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COMMON DEFECTS IN PUBLIC INSTITUTIONAL BUILDINGS IN MALAYSIA

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Abstract: Malaysia is a country developing swiftly in all industries, including the construction sector. However, some buildings are laden with defects, increasing the risk of catastrophic events that could endanger the occupants. This paper aims to comprehensively assess public buildings to identify common defects, determine the root cause and propose effective solutions. Data was collected by site inspection and semi-structured interviews. Five (5) public buildings in the Klang Valley were built more than 10 years ago and 5 respondents were chosen from each public institution's building, for a total of 25 respondents. Content analysis of data revealed that there were three (3) common types of defects: Hairline cracks, water ponding on the flat roof and damaged sinks. Three (3) solutions were suggested for each defect stated, namely well-planned maintenance, focus on the gradients and focus on the discharge outlets. The research also found the most common time when defects occur in a building. This research sheds some light on this issue and the relevant parties can utilise its findings to improve maintenance practices. Indirectly, it will put the country on a path toward building economic and social resilience in line with the United Nations Sustainable Development Goals (SDGs) No. 9, industry, innovation, and infrastructure, which highlighted that investment in infrastructure and innovation are crucial drivers of economic growth and development.

Keywords: SDGs No. 9, building maintenance, building defects, public institutional buildings.

Introduction

Despite rapid technological advancement, the building construction industry is still plagued by issues with defects (Ismail *et al.*, 2015). These problems occur for many reasons, such as poor workmanship and faulty design and construction, thus lowering the value of the building itself. These building defects have become a serious issue in recent years, and they are reflected in the cost and time spent to rectify them. If the structure begins to fail to operate as it should, immediate action must be taken to correct the problem (Sravani T, 2020). This is a typical issue in Malaysian building projects. The majority of faults in the projects are not correctly recorded and monitored, resulting in the client not being aware of the defects and being left unattended for a very long time (Isa *et al.*, 2016).

A building may serve as a shelter from the environment as well as provide safety and privacy to its users or occupants. Nevertheless, the function of a building may evolve through time. Some buildings change their functions to suit the surrounding development, whereas some retain its design function for a very long time. In today's world, a building serves a variety of functions to facilitate human activity. As people's lifestyles change, their roles change as well. In short, the function of a building in supporting our daily activities evolves. However, owing to external and internal factors, not just design function but actual building performance may suffer. External factors are primarily caused by the weather, whilst interior ones are caused by the building's age and the need for proper maintenance (Zubair *et al.*, 2020). Ultimately, a building aims to provide people with a pleasant living and working environment.

Generally, a building can be categorised into several roles, such as administrative, institutional, industrial, commercial, residential, or mixed functions. This research will focus on public institutional buildings. The justification for this is based on the findings by Norazman *et al.* (2019), who stated that not all institutional buildings have frequent maintenance due to insufficient guidelines and funds. Lack of managing and maintaining the performance of public institutional buildings and facilities can cause serious defects that disturb their design function. Olayinka (2020) also found that many public institutional buildings were in bad shape and lacked maintenance. Defects are common in the construction industry worldwide. Building defects and damage can be categorised into 2 types: Structure and non-structure, as reported by Plebankiewicz and Malara (2020). A structural defect may be known as physical damage, which is caused by the failure of the load-bearing element of the building. An example of physical damage is a broken column and beam failure. Non-structural defects are damaged building components, such as windows, roofs, and walls. Regardless if the damage poses a safety risk to the occupants, the defect in the building should be minimised to ensure it can operate according to its functionality (Hanafi e*t al.*, 2018).

Isa *et al.* (2016) showed that most of the damage in public institutional buildings are caused by architectural defects, followed by mechanical, electrical, and lastly, civil defects. The research also revealed that the defects were caused due to work not being done according to specification, poor workmanship, and excessive water ponding. According to Wahab and Lawal (2011), most of the defects recorded were hairline cracks on the wall/floor. The second is peeling paint, followed by structural cracks on the wall. Hanafi *et al*. (2018) made similar findings, highlighting that the most common damage is hairline cracks on the wall/floor, followed by roof defects, and building accessories, such as doors and sinks.

A survey by Ismail *et al.* (2015) found that 72% of defects were serious, 11% were moderate, and 17% were minor. This survey shows that defects can happen to any type of building, not only old ones. A building in a warranty period can also face defects. Ismail *et al.* (2015) recommended that all parties improve construction practices to ensure defects can be prevented.

The findings show that construction industry players across the globe face defect issues and should be aware of the common defects in buildings in order to minimise them. This research references past defects reported in other studies, such as the damage at University Technologi MARA (UiTM) Perak by Isa *et al.* (2016), and Wahab and Lawal (2011) who reported on the common defects at the University of Ilorin, Nigeria. The objectives of this research are: (i) To identify common defects in a public institutional building; (ii) To determine the cause of these common defects; and (iii) To suggest solutions to these common defects.

Literature Review

Defects can reduce the performance of a building (Hong, 2016). Isa *et al*. (2016) defined construction defects as a deficiency or shortcoming in the construction, materials, utilities, or other facilities of a building that can affect its operation, efficiency or occupant's requirements. This was echoed by Konior *et al*. (2020), stating that defects can make the building unable to fulfil its function. A building defect or damage is an event that involves a component or structure failing to provide service due to reaching its serviceability limit. When this happens, reliability theory states that it is still for use but it is known as faulty.

