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A Case Study on Moisture Problems and Building Defects

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Abstract

Hospital buildings are one of the complicated buildings that normally associate with a moisture problem. Besides environment factor, the different operation hour, poor workmanship and improper waterproofing installation also contributes to the moisture problems. Controlling the moisture problems seem to be vital in ensuring the building functionality. This study identifies the moisture problems and its causes for the Hospital buildings in Malaysia. Based on various records obtained, this study discusses the defects according to four major building elements that are ceiling, wall, floor and roof. This paper concludes that the identified defects have great potential to affect the hospital building function.

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1. Introduction

Definition of moisture problem is "any visible, measurable or perceived outcome caused by excess moisture indication indoor climate problems or problems of durability in building assemblies caused by various leaks of water" (World Health Organization (WHO), 2009). However, WHO (2009) also had identified "moisture can be transported in both vapour and the liquid phase by diffusion, convection, capillary suction, wind pressure and gravity (water pressure)." Moisture problem commonly happens at every building. The issues of moisture that caused building defects are mainly recognised by many scholars such as Soronis (1992); Kian (2001); Chew (2005); Kubba (2008); WHO (2009); United States Environmental Protection Agency (EPA) (2013). According to Almas et al. (2011), moisture known as a

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major caused of building defect by 76 per cent and WHO (2009) identified that moisture caused 75-80 per cent of building envelopes defects.

Record shows billions of dollars have been spent to rectified defect due to moisture problems in the United States property (Kubba, 2008) and study done on 420 buildings in Sweden shows that a moisture cause in vivid microbial growth with 65% of the buildings (Wessén et al. 2002). Kubba (2008) has stated the “water is typically the main culprit” for microbial growth that lead to sick building syndrome. In addition, moisture is also known as a main source to poor indoor air quality, unhealthy buildings and mould growth (Kubba, 2008). There are many ways that moisture can enter to the buildings such as rainwater penetrating through leaks in walls, floors, roofs, windows and doors (Kubba, 2008).

Malaysia is a tropical country. The average temperature of Malaysia is constantly high around 26C throughout the year with humidity about 80% and high rate of evaporation. In addition, the rainfall is heavy with more than 2500mm (International Business Publication, USA, 2008). Compared to other western country, Malaysia is heavily exposed to moisture problems which lead to adverse on health effect, deteriorate the building faster and affect its functionality. The objective of this paper is to identify the moisture problems that occurred at the hospital building, the causes of moisture problem and the building defects.

2. Literature Review

There are ten (10) common moisture problems in buildings that were identified by WHO (2009); (1) rainwater or groundwater leaking into the enclosure (roof, wall, windows and foundation), (2) plumbing leaks and spill, (3) water wicking from capillary suction through porous building materials (concrete or wood), (4) rainwater, condensation or plumbing water, (5) infiltration of warm or moist outside air through cracks and holes in the enclosure during warm and humid weather, (6) exfiltration of warm or moist indoor air through cracks and holes in the enclosure during cold weather, (7) unvented or poorly vented sources such as swimming pools, (8) insufficient dehumidification by heating, ventilating and air-conditioning systems, (9) poor condensate drainage due to heating, ventilation and air-conditioning system deficiency and (10) enclosure of wet materials in building during construction.

The main building moisture problems are caused by leaking at building elements such as roof, wall and ceiling. For instance, a study done by Chew (2005) identified that among 14 major defects at walls and floors are water leakages through cracks, water leakages through pipe penetration, and water leakages through joints. According to Chew (2005) water leakage ranks as the highest (53 per cent) of presence defect at wall and floor. The issue of waterproofing is known as the main contributor to the failure of the building that leads to the moisture problems. For example, Kian (2001) identified that the flat roof leaky due to waterproofing that was not applied properly by the contractor (Kian, 2001). Waterproofing function is to preserve a structure of building through accepting of natural forces and their effect during life-cycle (Kubba, 2008). Besides that Kian (2001) added that the chosen of wrong type of tiles and failure to follow the standard roof gradient resulted in water leakage. In Malaysia, the problems of leakage at buildings are always happen due to tropical condition, improper design and poor workmanship. For instance, Ahzahar et al. (2011) revealed on the roof leakage at the Parliament building and few cases of pipes leakage and ceiling collapse at the government buildings.

