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Evaluation of Cracks in Affordable Housings in Selangor: A Fundamental Approach

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ABSTRACT

Selangor, a densely populated state and economic hub of Malaysia, faces escalating demand for housing due to rapid urbanization and industrialization. This influx has led to a surge in affordable housing developments aimed at mitigating housing shortages and alleviating homelessness. However, many of these buildings suffer from structural defects such as cracks, which compromise their safety and longevity. This study focuses on investigating the prevalence, causes and impacts of cracks in affordable housing buildings in Selangor. Through case studies and expert interviews with a property manager, building surveyor and civil engineer, the research identified soil movement, vibrations, weather conditions and moisture changes as primary factors contributing to structural cracks. It revealed that 86 documented cracks across three buildings predominantly stem from soil movement (59 %) and underscores the urgency of proactive maintenance and non-destructive testing (NDT) to detect and address defects early. The findings highlight the necessity for tailored preventive measures and regular inspections to enhance the structural integrity and durability of affordable housing in Selangor, thereby ensuring safer living conditions for residents.

1. Introduction

Selangor is a state that have high population because it is the economic centre which many of factories have been built. When the factory has been built, job opportunities increased, and it made many people to migrate to Selangor for work. Because of the increased population in Selangor, the request for accommodation rose and it made the house price to become expensive. Due to the increased in house price, many residents of Selangor do not have their own house. They choose to rent apartments or landed houses in that state instead of purchasing. Because of this issue, the government provided incentives to developers to build affordable housing to help residents to purchase their own houses with affordable price. In 2025, the incentive for affordable housing will be increased with a target of 60,000 total units to be added [1]. In Malaysia, there are many housing buildings been built because the population of this country is growing rapidly which led to the request of housing development to also increase. However, eventhough many housing buildings have been

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built, some of the buildings did not use a suitable material and it made some of the buildings being defected with minor to major faults [2]. The defects that normally occur in housing buildings are pipe leakage, cracks, ceilings collapse and others. These type of defects needed to be taken into serious attention to protect the building from any harm. For housing buildings, not only the building needs to be given attention, the environment of the building also needs to be taken into account to make sure the building is safe [3]. Building safety is very important in many aspects. Because of the defects that occur in the building such as cracks, damages and leakage, it is very important to identify the factors that might cause building defects. After the factors have been identified, it can reduce the impact on the building and the lifespan of the building will be increased [4].

Based on observations, there are much research about structural integrity and building defects that happen on residential building but the research about the basic approach for resident to identify the defects that occur on the building is still minor. The lack of knowledge about these cracks make the user ignore the defects until the defects become severe because of late maintenance. This study was aimed to fill the gaps from each research about cracks on affordable housing buildings. The location of this study was focused in Selangor because this state is one of the states that have high population. Based on the data from Building Commissioner and PBT 2021, Selangor recorded as having high statistics of maintenance and damage complaints in Peninsular Malaysia which was 1257 of complaints, equivalent to 30.85 % complaints from the total of complaints been recorded in that year. The local authorities have come out with the resolution in total 935 complaint. In view of that, this study aimed to address this gap in knowledge by conducting a fundamental assessment of crack and structural integrity in affordable housing buildings in Selangor. The study investigated the prevalence and causes of cracks in these buildings, as well as the impact of cracks on structural integrity. This study also developed recommendations for preventing and repairing cracks in affordable housing buildings.

2. Literature Review

2.1 Prevalence of Cracks in Affordable Housing

One of the states with a large population is Selangor, which led to a rise in the building of reasonably priced homes to enable residents to live comfortably and lower the state's homeless rate. Due to vibrations during construction, most inexpensive buildings older than five years may have small cracks in them [5].

(a) Structural crack.

Structural cracks are formed due to incorrect structural and faulty construction which can threaten the safety of a house. Examples of structural cracks are the cracks in beam, column, slabs and footings [5].

(b) Flexural crack.

Flexure implies twisting, cracks in strengthened concrete beams subjected to the most part beginning in the strain zone i.e. delicate of the beam [6]. The width of flexural cracks in reinforced concrete beams may remain narrow from the surface to the steel in the short term.

(c) Torsional crack.

