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Building Defects in the Coastal Environment of Malaysia: An Investigation of the Main Agents and Contributing Factors

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Abstract

Residential, office, commercial, and other types of buildings are just a few of the many various types of structures that require maintenance today. Building defects are certainly influenced and affected by a variety of environmental factors, such as those present on the coastal environment or in close proximity to the sea. One example of this is the salt air that is prevalent in these locations. The majority of people usually believe that construction near the sea is one of the most ideal areas to live in terms of aesthetics and ecological. Having a residence near the ocean has some disadvantages, such as the possibility of problems appearing faster than in non-coastal areas. Therefore, the goals of this study were to establish the primary causes of the problems and provide coastal defect prevention to reduce subsequent problems. To settle this situation, a reasonable decision has to be made. Four case studies were conducted as part of this research, and data were collected through observation, questionnaires, interviews and a review of the literature. The presence of saltwater and rains, powerful waves, and persistent rainfall (during monsoon season) were some of the most common factors that led to structural damage in coastal residential buildings. Additional types of architectural issues that were discovered as a consequence of this research include corrosion, rot on structures, and cracks as a direct result of erosion. As a result, choosing the right materials can considerably minimise or decrease damages and could enhance the overall performance of each structure when performing routine inspection and maintenance.

Keywords: Environmental, Coastal, Building Defects, Corrosion, Saltwater, Maintenance.

Introduction

The topic of building defects in coastal structures is highly important due to the increasing construction activities along coastlines and the vulnerability of coastal ecosystems

to environmental changes. With the advancement of technology in the construction industry, it is crucial to ensure that coastal structures are designed, constructed, and maintained in a manner that can withstand the unique challenges posed by coastal environments. Building defects in coastal structures can have serious consequences such as safety risks, increased maintenance costs, negative impacts on coastal ecosystems, and potential loss of property and investment. Therefore, understanding and addressing the issue of building defects in coastal structures is critical to ensure the sustainability and resilience of coastal communities and environments.

Additionally, a variety of factors can cause failures and defects in structures, and the construction industry must continue to focus on this important issue (Chin Hang, 2016). As according National Building Agency (1985), building defects can be the result of a design error, poor workmanship, the building not being constructed in accordance with the original design, or factors that do not meet the design standards (Halim et al., 2010). Any ecosystem with structure, diversity, and circulation can be discovered in coastal ecosystems, which are developed where land and water meet. There are many various types of flora and animals that can be observed there, including salt marshes, mangroves, wetlands, estuaries, and bays.

Nevertheless, due to human activity, the introduction of non-native species, and other factors, certain coastal ecosystems are currently battling to keep their diversity. Coastal ecosystems are particularly vulnerable to environmental changes (Council, 2015). Sea-level rise (SLR), which has affected coastal habitats, has made coastal regions susceptible to many dangers, including inundation and erosion (Williams et al., 2018). The length of Malaysia's coastline, which includes the Sabah and Sarawak coasts, is roughly 4,800 kilometres. The geologically stable Sunda Shelf is where the coastal region of Malaysia is located. About 73 percent of Malaysia's whole coastline is its entire length. Building defects are among the most important problems that all parties should be aware of, as is common knowledge. There can be a wide variety of issues for individuals, especially occupants, when a structure does not always function as it should.

Based on a number of studies, this research revealed problems in the construction of coastal structures. Materials and construction techniques should be able to survive coastal climate conditions such as flood and wind damage, wind-driven rain, corrosion, moisture, and deterioration caused by sunlight, ageing, insects, chemicals, temperature fluctuations, or other factors (B2B Purchase, 2018).

The study on building defects in coastal structures is significant as it can contribute to improving the quality, safety, and durability of coastal structures. By identifying the common causes and types of building defects in coastal structures, the study can provide insights into the challenges and issues faced by the construction industry in coastal areas. This can help in developing effective strategies and solutions to prevent, mitigate, and rectify building defects, and improve the overall performance and lifespan of coastal structures. The findings of the study can also serve as a basis for developing best practices, guidelines, and regulations for the design, construction, and maintenance of coastal structures, and contribute to the advancement of knowledge in the field of coastal engineering and construction.