Building defects may happen in both new and existing buildings. New buildings may have problems due to non-compliance with the building code and permissible tolerances and requirements. The old buildings or those that are no longer covered in the defect liability period (DLP) may not fit that criterion and must be judged against the standards in place at the time of construction or renovation (Sravani T, 2020).

Construction defects can be divided into two categories: Structural defects and non-structural defects.

Structural Defects

A structural defect is a significant or critical flaw in the building's construction, such as big cracks, bowing, and settlement, as highlighted by Talib and Sulieman (2020). Any problem in a structural element that is related to poor design, defective or poor workmanship, defective material, or a combination of these, is a structural defect. Earth retaining walls, columns, beams, and flat slabs are all part of the building. Deterioration, overloading, wear and tear, and poor maintenance can cause structural defects over time. They need to be fixed to preserve the structure of the building and avoid further failures. Omar Bakri and Othuman Mydin (2014) added that the key to maintaining the "health" of a building is regular inspection. Steel corrosion, fractures, and deflection are common structural defects. Improper soil analysis, site selection and the use of substandard materials can all contribute to these flaws. Most structural issues may be avoided by suggesting precise and detailed design and planning. According to Zubair *et al*. (2020), common structural building defects can be categorised as a crack in the foundation, which is the substructure; a crack in the floor or a slab, which is the superstructure; and a crack in the wall, also a superstructure apart from steel corrosion and component deflection.

Non-Structural Defects

Non-structural defects are minor damage in the building, such as detached fixtures, biological dampness and wear and tear (Talib & Sulieman, 2020). A non-structural fault in a residential structure is a defect in a non-structural element of the structure because of poor construction work. This includes brickwork faults, moisture in ancient structures, and plasterwork faults. Zubair *et al*. (2020) highlighted that common non-structural defects in student accommodation are defects in the plaster, dampness, and cracks.

Causes of Building Defects

According to the research, failure can result from a single error, and these defects can include technical issues and unexpected deficiencies in material performance (Plebankiewicz & Malara, 2020). There are several factors of defect and failure, such as types of building materials, errors or mistakes during construction, corruption during construction, lack of supervision and also design error. Defects and failures in the construction of buildings require not only identifying the causes of the defect but also the cost of repair. According to Isa *et al.* (2016), most of the defects in a building are because of the weaknesses in the project implementation process. Other than that, poor design decisions, selection of materials, supervision and workmanship are the most significant contributors to building defects. According to Awol *et al.* (2016), some defects, such as leaking pipes, cracking, peeling paint, dampness, broken tiles, and electrical faults, happen because of weak design, poor workmanship, and quality of the material.

Yamov and Belyaeva (2019) reported that technological issues are the main cause of defects in multi-storey buildings. Technological issues are mistakes that have been made during the construction, such as not complying with erection standards and long-delayed construction. Other than that, there are operational causes, which are poor and improper building maintenance that will cause more damage to the building and increase the cost of repairs. An example of operational causes is the absence of technical service and a lack of response to force majeure situations. Salim *et al.* (2016), emphasise that a building defect is a fault or mistake that lowers the value of the structure and, if ignored, can put building occupants at risk. A defect can be caused by a variety of causes, including poor workmanship, design defects, incorrect material choices, and so on. Communication between members of a group is critical to a project's success. The interpretation of design cannot be applied easily due to a lack of two-way communication. The majority of architects concurred based on their research. However, the design fault, the major source of building problems, is poor workmanship and materials.

Construction Deficiency/Poor Workmanship

The majority of construction faults are due to poor workmanship, a lack of knowledge of how non-traditional materials should be handled and placed, and poor supervision, as reported by Hasan *et al.* (2016). According to Omar Bakri and Othuman Mydin (2014), the construction process might also play a role. For example, improperly applied or prepared construction mixes that use water can cause difficulties in the finished structure by retaining moisture. Unskilled workers or poor workmanship was likely used to keep construction costs low due to a lack of funds (Awol *et al.*, 2016). According to Isa *et al.* (2016), workmanship is the main cause of architectural defects in Malaysian university buildings, such as finishes, walls, and floors. The same goes for the window. Workmanship is the common cause of defects compared to natural causes. Poorly installed doors and fittings are also because of bad workmanship rather than lack of protection and maintenance faults.

Lack of Consideration in Maintenance During Design

According to Salim *et al.* (2016), some architects are too focused on developing a creative building design to the point that they overlook the maintenance aspect. This design fault leads to challenges in maintaining operational work and a lack of knowledge about maintenance access. Maintenance access points are necessary to ease the way of staff to do their work and decrease maintenance risk and costs. Maintenance costs will rise as a result of the difficulties in accessing the affected area. The availability of maintenance instruments should be taken into account during the building design stage. This is to minimise any increase in maintenance costs. For maintenance work that is unexpected, specific and custom-designed maintenance tools and equipment should be considered. It will raise the maintenance operating costs since specific expertise is required to operate the equipment. As a result, these concerns must be thoroughly considered throughout the design phase otherwise, the building's problems will progress to the point of causing catastrophic damage.