Usually beams are subjected to torsion along with bending moment and shear force [7].

(d) Tension crack.

Tension cracks are usually caused by shrinkage or temperature changes. Tension cracks usually occur in those members where restraint is provided in the longitudinal movements [7].

(e) Shrinkage crack.

Shrinkage cracks are commonly caused by a change in the moisture of concrete. This type of horizontal cracks are due to evaporation of moisture from the concrete surface when ambient air is created.

(f) Splitting.

Splitting cracks are formed in concrete columns because of inadequate reinforcement steel and/or inferior concrete quality [8]. Otherwise, these types of cracks appeared probably due to reaching the maximum load-carrying capacity.

(g) Diagonal crack.

Diagonal cracks usually starts from the tension surface of the concrete member. Cracks develop in concrete columns due to adequate cross-section and insufficient reinforcement steel [8].

(h) Horizontal crack.

Horizontal cracks are formed in the reinforced concrete column at the junction of beams and columns due to shear forces [8]. The horizontal cracks are commonly found high in the wall which are probably caused by frost damage.

(i) Non-structural crack.

Non-structural cracks are the result of induced stresses in building constituents and due to internal forces developed because of variance in moisture content, crazing, temperature change and others. Cracks on the parapet wall, wall and the driveway is called non-structural cracks.

2.2 Causes of Cracks in Affordable Housing Buildings

In 2012, Abdul-Rahman *et al.,* (2014) [9] discussed about defects that occur on affordable housing, so that solutions may be devised to raise the quality of housing stock in Malaysia. Most researchers agree that the major defects are caused by cracks and leaking.

(a) Moisture changing.

Building materials' molecular spaces may fluctuate because of the process of alternating contraction during dry conditions and expansion during wet conditions. This movement cycle modifies the material's stress and causes fissures [10].

(b) Growth of vegetation.

Based on Fatt, (2023) [11], vegetation such as trees can cause cracks in buildings through their expansion root systems and effects on soil moisture. Roots growing under foundations can exert pressure that causes cracks wide at the base and narrowing upward. Seeds from bird droppings can take root in cracks and further damage walls over time. When located near shrinkable clay soil, tree roots can dehydrate the soil to cause settlement and foundation cracks or upward pressure when trees are removed and soil swells with moisture [11].

(c) Incorrect design.

Design and specifications for the building that are incorrect can be the main factor of malfunction of building. When do the on-site process, type of soil is to be taken into account for the building design. As for the house building, it needs a different specification for design [12].

(d) Climate changes.

Wet seasons cause reactive soils to become saturated quickly. When reactive soils become wetter, they lift. Dry seasons cause reactive soils to dry out. When they become dry, they drop [10]. The resulting in sudden volume changes and movement in the soil can shift a building's foundation [5]. Exposed soil dries faster than the covered soil under the foundation. Exposed soil as well as nearby trees may draw moisture from the transition zones which can cause a differential settlement. An uneven movement of the building can cause cracking due to an immense strain on the structure, specially building elements i.e. concrete and bricks which have limited tensile strength [12].

2.3 Impact of Cracks on Structural Integrity

(a) Reduced load-bearing capacity.

Cracks and cavities belong to two basic forms of damage to the concrete structure, which may reduce the loadbearing capacity and tightness of the structure and lead to failures and catastrophes in construction structures [13]. One of the most prevalent faults in concrete constructions is cracking, which if left unchecked, can greatly diminish the longevity of the building. For the past few years, scientists have worked to understand the complex mechanics behind concrete cracking [13].

(b) Compromised longevity.

Cracks in the structure detract from its appearance and in severe situations, may make occupants uncomfortable [14]. Defects and damage that arose in the structure of first young and then mature concrete play a major role in determining the strength and longevity of concrete structural parts [14].

(c) Financial burden to resident.

Residents may face increased expenses related to fixing structural issues, including hiring professionals, purchasing materials and covering temporary accommodation costs during repair periods [15]. The financial constrain is particularly challenging for individuals and families already grappling with limited financial resources, which is common in affordable housing communities [15].

