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The Impact of Climatological Factors on the Multifaceted and Multisystemic Deficiencies of Building Anatomy

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ABSTRACT

The construction industry has long been a significant area of human endeavour, and environmental degradation has been recognised as a specific factor contributing to defects in buildings. Defects in building can be multi-faceted and multi-systemic. Considerable focus has been placed on the possibility of mitigating the effect of climate change by decreasing human-caused emissions of greenhouse gases. Nevertheless, it is also acknowledged that built environments will be vulnerable to some effects of environmental degradation. The durability of buildings worldwide differs significantly, although it is generally expected that buildings ought to possess a lifespan of several decades. The process of weathering causes the deterioration of building materials, which, if not addressed, can result in an accelerated rate and potentially more severe deterioration. Modifications to maintenance schedules could accommodate slight alterations to the rate of degradation. Nevertheless, in order to achieve substantial enhancements in the pace of degradation, it may be necessary to make changes. On a global scale, the occurrence of any novel degradation mechanisms seems improbable. Yet, sometime in the future, earlier inconsequential issues may begin to assume importance at the local scale, due to a dearth in regional expertise or awareness. Therefore, this study was conducted to determine the influence of climatological factors on defects in buildings. The findings revealed that the primary causes of damage resulting from climate were moisture, fungal growth, mold, blistering, and corrosion. The problems originated from several factors like rain, condensation, atmospheric moisture, water leakage, humidity, high temperatures, UV radiation, dampness, oxygen, salt, and acids.

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1. Introduction

The building sector has been a major source of human activity; the detrimental effects on the environment have been admitted as a separate factor causing defects in constructions [1]. Significant attention has been directed towards the potential for reducing the impact of climate change by reducing anthropogenic emissions of greenhouse gases [2, 3]. However, it is also recognised that constructed ecosystems will be susceptible to certain consequences of environmental deterioration [4, 5]. The longevity of structures varies greatly internationally; however, it is generally anticipated that buildings should have a lifespan of several decades. In global evaluations, it is typical to use a standard assumption of 50 years [6-8]. Weathering leads to the degradation of building materials, which, if left unattended, can lead to an increased rate and perhaps more severe degradation. Adjustments to maintenance schedules could accommodate minor changes to the rate of deterioration [9].

However, in order to significantly improve the rate of degradation, it may be essential to implement alterations. Globally, the likelihood of encountering new degradation processes appears highly unlikely [10]. However, at some point in the future, formerly unimportant concerns may become significant at the local level because there is a lack of regional knowledge or awareness [11]. The term weather refers to the many atmospheric parameters that are present in a particular place at any given moment, including temperature, humidity, precipitation, wind direction and speed, air pressure, and cloud cover [12]. This dynamic feature of our environment is always changing and influencing the world around us. It is shaped by elements such as geology, solar radiation, ocean currents, and air circulation patterns [13].

Building flaws can be complex and have different levels of influence and implications on a property, depending on the specific type of defect [14]. Furthermore, both committees and owners often find the location of problems to be a significant source of complexity and anxiety, as it has the potential to give rise to several defects. The problems with the most significant influence on numerous building systems and the highest occurrence of cross-system defects are water ingress and dampness. An exemplary instance of a single flaw that escalates into a multi-systemic issue is the failure of a waterproofing membrane caused by climatological factors [15]. The fault in question is solely derived from a single component, namely the membrane. Nevertheless, when the membrane fails, water enters and negatively impacts other construction components, including wall cladding. Water ingress commonly undermines the integrity of the wall cladding, leading to further structural flaws, and subsequently causing a cluster of interconnected faults. The membrane problem may have been initiated due to factors such as poor craftsmanship or the use of faulty or unsuitable building materials [16].

Numerous businesses, including transportation, emergency services, agriculture, and most crucially, construction, depend on an understanding of and ability to forecast weather patterns [17]. Weather predictions offer useful information that may support smart decision-making, activity planning, and ensuring safety in potentially hazardous circumstances [18]. Weather has a big impact on exposed building conditions, especially external ones. Building flaws can be caused by a variety of meteorological conditions, such as humidity, freeze-thaw cycles, wind, sunshine, extremely high temperatures, storms, and UV radiation [19-25]. For instance, a building's external envelope may have gaps, fissures, or poorly sealed apertures that allow humidity from rain, snow, or excessive moisture levels to seep in [26, 27]. Problems like rot, the formation of mould, and the deterioration of building components like wood, plasterboard, and insulation might be caused by this moisture intrusion [28]. To address these weather-related risks effectively, it's crucial to implement proper design, construction, and maintenance protocols [29]. This involves maintaining a well-sealed building envelope, selecting durable and weather-resistant materials, installing efficient drainage systems, and conducting routine inspections and repairs to address any damage or weaknesses [30-32]. Moreover, compliance with local building codes and standards is vital for bolstering a building's resilience against weather-related threats [33].

