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Case Study: Inter-floor Leakage in High-Rise Residential Buildings in Malaysia

(Kajian Kes: Kebocoran Antara Tingkat di Bangunan Kediaman Bertingkat Malaysia)

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ABSTRACT

Building defects are a common issue in the construction industry. Defects of high-rise buildings, such as cracks and leaks, are often caused by poor workmanship, and insufficient and low-quality building materials. Other contributing factors to building defects are inadequate cooperation during construction, poor design and improper installation. Inter-floor leakage is a widespread matter in new homes, leaks are detected late and repeated leaks occur even after repairs have been carried out. Inter-floor leakage often occurs in new homes. Leaks are detected late and repeated ones occur even after repairs are carried out. This study aims to diagnose buildings with inter-floor leakage problems by using several diagnostic tools and techniques like visual, destructive and non-destructive tests. Experts use testing equipment to determine moisture and appropriate maintenance or repair. A case study is carried out on a residential unit with a leak in the ceiling due to a crack on the rooftop. The findings of the study can provide knowledge about building diagnosis to property owners and property managers, identifying the cause of leaks and enabling early detection of building defects and suggested repairs to prevent similar leaks from occurring. By utilizing diagnostic tools and techniques, owners and property managers can detect problems early, minimizing damage and expenses in the long run. Based on the study, existing cracks can be converted into expansion joints, white paint can be used on the walls to control heat, installed thermal insulation to control solar energy stress and waterproof membrane can be applied to prevent moisture penetration.

Keywords: Inter-floor leakage; building defect; cracks; moisture; diagnosis

ABSTRAK

Kecacatan bangunan adalah isu yang biasa berlaku dalam industri pembinaan. Kecacatan bangunan bertingkat, seperti permukaan retak dan kebocoran, sering disebabkan oleh kerja yang tidak cekap oleh perunding dan pekerja buruh, dana yang tidak mencukupi dan kualiti bahan binaan yang rendah. Faktor-faktor lain yang meyumbang kepada kecacatan bangunan ialah mutu kerja yang lemah semasa pembinaan, reka bentuk yang lemah dan pemasangan yang salah. Kini kebocoran antara tingkat kerap berlaku di kediaman baru, kebocoran lambat dikesan dan kebocoran berulang berlaku walaupun pembaikan telah dijalankan. Penyelidikan ini bertujuan untuk mendiagnos bangunan yang mengalami masalah kebocoran antara tingkat dengan menggunakan beberapa alatan dan teknik diagnosis kategori iaitu ujian visual, destruktif dan tidak destruktif. Pengujian dijalankan oleh pakar menggunakan peralatan ujian untuk menentukan kelembapan dan penyelenggaraan atau pembaikan yang sesuai. Kajian kes dijalankan ke atas sebuah unit kediaman yang mengalami kebocoran pada bahagian siling yang disebabkan oleh rekahan pada bumbung luar. Penemuan penyelidikan ini akan memberi pengetahuan kepada pemilik dan pengurus harta mengenai diagnosis bangunan, mengenalpasti punca kebocoran, pengesanan awal kecacatan bangunan dan cadangan-cadangan pembaikan untuk mengelakkan kebocoran yang sama berulang serta membantu mengawal perbelanjaan. Dengan menggunakan alatan dan teknik diagnostik, pemilik dan pengurus harta boleh mengesan dan menangani masalah lebih awal, mengurangkan kerosakan dan kos dalam jangka masa panjang. Berdasarkan kajian, rekahan sedia ada boleh ditukar

kepada sambungan pengembangan, cat putih boleh digunakan pada dinding untuk mengawal haba, penebat haba dipasang untuk mengawal tekanan tenaga suria dan membran kalis air digunakan untuk mengelakkan penembusan kelembapan.