2.4 Prevention and Repair of Cracks

Affordable housing in Selangor faces challenges related to structural integrity, particularly with the occurrences of cracks. This literature review identifies key prevention strategies essential for ensuring the longevity and stability of such housing units. Environmental factors, particularly Selangor's tropical climate, necessitate the use of materials resistant to high temperatures and humidity. Slip planes can be a preventive method because these enable elements of the construction to slide in relation to each other to help reduce stress in the adjacent materials. By carefully considering the design and positioning of movement joints and slip planes, this will ensure they don't affect the stability of the wall or any of its functions [16,17]. Addressing cracks in affordable housing structures in Selangor necessitates comprehensive repair strategies to ensure the longevity and structural integrity of these dwellings [18]. Timely identification of cracks is paramount, requiring routine inspections by trained professionals who can discern subtle signs of structural distress.

Professional assessment becomes a cornerstone, offering an in-depth understanding of the underlying causes of cracks, whether due to settling, material fatigue or other factors [9].

3. Methodology

3.1 Sampling Techniques

Table 1
Sampling techniques

Research question	Research objective	Research method	Research strategies/method
How do the types and sizes of cracks vary among different affordable housing structures in Selangor?	To assess the prevalence of cracks in affordable housing buildings in Selangor.	Case Studies	Observation
What are the primary factors contributing to the development of cracks in affordable housing buildings in Selangor?	To identify the causes of cracks in affordable housing buildings in Selangor	Case Studies and Interview	Observation and analysis
How to overcome the causes to prevent the development of crack in affordable housing Selangor?	To recommend the best solution for the damages that occur on building.	Interview	Analysis

3.2 Case Studies

This study was to comprehensively examined and address structural challenges in affordable housing buildings in Selangor by assessing the prevalence and causes of cracks and proposing effective strategies for prevention and repair. The selected buildings for the study have met the criteria that were suitable which is the building must be an affordable housing building, building is located in Selangor and is a multi-storey building. This criterion was to ensure this study achieved the objective. The observation on this building took one week to observe wether the cracks that occur on the buildings display a different length or width.

Based on the observation in this case study, all Figures 1 - 4 show that this building does not have any structural defects but still need a serious attention. Based on Figure 2, this floor settlement occurs on each building. This settlement might cause the cracks that occur at the wall and the floor i.e. Figure 3 and 4.

Fig. 1. Crack on balcony wall

Fig. 2. Floor settlement

Fig. 3. Crack on the floor

Fig. 4. Crack on the wall

3.3 Interview

For the interview session, we have interviewed three different persons that are expert about cracks that normally occur in buildings. These experts were from three different backgrounds which were property manager, building surveyor and civil engineer. This comprehensive approach was to define the main cause of cracks that occur in the building and get the advice about preventive measures on these cracks.

4. Results and Discussion

4.1 Building Condition Assessment

For this study, collecting data at affordable housing was with limitations. The limitation of this study was that the research could only access the exterior of the building and get the report from the residents regarding the situation. This study focusses on one case study with three different buildings to get the different condition to do comparison and understanding the issues. Overall findings were categorized and based by the blocks of the building. Table 2 show the example of defect analysis using BARIS assessment.

Table 2
Defect analysis using BARIS assessment

Defect sheet: 1	Level	2nd Floor		
Photo:	Location	Blok A		
	Element	Wall		
	BARIS			
	Condition	Priority	Matrix	Colour
	3	3	9	
	Defect Description			
	Fine crack line (1 < mm width)			
	Possible Cause			
	Vibration			
	Remedies			
	Reapply plaster coating			

In overall, there were 86 cracks that occurred in the three inspected buildings. As for the observation, these building does not have major structural cracks. Most of the ground floor level houses were in Fair Condition (Yellow Color). This result shows that the building is not in serious condition but need attention from the professionals. Based on Table 3, block B has the highest number for total of cracks and mostly from the ground floor level.

Table 3
Total of cracks

Type of block	Total of cracks
Block A	29
Block B	42
Block C	15
Total	86

Table 4 shows the number of flaws corresponding to the possible causes. The study indicated that the soil movement, vibration and weather condition were the main possible causes responsible for the 86 documented cracks.