The weather in Malaysia poses significant challenges to construction. All structures are susceptible to the effects of wind and rain. Furthermore, the city's severe temperatures and abrupt temperature fluctuations worsen external issues by inducing both the expansion and contraction of building facade components, resulting in the lifting and shifting of construction supplies. Once the impacts of weather become noticeable, it is likely that significant damage has already taken place in the brickwork, reinforcing steel, and wall connectors. Frequently, the deterioration commences at the highest point of the edifice due to the presence of roofing and sheeting that allow water to seep in [34]. Leaks that occur within and around aluminium glazing in contemporary structures can spread and result in harm to both the exterior walls and internal areas. The corrosion of structural components can compromise the stability of the building's exterior. The occurrence of concrete cracking in posts, frames, slab, and balcony is evident due to the corrosion and expansion of steel reinforcement bars [35]. The most reliable method to overcome Malaysia's shifting environment is through the consistent monitoring and prompt correction of weather-related issues, coupled with routine maintenance. Hence this research was conducted to determine the influence of climatological factors on defects in buildings.

2. Methodology

The methodology employed involves conducting a literature analysis and making direct observations in the study area to get precise and thorough data. A literature review is conducted by referencing multiple previous research to gather information pertaining to the impact of weather on construction flaws. Furthermore, the researchers also chose various case studies to obtain more precise information regarding real-time occurrences. The researchers have commissioned multiple buildings in the northern part of Malaysia to perform their study. Researchers employ several equipment, including cameras, moisture metres, and measuring tape. This tool can streamline the process of recording and analysing data.

2.1 Case Study 1

Figure 1 shows the growth of the fungal organism that develops on the exterior surface of the structure. Observation methods are employed to ascertain the issues that arise. Researchers utilised a gadget known as a camera to document the state of the flaw. Upon investigation, the researchers discovered that the defective region was near the bathroom area and had a pipeline. Researchers have additionally discovered the presence of a minor pipe leakage that leads to the continuous and unyielding acceleration of fungal growth in the water. Additionally, scientists have discovered that the section of the wall that is directly exposed to rainwater is also a contributing element to the proliferation of the fungus. This has impacted the landscape in the surrounding area and resulted in the building becoming more disorienting. The proliferation of several fungus species leads to the development of a slippery surface, posing a potential hazard to individuals who have previously traversed the area.

Fig. 1. Sign of fungal growth

2.2 Case Study 2

Researchers employed observational techniques to gather data on the abnormalities that transpired on the building's second level. The researchers utilise a tool, specifically a camera, to capture the circumstance in the form of photographs for enhanced clarity and traceability. Following the completion of the investigation, the researchers discovered the presence of moisture in the balcony area located on the building's second floor. The researchers discovered that the situation was quite unfavourable, with existing tiny cracks and dampness resulting from a lack of repair work as shown in Figure 2. This circumstance poses a threat to users in the area.

Fig. 2. Crack and dampness on the balcony

3. Specific Agent of Defects and Its Potential Flaws

Weather is a prominent factor in the development of building faults, which can lead to problems such as dampness, fungal growth, mould, blistering, corrosion, and disintegration. Several external issues arise due to intrinsic deficiencies in architectural or structural design, as well as the use of inadequate or unsuitable materials that are unable to survive the tropical temperature of the country. The combination of elevated humidity and frequent intense rainfall can worsen problems such as moisture accumulation, fungal and mould proliferation, and corrosion. In addition, the strong sunshine and changing temperatures can cause surface degradation, blistering of coatings, and thermal expansion and contraction of materials, which can further weaken the structural integrity of structures. Each of these weather-related problems has potential flaws.

3.1 Dampness

Dampness in buildings is a prevalent problem that can result in harm to the structure, health risks, and reduced indoor comfort. Figure 3 shows a visible dampness occurred on the external wall. Rainfall, namely weather-related elements, significantly contribute to dampness. In places characterised by elevated humidity and frequent precipitation, such as tropical climates like Malaysia, structures are more prone to the infiltration of moisture and the occurrence of dampness issues. There are several inherent weaknesses in how weather leads to wetness.

Fig. 3. Visible sign of dampness on external wall

3.1.1 Structural damage

Persistent exposure of building materials to rainwater can result in structural weakening, causing fractures, deterioration, and dampness within the building. In Malaysia, where heavy or continuous rainfall is frequent, water can infiltrate the building's envelope through cracks, capillaries, or inadequately sealed connections in the walls [36]. This infiltration permeates masonry and other construction components, resulting in gradual deterioration of the structure. The continuous presence of moisture undermines the architectural strength of the building, resulting in the formation of serious cracks, deterioration, and ultimately lead to infiltration of moisture into the building [37].