Lack of Regular Maintenance

A building that has had improper and poor maintenance will face more damage and expensive repair work if left unattended (Yamov & Belyaeva, 2019). Building owners also often ignore the need for technical building control in bearing structures. In certain cases, there is a lack of proper monitoring of the serviceable condition of the structure, as well as the proper functioning of the building facilities, as shown by markings in supervision records and professional passports. Often, regular maintenance and remedial repairs were ignored to keep the buildings in use (Yamov & Belyaeva, 2019).

Types of Building Defects

Based on findings by Awol *et al*. (2016) and Hong (2016), there are several types of defects such as leaking pipes, cracking, electrical faults, paint problems, broken tiles, excessive mould, roof leakage, dampness, corrosion of reinforced steel, foundation failure, honeycomb, erosion of mortar joints, defective plaster rendering and timber rot. Talib and Sulieman (2020) added that the common manifestations of defects are dampness and cracks. However, these defects may lead to cracks where it's impossible to figure out the root cause of the problem and a way to fix it. Roofs, floors, ceilings, walls, toilets, doors and windows are the usual part of a building that suffer defects.

Cracking

According to Awol *et al.* (2016), cracks that appear on the finish or plaster of walls can affect the appearance of the building structure, but it does not pose any safety concern. The cause of cracking is water seepage, which causes the

Table 1: Classification of visible damage to wall (Omar Bakri & Othuman Mydin, 2014)

Classification of Damage	Degree of Damage	Description of Typical Damage	Approximate Crack Width (mm)
0	Negligible	Hairline cracking that is less than 0.1mm in width is classified as negligible. No action is needed.	Up to 0.1
1	Very slight	Fine cracks can be easily treated during normal decoration and the defects are usually limited to internal wall finishes and crack rarely visible in external brickwork.	Up to 1
2	Slight	In this category, crack is easily filled. Suitable linings can hide recurrent cracks. Although cracks are not always evident from the outside, some exterior reappointing may be necessary to ensure weather tightness. Doors and windows may be a little loose and need to be eased and adjusted.	Up to 5
3	Moderate	A crack that needs to be opened and patched by a mason. External brickwork must be repointed and maybe a small section of brickwork to be rebuilt. Doors and windows are stuck closed. Service pipes may crack. Weather tightness is frequently impaired.	5 to 15
4	Severe	Damage is extensive, necessitating the removal and replacement of parts of walls, particularly around doors and windows. The frames of the windows and doors are damaged, and the floor is uneven. There is visible wall tilting or bulging, as well as some beam bearing loss. Service lines have been interrupted.	15 to 25 but also depend on the number of cracks.
5	Very severe	Damage to the structure necessitates a substantial repair effort requiring partial or total reconstruction. Beams lose bearing, walls fall, and shoring is required. Windows are damaged and broken. There is a risk of instability.	Usually greater than 25 but depends on the number of cracks.

reinforcement to corrode (Jamaluddin *et al.*, 2018). Other than that, since concrete has low tensile strength, any induced tensile stress could cause cracking. Cracking may happen during construction and throughout the building's lifetime, they will be subject to minor movement. This could be due to the product drying out or decaying, or it could be due to expansion and contraction due to temperature exchange. Cracking can also be caused by superimposed loads, such as shifting occupants or furniture, as well as wind. Since certain construction materials are susceptible to vibration, cracking is unavoidable. Furthermore, there are many causes of cracks, such as settlement, water pressure and microorganism growth (Talib & Sulieman, 2020). According to Hong (2016), there are many types of cracks that can occur on the surface of the building, such as transverse and longitudinal cracks, shear cracks, crazy cracks, plastic settlement cracks and cracks due to plastic shrinkage. There are different states and degrees of crack damage. Table 1 presents the classification of wall cracks (Omar Bakri & Othuman Mydin, 2014).

Mould and Fungi

The development of mould and fungi are common symptoms of excessive dampness. Mould and fungi can grow if they get enough moisture and also nutrients (Awol *et al.,* 2016). The growth of mould and fungi can also affect the appearance of a building, which may lead to health issues for occupants. According to Talib and Sulieman (2020), the fungus that causes dry rot is known as *Sepula lacrymans* and it prefers a moisture content of 30% to 40% and a temperature of 23°C. Usually, dry rot will attack wood fixed in warm, damp, and poorly ventilated internal conditions. As mentioned by Omar Bakri and Othuman Mydin (2014), mould and fungus can be found in both indoor and outdoor environments. Concerns regarding indoor mould exposure have grown in line with public knowledge that mould exposure can have several negative health consequences. Moulds generate and release millions of spores that can be spread by the air, water, or insects. Mould spores may start growing and absorbing whatever they settle on. Moulds slowly degrade the materials on which they grow, so removing them prevents damage to building materials and furniture.

Flat Roof Defects

Flat roof defects are frequently exposed to the environment, especially to temperature changes, solar radiation, and wind impact. Because of the form of the structure, such as services coming through the roof covering and internal gutters, roofs are particularly vulnerable. Omar Bakri and Othuman Mydin (2014) highlighted that the effect of a flat roof fault may be amplified by a matching defect on the slab or other component. Flat roof defects are separated into 2 categories: (1) Structural defects and (2) Waterproofing material defects. According to Awol *et al.* (2016), blocked gutters, leaking downpipes, leaky roofs, and poor gradients were among the flat roof faults discovered. Plant growth and the buildup of leaves and debris cause blocked gutters. As a result, when it rains heavily, the rainwater will overflow. According to Okuntade (2021), aside from being one of the building's main components, the roof can also serve as a weather screen, protecting clients or renters from the rain and sun. As a result, it is vital to take care of any decaying flat roof finishes.