Table 4
Number of flaws with their possible causes

Possible causes	Total of cracks	Percentage (%)
Soil Movement	51	59
Vibration	12	14
Weather Condition	18	21
Moisture Changing	5	7
Total	86	100

As shown in this table, majority of cracks was caused by soil movement because during visual inspection, researchers found all the building that have same issues at the ground level which is settlement. The cracks associated with soil movement was 59 %, weather condition 21 %, vibration 14 % and moisture changing 7 %.

4.1.1 Causes of cracks that occur on the affordable housing building

Based on the interview session with these professionals with different backgrounds, all of them have different opinions of each crack that occurred in the building.

(a) Property manager

i. Environmental exposure

Buildings' ground floors were especially vulnerable to external factors that might make it more difficult for building components to move around, which can eventually result in gaps between them. This process was greatly influenced by elements i.e. humidity, sunshine and precipitation moisture. For example, rain can seep into building materials allowing the components to absorb moisture and swell. Wood and other materials may expand and contract because of repeated cycles of soaking and drying that erode their structural integrity over time. Particularly at weak places like joints and material interfaces, this expansion and contraction may put strain on the structure's framework and cause cracks and separation gaps. Direct sunlight can also facilitate thermal movements in construction materials. Materials that can heat up and expand are masonry and concrete when exposed to strong sunshine. On the other hand, these materials contract and cool down at night or during colder weather. Particularly in areas where materials are constrained or linked, i.e. the ground floor intersection of the building and foundation, these temperature swings may cause stresses in the structure. These heat cycles have the potential to erode joints and connections over time, which can cause separation gaps to appear as the materials move in relation to one another.

ii. Age of the building

Concrete ages and experiences wear and tear. This can include drying-related shrinkage, abrasion of the concrete's surface and a slow deterioration of its strength. These elements have the potential to cause cracks over time, particularly in locations that are frequently used or exposed to the elements. Since it was constructed in 2010, any flaws in the structure are expected, given its age. Because of mechanical abrasion and friction, concrete surfaces may gradually deteriorate throughout this time. This is especially typical in regions with considerable traffic or where large trucks or machines are driven. Concrete's surface layer erodes with time, exposing the underlying material to more environmental elements that could compromise its structural integrity and make it more susceptible to cracking. The concrete may start to show obvious fissures as a result of these accumulations. These fractures can develop on surfaces or along structural joints, and they might differ in size and direction. If ignored, they can jeopardise the structural integrity of the concrete by acting as indications of underlying tensions inside it. If cracks are not fixed right away, more moisture may seep in and cause degradation to speed up.

(b) Building surveyor

i. Environmental factor

Abrasion happens because of mechanical wear and tear on the concrete surface. Foot traffic, moving cars or abrasive items rubbing against the surface can all cause this. Repeated abrasion can erode the concrete's protective layer over time, leaving it more vulnerable to chemical and moisture intrusion. The location of this study was located near a main road which has many moving cars and heavy load vehicles using that access to go to other places. Moisture infiltration happens when water seeps through the concrete's pores or fissures. Even when concrete looks solid, it might nonetheless have pores that let water soak through. A process known as reinforcement corrosion may begin when moisture meets the steel reinforcement contained in the concrete. This occurs because oxygen and water work together to erode the steel's protective coating, leaving it vulnerable to corrosion. The expanding steel puts strain on the surrounding concrete as it corrodes. Over time, the building's structural integrity may be weakened by cracking and spalling brought on by this progress. The degradation caused by these environmental factors often manifests as visible signs on the concrete surface. These signs may include cracks, spalling, discoloration and surface roughness. Cracks can vary in size and orientation, depending on the extent of the environmental exposure and the condition of the concrete. Spalling, where concrete flakes or chips off, typically occurs in areas where reinforcement corrosion has caused significant internal pressure buildup.

ii. Soil condition

The soil beneath a building is fundamental to its stability. Poor soil conditions, such as expansive clay soils or soils with high organic content, pose significant challenges to structural integrity. Expansive clay soils, for example, have the tendency to swell when they absorb moisture and shrink as they dry out. This cycle of expansion and contraction exerts uneven pressure on the foundation of the building.