3.1.2 Increased moisture ingress

The kinetic energy of humid wind speed can result in increased water infiltration into the structure, intensifying moisture-related problems and potentially leading to long-term structural deterioration [38]. Moist winds can worsen moisture problems by forcing rainfall into the structure through openings like windows, doors, or any other holes in the building's outer covering. The heightened infiltration of moisture exacerbates issues with wetness, particularly in regions susceptible to high levels of precipitation and strong winds. Moisture-laden winds can also exert pressure on water, causing it to infiltrate cracks or tiny channels in the masonry, thereby exacerbating dampness.

3.1.3 Mold and mildew growth

Excessive moisture resulting from condensation can create optimal circumstances for the proliferation of mould and mildew, which can cause health problems and degrade the quality of indoor air. Insufficient airflow in conjunction with low temperatures might result in the formation of condensation [39]. Condensation happens when warm interior air comes into contact with cold surfaces, such as walls or ceilings, resulting in the collection of moisture. Over time, the accumulation of moisture can lead to dampness and encourage the proliferation of mould and mildew, worsening the issue.

3.2 Fungus and Mold

The weather has a vital impact on generating favourable conditions for the growth of fungus and mould, which can pose substantial hazards to both the structural integrity of buildings and the health of the people inside. In areas characterised by high levels of moisture and frequent rainfall, such as tropical regions, the confluence of water damage caused by intense precipitation, raised humidity levels, and the dissemination of mould spores can result in extensive proliferation of fungi indoors [40]. There are certain inherent weaknesses in how climatic conditions contribute to the growth of fungus and mould as shown in Figure 4.

Fig. 4. Fungus and mold growth

3.2.1 Damage to structure

Intense rainfall can cause water damage, which can gradually weaken the construction materials of a building, resulting in deterioration, decay, and impaired structural strength as shown in Figure 5. Inclement weather conditions, such as torrential rainfall, can result in water infiltration into structures, resulting in the formation of leaks in roofs, walls, or windows. These leaks facilitate the presence of the moisture required for the proliferation of mould and fungi [41]. As moisture builds up in the building components, it provides an optimal habitat for mould spores to develop and proliferate.

Fig. 5. Concrete surface deterioration

3.2.2 Indoor air quality

Elevated humidity levels can result in poor indoor air quality and health concerns for individuals due to the existence of mould spores and fungal propagation. Mould and fungi thrive in tropical areas due to the high amounts of humidity. When the air reaches its saturation point with moisture, it becomes more conducive for mould spores to initiate growth and multiply on various surfaces [42]. Poor ventilation worsens this issue by retaining moisture within, so further encouraging the growth of mould.

3.2.3 Indoor contamination

Outdoor sources of mould spores can transmit and cause indoor contamination, heightening the likelihood of mould growth on surfaces and degrading the quality of indoor air. Weather phenomena, such as wind and precipitation, have the potential to impact the dissemination of mould spores in both indoor and outdoor environments. Figure 6 shows the sign of mold spores. Aerial fungal spores can be transported by atmospheric currents, water, or insects from external origins to inside settings [43]. Upon landing on a damp surface within the building, these spores have the ability to initiate growth and reproduction.

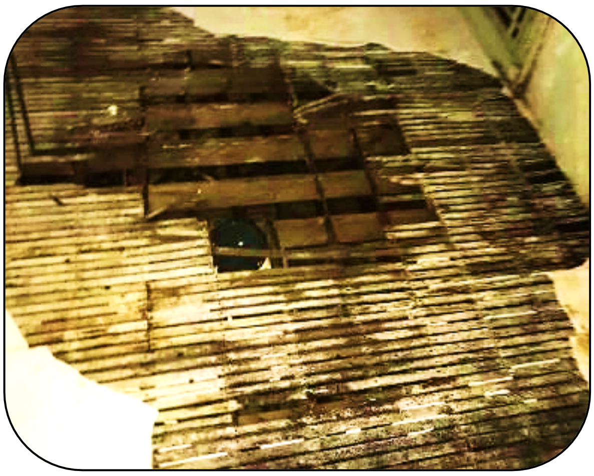

Fig. 6. Sign of mold spores

3.3 Blistering

Blistering, in the context of weather, commonly refers to the development of blisters on surfaces, such as paint or coatings, as a result of severe weather conditions. Figure 7 demonstrates the blistering that occurred on wall. Malaysia experiences a generally hot and humid environment. Blistering, a form of weathering, is caused by the impact of different weather conditions on surfaces [44]. There are several inherent weaknesses in how meteorological conditions lead to blister formation.