Spalling

Spalling, commonly known as spallation, is a situation in which construction elements such as plaster, concrete and limestone suffer surface failure because of excessive humidity, weathering, and corrosion. If not handled quickly, spalling on concrete materials may be highly harmful. The spalling process will be accelerated with the application of natural and mechanical agents. Latip *et al.* (2020) highlighted that gravity causes ceiling concrete to spall, resulting in debris that will collapse and damage property, as well as cause public injury. Spalling is technically a minor structural issue, but if left untreated, the danger of injury grows. The damage starts at the concrete's reinforcing bar, which has little impact on the mix's initial strength. Spalling is a widespread but poorly understood phenomenon in older concrete structures. The presence of external ferrous components that mix during the preparation of concrete contributes to reinforced rod corrosion, which is a major cause of spalling. Steel-framed windows, metal pipes, concrete ceilings, beams, columns, and concrete ladder areas are all susceptible to spalling. Corrosion of steel reinforcement is a major source of damage to aged concrete structures in general.

Water Ponding

According to Che-Ani *et al.* (2015), flat roofs and water ponding are prevalent issues. It may cause major issues for structures, particularly wetness, which can damage the structure and serve as a breeding ground for pests, plants, algae, and fungi. Furthermore, water ponding can put an undue strain on a building's structure, resulting in the roof collapsing. As a result, using a reliable monitoring mechanism to avoid any water ponding on flat roof surfaces is critical. This implies that the detrimental influence of moisture on the building was realised a long time ago. Thus, it is obvious that moisture is the major cause of construction faults, and water ponding is the major cause of moisture issues. Therefore, it is necessary to make sure that the flat roof area is clear of water ponding issues by conducting roof inspections thoroughly and periodically to identify any problems that may occur.

Defect Prevention Solution

According to Isa *et al.* (2016), several initiatives can minimise defects in a construction project. Hasan *et al*. (2016) describe 3 potential steps for mitigating poor workmanship, which are strict supervision, proper construction management, and manpower management.

Strict Supervision

One of the criteria for construction activity is to boost productivity by strict onsite supervision. Contractors or subcontractors can be supervised daily so that any workmanship issues can be detected and remedial work can begin immediately. Furthermore, supervisory staff must have the skills, experience, and capabilities to effectively control the building work and supervise the workers (Hasan *et al.*, 2016). According to Hong (2016), defects in the building can result in extra effort being expended to correct all of them. However, defects can be minimised by strict supervision of the work.

Proper Construction and Manpower Management

Construction performance will be improved with proper management. Construction labour performance is influenced by the ability of managers to plan, organise, and lead the project. Quality issues can occur if a construction manager fails to direct and control the construction project, underscoring the importance of proper construction management (Hasan *et al.,* 2016).

Manpower management in terms of the quantity and efficiency of skilled labour is a critical determinant of contractor success, and employers place a high value on it. A well-planned manpower scheme in a building project would result in a project of high quality. Furthermore, manpower is a valuable resource that can influence building efficiency. As a result, workforce control in any building project should be carefully planned (Hasan *et al.*, 2016). Other than that, the employer also needs to provide training and education to employees. Proper building design and communication with all parties are also necessary.

Building Maintenance

Maintenance is described as any action to maintain an item that requires functionality (Chua *et al.,* 2018). It is the combination of all technological and administrative acts, including monitoring and keeping or recovering an object in a state where it can perform. Maintenance is vital to prevent the building from deteriorating, thus making it less effective and functional. Awol *et al.* (2016) added that maintenance is one of the processes to ensure that building conditions are at optimum function. Maintenance can be categorised as planned and unplanned. Planned maintenance is organised with a proper schedule throughout a time frame, and is also documented and monitored. A proactive approach to scheduled maintenance involves routinely scheduling tasks rather than waiting for disruption or complications to occur. The maintenance schedule is developed based on past results and lessons learned from similar facilities. While unplanned maintenance is more ad-hoc and is reactive and corrective. It is a form of maintenance that does not follow a schedule. Any kind of maintenance activity that has no fixed schedule in all areas is classified as unplanned maintenance. Unplanned maintenance assists in the repair of current faults. It includes all unplanned actions that occur as a result of a product or system failure (Hong, 2016).