Hassanain and Harkness (1998) identified that moisture can also travel from the wet area to dry area. Moisture and vapour can penetrate from the external wall to the internal wall then degrade the internal finishes due to lack of provision of air or vapour barrier. Besides that, moisture from outside or indoor air can go through the cracks and holes that caused condensation in wall and ceiling (WHO, 2009). However, the EPA (2013) has come out with two recommendations to control the moisture problems that are (1) preventing water intrusion and condensation and (2) limited the areas that routinely wet such as bathrooms, kitchen etc. and try to drying them out when it get wet. In order to control the moisture problem, EPA (2013) also recommended it is adequate that the vulnerable materials are in dry condition

and if they do get wet, the buildings materials need to be dried out quickly to avoid dampness or any defects.

For hospital buildings, a study done by Chong and Low (2005) on the four (4) hospitals in Singapore concludes that moisture problems are rainwater and water from wet area, besides water seepage due to poor material performance, concrete, waterproofing membrane and workmanship. Besides that, Hassan et al. (2011) highlighted the issues of moisture problems on the four (4) hospitals in Malaysia are condensation from the air conditioning due to two attached rooms with different temperature, leakages of pipe, water seepages and surfaces which expose to weather and not resistance to weather.

2.1 Causes of moisture problems

There a lot of causes that creates moisture problems such as environment (Soronis, 1992; Chew et al., 2004; Blocken et al., 2012), poor workmanship (Kubba, 2008; Ahzahar et al., 2011), improper design (Kubba, 2008; Al-Hammad et al., 1997) and ventilation factors (WHO, 2009; Ge et al., 2011).

Environment factors such rainwater, wind, groundwater and temperature caused the moisture problems to the buildings. For a tropical country, the environment condition is consistently wet and humid with temperature from 25°C to 34°C (Chew et al., 2004). Therefore, it can cause damage to the materials, mainly facade of the building due to expansion and contraction stress (Chew et al., 2004). In general, the building envelope is design to prevent from nature's elements and weathering elements into interior spaces and to protect the building structural components from deterioration (Kubba, 2008). A defective roof that allow the water penetration can cause damage to structural building, interior, fitting and furniture, and also leads to sick building syndrome and affect the indoor air quality (Olanrewaju et al., 2010).

Normally workmanship problems are due to faulty of contractor. Poor workmanship is known as one of the main factors that lead to the building defects (Ahzahar et al., 2011). Study done by Pheng and Wee (2001) on 53 buildings in Singapore's school buildings identified that the numbers of building defects less when the building constructed by the ISO 9000 certified contractors compared to non ISO 1900 certified contractors. The result shows that 9 per cent of dampness defect and 11 per cent of stain defect occurred on building constructed by the non ISO 900 certified contractors compared to none of dampness defect and 10 per cent of staining problems happen on building constructed by ISO 9000 certified contractors. The discussion concludes that the number of building defects can reduce by using a specialist and skilled workers.

Many scholars highlighted on the effect of design factors to moisture problems. For example according to Al-Hammad et al., (1997), architects suppose minimise the irregular forms that will collect moisture, dust or water. Besides that, one of the improper design factors is selection of materials. Study done by Chew (2005) reported that selection of materials in terms of durability is most important in order to control the occurrence of building defect. Besides that, ventilation factor will also cause air and moisture to flow and enter through the building envelope that will affect the structure of buildings. WHO (2009) identified the ventilation into three categories that are (1) natural ventilation depends on openings in the buildings and air movement; (2) and mechanical ventilation such as mechanical supply and exhaust system; and (3) Hybrid (mixed-mode) ventilation that use an auxiliary low energy extract fan or natural ventilation that combined with a fully independent mechanical system. The ventilation function is to control humidity because it is limiting the use of outdoor air ventilation (WHO, 2009) while Ishak et al. (2007) stated that the poor ventilation will lead to mould growth.

High indoor humidity can cause mould growth and bacteria (Institute of Medicine, 2004). The amount of water vapour in the air is the same even though the temperature is change (either to increase or reduce humidity) to avoid mould growth, dampness or condensation problems. The condensation will also lead to mould growth when the dew point of the air is above the temperature of the surface, and then the water vapour will condensate onto that cold surface (EPA, 2013). For instance, condensation will happen when

the indoor air dew point (DPT) is higher than the temperature at the surface chilled ceiling (Ge et al., 2012). This situation looks like a trend at the hot and humidity regions (Munna, 2002). Besides that, the moisture can be caused by improper designed or construction of vapour barriers in walls, roofs and floors that normally created from the use of air conditioning and construction in hot and humidity climates (Kubba, 2008). Besides that, the condensation also normally happens due to different temperature between indoor and outdoor temperature.

