulty which includes leakage, condensation, decayed, peeling paint, staining and etc (Chong and Low, 2006). Building defects also consider as maintainability problems in buildings (Silva, 2012) that can be eliminated and minimised with proper monitoring and action during the design stage because the appearance of defects is due to decision and action at design stage. Hospital Sultanah Bahiyah, Alor Setar located at Northern part of Peninsular Malaysia, was completed on February 2007 with a construction cost of costs RM 560 million and started the operation on September 2007. This hospital maintained by Faber Medi-Serve Sdn. Bhd as an outsourcing company to maintain the hospital services. Based on secondary data, this study is will identify the category and causes of building defects of Hospital Sultanah Bahiyah in Alor Star. The result will be discussed in relation to each categories that are enclosure, setting and fittings of hospital buildings.

2.0 LITERATURE REVIEW

Building Defect A defect is deemed to occur when “a component has a shortcoming and no longer fulfils its intended function” (Georgiou, 2010, page 371). Pheng and Wee (2001) define building defect as “failure or shortcoming in the function, performance, statutory or user requirements of the structure, fabric, services or other facilities”. Defects in buildings are commonly classified as patent and latent defects (Rhodes and Smallwood, 2002). Patent defects can be clearly recognised during inspection under construction and Defect Liability Period (DLP), while latent defects usually appear over time when the building is occupied (Isa et al., 2011). The common building defects are structural defects which result in cracks or collapse; defective or faulty electrical wiring and/or lighting; defective or faulty plumbing; inadequate or faulty drainage systems; inadequate or faulty ventilation, cooling or heating systems; inadequate insulation or sound proofing and inadequate fire protection/suppression system (Ahzahar et al., 2011). Kian (2001) who studies on factors affecting building defects in Singapore has identified the common defects that are leakage, cracking, corrosion, popping tiles, bad plumbing, tile spot and stains, water penetration and buckling. For hospital buildings, a study done by Chong and Low

(2006) at four hospitals in Singapore identifies the building defects such as plaster cracks, peeling and blistering of paint, staining, tiles cracks, discoloured tiles, sagging, leakage and fungus. In Malaysia, there are few cases on public building defects. For example, the former Minister of Housing and Local Government Dato[“] Seri Ong Ka Chuan states that in 2005, the ministry received 356 complaints regarding the building defects at public buildings, while in 2006 and 2007, there were 238 and 192 respectively (The Star, 2008). The normal building defects reported are wall cracks, plumbing problems, roof leaks, poor plastering work and paint work and ground settlement. Another study on hospital building in Malaysia is done by Hassan et al. (2011). They identify the building defects are hair-line cracks, cracks, fungus, peeling paint, discoloured paint, blistering of wall paper, staining, water marks on ceiling, ceiling collapse, sagging, sweating of wall, frost, pot holes, counter top decayed, cabinet decayed and fitting damaged.

Causes of Building Defect The causes and effects of defects are a consequence of „weaknesses“ in the project implementation process. Josephson and Hammarlund (1999) and Gryna (1988) define cause of building defect as a proven reason for the existence of a defect. Researchers identify the main causes of building defects are weather or climate (Richardson, 2001; Ahzahar et al. 2011), soil impact or settlement (Richardson, 2001), workmanship (Richardson, 2001; Kian, 2001; Ahzahar et al. 2011), design (Richardson, 2001; Kian, 2001; Ahzahar et al. 2011), environment (Richardson, 2001), materials selection (Ahzahar et al., 2011) and maintenance issues (Richardson, 2001; Ahzahar et al., 2011). Besides that, there are a few new findings on the causes for example Richardson (2001) adds on the chemical reaction, structural movement and site working conditions; Ahzahar et al. (2011) mention on the location of building, building type and change in use; Olanrewaju (2012) highlights on methods of construction, regulations and rules and standard while Shabha (2003) and Isa et al. (2011) focus on poor supervision during construction besides condensation, water ingress and cold bridging along with lack of thermal insulation.

3.0 METHODOLOGY

Data collection was conducted using a case study. To identify the category and causes of building defect, a document review has been conducted. All the documents are available from hospital engineering department and Faber Medi-Serve. The documents that we reviewed were: 1. Condition Appraisal: Report provides the list of overall defects during the Defect Liability Period (DLP) includes major defects. 2. Technical Report: Report that was produced in relation to the system (Engineering based) 3. Technical Advice: Written advise based on request/complaint from the end user. Normally include small defects 4. Reimbursable Work: Additional works outside the scope of Faber Medi-Serve Terms of Reference (TOR) which include upgrading/repairing works 5. Hospital Building Plan 6. Previous contract Document, Standard and Specification and etc.