Fig. 7. Blistering on wall

3.3.1 Harm to structure

Malaysia experiences frequent high temperatures and humidity due to its tropical environment. When construction materials such as wood, concrete, or metal are subjected to these conditions, they have the ability to take in moisture from the surrounding atmosphere. As temperatures increase, the moisture that is confined can expand within the substance. If the surface is covered with an inflexible substance, like paint, that cannot expand or contract along with the material underneath, it may form bubbles or blisters. Over time, the repetitive patterns of expansion and contraction caused by temperature fluctuations can gradually undermine the strength and stability of the building elements, resulting in structural harm [45].

3.3.2 Water infiltration

Malaysia frequently encounters precipitation and elevated levels of humidity, especially during the monsoon seasons. When buildings are subjected to rainfall or elevated levels of humidity, moisture has the ability to infiltrate the building envelope by means of cracks, gaps, or inadequately sealed surfaces. Blistering of exterior coatings or surfaces enables water infiltration into the building's structure, resulting in moisture damage, proliferation of mold, and decay. Trapped moisture can also undermine the efficacy of insulating materials and facilitate the proliferation of detrimental bacteria.

3.3.3 Reduced aesthetic appeal

The high intensity of sunlight and UV radiation in Malaysia can expedite the deterioration of exterior coatings and paints. UV light degrades the chemical bonds of coatings, diminishing their ability to adhere to the surface and resulting in blistering or peeling. Consequently, buildings might exhibit unattractive blistered regions on their outer surfaces, which can impact their visual appeal and overall appearance. The convergence of elevated temperatures, humidity, and ultraviolet radiation engenders optimal circumstances for the formation of blisters, hence precipitating a gradual decline in the aesthetic quality of structures over the course of time.

3.4 Corrosion

The weather has a substantial impact on the corrosion of buildings and structures, especially in locations with varied climates like as Malaysia. The presence of elevated humidity, regular precipitation, near to the shore, and urban pollutants all generate an environment that is favourable for the corrosion of metal surfaces. Moisture, oxygen, salt, and acidic compounds resulting from industrial pollutants or acid rain serve as catalysts for corrosion in this tropical climate, causing structural damage. There are several inherent weaknesses in how weather leads to corrosion.

3.4.1 Structural weaknesses

Corrosion causes a decrease in the strength of metal parts, which can result in structural instability and possible collapse if not addressed. Structures that are subjected to rainfall, elevated levels of moisture, or coastal conditions are more prone to corrosion. Weather events can cause moisture to infiltrate building materials, resulting in the development of rust on metal components such steel beams, reinforcements, and fasteners. Prolonged exposure to moisture speeds up the corrosion process, which undermines the structural stability of the building as time goes on [46].

3.4.2 Material’s degradation

The presence of salt spray can induce corrosion, which can greatly diminish the durability of building components and undermine their structural stability. This can result in expensive repairs and ongoing maintenance. Buildings situated in coastal regions, like Penang, are vulnerable to salt spray transported by sea winds. The presence of moisture can accelerate the corrosion of metal surfaces, particularly when exposed to salt. The presence of chloride ions in saltwater facilitates the degradation of metal, leading to expedited corrosion and deterioration of construction materials such as steel, aluminium, and even reinforced concrete.

3.4.3 Surface damage

Acid rain erodes and diminishes the strength of building materials, resulting in surface deterioration and undermining the protective coatings that prevent more corrosion. Acid rain, resulting from the combination of atmospheric pollutants and moisture in the air, can expedite the corrosion of building components [47]. Acid rain's acidic properties accelerate the rate at which metals corrode, especially on surfaces that are exposed, such as roofs, facades, and metal cladding.

4. Origin of Defects

4.1 Moisture

Moisture refers to the existence of water, typically in minimal or even negligible quantities. Moisture can be present in the form of water vapor, condensation, and within or on the structure of a building. It can lead to dampness, which can create issues including discoloration, mold growth, mildew, and compromised indoor air quality. Moisture in buildings can stem from various sources, which will be presented in the following section.

4.1.1 Rain

Rain, particularly when driven by strong winds, has the ability to infiltrate building structures through joints and cracks that may otherwise remain watertight under normal weather conditions. Additionally, gutter overflow can exacerbate the issue by collecting and directing water against walls, further contributing to dampness and moisture. Some practical corrective measures are as follows:

i. Ensure proper waterproofing of exterior surfaces, including roofs, walls, and windows.
ii. Regularly inspect and maintain gutters and downspouts to prevent overflow and ensure proper drainage away from the building.
iii. Seal any cracks or gaps in the building envelope to prevent water ingress.
iv. Consider installing weather-resistant barriers and flashings to further protect vulnerable areas.