Methodology

Site inspection and semi-structured interviews were used in the data collection. Five public institution buildings in Klang Valley that were built more than ten years ago were subjected to a site inspection. All buildings were randomly selected and permission was granted to inspect them for the research. During the site inspect, the researcher logged all the defects. Findings from the site inspection were used to formulate the questions for the semi-structured interview. Convenience sampling was used to select the respondents for the interviews. Five respondents were chosen from each of the five public institution buildings, for a total of 25 respondents. Having respondents from different public institution buildings allows them to provide diverse perspectives. All respondents that agreed to be interviewed requested to remain anonymous, thus no name and organisation are mentioned in the paper. The researcher assures all respondents that all data collected would be kept confidential even though the findings would be published. This assurance is crucial so that all respondents are transparent and willing to express their opinions and comments. All respondents have vast experience in building defects and are very familiar with public institution buildings. Each interview session lasted 45 to 60 minutes, and the entire data collection using the semi-structured interview was completed in 3 months. Due to the pandemic, all the interview sessions were done online using Google Meet. The entire interaction was recorded to assist the researcher in accessing and analysing the data collected. The semi-structured interview questions were broken down into 4 sections. Each section was designed with a specific objective and was thoroughly examined. The sections are as follows:

- **Section 1:** This is the ice-breaking session, where the researcher summarises the research context for the respondents to understand its objectives. The researcher also stated that all data gathered would be kept confidential.
- **Section 2:** In this section, the researcher recorded the respondent's demographics, which include their designation in the organisation and years of experience working with building defects.
- **Section 3:** This section focuses on the identification and causes of the defects. The researchers showed the respondents photographs from the site inspection and asked them to comment on the types and causes of the defects.
- **Section 4:** The final section focuses on suggesting solutions to the defects, which include mitigation steps that might reduce the likelihood of defects.

Content analysis was done following the recommendations provided by Mohd Fateh *et al.* (2020). All the findings were grouped into a theme to give better clarity and understanding of the data.

Results and Discussions

Respondents' Demographic Profile

The researcher collected the respondents' demographics, which included their designation and years of experience with building defects. This is to ensure the data is relevant to the research. Based on the findings, all respondents have vast working experience with building defects, thus making the data convincing and reliable for the research. Table 2 presents the position of the respondents, while Table 3 summarises the years of experience with building defects.

Table 2: Designation of the respondents

Designation of the Respondents	No. of Respondents	Percentage Distributions
Technician	10	40%
Engineer	6	24%
Facilities Manager	6	24%
Senior Lecturer	3	12%
Total	**25**	**100%**

Table 3: Summary of respondents' years of experience with building defects

Years of Experience with Building Defects	No. of Respondents	Percentage Distributions
1 to 5 years	3	12%
6 years to 10 years	8	32%
11 years and above	14	56%
Total	**25**	**100%**

Hairline Crack

The majority of respondents agree that hairline cracks need only minor repair work. It may occur in the wall or floor, but cracks along beams and columns are serious. Some respondents say that the cracks can extend if not monitored closely. Therefore, it is a bad idea if the maintenance team did not take any further action and just left it unattended for a long period. Moreover, some respondents also stated that it can be hazardous to building occupants if, for example, snakes or other poisonous species inhabit the void. Table 4 presents the summary of the comments from the respondents for 'hairline cracks,' which can be grouped into 2 themes: Cosmetic cracks and close supervision. Table 5 summarises the causes of hairline cracks. Three themes were found from the findings: Soil settlement, poor workmanship and building design. Lastly, Table 6 listed the suggested solutions for 'hairline cracks.' The suggested solutions can be grouped into 3: Strict and close supervision, early maintenance work, and soil investigation.

The findings are supported by Yee and Zainal (2021), and Chitte (2018) stating that hairline cracks are the most prevalent issue in any form of construction. Hairline cracks can be caused by a variety of factors, such as moisture movement, heat movement, foundation movement, soil settlement, cracking caused by vegetation, elastic deformation, creep movement and chemical reactions. Apart from solutions suggested by the respondents More and Hirlekar (2008) also suggested using additional materials for the crack-curing process, including epoxy injection, routing and sealing, stitching, drilling

Table 4: Summary of comments from the respondents for 'Hairline Cracks'

Themes	Comments
Cosmetic cracks	Can be identified as cosmetic cracks on a wall surface and the other is a crack due to settlement at the apron. This type of defect is categorized as a non-structural defect as the cracking does not connect with the structural system.
	It is a cosmetic crack. These types of cracks can be identified by observing the width of the crack. From then, we can estimate the size of the crack using the acquired measurements.
	It is considered a minor crack on a surface. All cracks are categorised as non-structural.
	The defect is categorized as a non-structural defect since does not involve a beam, column or slab element. Nevertheless, it can create another defect when moisture starts seeping into the crack.
Close supervision	It needs to be measured using a crack depth measurement system. If the width of the crack is less than 10mm, no further action is needed as it will not affect the building structure. However, it is still advisable to go through a monitoring session as a precaution. There are several types of cracks that can happen at structural elements such as shear cracks or bending cracks.
	If the defect occurred near the column and beam it can be a serious defect. Nevertheless, it is a good practice to monitor the crack to ensure it does not expand further.