Kata kunci: Kebocoran antara tingkat; kecacatan bangunan; retak; lembapan; diagnos

INTRODUCTION

According to the United States Environmental Protection Agency (Leak Facts | WaterSense | US EPA n.d.), leaks in the average household can account for over 10,000 gallons of water wasted each day. This problem leads to high water bills, environmental hazards and risk for your home. Water leaks may seem as a common occurrence, with many homeowners familiar with dripping tap pressure. However, not all leaks are apparent. At times, leaks in pipelines under slabs or other hidden areas can be noticed and cause serious damage. Leaks can be emotionally stressful to deal with. Efforts to find the source of the leak and stop the water travel may cause adverse experiences for several unlucky homeowners. While leaks are often caused by plumbing problems, water may appear for many other reasons. Untreated leaks can cause structural damage, health problems, unnecessary costs and other problems. Examples of leaks include roof leaks, window leaks, groundwater intrusion and damaged tile grout. In strata housing, inter-floor leakage is one of the problems that can be brought to the management tribunal level. This issue is tried under the Strata Title Board (STB) in Singapore and in Australia Owners Corporations Act 2006. The concern is also administered under the Victorian Civil and Administrative Tribunal Act 1998 (VCAT).

Claims filed to *Tribunal Pengurusan Strata* (TPS) recorded inter-floor leakage were among the highest cases received from 2017 to 2018 (Tan 2018). The tribunal received 4,390 cases, the highest of which were arrears of maintenance charges and inter-floor leakage. Inter-floor leakage also frequently occurs in Singapore. The STB received 289 complaints from 2013 to 2014 (Times 2017), of which 188 were due to leaks between floors, accounting for 65% of cases overall.

HIGH-RISE RESIDENTIAL BUILDING ISSUES

Inter-floors leakage is one of the most frequent defects in high-rise residences, reaching 30.6% in Kuala Lumpur (Mohamad, Sufian & Syed Abdul Kader 2017). Moisture and cracks are the most common concerns in buildings in Malaysia and other countries around the world due to weather conditions, the type of building materials used and wear and tear (Ismail et al. 2017; Talib, Ahmad & Sulieman 2015; Meng et al. 2014). (Forcada et al. 2016) proved that building elements such as internal walls (60%), windows (17%) and mechanical and electrical systems (9%) are the most frequent or prone to have defects. While the remaining 5% are doors, exterior walls and roofs. Areas that often have defects after vacant possession are bedrooms, bathrooms and kitchens (Crommelin et al. 2021) caused by the lack of quality work during construction (Al-Aidrous et al. 2023). In reality, as noted by (Hopkin et al. 2016), building defects and damage are common in new homes. These matters arise in residences that have just been completed, buildings that are still under the Defects Liability Period (DLP), and buildings that have been occupied for less than two years from vacant possession. Although there are building constructions using Industrial Building System (IBS), the system still faces issues of incompatible systems with Malaysia climate, increased cost, quality of building materials and lack of skilled labour. According to (Mohammed Izrai Abd Razak et al. 2023) conflict between designers, manufacturing and installation happen when there is building failure such as leaks, cracks and collapses.

As such, an owner or a buyer must possess relevant knowledge or information on strata residence management in terms of responsibility of repair work, diagnosis of inter-floor leakage and early detection of building defects. High humidity can cause cracks on walls and buildings, and instigate fungal growth. The Strata Management Regulations 2015 (Malaysia 2015) defines inter-floor leakage as any dampness, moisture or water penetration in the ceiling, common property or limited common property along with the leakage in a strata title under Clause 55(1). This inter-floor leakage problem requires attention, as covered from regulations clause 55 to 64.

INTER-FLOOR LEAKAGE THEORY

When an existing building is faced with water penetration, there are established steps that can be taken to identify the source of leakage and determine the most effective repairs. According to the 90% over 1% and 99% principles, water infiltration usually takes place at the terminations and transitions within the building envelope, rather than directly through the water barrier or diverter system. Moreover, it is found that only 1% of the cases involve material or system failure, while 99% of the time it is due to poor installation or labour techniques (Kubal 2008).