(c) Civil engineer

i. Foundation settlement

Foundation settlement is one of the main causes of separation gaps. Because various areas of a structure have varied soil conditions beneath them, foundations can settle unevenly over time. The ground floor slab may tilt or slightly sink because of this differential settlement, creating spaces between the floor slab and surrounding walls. Improper soil compaction during the excavation and backfilling phases can create voids or uneven density beneath the foundation, contributing to differential settlement. Additionally, inadequate drainage around the building can lead to fluctuations in soil moisture levels, exacerbating soil movement and settlement over time.

ii. Vegetation factors

Tree roots which may reach well beyond the canopy, search the soil for moisture and nourishment. These roots can put a lot of pressure on the earth in all direction up, down or sideways. The compacting or shifting of the soil due to this pressure may result in uneven settling of the building foundation. Changes in soil moisture content are one of the main ways that vegetation causes separation gaps. Soil shrinks because of the tree roots absorb the rainwater, which may cause differential settling near the foundation. On the other hand, the soil may get wet during times of intense irrigation or rainfall, which might cause swelling and possible disturbance near the foundation.

4.1.2 Preventive measure to prevent the spreading of cracks

(a) Non-destructive testing (NDT test)

Building separation gaps and cracks cannot always be apparent from the outside. Non-Destructive Testing (NDT) techniques, such infrared thermography, ground-penetrating radar (GPR) and ultrasonic testing (UT), can look beyond the surface to find hidden flaws in materials or buildings. With the use of these skills, engineers may determine the degree of degradation or damage that would not be seen through visual inspection alone. Proactive maintenance interventions are made possible by NDT's early identification of fractures and separation gaps. Property owners can reduce the chance of structural collapse and the expenses related to major future repairs or replacements by taking care of minor flaws before they get worse. NDT provides quantitative data on the condition of building materials and structural components. By evaluating the size, depth and distribution of cracks, the extent of separation gaps; engineers can assess the structural integrity and determine whether repairs or reinforcements are necessary to ensure the building's safety and longevity.

(b) Engage with professional engineer

Regular consultation with structural engineers is vital for maintaining building integrity. Engineers can conduct detailed assessments, recommend remedial actions and provide expert advice on complex issues. For major renovations or when significant structural changes are planned, engineers ensure that designs meet safety standards and are robust enough to handle additional loads. Engaging professionals ensures that preventive measures are effectively implemented and maintained. To mitigate separation gaps, civil engineers should prioritize thorough site investigations and soil testing before construction begins. Proper foundation design, including adequate reinforcement and detailing at joints, is critical. During construction, quality control measures should be strictly enforced to ensure proper compaction of soil and accurate placement of structural

elements. Ongoing monitoring and maintenance programs should also be implemented to promptly address any issues that may arise post-construction.

(c) Regular inspection

Based on building surveyor's perspective, it needs to do a regular inspection to prevent the cracks spread to wider area that will minimize the quality of the building. Building surveyors should conduct comprehensive inspections of the building at regular intervals, focusing on key structural elements such as foundations, walls, floors and ceilings. These inspections help identify early signs of deterioration, including minor cracks or gaps that could develop into more significant issues if left unaddressed. Implementing a condition monitoring system is crucial. This can include visual inspections, photographic documentation and the use of sensors to monitor structural movement. By tracking changes over time, surveyors can detect patterns and predict potential problem areas, enabling timely intervention. Surveyor also need to establish a preventive maintenance program to ensure that minor issues are addressed before they escalate. This program should include routine tasks such as cleaning surfaces, sealing minor cracks and repairing gaps. Regular maintenance not only preserves the aesthetic appeal of the building but also prevents structural weaknesses from developing.

5. Conclusions

This study addresses structural challenges in affordable housing buildings in Selangor by assessing the prevalence and causes of cracks and proposing strategies for prevention and repair. Observations and expert interviews revealed that soil movement, environmental conditions, vibration and moisture changes are primary causes, with soil movement being the most significant. Environmental exposure, building age, abrasion and foundation settlement were identified as key factors contributing to these structural issues. Preventive measures include non-destructive testing (NDT) for early detection, engaging professional engineers for regular assessments and conducting regular inspections and maintenance by building surveyors. These integrated approaches can significantly enhance the structural integrity and safety of affordable housing, ensuring a better living environment for residents.

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