Table 5: Summary of the causes of the 'Hairline Cracks' from the respondents

Themes	Causes
Soil settlements	The soil around the buildings may have been previously a soft soil area.
	The soil composition of the site can contribute to the formation of the defect.
	The surrounding development also plays a significant role, especially if piling had been done.
	The cause of the defect is the environment, such as soil settlement. The apron element should attach to the ground beam to prevent the defect from happening.
Poor workmanship	The cause of the defect is triggered by poor workmanship, where they might have used the wrong method during the concreting process.
	The type of cement used must be chosen correctly so that it is suitable for the range of the projects.
	The main cause of the defect is because of poor workmanship during concreting work or compaction work.
	Using the wrong ratio of cement mixture or not following the standard can be one of the causes. This will produce a low quality of concrete and materials which affect the construction.
	The overuse of lime in plastering work can lead to a crack.
	The causes of the defect are poor design, for example, there is no reinforcement at the apron to link with the ground beam.
	The cause of the defect is poor workmanship for example workers did not follow Public Works Department standards during concreting work.
Building design	Poor design also can contribute to these defects where the building design might be overloaded and cause cracks.
	Weak in design. The reinforcement in the apron should be attached or linked to the ground beam.

and plugging, gravity filling, and overlay and surface treatments. Thagunna (2014) proposed that many remedial and preventive actions can be implemented to fix hairline cracks, including the use of fine aggregates, coarse aggregates, stitching, dry packing, epoxy injection, plugging and drilling, sealing, and routing, sealing cracks with gravity filling and polymer impregnation.

Water Ponding on Flat Roof

Respondents said that if water ponding on the flat roof is not repaired, it can become a serious problem and create another defect. Since the defect happens on the slab, it requires extensive repairs. Water ponding happens because there is no gradient on a flat roof and can also cause mould growth. Although water ponding is categorised as a non-structural defect, it can be serious if left unattended. A flat roof is not designed to retain water for a long time and serious damage can result from prolonged ponding, especially if there are cracks on the roof. The drainage and discharge outlets also need to be looked into as they are the only channel for the water to flow out.

Water can seep through the slab and cause other defects, such as spalling concrete and corrosion of any steel element in the building. Table 7 presents the summary of the comments from the respondents for 'Water Ponding on Flat Roof,' which can be grouped under 2 themes: Leading to other defects and mould/mosquito breeding. Table 8 summarises the causes of 'Water Ponding on Flat Roof'. Three themes were formed from the findings: Poor maintenance, discharge outlet, and lack of

Table 6: Summary of the suggested solution from the respondents for 'Hairline Cracks'

Themes	Suggested Solution
Strict and close supervision	Strict supervision during construction will ensure that all materials follow specifications.
	Strict supervision during construction might help. This is to ensure that all compaction and concreting work is on par with the standard procedure of construction.
	Strict supervision and proper management. This implies making sure all workers should have adequate knowledge and skills in construction.
	Frequent monitoring is important to identify whether the crack is active or non-active.
	Strict supervision during reinforcement work is important to ensure that workers do not cut corners.
	Strict supervision during construction by the consultant to ensure that the quality of work is archived. Supervision from the consultant should start from the preliminary stage of construction until the handover. Consultants need to verify and check every work that has been done by the contractor.
	Strict supervision during construction such as during infrastructure work needs to follow JKR.
	Proper manpower management using skilled workers during construction.
	The precaution that can be done is proper design such as the apron reinforcement should be attached to the ground beam.
	An early measure that can be taken is ensuring proper construction management. This implies the need to ensure the best weather during concreting work.
Early maintenance works	Precautions that can be taken includes plastering cracks because of shear and shrinkage. It is good to rectify the crack while it is still small to avoid it becoming worse.
	Performing early planned maintenance might minimize cracks at an early stage.
	Repair the cracks, such as by rendering and strengthening. Early maintenance can prevent cracks from getting bigger.
	After 10 years, this type of crack is inevitable and the only way to fix it is by planning regular maintenance and patching or repairing the crack.
Soil investigation	Taking random soil samples for testing. The outcome of the test will determine whether the soil in the area is active.
	A soil investigation might determine an appropriate solution.

gradient. Finally, Table 9 listed the summary of the suggested solutions from the respondents for 'Water Ponding on Flat Roof'. The suggested solution can be grouped into four groups: Scheduled/regular maintenance, the emphasis on the gradient, discharge outlet, and source of water.

Talib and Sulieman (2022) highlighted that a flat concrete roof often suffers leakage problems. The findings are comparable to those of Zaid *et al.* (2022), which highlighted that flat roof maintenance in Malaysia is comparatively sparse. Nevertheless, Jones (2021) conveyed that maintaining a roof is always paramount. Most roofs can be properly maintained by focusing on roof repair within 15 years, and the cost is much lower than replacement. Roof replacement or installation of a permanent solution should be considered when all repair options have been exhausted, or when repairs become too difficult or expensive. The findings demonstrate that the present flat roof maintenance features used in the case studies are insufficient for Malaysia's tropical environment. Zaid *et al.* (2022) also suggested that attention needs to be given to the flat roof, especially to the rainwater collecting system, pest control, accessibility, and irrigation cleaning.