Presence of water, a force that drives the water to the dry areas and a cavity, void or cracked line are some of criteria before leakage occurs. These criteria are particularly

relevant in diagnosing physical water leakage. In building science considers moisture through its mechanisms of air flow, moisture flow and heat flow. The principles in building science dictate heat flow are from warm to cold, moisture flow is from warm to cold and gravity acts downward. (Zheng & Wood 2020) the leakage-pressure relationship has been introduced and the theoretical interpretation of the flow through the building envelope has been made from the fluid mechanics' perspective which is building leakage pathways consisting of a number of leaks in parallel.

Therefore, this study aims to investigate the causes of leaks that are likely to occur as a result of poor waterproofing or cracks in the building walls. Unfortunately, there are numerous utilities and services that may contribute to dampness and leakage. The common sources are, but not limited to domestic pipes, waste pipes, rainwater down pipe and condensation.

METHODOLOGY

Observation and several tests were carried out at the subject property and other areas of the building to identify sources of leakage. The process of investigation is testing hypotheses, reviewing historical data or service records, conducting a preliminary site assessment, followed by testing and /or destructive inspection. The next step is data collection, data analysis and report preparation.

Testing is conducted by a specialist using test equipment to determine moisture and appropriate maintenance. Inspections consist of three categories: visual, destructive and non-destructive tests. The non-destructive test aims to determine the leaking path by recreating the leak at localised spots or building components without performing hacking or demolition. The tasks' inspection tools include as follows: -

1. Camera: to take some photo of subject property evidence of defect and documentation of building;
2. Moisture metre: to measure the amount of moisture content in a material or substance such as concrete, wood or drywall. The device provides a reading ranging from 0% (totally dry) to 6.9% (saturated dampness);
3. Infrared thermography camera: to measure temperature variances of a component as heat flows through, detection of leaks, thermal bridge and structural defect. Precise measurement ranging from 4 °F to 482 °F (20 °C to 250 °C) with 2 percent or 2 °C accuracy; and
4. Drone with an infrared thermal camera were used to provide both visual and infrared images of a building from different angles.

Once the source of leakages is identified, the expert will suggest repairs to prevent the leak. After the repair work is completed, monitoring of repair works continues until no other leaks are detected. The cost of repairs borne by the building management if the cause is from common property and borne by the owner if caused from the subject unit.

CASE STUDY OF INTER-FLOOR LEAKAGE

The subject of this case study is a freehold condominium unit located at Batu 9 Cheras, Selangor with vacant possession in July 2017. The housing scheme is accessible to Cheras-Kajang Highway, Jalan Cheras and Jalan Hulu Langat that leads to KL and Kajang. Some nearby landmarks include Central Brigade PGA Cheras and Central Selangor District Forest Office. The condominium is equipped with facilities such as a swimming pool, badminton hall, playground and 24-hour security. It is part of a three towers complex consisting 596 units with built-up areas ranging from 1,127 to 1,557 square feet.

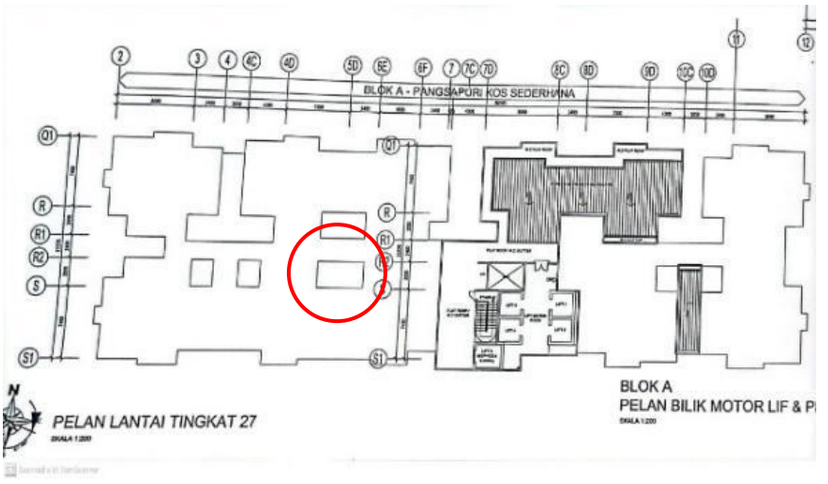

FIGURE 1. Floor plan of level 27, in the circle is the subject unit

The subject unit of this study is located on the 27th floor of the building block and has a rooftop over it as depicted in Figure 1. It consists of three bedrooms, two bathrooms, a kitchen, a balcony and a yard, with a built-up area of 1,127 square feet.