2.2 Building defect caused by moisture problems

Defect defined by Georgiou (2010) as “a component has a shortcoming and no longer fulfils its intended function”. However, building defect is “a failure or shortcoming in the function, performance, statutory or user requirements of the structure, fabric, services or other facilities” (Pheng and Wee, 2001). Building defects can categories into two which are patent and latent defects (Rhodes and Smallwood, 2002). Patent defects can be identified during construction’s inspection and during Defect Liability Period (DLP) contrast to latent defect that will occur after the building is occupied (Isa et al., 2011). Normally, building defects will occur through wear and tear (Olanrewaju et al., 2010). There have a lot of types of building defects that are cause by moisture problems such as staining, discolouration paint, peeling paint, blistering of wallpaper, corrosion and mould.

The staining problems in rendered wall are due to different moisture contents with various origins such as ground, rainfall and etc. (Flores-Colen et al., 2008). Rainwater is one of the major causes for staining problems on façade (Hassanaian et al., 2013). For the discolouration of paint, peeling paint and blistering of wallpaper are due to water seepage and leakages (Kian, 2001; Hassan et al., 2011). The corrosion defect happened at metal sheeting and AI sheet due to (1) materials such as incompatible materials and presence of micro-organism, (2) environmental factors such as pollution, direct exposure and moisture infiltration, (3) chemical effects (Chew et al., 1998). For mould to grow, it needs four elements such as viable spores, a nutrient sources as wood, carpet or etc., moisture, and warmth (Kubba, 2008). WHO (2009) has stated that the growth of microbes such as mould, fungi, bacteria are cause by excess moisture at the building elements that will pollute indoor air quality that can an adverse effect on health risk. Most mould problems occurred at ceiling, floor and wall. For hospital study done by Hassan et al. (2011) stated moisture problems have caused building defects such as peeling paint, discoloured paint, blistering of wallpaper, staining, sweating on wall and water marks or fungus.

3. Methodology

In order to answer these two objectives, this study based on secondary data from Hospital and Faber Medi-Serve Sdn. Bhd (the company who run the hospital maintenance). The documents are:

- Technical Advice: Written advise based on request/complaint from the end user. Normally include small defects
- Reimbursable Work : Additional works outside the scope of Faber Medi-Serve Terms of Reference (TOR) which includes upgrading/repairing works
- Condition Appraisal: Report provides the overall defects list during the Defect Liability Period (DLP) includes major defects.

All the building defects occurred at the Hospital Sultanah Bahiyah building can be obtained in this report. In order to identify the moisture problems at hospital building, we have to analyse all the documents to find out the building defects that related to the moisture problems. The root cause of the defects has been identified and categorised accordingly. The data covers from the period of 28 February 2007 to 27 February 2009 (during defect liability period) and until January, 2014. To conduct this research, we need to get approval from the Ministry of Health Malaysia and Director of Hospital Sultanah

Bahiyah, Alor Setar. Besides that, the constraint in getting these approvals, we also need to cross check these three documents in order to make sure there will be no overlapping defect reported.

4. Findings

4.1 Background of Hospital Sultanah Bahiyah, Alor Setar

Hospital Sultanah Bahiyah is located in Alor Setar, some 10 minutes' drive from the Alor Setar Utara Exit. The hospital started operation on 29th September 2007. The Hospital is a 660 bed general Hospital with facilities including a 24-hour accidents and emergency service, specialist out-patient and in-patient, surgery, paediatric, forensic, radiology and many more besides providing drive through pharmacy. However, the number of beds has increased from 660 to 743 beds. This hospital is divided into four blocks as Supporting Medical Block, Medical Block, Main Block and Administration Block. The hospital serves the northern part of the Malaysia. The hospital has been taken care of by the Faber Medi-Serve Sdn. Bhd. The Ministry of Health had outsourced the five services such as Biomedical engineering Maintenance Services, Cleansing Services, Clinical Waste Management Services, Facility Engineering Maintenance Services, Linen and Laundry Services and Maintenance Management Information System to the Faber Medi-Serve Sdn. Bhd. This company served for the northern region of Peninsular Malaysia which comprising Perlis, Kedah, Pulau Pinang and Perak as well as Sabah and Sarawak.

4.2. Result

Based on the data given, most of the building defects occurred was moisture issues that come from many root causes. Therefore, the elaboration of result will be according to the building elements. This study will focus on building defect that occur at ceiling, floor, wall and roof.

4.2.1 Ceiling

For the ceiling issues, most of the moisture problems are leaking and condensation. One of the leaking causes is improper design. The leaking always happens at the Medical Outpatient Department (MOPD) Specialist Clinic, Administration Office, Intensive Cardiology Laboratory (ICL) Clinic and Store room at High Dependency Ward (HDW) due to rainwater entering the building through the louvres window, then crawling through the air ducting then to the ceiling. Figure 1 below shows the short awning for the roof which enable the rainwater to enter into the building. Hospital Sultanah Bahiyah is a high rise building, surrounded by paddy field with no big or huge tree, expose to strong wind and heavy rain.