4.1.2 Condensation

Condensation can occur when humid air condenses on cooler surfaces within or between building materials. This humidity originates from various sources, including water vapor produced by building occupants. When warm, moisture-laden air comes into contact with cooler surfaces, such as windows or walls, it loses its ability to hold moisture, leading to condensation. Over time, this condensation can result in dampness. Here are some effective remedial actions:

i. Improve ventilation to reduce indoor humidity levels and allow moist air to escape.
ii. Insulate cold surfaces to prevent condensation from forming.
iii. Use moisture-resistant materials in areas prone to condensation.

4.1.3 Moisture in the air

Moisture in the air, especially from hygroscopic salts, can extract moisture from the surroundings, even in conditions where condensation does not occur. Hygroscopic salts have the ability to absorb moisture from the air, creating a damp environment within building materials. This moisture absorption can lead to dampness that fluctuates with changing atmospheric conditions. As humidity levels rise and fall, the salts release and absorb moisture accordingly will causing dampness. Some feasible corrective procedures are listed below:

i. Address sources of moisture ingress, such as leaks or seepage, to prevent moisture building up.
ii. Improve ventilation and air circulation to reduce humidity levels indoors.
iii. Use dehumidifiers or moisture-absorbing materials to maintain optimal indoor humidity levels.

4.2 Fungus and Mold

Microscopic fungi are significant biological contaminants in interior environments, and they are commonly found on various surfaces such as building materials, carpets, ceiling tiles, insulations, wallpapers, and in heating, ventilation, and air conditioning systems. Molds can proliferate on any substances, provided as there is sufficient moisture and oxygen. Exposure to fungus in interior environments, particularly in buildings with water damage, can lead to many negative health effects [48]. These include allergies, asthma, hypersensitivity pneumonia, irritation of the mucous membranes, diverse toxic effects, and perhaps fungal infections in individuals with weakened immune systems. These effects can occur alone or in combination. Antifungal protection is an urgent necessity due to the potential for major unfavourable health effects.

4.2.1 Water leakage

Water leakage from plumbing or roof gutters due to weather-related factors can contribute to mold and fungi growth in buildings. Heavy rainfall, strong winds, or storms can cause damage to roof gutters, leading to leaks that allow water to penetrate the building envelope. Similarly, severe weather events can result in plumbing issues such as burst pipes or leaks, introducing moisture into the building structure. Some practical corrective measures are as follows:

i. Ensure that roof gutters are properly installed and sealed to prevent water from seeping into the building. Use high-quality materials and sealants that can withstand harsh weather conditions.
ii. Apply waterproofing membranes or coatings to vulnerable areas such as roof surfaces, walls, and foundations to prevent water penetration during inclement weather.
iii. Regularly monitor for signs of water leakage, such as damp spots or water stains on walls and ceilings and address any issues promptly to prevent mold and fungi growth.

4.2.2 Moisture

Moisture in the walls can accelerate the growth of mold. This moisture may result from the use of improper materials in environments with limited sunlight exposure. When buildings receive less sunlight, moisture could accumulate more easily, especially if the materials used are not resistant to moisture. This creates an environment conducive to mold growth. Some feasible corrective procedures are listed below:

i. Enhance ventilation in areas prone to moisture building up, such as bathrooms and basements. Install exhaust fans to remove moisture-laden air and promote airflow. Consider adding vents or air vents in crawl spaces and attics to prevent moisture building up.
ii. Increase sunlight exposure to damp areas by trimming back trees or shrubs that obstruct sunlight. Consider adding windows or skylights to allow more natural light into the space, which can help dry out damp surfaces.

4.2.3 Humidity

Higher humidity levels can also promote the growth of mold. In areas surrounded by abundant trees and with reduced direct sunlight, the degree of humidity around the building tends to be higher. This elevated humidity, combined with the lack of sunlight penetration, creates conditions favourable for mold growth [49]. Mold thrives in moist environments, and high humidity levels provide the moisture necessary for its proliferation. Here are some effective remedial actions:

i. Use dehumidifiers to reduce humidity in indoor spaces, particularly in areas with poor ventilation or high moisture levels. Maintain relative humidity levels below 60% to inhibit mold growth.
ii. Promote air circulation throughout the building by using fans or ceiling fans. This helps distribute air evenly and prevents stagnant, humid conditions that can foster mold growth.
iii. Manage landscaping around the building to reduce the amount of shade and moisture-retaining vegetation. Trim back overhanging branches and foliage to allow more sunlight to reach the building and reduce humidity levels.

4.3 Blistering

Blistering is the result of air becoming trapped in the concrete and being unable to escape due to a seal formed during finishing or a surface that sets quickly. Localized pockets of air accumulate beneath the impermeable surface barrier, resulting in the formation of blisters. Blistering in buildings can originate from various sources.