The property is currently owner-occupied. However, a leakage issue in the master bedroom has been identified since the DLP. Despite attempts to fix the defect, the leak has persisted. Water dripping and yellowish damp stains on the plastered ceiling suggest seepage from the rooftop, suspected a waterproofing failure or external wall cracks from the motor lift room as shown in Figure 2.

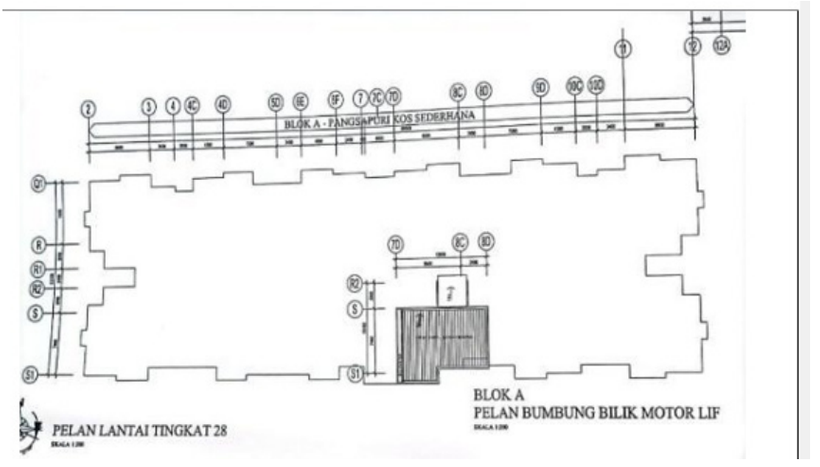

FIGURE 2. Floor plan of the rooftop and motor lift room

On May 11, 2022, investigators assessed and investigated the affected units on 27th floor and rooftop area on 28th floor. They used multiple approaches to identify the root causes holistically. The assessment scope is to identify possible sources of leaking and dampness. To determine the level of humidity and the appropriate repair method, experts carry out tests using equipment on the roof of the subject unit.

This test consists of three categories, namely, Visual, Destructive and Non-Destructive Tests. The equipment used during the test are humidity detector (humidity metre), infrared thermography camera and drone. Figure 3 is a damp spot discovered under the metal roof.

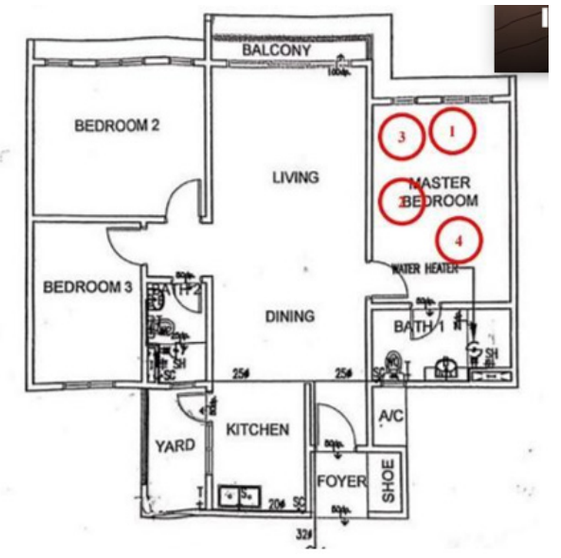

FIGURE 3. Floor plan of the subject unit and dampness test spots / locations

The origin of the dampness came from cracked external walls and poor waterproofing on the concrete flat roof under the metal roof. The investigation finds the following: -

1. A crack in the parapet wall;
2. A crack in the wall next to the Lift Motor Room; and
3. Improper slope and termination of concrete flat roofs.