However, we need to cross check these three documents, i.e., Condition Appraisal, Technical Advice and Reimbursable Work in order to make sure that there will be no overlapping defect reported. All the defects will be elaborated according to the building’s elements. Hospital

Sultanah Bahiyah encompasses single and multistorey buildings with 660 beds in strength and was commissioned in year 2007. Since then, the hospital provides important healthcare facility to the Kedah residents. Initially, the project cost was RM 500 million but after changes of standard and requirement from MOH, the final project cost was RM 550 million. The construction project starts at 16 August 2000 and it was supposedly completed on year 2003. However, this project had been delayed and the contractor gets 5 times extension within 4 years to get completed in year 2007. Besides that, the problems on contractor rose especially with regards to changes of subcontractors and lack of skilled workers. Changes in designs, addition of new medical wards and changes in latest equipment have exacerbated the delay.

4.0 ANALYSIS

Building defect has been categorised under three elements that are enclosure, settings and fittings. For enclosure, it consists of external wall, external ceiling, external floor and roof; setting includes internal building elements such as internal wall, floor and ceiling while fitting elements cover roof gutter, sanitary fittings, built-in cabinet and etc. Table 1 and 2 show the categorisation of building defects and causes of building defects.

Table 1 Categorisation of building defects
 Enclosure Settings Fittings • Hair Line Crack • Staining • Peeling Paint • Watermarks • Fungus • Discolouration • Sweating of wall • Peeling Paint & Wall Paper Finishes • Watermarks • Fungus • Ceiling Collapse & Sagging • Corrosion • Decayed • Stagnant & Over Flow • Broken

Table 2 Causes of building defects
 Enclosure Settings Fittings • Workmanship • Water proofing • Manufacturer specification • Design • Materials • Environment • No accessibility • Workmanship • Condensation • Weather / Climate • Materials • Environment • No accessibility • Water proofing • Hospital's requirements ☐ Workmanship ☐ Materials ☐ Environment ☐ Vandalism ☐ Manufacturer specification

The major defects identified were peeling paint, staining, watermarks, fungus, crack, ceiling collapse, sagging, corrosion, blistering of wall paper and decayed. Below is the explanation for Table 1 and 2 according the above categorisation.

Enclosure Discolouration, fungus, sweating of wall and crack were the example of defect identified at the external wall area. After four (4) years running the operation, the defects can be clearly seen at the external wall painting of Hospital Sultanah Bahiyah building. The external wall painting at few locations of the building started to faded. Fungus and algae infected due to continuous dampness of the wall, dirt collection on wall and natural cause due to long term exposure exceeding the designed life spans for algae resistance durations. The temperature inside the hospital building and outside has a huge different. The water drops will appear on the wall that caused the sweating of wall due to condensation process. As a result, fungus was appeared and discolouration to the wall. For roof element, the major defect is corrosion at the roof gutter which leads to the leakages problem. The improper installation of galvanized iron gutter which is the failure to fix the proper gradient of roof gutter has given a problem water to flow the rain water into the rain water down pipe. As a result, it leads the water stagnant at the

roof gutter and the oxidation process happened. Besides, the maintenance provider claimed that galvanized iron gutter was not painted as mentioned in the contract drawing "500mm width GI Gutter, Painted finish c/w Siphonic Rain Water Outlet system to detail" and as-Built drawing specification "GI Gauge 18 Gutter, Painted Finish c/w Rainwater Outlet System, to detail". Therefore, this condition will lead to corrosion, leakages and shorten its life span such as the leakages problem at the roof gutter could deteriorate the ceiling installation at the roof eaves areas.

Settings The issue of floor defect arose from 2008 until now. The wrong selection of epoxy floor paint has created the peeling paint at the floor. According to observation, the commercial storage room (as stated in the contract) should be using pallet lift, because that the area will receive heavy load. However, the current floor paint is only use „Light Duty Epoxy“, thus the floor paint was peel off due to heavy load. Besides that, the major Hospital building floor defect is staining, which the black spot or black stain is appear at vinyl floorings outside the toilet areas and spread to another area nearby. This defect was occur due to the water seepages from the toilet area which then penetrated through the concrete slab and spread to concrete beams and its perimeter walls. There have few possibilities contribute to water seepage:

1. Failure of water proofing are either contractor not done it correctly or lack of supervision.
2. A possibility of pipe leaking inside the wall, if it not a failure of water proofing.
3. Probability habit of patient during taking bath had help in causing water seepage problem.
4. How the maintenance team doing their job while cleaning the floor had been deliberated where they do not work properly, they used a lot of water that probably cause water seepage and deteriorate faster of the floor finishes.