Fig. 1. Cause of leakage: rainwater enters through the louvres due to shortness of awning

Most of problems arise due to poor workmanship. Ceiling leakage also caused by improper installation of waterproofing. Figure 2 shows the leakage problems came from AHU room which is located above the Operation Theatre room area. There are no waterproofing layers at the AHU room slab. Besides that, the improper plastering works at the AHU room wall had cause water seepage through the exterior wall then spread into the concrete slab and beam to the Operation Theatre room ceiling. The improper drainage such as scupper drain contributed to this matter. Result from this issue are stains of water marks, stalactite and stalagmite and mould growth at the Operation Theatre concrete ceiling. Indoor pollutants like this could contribute to: 1. failure of bacteria count test at the operation theatre and 2. the movement of the beam that supported the wall. The movement of this structural element could happen due to deterioration of the concrete and corroded steel reinforcement because of continuous in contact with water or aggressive chemicals over the years and will jeopardize the structures. The leakage problem also happened at many roof areas due to no inadequate gradient level and waterproofing failure will contribute to the water seepage through the wall then spread into the concrete slab and beam then to the ceiling.



Fig. 2. Leakages due to poor workmanship at AHU room above Operation Theatre (a) The improper wall plastering at AHU room, the water can enter through the wall (b) The leakages sign at the beam under the AHU room slab

The next cause of defect is condensation. The issue of condensation affect the ceiling because the different temperature has created the water drop below the floor slab and above the ceiling. The issue of water drop above the ceiling also caused by no insulation layer on an outlet pipe, refrigerator pipe, ducting air conditioner and other type of pipe as shown in Figure 3 below. Thus, it creates the watermarks on the ceiling.



Fig. 3. Watermarks on ceiling due to water drop (condensation) from Exhaust Fan Ducting system at Pharmacy Store

Figure 4 shows the ceiling dampness and has mould growth due to condensation problem. The condensation happened due to different temperature between the floors above and below. This picture explains at the Rehabilitation Unit which is below the Pathology Unit and Blood Bank Room. The temperature of Rehabilitation Unit is 22°C compared to Pathology Unit, and Blood Bank is 19.5°C. The separation floor has not been equipped with any thermal barrier to avoid the heat transfer between two

floors. The situation happened because the room above operated 24 hours however the room below only operated for 8 to 12 hours. Therefore, the difference of temperature between two floors created the heat transfer.



Fig. 4. Condensation cause dampness and mould growth at the Rehabilitation Unit's ceiling

4.2.2 Floor

The moisture problem that happens on the floor is water seepage that is related to the improper waterproofing installation. The affected area is at vinyl and carpet floorings outside the toilet areas as shown in Figure 5 below. The water from the toilet area penetrated through the concrete slab. Based on inspection in year 2008, the areas that were affected from this leakage problem were medical area level 2 and Toilet, Corridor, Room 2B, Room 5-8, On Call Room (OCR) and Ward 2A at level 3. However within the next 4 years, the leakage problem has spread to the whole 7 Storey Ward Block. As a result, it creates building defects such as black staining and mould growth. If this problem is not resolve, it will rust the reinforcement bar and cause concrete spalling problem at the soffit slab.



Fig. 5. Black staining and dampness on floor finishes at 7 Storey Ward Block due to water seepage from toilet area

4.2.3 Wall

After four (4) years running the operation, the defects were clearly seen at the external wall of Hospital Sultanah Bahiyah building. The external wall paintings at a few locations of the building started to faded and were stained. Fungus and algae infected due to continuous dampness of the wall, dirt collection on wall and natural causes. On the other hand, the temperature inside the hospital building and outside has a

huge different that causes the sweating of wall due to the condensation process. As a result, mould growth appeared and there was discolouration to the wall. All the moisture problems arise due to environment factors and condensation as shown in Figure 6 below.

