The Effect of Design on Maintenance for School Buildings in Penang, Malaysia

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Structured Abstract

Purpose This study focused on identifying building elements with design defects and established the relationship between design defects and difficulties in carrying out maintenance works.
Design/methodology/approach A total of four cases have been selected covering primary- and secondary-level for both National and National-type schools (commonly known as vernacular schools). Interviews with school management were carried out throughout the study to assess the common design defects in the buildings.

Findings A list of the design defects that have caused high maintenance cost was tabulated. It could be concluded that the most common design defects are building façade and missing slot underneath the floor slab which led to more defects.

Research limitations/implications Only 4 school in Penang, Malaysia involved in this study. Data gathered from the school management and maintenance personnel. No data has been obtained from the designers because difficulties in tracing the designers record since the school age are more than 20 years.

Practical implications The study recommended that expert maintenance personnel shall be employed in the design stage to minimize design defects in school projects which in turn minimize the cost of building maintenance.

Social Implications Safety and health of the students could be affected if there is no accurate measures being adopted to overcome the issue.

Originality/value Very limited study has been carried out with regards to design maintenance for school building in Malaysia.

Keywords: design defect, maintenance, school building, Malaysia

Article Classification Research paper
Introduction

Maintenance issue often arises when the building performance is not meeting the standards and quality designed. In Malaysia, building maintenance works were previously dominated by the Property Manager, owners and Public Works Department (Ali & Alias, 2011). However, this has changed since the completion of the Dayabumi Complex in Kuala Lumpur in 1984, coupled with the establishment of private maintenance firms providing professional advice. In developed countries such as the United Kingdom and Australia, similar problems surfaced in building maintenance whereby various factors in the design and construction resulting in building defects was found. Most of them were attributed to design and construction faults. Moreover, Koo (2000) said that in Singapore, most of the high-rise buildings are experiencing difficulties in maintenance due to the lack of an access system thus increasing the cost in the maintenance of the building façade. Furthermore, maintenance costs and building maintainability have been neglected in the design and construction stages, resulting in buildings that are difficult or costly to maintain. Any negligence during the design phase could result in difficulties in building maintenance thus increasing building life cycle cost in the future. This statement is supported by a study carried out by Ramly et al. (2006) which showed that about 47% of defects in Public Housing in Malaysia was contributed by design related negligence. The study also showed that that almost 40% - 50% of all non-conformances are the result of the design error and in reality, a lot of design flaws happened during and upon completion of the buildings. Hence, design has a significant impact on building condition after completion, especially in maintenance works, as the design will affect building performance, physical characteristics and durability.

Similar problem is experienced by schools in Malaysia. In maintaining the facilities of a school, Baker and Peter (1963) described that the challenge would be greater because the occupancy of schools is made up of young people and they will cause more wear and tear in addition to any expected weathering and obsolescence. In addition, the school custodian and the principal are jointly responsible for its care and operation, which are indirectly responsible for the priceless lives of hundreds of children and teachers of the schools. In Malaysia, Mstar (2011) reported that the Minister of Education has pointed out 600 out of the 10000 schools audited were rated as poor and required maintenance. This has resulted in an increase in the allocation of the maintenance budget for school buildings of 1 billion Ringgit Malaysia for the year 2012 (Malaysia, 2011).

Therefore, this paper attempts to identify types of design defects that contributed to high maintenance cost for school buildings in Penang. The study extended to identify possible solution to overcome the issue. The growing importance of maintenance sector, poor maintenance performance and the lack of research in this area provide impetus for this study.

Design Defect and Maintenance

Buildings cannot remain new throughout their entire life. A newly completed building also requires maintenance. Moreover, it is not possible to replace or rebuild all buildings at one time. The value of a building decreases unless maintenance is carried out on the building (Lateef et al., 2010; Ali et al., 2009). Maintenance works are the only way to maintain and increase the value of the property. Therefore, the need for maintenance will only intensify. Building maintenance and the performance of the building constantly affect people’s comfort and productivity.
Archifacts (2012) define defect as an aspect of the design, building work or materials which does not conform to the requirements of the contract under which they were procured and categorized into two; latent and patent. The patent defects are caused by normal wear and tear while the latent defects are referred to construction workmanship defects. Ramly et al. (2006) notes that design defects are the faults that have been built-in since the construction of building on the “drawing board”. The deterioration of materials and components that have taken place to some degree is controllable with the decision made during the design stage. Maintenance problems can also arise from faulty design decisions. Gibson (1979) notes that faulty design decisions are the most common faults which could be categorized as follows:

a. Failure to follow well established design criteria in the choice of structural system and selection of materials.

b. Ignorance of the basic physical properties of the materials.

c. Use of new materials or innovative forms of construction which have not been properly tested in use.

d. Misjudgement of user and climatic conditions under which the materials have to perform.

e. Difficulty in executing the design due to impractical issues.

f. Poor communication between members of the design and construction teams.