4.3.1 High temperatures

High temperatures can cause materials to expand. If a surface is coated with a substance that cannot expand or flex with the underlying material, such as paint, it may bubble or blister [50]. The potential flaw here is that the blistered area may weaken the coating's adhesion to the surface, leading to premature failure. Practical corrective measures are listed below:

i. Use coatings that can flex and expand with the underlying material, such as elastomeric paints or coatings designed for high-temperature environments.
ii. Ensure that surfaces are properly prepared before applying coatings. This includes cleaning, priming, and repairing any defects to promote better adhesion and flexibility.
iii. Install thermal insulation materials to reduce the surface temperature of substrates, minimizing the expansion that can lead to blistering.

4.3.2 Ultraviolet radiation

Exposure to ultraviolet (UV) radiation from sunlight can degrade coatings over time, making them more susceptible to blistering. UV radiation can break down the chemical bonds in coatings, weakening their adhesion to the surface and causing them to blister or peel. The flaw is that blistering due to UV exposure can accelerate the degradation of the coating, leaving the surface vulnerable to further damage. The list of workable remedies is provided below:

i. Select coatings specifically formulated to resist UV degradation. UV-resistant coatings contain additives that help protect against UV radiation, prolonging the lifespan of the coating.
ii. Implement a regular maintenance schedule to inspect and recoat surfaces exposed to high levels of UV radiation, such as exterior walls, roofs, and outdoor structures.
iii. Where possible, provide shade or shelter to reduce direct exposure to sunlight, minimizing the effects of UV radiation on coatings.

4.3.3 Moisture

Moisture can penetrate into coatings, causing them to swell or soften. When the moisture evaporates faster than it can escape through the coating, it forms blisters. This is particularly common in humid conditions or when surfaces are exposed to rain or high humidity. The flaw is that blistering exposes the underlying surface to further moisture infiltration, potentially causing corrosion or degradation [51]. The following are practical corrective measures:

i. Apply waterproof coatings to prevent moisture penetration into the substrate. These coatings create a barrier that protects against moisture ingress and reduces the chance of blistering.
ii. Ensure proper drainage systems are in place to redirect water away from coated surfaces, reducing the risk of water accumulation and subsequent blistering.
iii. Increase ventilation around coated surfaces to promote drying and prevent moisture buildup. This is particularly important in areas prone to high humidity or moisture.

4.4 Corrosion

Corrosion is the term used to describe the chemical compounds that are produced as a result of the interaction between metal and a corrosive environment. Oxide coatings, scale, or rust may persist on the surface of metal structures because of corrosion [52]. Corrosion in buildings can originate from various sources.

4.4.1 Wetness

The tropical climate of Malaysia exposes buildings to high levels of humidity and frequent rainfall. Moisture from rain, humidity, or condensation provides the medium for chemical reactions that initiate corrosion on metal surfaces. As water comes into contact with metal, it facilitates the dissolution of metal ions, leading to the breakdown of the metal's structure over time. The prolonged exposure to moisture in Malaysia's humid environment accelerates the corrosion process, especially on unprotected or poorly maintained metal surfaces. Here are some effective remedial actions:

i. Apply corrosion-resistant coatings such as paint, epoxy, or polyurethane to metal surfaces to create a barrier against moisture. Ensure proper surface preparation and regular maintenance to maintain the integrity of the coating.
ii. Seal gaps, joints, and penetrations in the building envelope to prevent water infiltration. Use weatherproof sealants around windows, doors, and other openings to keep moisture out.

4.4.2 Oxygen

Oxygen is abundant in the air, and when metal surfaces are exposed to oxygen, they undergo oxidation, leading to the formation of metal oxides or rust. In Malaysia's tropical climate, where air circulation is generally high, oxygen readily reacts with metal surfaces, particularly those exposed to moisture [53]. This continuous exposure to oxygen accelerates the corrosion process, causing metal components to deteriorate more rapidly. These are some good corrective actions:

i. Apply corrosion-resistant coatings to metal surfaces to create a barrier that prevents direct contact with oxygen. Regularly inspect and maintain coatings to ensure their effectiveness.
ii. Use galvanized steel or aluminum for metal components exposed to outdoor environments. Galvanization forms a protective layer that acts as a barrier against oxygen and moisture.

4.4.3 Salt

Coastal areas in Malaysia are particularly susceptible to corrosion due to salt spray from the sea. Salt, especially chloride ions, is highly corrosive to metal surfaces and increases the conductivity of water, making it more corrosive. In coastal regions, salt spray carried by sea breezes can deposit on building surfaces, accelerating corrosion on exposed metal components such as steel reinforcement, fasteners, and exterior cladding [54]. This phenomenon is especially pronounced during the monsoon season when heavy rains and strong winds prevail. Here are some efficacious measures to address the issue:

i. Regularly rinse building surfaces exposed to salt spray with fresh water to remove salt deposits. Wash exterior surfaces with a mild detergent solution to prevent salt building up.
ii. Select materials that are resistant to corrosion, such as stainless steel or aluminium, for metal components in coastal areas. These materials are less prone to corrosion in salt environments.