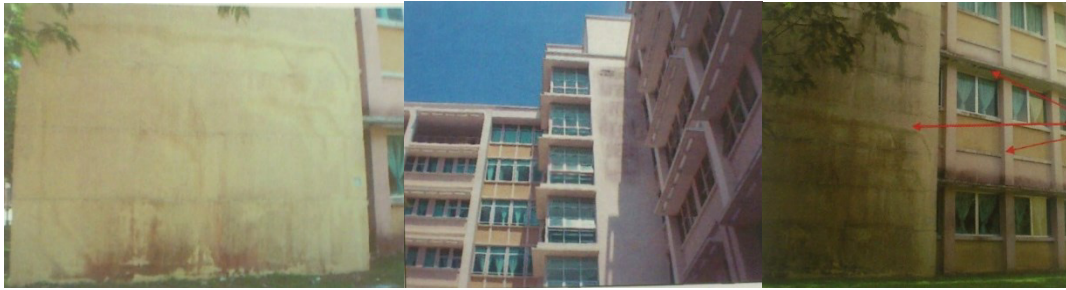


Fig. 6. Wall staining and paint discoloured at Hospital's external wall due to environments and condensation factors

Besides that, the water seepage from the toilet areas also affected the internal wall buildings. Observation showed that the peeling paint and blistering of wallpaper finishes occurred due to failure of water proofing layers on the toilet wall that caused water to penetrate through the toilet wall and affect the perimeter wall outside as shown in figure 7 below. It happened at medical ward 7A and 7B at level 7, 6A and 6C at level 6 Ward Block.



Fig. 7. Peeling of wallpaper at level 7 and 6 Ward Block due to waterproofing failure

4.2.4 Roof

For roof element, the defect is corrosion at the roof gutter which leads to the leakage problem as shows in figure 8 below. The improper installation of galvanized iron gutter which is the gradient of roof gutter was not levelled well to flow the rain water into the rainwater downpipe. As a result, it has created the stagnant water at the roof gutter and the oxidation process happened. Besides that, the 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 Finishes c/w Rainwater Outlet System, to detail". Therefore, this condition will lead to corrosion, leakages and shorten its life span. There is potential of mosquito breeding.

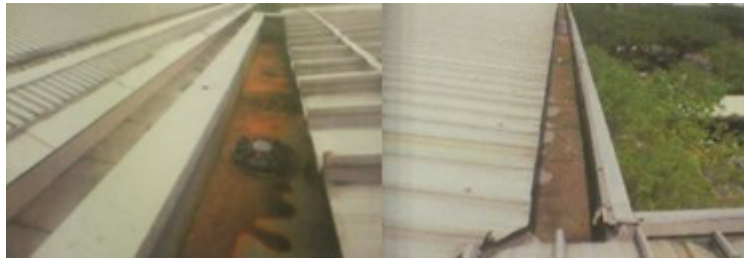


Fig. 8. Corrosion at roof gutter due to poor workmanship

5. Discussion

Based on the result obtained from Hospital Sultanah Bahiyah, it showed that the moisture problems are one of the main causes of building defect. This statement was also supported by many scholars (Chew, 2005; Kubba, 2008; WHO, 2009; Ahzahar et al., 2011; EPA, 2013). The moisture problems that occurred at Hospital Sultanah Bahiyah were leakages, water seepage, condensation and stagnant water. These moisture problems were caused by (1) environment such as rainwater, wind and temperature, (2) poor workmanship especially failure waterproofing installation poor construction quality which was not according to building standard and contract, (3) improper design which failure to consider impact of environment factors and (4) ventilation factor due to exhaust fan ducting and air-conditioning system. The moisture problems have lead to building defects at the main building elements such as roof, wall, ceiling and floor. The examples of defects were peeling paint, blistering of wallpaper, staining, discolouration, watermarks, mould growth and corrosion or decay. In a long term, moisture problems would also lead to failure of building structure if not rectified early. Moreover, moisture problems can adverse on health such as asthma due to fungus (*Stachybotrys chartarum*) known as black mould that grows on timber, wall liner (plasterboard) and ceiling tiles and contain moisture-saturated (Kuhn, 2003).

6. Conclusion

The purpose of this research is to identify the moisture problems that occurred at the hospital building which leads to building defects in tropical countries such as Malaysia. This study has identified many building defects occurred due to moisture problems. From the result of this study, we can conclude that moisture problem is one of the serious causes of building defects. Hospital Sultanah Bahiyah can be categorised as a new hospital which has been in operation for less than ten (10) years. These findings would provide an interesting view of moisture problems that affect the hospital functional performance. Based on the finding, it is suggested that these problems should be highlighted during early project development. All relevant parties should work together from design until building completion and putting an effort to minimise the moisture problems throughout the building life. Besides that, it will be critical for hospital building to control the moisture effect for a good indoor air quality. For hospital building, the issue of safety especially in terms of providing environment that is free from unnecessary viruses and bacteria should be the main concerns of stakeholders. Therefore, this paper suggests the stakeholders to seriously look into work coordination among project team to ensure the quality of the constructed building. Consideration of the identified causes at the early construction stage would help to minimise the moisture problems and increase the indoor quality environment. This study is a part of a larger study on identification of building design defect on two hospital buildings in Northern part of Peninsular Malaysia.

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