Therefore, it is important that the earlier decisions and initiatives are taken into consideration during the design phase to ensure the proposed building design is maintenance-friendly and sustainable throughout the whole life cycle of a building.

Research Method

Qualitative research method was used in the collection of data relating to the existing maintenance practices by the maintenance personnel and school management. Face-to-face interviews were conducted with the maintenance person in-charge of each of all 4 case studies, principals and development officers. According to Ali (2010), the best way to obtain information on the buildings is by interviewing the owners and the building managers. The number of maintenance managers was small in the four cases to be studied. By using the qualitative method, it will not restrict the respondents’ approach towards the interview survey and the results place more emphasis on the experiences of the respondents (Naoum, 2007). The interviews focused on school buildings, building maintenance schedule, elements with higher maintenance costs and faulty design elements. The list of design defects that cause high maintenance cost to the management was made available. The selection of building elements that contributed to high maintenance cost in this study were based on researcher’s observation from a walk through building survey on the schools. From the survey, the researcher list down the identified defects which further discussed during the interview session with the school maintenance personnel. However, due to confidentiality, the school management did not show the actual maintenance cost. A list of the elements of design defects was generated through data analysis. Besides, solutions and recommendations were provided as alternatives to tackle the problems.

Results and Discussion

The four cases in the study are:
Data obtained from the interviews were analysed in terms of the building elements. Although the design defects are difficult to solve as they are deeply rooted, the solutions and recommendations provided could possibly be considered as a guide and alternatives to ease the maintenance works. Summary of the results are as follows:

i. Rain Water Down Pipe (RWDP)
   The RWDP on the external wall without any protection is directly exposed to the sunlight, strong wind and rain water. Bending and undersized RWDP led to breakage of the pipes connections and leaking RWDP lead to the growth of vegetation and stains.
   The protection to prevent the bending of RWDP is by providing durable and suitable brackets as well as installing the RWDP in the structural elements. Another method is constructing a separate riser just to accommodate the riser, making it easier to repair or remove any clog without the need for scaffolding / machinery (cranes), thus reducing the maintenance cost in the future.

ii. Brickworks / Façade Wall
   External wall of the buildings tends to have stains due to the splashing of rain water and rusty stains. The stain spoils the appearance of the buildings and it is easier for the stain to deposit on the face bricks which is the decorative elements. Besides, the main problem on the brick wall is efflorescence.
   The stain / efflorescence defects on the walls can be reduced only through the use of materials. More durable exterior paint should be chosen instead of normal emulsion paint. Extending the eaves overhang of the roof can provide more shading to the façade from sunlight and rain water.
   During the design stage, the ceiling walkway shall be designed specifically for maintenance and housekeeping. However, in the cases of this study, there are no walkways and the conventional method for cleaning is by using the extendable sticks to clean the spider webs. The fused light bulbs have been replaced with collective order concurrent with erecting scaffolding.

iii. New Extension for Shading Purpose
   The open area (originally the landscape area) between the building blocks is covered up for events and extracurricular activities. The problems that arose were the connections between both new and old structures which tend to leak during rain, and the extensions were with low headroom, poor lighting and bad ventilation system. Extra lighting and ventilation are required.
   The low headroom and darker environment can be improved during the design stage by constructing an Arch Rib form structure rather than a simple box design or typical beam-and-column design with similar column height. The inverted “U” shape roof structure allows more sunlight and better ventilation. Transparent roof light (GRP/PVC) can also be adopted to provide natural lighting.

iv. Ventilation and Lighting System in Badminton Hall
   Ventilation and lighting requirements in an enclosed hall have forced the school management to install new ventilation fans. However, the newly installed fans on the wall
created problems in terms of leakage and penetration of rain water. The new system also faces the access problems in terms of cleaning and maintenance.

The enclosed hall can be equipped with adjustable penda flour light instead of the common ceiling-recessed spot light. The adjustable light can be adjusted according to the needs. Therefore, the access to replace/repair the light bulbs can be done easily by the in-house staffs using portable stair.

v. End of the Drain
Common defects are the clogging of the drains due to the defects of inappropriate gradient of drains. The clogging could lead to flooding especially during the monsoon season and the growth of vegetation as well as the breeding of the mosquitoes and cockroaches.