Infrared thermographic imaging is widely adopted because of the unique attribute of water with relatively higher thermal capacity than most materials. Water is cooler in an indoor environment, and warmer in an outdoor environment. Therefore, when exposed to solar energy during the day, areas with hidden water pockets on the concrete flat roofs are warmer during the evening. However, verification with a moisture metre is necessary because not all cold surfaces are damp surfaces.

Inspections and tests are carried out on the flat roof of the subject unit by dismantling the metal roof for a thorough inspection as shown in Figure 4. Tests show high levels of moisture in the soffit. Excessive heat on the roof has caused severe cracking of the outer and parapet walls. Inadequate heat control measures and worsening climate change can exacerbate cracking in the future. As a result, rainwater seeps through cracks and pools at the very bottom of concrete flat roofs with poor gradients and terminations.

FIGURE 4. Metal roof at the rooftop were dismantle to test dampness at Location 1 and 2

Below, Table 1 shows the moisture metre test readings using a digital concrete moisture metre range: 0% (completely dry) to 6.9% (saturated moisture).

TABLE 1. Result of moisture meter test

Spot of test	Moisture meter reading	Diagnose	Causes	Suggestion
Location 1	4.7%	High level of dampness on the soffit	Seepage from external wall cracks/roof	Repair external wall cracks, heat control and re-waterproofing
Location 2	3.6%			
Location 3	3.9%	Cracks and high level of dampness on the external walls	Seepage from external wall cracks and migration of rainwater into to the metal roof	Repair external wall cracks, heat control and re-waterproofing
Location 4	3.9%			

Tests using drones with an infrared thermal camera on flat roof areas in Figure 5 show that the efflorescence (white spots) appear darker in infrared thermographic imaging. Efflorescence is the formation of a powdery deposit on the surface of brick work, stone, or other materials due to moisture loss when exposed to air.

FIGURE 5. Rooftop area and infrared thermographic imaging at Locations 1 and 2

The picture shows a damp spot on the rooftop. Infrared cameras indicate moist material; that is, hot areas are shown as red while cold areas are shown as blue on the device's LCD display. The device produces thermal images of materials and provides quick identification of potentially damp areas by showing temperature variations on the surface.

Although these devices do not directly detect humidity or measure moisture, they do indicate warmer and cooler zones. Figure 6 shows water pockets in orange and red patches. The diagnosis is that cracks and high moisture levels on the exterior walls cause seepage from the exterior wall cracks and passage of rainwater to the metal roof.