4.4.4 Acids

Acidic substances, whether from industrial pollutants or acid rain, can further exacerbate corrosion in Malaysia's urban areas. Industrial activities and vehicle emissions release pollutants into the atmosphere, leading to the formation of acid rain. Acidic rainwater can react with metal surfaces, accelerating the oxidation process and causing corrosion to occur more rapidly, particularly on unprotected or poorly maintained metal structures [55]. Here are some effective remedial actions:

i. Apply acid-resistant coatings to metal surfaces to protect against corrosion caused by acidic substances. These coatings form a barrier that prevents acid penetration and oxidation.
ii. Implement measures to reduce industrial pollutants and vehicle emissions that contribute to acid rain formation. This may include adopting cleaner production technologies and promoting sustainable transportation practices.

5. Step-by-Step Procedure for Conducting a Defect Evaluation

There are some defects caused by weather, which include dampness, fungus and mold, blistering, corrosion, and decay. The following is the step-by-step procedure for conducting a defect evaluation for each defect caused by weather.

5.1 Dampness

i. Conduct an overall inspection to identify any signs of dampness. The signs of dampness include water stains, paint peeling and mold growth in the affected area.
ii. Utilize tools which are moisture meters to measure the moisture content at the defected area.
iii. Identify the source of moisture intrusion such as from leaks in plumbing and find any visible cracks or gaps that water can penetrate which cause the dampness.
iv. Document all the findings by taking photographs of the defects and the moisture readings to support the evaluation process.
v. Provide recommendations to rectify the dampness issues based on the finding such as repairing leaks, improving ventilation or replacing the damaging material with new material.
vi. Conduct regular maintenance inspection to ensure the dampness issues are resolved and not relapsed.

5.2 Fungus and Mold

i. Conduct a visual inspection to look for discoloration and patches of mold that can be signs of fungus and mold.
ii. Utilize moisture meters to measure the affected area and identify the areas with moisture levels because moisture is the main factor for fungus and mold growth.
iii. Collect the samples of fungus and mold for laboratory analysis that can involve swabbing the defects surfaces for spore analysis.
iv. Identify the types of fungus and mold because different types of fungus and mold require different remediation methods and pose varying health risks.
v. Find and repair the source of moisture intrusion as dampness contributed to fungus and mold growth.
vi. Conduct remediation measures based on the type of fungus and mold present which can include removal of the affecting materials and addressing moisture sources.
vii. Conduct regular maintenance inspection to ensure the mold and fungus issues are resolved and not relapsed.

5.3 Blistering

i. Conduct a visual inspection and examine the blistering surfaces by noting their size, shape and distribution.
ii. Clean the surface to remove any debris and contaminants that may hide the defects.
iii. Document the findings by taking photographs of the blisters to document the location and the characteristics of the blisters.

iv. Measure the diameter and depth of the blisters using appropriate tools, which is the calipers or depth gauges.
v. Determine the cause of blistering and conduct tests to analyze the environmental factors, moisture content and material properties.
vi. Provide recommendations for the blister remediation that include surface preparation, coating selection and application techniques that suitable for the weather at the selected areas.
vii. Conduct regular maintenance inspection to ensure the blistering issues are resolved and not relapsed.

5.4 Corrosion

i. Conduct a visual inspection of the surface to examine the corrosion areas by noting their size, shape and distribution.
ii. Clean the surface to remove any debris and contaminants that may hide the defects.
iii. Document the findings by taking photographs of the corrosion to document the type of corrosion as well as any visible signs of degradation.
iv. Measure the dimension of the corrosion that includes depth, width and length by using calipers or depth gauges.
v. Determine the cause of roots for the corrosion with factors such as the moisture temperature and chemical exposure.
vi. Provide recommendations for addressing corrosion defects that include surface treatment and corrosion protection measures.
vii. Conduct regular maintenance inspection to ensure the blistering issues are resolved and not relapsed.

5.5 Decay

i. Conduct visual inspection for signs of decay which is discoloration, cracking or fungal growth.
ii. Use a probing tool to test the wood integrity which soft and spongy areas indicate decay.
iii. Measure the moisture content of the wood using a moisture meter. High moisture levels can contribute to decay.
iv. Identify the type of decay organism present whether it is brown rot, white rot or soft rot.
v. Document the location and shape of the decay using photographs.
vi. Evaluate the environmental conditions such as moisture levels, temperature and exposure to identify potential causes of decay.
vii. Provide recommendations for addressing the decay that may include repair and replacement of the damaged wood.
viii. Suggest preventive measures to mitigate future decay such as improving the ventilation and treating wood with preservatives.