Sink Defect

The defect known as detaching is when there is a gap between the elements at the sink pipe. According to (Talib & Sulieman, 2020), detachment is also known as the separation of each element, and needs to be repaired as soon as possible. Respondents agreed that these defects only need minor repair work and do not disturb any structural elements. Repair and replacement work need to be done because if not, the sink will not work properly and the area will be a mess with excess water. Few respondents highlighted the safety factor of the defects, where users can slip and fall due to excess water. One respondent stated that it must be a leaking pipe since there is a water leak at the sink pipe. The defect is only a cosmetic or accessory defect and is classified as a non-structural defect. The defect did not affect the building structure. Table 10 presents the summary of the comments from the respondents for 'defect at the sink,' which can be grouped under two themes: Broken element (bottle trap) and minor/wear and tear. Next, Table 11 summarises the causes of the defect at the sink. Two themes emerged from the findings: Wear and tear material and irresponsible users. Finally,

Table 7: Summary of the comments from the respondents for 'Water Ponding on Flat Roof'

Themes	Comments
Lead to other defects	Water ponding is categorized under non-structural defects. Nevertheless, it is still a problem because it can directly affect the durability of the slab especially if the slab doesn't have waterproofing. When this happens, it can snowball into bigger defects.
	The defect can affect the structure of the building especially if there are any cracks in the slab or wall. Water can seep into the cracks and affects other materials such as corroding the steel, short circuit electrical components (corrosion) or reducing the durability of the concrete.
	It needs to be considered as a serious defect because it can initiate other defects.
Mould and mosquito breeding	The moisture is a good environment for the mould to grow. Not only that, it can be a good mosquito breed ground if the water is untouched for a few days.

Table 8: Summary of the Causes of the 'Water Ponding on Flat Roof' from the respondents

Themes	Causes
Poor maintenance	Due to the blockage at the discharge outlet and roof level. The defect can worsen if there is no maintenance.
	A clogged drain that does not allow excess water to flow and causes it to pond.
	Poor maintenance where vegetation starts to grow all over the discharge outlet.
	No regular maintenance, which makes the gradient and drainage system ineffective.
Discharge outlet	Improper discharge outlet which includes the location, sizes and shapes.
	The number and location of discharge outlets on the roof are not strategic enough to clear the water effectively.
Lack of Gradient	The cause of the defect is poor workmanship during construction because there is no gradient to ensure the water drains.
	In some cases, the drawing already stated that a gradient is required but labourers fail to build the correct angle for the gradient.

Table 9: Summary of the suggested solution from the respondents for 'Water Ponding on Flat Roof'

Themes	Suggested Solution
Schedule/Regular Maintenance	Scheduled maintenance is the key. The water needs to be clean, and checks need to be carried out to ensure the drain functions.
	Monthly maintenance to ensure there is no water ponding on the flat roof. Any ponding needs to be cleared to prevent mould growth.
	The drainage pipe in the surrounding area also needs to maintain to ensure there is no overflow of water on the flat roof.
	Regular cleaning of the flat roof is necessary. This includes cleaning all the mould, vegetation or any clogs in the drainage and outlet points.
The emphasis on the Gradient	Strict supervision during construction to ensure that the installation of waterproofing is correct and construction of the gradient follows the specification and design.
	Engage skilled workers to ensure the gradient is constructed as per specification and drawing.
	The gradient needs to be checked/tested regularly to ensure that the 'gradient' is still there.
	Reconstruct the gradient, but this option is expensive and is considered a major refurbishment.
Discharge Outlet	The drainage system needs to be maintained to prevent any clogs to the drainage system.
	Relook the discharge point. It may need some refurbishment work, such as adding the number of outlets or redesigning the location for better water discharge.
Source of Water	Check whether there is another source of water besides the rain. This is because sometimes the excess water comes from multiple sources, such as leaks in the water tank.

Table 10: Summary of the comments from the respondents for 'Defect at the Sink'

Themes	Comments
Broken element (Bottle Trap)	It is a broken element. The linkage from the sink to the discharge outlet is disconnected therefore making the sink defective.
	It is either broken or missing. This can be seen clearly as the connector between the two elements is already broken and water is gushing through it as the sink is being used.
	The bottle trap is broken or detached. Water flows gushes out from the bottom of the sink when it is used.
Minor/Wear-tear defect	It is only a minor defect. The accessories (trap bottle) are worn out and need replacement.
	It is a wear and tear defect. A simple replacement will sort it out.

Table 12 lists the summary of the suggested solutions from the respondents for the 'Defect at the Sink.' The suggested solution can be grouped into two groups: Planned maintenance and heavy-duty material.

Buxton *et al.* (2019) reported that the indicators of the Sustainable Development Goals (SDGs) include access to usable water, sanitation, and hygiene in institutional buildings. The development of an understanding of which intervention components are most effective

Table 11: Summary of the causes of the 'Defect at the Sink' from the respondents

Themes	Causes
Wear and tear material	The cause of the defect is due to the lack of maintenance and the usage of low-quality materials.
	The cause of the defect is poor materials, such as the use of steel screws that rust. The rusty screw causes broken elements at the sink.
	The cause of the defect is poor materials. Low-quality materials usually do not last long and break quite easily. Therefore, it is better to choose other materials of higher quality so they can be used in the long-term.
	The cause of the defect is poor materials since it has its lifespan, especially under mechanical defect categories.
	The cause of the defect is poor material such as the screw getting rusty and the rubber worn out.
	The material such as the rubber is already worn out and the screw is already rusted.
Irresponsible actions	The root of this issue might be caused by people's inconsiderate actions. Irresponsible actions such as throwing rubbish in the sink could be the primary cause of the defect. The rubbish will end up forming a clump that will clog the sink. As a result, the sink cannot withstand the pressure and the element breaks.