The improper gradient of the drain makes it difficult to be repaired. However, the respondents have tried to fix some parts of the drains by simply hacking it off to partly solve the problem. Ponding will still exist unless the drains are relaid by skilled workers. Frequent cleaning of water ponding should be conducted to ensure a healthy environment free from dengue.

vi. Ironmongery
All cabinets and openings of ironmongery have a problem of rusting and lost due to the inappropriate design of space utilization. The wrong selection of the materials has contributed to this problem too.

The ironmongery is frequently replaced and this is unavoidable because of the lack of space in the schools. The only way to eliminate the frequent replacement is to have suitable space in the classrooms. Besides, the management is able to reduce the problem by instructing the students to be more gentle with ironmongery.

vii. Gutter
The inappropriate selection of gutter materials and the connections has led to leakage and clogging of the system. The use of zinc pieces instead of the proper gutter materials could lead to distortion under the weight of water ponding, thus causing water leakage. Clogging due to improper gradient and the deposition of dirt could result in the collapse of the gutter.

Besides using the appropriate materials to reduce clogging is done by installing PVC wire mesh over the gutter to act as a filter. Locations prone to breeding of mosquitoes can be eliminated by using copper-made gutter or putting copper-made one-cent coin in the gutter as this method is widely used in residential areas.

viii. Roof
Flat roof without proper channel to drain the water tends to have ponding on the surfaces. The ponding not only causes stubborn stains, it leads to the breeding of the mosquitoes and related health issues. Pitched roof without proper connections between the roof tiles can result in the penetration of rain water into the roof structures. The materials manufactured will differ from batch to batch even though the models are similar. The incompatible roof tiles will create holes within the overlapping. The use of reinforced cement roof sheeting causes the bending of the sheeting under external forces leading to the penetration of rain water through the overlapping. Furthermore, asbestos-cement sheets used which will cause very high health risk to the occupants.

Effective channels with proper gradient shall be ensured during the design stage. Frequent cleaning can only be done for those existing buildings to prevent the clogging of water outlets on surfaces and to clean away the weeding. Proper sealants must be used to seal the
surrounding frame of the access door to the roof top (usually from highest occupied floor) to avoid the penetration of rain water into interior spaces. Refurbishment can be done on the existing flat roof with cold-applied EPDM to prolong the roof life and eliminate the defects. For the pitched roof, it is recommended to use the small roof tiles rather than rectangle corrugated reinforced cement roof sheeting which are prone to bending under the heat of the sun and it can lead to the penetration of rain water through the overlapping. Metal sheeting can be used to replace the current clay tiles. Proper metal capping on the wall-roof abutments can be installed. The existing asbestos-cement sheets must be eliminated for the sake of a healthy environment.

ix. Slot under the Parapet Wall
The purpose of the slot is to stop the flow of the rain water splashing on the façade/parapet wall to the underneath the floor slab. Simple cleaning can easily remove the dirt and stain. However, the missing slot will make the cleaning to cover the bigger area. Without the slot, it will lead to ponding on the floor and raise safety issue of the occupants.

Edge slot is sometimes forgotten during the design and construction stage due to negligence while frequent cleaning is the only way for the existing buildings.

x. Road Cracking
Road cracking due to the improper utilization of the space, for instance, bicycle park used for cars. Initially the drive way was designed for light-duty use. However, the areas are now used for medium/heavy-duty usage. This is due to the lack of the space allocated for heavy usage during the design stage. The cracked holes caused water ponding problem, leading to the breeding of mosquitoes and safety of the occupants.

Floor cracking on the road surfaces can be temporarily repaired by simple concrete patching. However, the correct repair method for cracking holes shall be used by the contractor to prevent frequent cracking.

Findings from face-to-face interview shows that the bending RWDP can be reduce through provide more protection to the RWDP, so that can be shaded from the direct exposure to nature elements (sunlight, rain and winds). The protection can be enhanced by providing durable and suitable brackets as well. The protection can be provided by installing the RWDP in the façade wall or covered together with the columns. This method can be done only during the construction period to include the RWDP in the wall or columns as mentioned by Ali, (2011). Perhaps, another method is constructing a separate riser just to accommodate the riser. This method can be seen in the new building of School B in the case study. The riser is attached together with the columns but not embedded in the structure elements.