6. Propose Action Plan for Defects Avoidance

6.1 Incorporate Weather-Resistant Materials into the Construction Design Process

During the design process, the selected materials and construction methods should be resistant to weather [56-58]. Various studies have highlighted the importance of using materials with high weather resistance properties [59, 60]. For instance, high weather-resistant steel has been found to possess excellent weather resistance, mechanical properties, and superior economy [61, 62]. The example of weather-resistant material is the waterproof membrane for flat roof that can avoid rainwater penetration into the building structure during heavy rainfall. Additionally, can use lightweight materials such as foamed concrete for roofing elements [63, 64].

6.2 Implement Proper Drainage System

Proper drainage system can help to manage the surface water, groundwater and storm water. Research by the Malaysian Public Works Department (JKR) emphasizes the importance of effective drainage systems in mitigating the impact of heavy rainfall. Therefore, by implementation of proper drainage system can derived the rainwater away from the foundation of the building and avoid water accumulation that can weaken the building foundation and causing weather- related defects such as dampness and mold growth [65].

6.3 Conduct Proactive Maintenance Practices

Regular inspection and maintenance are crucial to avoid the defects caused by weather. To avoid weather-related damages to the building, the proactive maintenance practices are crucial. Scheduled inspections can detect weather- related defects at an early stage which can prevent major damages to the building [66].

6.4 Integrate Technology into Maintenance Practices

Integration of technology can help for defects avoidance in the future. The utilization of technology such as infrared thermography can detect hidden defects caused by weather such as moisture intrusion and corrosion by capturing thermal images that highlight temperature variations [67]. The utilization of infrared thermography can be used for defects avoidance plan because it can help detecting the defects before it happens. For example, infrared thermography can detect moisture in the wall that not visible to the naked eye which can be taken into action before the moisture seep through the wall. Infrared thermography is effective to identify cracks and defects in building envelopes which can allow for assessment of damage levels and indicated the necessary maintenance strategies [68].

6.5 Provide Training for Maintenance Personnel

Properly trained maintenance personnel are crucial for effective maintenance practices to prevent weather-related defects. Maintenance personnel should be trained and have skill to identify signs of weather damage, implementing proactive maintenance measures and safely performing rectification. Tan *et al.,* [5] stated that research on the impact of weather on the failure probability of components of power systems emphasizes the need to incorporate weather considerations into maintenance training and practices. By empowering the maintenance personnel with the knowledge and skills to address weather-related defects effectively, the defects occur due to neglect can be reduced.

6.6 Selection of Proper Materials

The selection of suitable building supplies is a vital component of every construction [69]. The selection of materials has a substantial influence on the lifespan, visual appeal, practicality, and ecological reliability of the building [70-75]. Given the wide range of choices, it might be challenging to select the most suitable materials for a particular project [76, 77]. To select the appropriate construction supplies, it is essential to have a comprehensive understanding of the project specifications [78]. Take into account the intended function of the building, whether it is for dwellings, businesses, or industrial purposes, and determine the particular requirements and expectations it must fulfil [79]. For instance, in a housing project, the main focus may be on the visual appeal, comfort, and energy efficiency [80]. On the other hand, in an industrial endeavour, the primary emphasis may be on the strength and security of the structure [81]. Comprehending the project specifications establishes the basis for choosing supplies that are in line with the purposes of the project.

7. Conclusions

This study provides a comprehensive analysis of the impact of weather on building conditions, focusing specifically on issues like as moisture, fungus and mildew, blistering, corrosion, and deterioration. This highlights the importance of using efficient design, building, and maintenance procedures to reduce the impact of these weather-related risks. The research was carried out utilizing literature review, observation, and case studies to gather thorough and precise data. The researchers utilized various tools, including cameras, moisture meters, and measuring tape, to assist the process of recording and analyzing data. Furthermore, this paper highlights practical solutions for dealing with weather-induced flaws. These include applying corrosion-resistant coatings to metal surfaces, utilizing galvanized steel or aluminium for outdoor metal parts, and implementing measures to decrease industrial pollutants and vehicle emissions that contribute to the creation of acid rain in the environment. Ultimately, this article highlights the need of understanding and forecasting weather patterns, implementing suitable building design and maintenance strategies, and utilizing modern diagnostic techniques to mitigate the impact of weather-related flaws on building structures. The main causes of climatological flaws were moisture, fungus and mildew, blistering, and rusting. Defects were caused by rain, condensation, moisture in the air, water leakage, humidity, high temperatures, UV radiation, dampness, oxygen, salt, and acids.

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