Table 12: Summary of the suggested solution from the respondents for 'Defect at the Sink'

Themes	Suggested Solution
Planned maintenance	The defect can be solved with planned maintenance. Changing the broken part should do the trick.
	Perform planned maintenance to ensure the leak does not last long and affects other elements, such as the floor trap and change the broken element.
	Scheduled maintenance means changing the element every time it is broken depending on the situation. Other than that, change the broken element with the new one.
	Proper maintenance needs to be done to avoid additional defects. As an example, the water leaking from the sink will make the floor slippery if left unattended. People might slip and fall because the surface was slippery.
	The element needs to be inspected at least once in three months. It needs to be on the checklist by the cleaner or the maintenance team. This is to ensure that the sink can function as it is.
	Regularly clean the sink and ensure there is no water leakage. Then only repair the broken parts.
	The defect is emergency maintenance. Immediate action should be taken as soon as a report has been made on the issue such as repairing the defect. It may be able to reduce the damage to another part of the sink
Heavy duty material	Since it is in an institution building, use a heavy-duty material. The sinks are being used regularly by students and staff.

in operating and maintaining usable services is required for progress toward these metrics. Buxton *et al.* (2019) added that inadequate or badly maintained facilities may deter toilet use and/or handwashing among the public. Building managers are in charge of planning resource allocations with assistance from the maintenance department. This is to ensure that cleaning checklists are completed as proof that regular cleaning is taking place. Once a month, a member of the team should provide advice if any difficulties are discovered (Buxton *et al.,* 2019). Weinbren and Inkster (2021) echoed this by highlighting that sinks, whether in a toilet or centralised locations, should be cleaned and maintained regularly per the manufacturer's instructions. The maintenance team should look at these facilities in their routine inspection.

Time Frame for the Defect to Occur in a Building

The majority of the respondents agree that there is no specific year that a defect can appear. Building defects can even appear during construction. The defect can appear because of a lack of supervision and workers who did not follow specifications during construction, such as improper installation of formwork or improper concrete cover. Usually, a building will be tested before handover to the client to prevent any defects from happening or becoming worse. Some respondents highlight that a defect may take time, about 5 to 10 year, before it appears. A respondent also added that structural defects may appear as early as 2 years because of overload. Usually, a building will be designed for 50 years, but defects will still happen for any reason. Table 13 presents the summary of the comments from the respondents for "When the Defect Will Appear," which can be grouped into 3 themes: No exact time frame, after 5 years, and after 2 years.

Table 13: Summary of the comments from the respondents for 'When the Defect Will Appear'

Themes	Comments
No exact time frame	There is no exact year or time frame that defects will appear. Nevertheless, if during the construction stage, the work is not being done properly, the defect might appear right after the Defect Liability Period (DLP) ends.
	No specific year for the defect to appear. To ensure that the work lasts as long as possible, make sure during the construction there is strict supervision.
	If the work does not follow the specification, the defect will appear very fast. For example, honeycomb in concrete works, or major cracks in the structure.
	There is no specific time when the defect can appear. This depends on the construction method and their workmanship. The defect can appear during the Defect Liability Period (DLP) and construction. If the building is constructed following all the specifications and procedures, a defect might appear after a long time.
	There is no specific time defect that can appear. The building will usually be undergoing testing before handover to prevent any defects. The building can suffer defects during construction and (checks) can prevent them before becoming worse.
	The is no specific year for the defect to happen. Usually, a building will be designed for 50 years to be stable but not for the defect to happen. Defects can happen because of any reason.
After 5 years	Usually, a critical defect will appear after more than 5 years. A non-critical defect may appear during the DLP period.
	A structure defect can appear after 5 to 10 years, depending on the materials. For the mechanical and architecture, the defect can appear during construction and depends on the supplier or distributor.
	For structure defects, it can be 10 years and it also can be less than 10 years if the renovation did not follow specifications.
After 2 years	Defects can appear before, during and after construction. If the defect is related to overload, it might be seen after 2 years. The type of defect that occurs depends on quality, workmanship, and user.

The findings are comparable with the past studies stating that it takes 5 to 10 years for a defect to manifest. These defects necessitate high maintenance costs, causing low satisfaction, increasing risk to the buildings, and so forth (Tetteh & Mensah, 2016; Yee & Zainal, 2021). This was echoed by Jones (2021), who highlighted that a building will typically endure between 12 and 15 years (with good upkeep), after which defects may begin to manifest. Talib and Sulieman (2022) stated that the majority of defects are identified long after a project has been completed. However, a significant number of problems occurred primarily during the post-completion phase, beginning with the tenant's move-in. Talib and Sulieman (2022) also added that there may also be some building defects that have been detected and need to be addressed from the drawing board or during the design phase. As a result, the designers' and clients' roles are important in resolving defects that happened at any stage.

Conclusion

In conclusion, even though DLP is a compulsory item in a construction project, defects will occur after the period ends. All stakeholders, including the client, must be aware of this matter. The results of the study indicate that the identified defects in the public institutional building include hairline cracks, water ponding on the flat roof, and defects at sinks. The study proposes three solutions for each defect, which involve well-planned maintenance, attention to gradients, and focus on discharge outlets. These findings provide valuable insights for building managers and maintenance personnel to address and prevent such defects from occurring, thereby ensuring the safety and functionality of the building for its intended purposes.

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