For the internal ceiling, defect such as crack, staining, watermarks, fungus also appear. Nonetheless, the issue of water proofing also affected the ceiling of Hospital building. The operation theatre of Hospital Sultanah Bahiyah faced leakages after three years in operation. The leakages problem came from the AHU room which is located above the operation theatre room area and this could happen due to the water proofing problem. The improper plastering works at AHU room wall had caused water seep through the wall then spread into the concrete slab and beam then to the operation theatre room ceiling. Additionally, there is no waterproofing layer at the AHU room slab. The sign can be seen from crack appearing at the cement render finishing slab at the AHU room. Leakages due to poor workmanship at AHU Room above Operation Theatre. Many places have the same cause which is no gradient level and water proofing layer at roof, thus water seep through the wall then spread into the concrete slab and beam then to ceiling. Plaster ceiling damaged due to leakages during rainy day. The next defect cause is condensation. Condensation happens due to different temperature between two sides such as above and below floor level or inside and outside building wall. The issue of condensation affect internal ceiling because the different temperature has created the water drop below the floor slab than drop above the ceiling. Therefore, fungus and water mark has appeared at "Bilik Gunasama", "Jabatan Oral, Maksilofial & Pergigian", Paediatric, Pharmacy Store, Supervisor Room, Surau, Call Centre, Emergency Storage room and others. Besides, the issue of water drops above the ceiling also caused by no insulation layer on outlet pipe, refrigerator pipe, ducting air

conditioner and other type of pipe. In relation to this matter, the incident of watermarks and dampness on ceiling (figure below) happen at pharmacy. The next ceiling defect is ceiling collapse. There were two incidents on ceiling collapse. The first incident was on 15th September 2009 at Physiotherapy Unit waiting area, which is after 2 years running the Hospital. The second incident was the suspended ceiling collapse at Corridor area of the Pharmacy store on 15th July 2010. The cause of this problem is the improper installation of hanger that was fixed with one number of fastener on metal stud at soffit slab while some hanger were suspended at the sprinkler pipe and electrical trunking. The workmanship problem was due to lack of supervision during fixing. It could be the contractor's faulty which did not follow the standard and specification including selection of material, method fixing and joining, and standard installation requirement.

Fittings The defect on sanitary fitting was caused by environment or vandalism. Most of the sanitary fitting such as tap pillar mounted hot and cold, wash hand basin, double tap sink, and etc. were easily broken due to no instruction provided. Most of the visitors come from the low and the middle class community. Therefore, most of them were not familiar with the latest design or new technology. The problem on built-in furniture is the pantry cabinet. Most of sink and cabinet decayed due to selection of material. The selection of material on sink and pantry cabinet were not strong and not water resistance. The pantry cabinet was built with steel as a main frame, covered with chipboard materials at its wall, drawers and doors. Chipboard, which is also called particle board, is a kind of soft wooden type product is made from various pressed materials including recycle paper and sawdust. The chipboard is not generally very durable due to the material is vulnerable to swelling, disintegrates and discoloration when exposed to moisture. The decayed condition is visible at the pantry cabinet due water ingress through the chipboard's veneer.

5.0 DISCUSSION

For floor element, the major defects that occurred were peeling paint, staining, watermarks and fungus. This study support previous studies done by Chong and Low (2006) which reveals the major floor defects occurred at four hospitals in Singapore that were cracks, water seepage, tiles delamination, stains, discoloured tiles, efflorescence and chipped tiles while Hassan et al., (2011) found the floor defects were hairline crack, fungus, crack, staining, and deterioration of vinyl corner guard protection. Nonetheless, it shows that the floor defects that occurred at this hospital were also happened at other hospitals. The causes of the peeling paint defects were due to heavy usage and supposedly used the appropriate types of painting such as "Heavy Duty Epoxy" floor paint. Besides that, for staining, watermarks and fungus that appear at vinyl flooring are happened due to water seepage and failure of water proofing that stated by maintenance team. These findings were in line with by Chong and Low's (2006) statement as they identify some of the floor defects happened due to moisture from wet areas and weather. The major ceiling defects were crack, staining, watermarks, fungus, ceiling collapse and sagging. A study done by Hassan et al. (2011) find watermarks, fungus, hair-line crack, ceiling collapse, sagging and peeling paint at four hospital in Malaysia. Besides that, Chong and Low (2006) find water seepage, stain, cracks and fungus/algae as major ceiling defects. They discover water leakage is the main factors