The efflorescence defects on the brickworks / façade wall can be reduced only though the use of appropriate materials. The design of the materials shall be in accordance to the site location and designers can provide additional protection to the wall surface, for instances protection to the rising dampness through sufficient and proper damp proof course. For the splashing of rain water directly on the façade, the method can be adjusting the orientation of the structure according to the local weather and raining pattern (Ramly et al., 2006). Another alternative is to extend the eaves overhang of the roof to provide more shading to the façade from sunlight and rain water (Ali & Alias, 2011). Besides, the specifications for the exterior wall must be taken into consideration by using the more durable and long-lasting paint. As explained by the interviewees, the old paint peeled off has been replaced with this so-called resistance paint and the walls require the repainting in 5 to 6 years intervals. If normal Emulsion paint chose to be used then probably repainting needed in every 2 years intervals.
The low headroom, darker environment underneath the extensions (covered corridors / places between blocks) is not suitable for any events. However the situation in School B which is lacking of spaces, the management is looking for any available spaces for extracurricular activities. Unavoidably, the place under the extension is chosen. The management is providing some lighting fittings and fans for lighting and ventilation purposes. The lighting problem can be solved easily by providing roof light during the design stages. However, this alternative was not considered during the extension. Therefore extra lighting fittings are needed, causing extra cost for installation and the energy cost incurred. Another alternative is the increase height of the extension to one more floor level height. The design shall in concurrently with the adjacent blocks’ first floor height instead of the current height with ground floor height (Ali & Alias, 2010). With this method the initial cost is slightly higher but savings in electricity bills can be achieved.

The badminton court in the school hall is using the adjustable penda flour light instead of the common ceiling-recessed spot light. The adjustable light can be moved up and down according to the need of the function. Therefore, the access to replace/repair the light bulbs can be done easily by the in-house staffs using portable stair while the adjustable lamps to the lowest height so as savings can be achieved since no heavy machinery or the scaffolding is needed. The ventilation fans which face the penetrating of the rain water is now seldom in used after the management installed air-conditioning system in the hall. Any major function is now ventilated by the system. The penetrating rain water is reduced by applying sealants surrounding the fans.

The ponding and vegetation growth required cleaning from time to time and will be more frequent during rainy season in Malaysia, especially from April to September. The improper gradient of the drain is difficulty to be repaired as told by the interviewees. They do try to fix some parts of the drains by simple hacking off and partly solve the problems but the ponding still existed unless re-lay the drain by skilled workers. Therefore, the housekeeping personnel in the schools are instructed to check and clean any ponding from time to time to prevent the breeding of the mosquitoes.

The replacement of ironmongery is unavoidable because the wrong usage of the spaces which substituting a science lab/workshop to a classroom. This supported statement by Ramly et al. (2006) who mentioned that a lot of changes need to be done due to vandalism or wrongly usage. To reduce the replacement frequency, the management is instructing the students to be more gently in using the doors and windows and reporting any vandalism immediately. The only way to eliminate the frequent replacement is to have suitable spaces for classrooms.

The design of the gutter must be in the appropriate materials, for instance, use PVC gutter instead of bending the zinc pieces. To reduce the clogging of the gutter due to the leaves, extra protection can be done by putting PVC wire mesh over the gutter when the buildings are next to the trees so as the wire mesh can act as a filter (Ali & Alias, 2011). Location which prone to breeding of mosquitoes can be eliminated by using the copper-made gutter as this method is widely used in residential areas.

To maintain the flat roof, effective channels with proper gradient shall be provided. Ponding is happened when improper gradient of the channel and the blocking of the water outlet to the gutter and RWDP. Frequent inspection is required however; it has been neglected by the school managements where they even not access to the roof top except by the outsourced contractor. For the pitched roof, perhaps the use of small roof tiles rather than rectangle corrugated reinforced cement roof sheeting is suitable Ramly et al. (2006). The corrugated sheeting is prone to bending under the sunlight exposure compared to the roof tiles. Once the bending happened, it leads to the penetrating of the rain water through the overlapping joints.
From the discussion, it could be concluded that the design defect which causing high maintenance cost for schools in Penang does not at critical stage and still under control. Physically, the schools are of good condition with minor design defects that do not affects the building structural safety but perhaps contribute to a little occupancy safety and health issue.

**Conclusion**

On the whole, based on findings from the case studies, it could be concluded that the maintenance management in government schools buildings falls under the satisfying condition. The structural safety is not affected by the design defect. However, some issues related to the safety and health of the occupants arose due to design defects. Lack of maintenance funds has forced the school management to think of the remedial methods with minimum cost. Hence, maintenance inputs need to be adopted in the design stage. This is to ensure that their opinion can be used as reference for the ease of maintenance in the future which can reduce design defects.

**References**