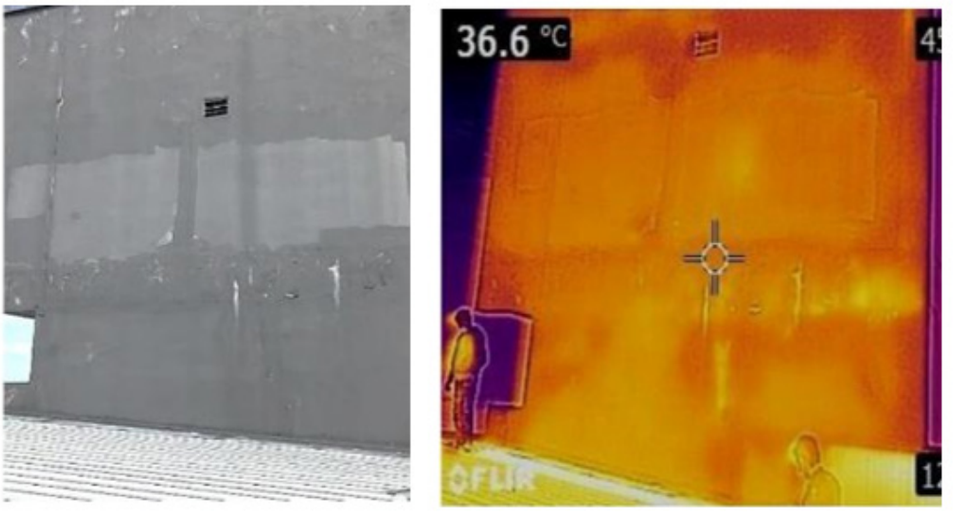

FIGURE 6. Rooftop area and infrared thermographic imaging at Locations 3 and 4

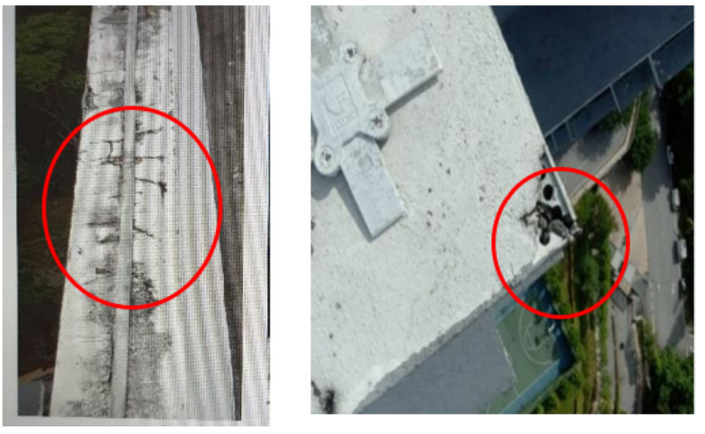

FIGURE 7 Cracks, chipped cement screeds and cavities in the walls

Additionally, cement debris and cavities in the walls closest to the leak area also contribute to water seepage into the unit, as shown Figure 7 below.

ANALYSIS AND RESULTS OF THE CASE STUDY

Such seepage, if not addressed properly and holistically, can lead to deterioration and cracking of concrete flat roofs. Debris and broken concrete fragments may endanger residents of the subject unit. In addition, the humid indoor environment is also unclean, and indoor mould can cause respiratory diseases to residents. As the subject building is new, the leak is not due to wear and tear, but indeed a latent defect due to poor workmanship, design and repair.

Despite numerous attempts to identify and fix the leak in the subject unit's bedroom, the leak recurred. Various approaches are used to reveal the cause holistically. Four damp spots are found under the metal roof. The source of the moisture comes from cracked exterior walls and poor waterproofing of the concrete flat roof under the metal roof. Defects at Locations 1 and 2 illustrate the cracked conditions of the parapet wall and those at Locations 3 and 4 outline pockets of water from the cracked wall in the Motor Lift Room that moved down due to gravity. Water seeps through the cracks and ends up as wet spots 1 and 2 with poor or no waterproofing, which occurs at the lowest point.

Cracks on flat roofs are severe due to exposure to maximum solar energy and differences in orientation and coefficient of thermal expansion of concrete and infill brick walls. Cracks can be avoided if control connections and thermal control are specified. However, leakage can be reduced by converting existing cracks into extension joints. Figure 8 shows the repair work of a wall adjacent to the lift motor room. Heat can be controlled by using white paint on the walls and installing thermal insulation which may reduce the stress caused by solar energy. Figure 9 shows the wall adjacent to the lift motor room after it is painted to white.

FIGURE 8. Repair work of a wall adjacent to the lift motor room.

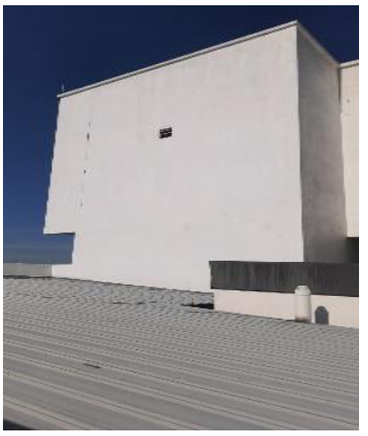

FIGURE 9. The wall adjacent to the lift motor room is painted to white.

Although the flat roof is protected by a metal roof, its poor slope causes rainwater to seep through the vertical flashing with gaps.