that contribute to the ceiling defects in Singapore. The leakages issues also happened at this hospital to poor plastering work that cause water seepage at AHU room and leakages at Operation Theatre ceiling. Besides that, the leakages also happened due to failure of waterproofing and gradient not level well at roof area. The rainwater that enters into the building through louvres due to shortness of awning also caused leakages and damages the ceiling inside the buildings. Besides that, condensation also is one of the main contributor for ceiling defects. The issue of condensation was happened due to different temperature between two areas or two floors, no insulation layer at the soffit slab and on M&E system. Hassan et al. (2011) also state condensation as one of the causes of ceiling defect that created fungus or watermarks on ceiling at four hospitals in Malaysia. The cause of ceiling collapse and sagging is poor workmanship that did not follow the standard and specification including selection of material, method fixing and joining and standard installation requirement. This subject was also agreed by previous study such as Hassan et al. (2011) that stated "poor workmanship and work not in accordance with specification are the major of these defects". The major wall defects were discolouration, fungus, sweating of wall, crack, peeling paint and blistering of wall paper. Previous studies done on hospitals by Hassan et al. (2011) stated that hair-line crack, fungus, crack, peeling paint, discoloured paint, blistering of wall paper, staining, hollowness/stretch, sweating of wall, unevenness of paint and Chong and Low (2006) found water seepage, plaster cracks, strain, peeling paint, discoloured and efflorescent. The causes of discolouration, fungus and sweating of wall defects are condensation that creates sweating of wall and weather. In Malaysia, humidity level is high, average of rainfall is high and expose to hot weather as tropical country. Therefore, in order to avoid problem especially condensation, thermal wall should be build. Normally, they will install the double wall or thermal wall to avoid heat transfer and control the temperature inside the building or room to control the humidity level. For crack on wall, it was happened due to improper plastering work and location. The hospital is located at paddy field, the settlement of the soil may affect the building but not in serious condition. According to Hassan et al. (2011), the crack happened due to shrinkage and expansion. The peeling paint and blistering of wall paper that occurred at Hospital Sultanah Bahiyah, Alor Setar due to failure of water proofing layer at toilet areas that cause water seepage and affect the outside wall. The study done by Hassan et al. (2011) identifies that the causes of peeling paint and blistering of wall paper were due to poor workmanship, water seepage, weather, condensation and pipe leakage. The main problem at roof element is corrosion. The roof gutter had corroded due to improper installation of galvanized iron gutter that failure to fix the proper gradient of the roof gutter has given a problem to rainwater to flow into the rain water down pipe and weather. Therefore, this subject leads to corrosion, leakages and shorten its life span such as the leakages problem at the roof gutter could deterioration the ceiling installation at the roof eaves areas. However, the stakeholder give their point of view by stated that sometimes it happened due to lack of maintenance especially at gutter area and rainwater downpipe. Besides that, the maintenance should know gutter system that required for regular cleaning. With regards to the issue on weather, the maintenance had highlighted that the number of rainwater down pipe should be increase due to the high of rainfall and heavy rain that knows Malaysia is a tropical country. The sanitary fittings were easily broken due to vandalism. The study done by Hassan et al. (2011) also justifies that the some of the sanitary fittings are missing, having a

problem and damage/broken due to vandalism and poor workmanship. The other reason of sanitary fitting easily to be broken is most of the visitor and patients are not familiar with latest technology. The maintenance team had suggested considering about community level in order to reduce the number of sanitary fittings broken. The problem on built-in furniture is the decayed pantry cabinet. The selection of material is not durable and not water resistance.

6.0 CONCLUSION

The categorization and causes of building defect have been listed according to three categories that are enclosure, settings and fittings. Analysis based on each building elements for each hospital concludes that for Hospital Sultanah Bahiyah, Alor Setar, the major defects are floor, ceiling, wall, roof, sanitary fittings and built-in furniture. Analysis on the causes showed the main causes of the defect were closely related to design and construction of the building. For Design and Built procurement system, contractor plays major role in the design and building construction. Besides that client, architect and Public Work Department has their own role in determining the functionality, accessibility, durability of the hospital based on selection of the right material, providing good workmanship and ensuring all the contract requirement were followed. This study suggest that it is important for all stakeholders to pay attention on the building aspects when designing and building hospital building to reduce or eliminate the superfluous cost due to unnecessary building defects.

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