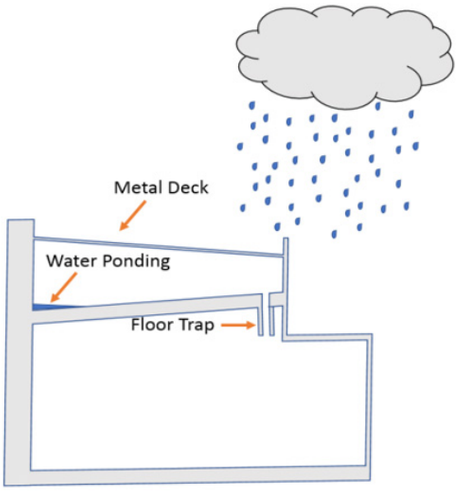

FIGURE 10. Cross section sketch of flat roof

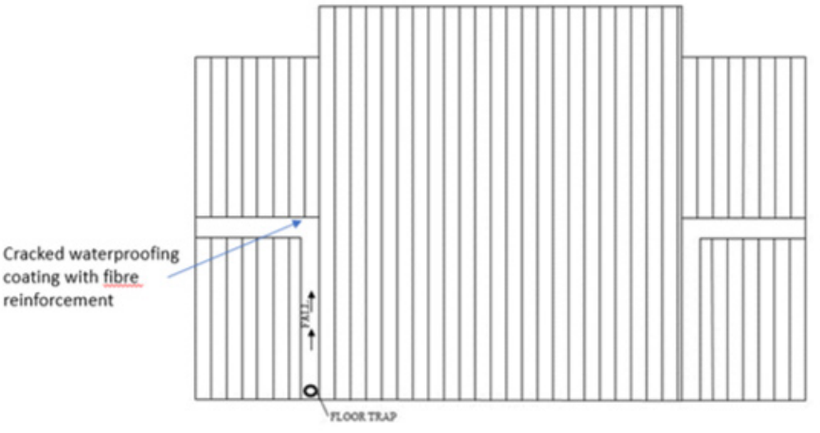

FIGURE 11. Metal roof sketch

The restoration waterproofing coating with fibre mesh reinforcement must be highly elastic to withstand all types of pressure and movement on a flat roof. Single-ply membranes were installed under the metal roof, as depicted in Figure 12.

FIGURE 12. Single-ply membranes are installed under the metal roof

The reading of the moisture metre on the waterproof coating in the trough with the incorrect gradient highlighted above clearly indicates the quality loss of the waterproof coating.

CONCLUSION

In conclusion, the leakage of the master bedroom of the subject unit resulting from the metal roof leakage is caused by poor gradient and poor workmanship. (Talib & Suleiman 2020) the metal roof building section has been analysed as the most problematic building component in any building that faces the problem of defects caused by leaks. In addition, appropriate preventive measures against the ingress of rainwater are not established and constructed properly, causing difficulties in habitability and comfort to the occupants of the subject unit (Siti Rosemawar, Tawil & Kuan 2022). Therefore, such leakage is tantamount to LATENT DEFECT.

Inter-floor leakage is a widespread problem in new homes and often occurs due to poor construction practices, inadequate cooperation, poor design and improper installation. Advance technology, aesthetic design, experienced development team and expensive building are not guaranteeing a perfect home. Construction should strictly follow the Uniform Building by Laws 1984 (UBBL 1984) with efficient enforcement.

Untreated leaks can cause structural damage, health problems, high water bills and environmental hazards. Detecting and addressing building defects can be a complicated process. However, by utilising diagnostic tools and techniques, identifying the cause of leaks, and enabling early detection of building defects. It is essential to take the necessary steps to diagnose, address, repair and maintain inter-floor leakage as soon as possible.

Based on the study, there are various ways to minimise leaks. These include transforming existing cracks into extension joints, applying white paint on the walls to regulate heat, installing thermal insulation to manage solar energy stress and using waterproof membrane or re-waterproofing to prevent moisture infiltration.

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