Literature Review

Building Defects

Building defects require cautious correction if there is to be any major issue in the future. It might also be called a defect or imperfection. A defect is also known as a deficiency. As a result, a building defect can be defined as any condition that reduces the value and

performance of the building. There are two types of defects. It is a combination of patent and latent defects. Patent (visible) defects are those that can be discovered through reasonable inspection, whereas latent (hidden) defects are those that are concealed within the structure and are difficult to discover. Eliminating latent building defects is a difficult task, as mentioned by (Chong and Low, 2006).

Design faults are major contributors to latent defects, and such flaws can only be avoided by improving design. The majority of latent defects appear themselves only during the occupancy stage, and gaining access to occupied buildings to gather information on these defects can be difficult. Design faults are major contributors to latent defects, and such problems can only be avoided by improving design.

Building defects can result from the original design being insufficient or faulty, from the building not being built according to the plan or using the proper method, by poor craftsmanship, from the building has been subjected to external forces, or from any combination of these factors. The presence of defects including noise interruption, solar heat gain, and glare that will have an influence on occupant comfort. However, they have been omitted since it is believed that they have no impact on the fabric or the services.

According to Ahzahar et al (2011), a building defect is the result of an architect's design error, a manufacturing problem, incompatible materials, improper material usage or installation, a contractor's failure to comply with the design, or any combination of these factors.

The Coastal Environment

According to Garten (2016), coastal areas or zones are located near coastal seas and associated land regions, and include islands, transitional and intertidal zones, salt marshes, wetlands, and beaches. Many coastal zones are threatened as a result of urbanisation, industrial pollution, runoff, and waste and sewage discharge. To protect coastal areas from pollution and overpopulation, the Coastal Zone Management Act (CZMA) was enacted in 1972.

Coastal development is increasing nowadays because Raza (2016) discovered that coastal regions have a high value of socioeconomic linked activities, such as aquaculture and fisheries, physical setting and land use, tourism, environment and natural resources, and other economic situations. However, increasing human population pressure—10% of the world's population now lives close to the coast—visitors, port facilities, desalination plants, marine traffic, and fish farms are all direct environmental pressures on coastal areas. These factors all contribute to the pollutants of substances of contaminants, including plastic pollution (Llorca et al., 2020).

Main Agents of Defects

Buildings can have defects for a variety of reasons. This should come as a surprise considering the variety of building materials and construction methods used, the various site conditions, and the different activities the finished structure will be used for. According to Hanafi et al (2018); Mydin et al (2012), mechanical, electromagnetic, thermal, chemical, biological, and natural disasters are the main causes of building defects agents.

Defects may also be caused by poor building materials and workmanship. This was discovered while investigating the factors that contribute to poor workmanship quality in Nigerian public building projects (Ntuli & Allopi, 2014). Another factor discovered was that

building defects are caused by weaknesses in the design, manufacturing process, or incorrect material installation (Hermawan et al., 2013).

In her study, Ahluwalia (2008) identified eight defect factors affecting building condition, including the type of building, facility condition, demographic factors, age or major year of building renovation, size, external and internal conditions, advancement in information technology, and maintenance regularity. Defects are classified based on their consequences. Those defects vary depending on the type of building, site, and user of the building. All of the aforementioned agents will impact the material, or more precisely, they will create a problem in a material used in the building. Changes could be made to the materials' composition or condition, to the structure's form, to its size, weight, and shape, as well as to its appearance, including its colour (Faqih et al., 2020).

As shown in Table 1, illustrates the researcher's understanding of the main agents of defects, which are the source of changes in building materials and elements and adversely affect the material and structure.

Table 1
Main Agents Summary of Defects and its effects to Material Changes

Main Agents	Sub Agents	Changes in the composition or condition of the materials used	Changes in structure form	Changes in shape, size and weight	Changes in appearance, including colour
Mechanical	Forces applied		√	√	
	Ground pressure		√	√	
	Dynamic		√	√	
	Vibration		√	√	
	Wind		√	√	
	Water				
Electromagnetic	Solar radiation	√			√
	Ultraviolet	√			√
	radiation	√			√
	The visible waveband	√			√
	Infra-red radiation				
Thermal	Temperature	√	√	√	
	Fire	√	√	√	√
	Climatic condition	√	√	√	√
Chemical	Water	√			
	Oxygen	√			
	Sulphates	√	√		
	Other chemical agents				
Biology	Human				
	Animal	√			√
	Plant	√			√

	Micro-organisms		
Natural disaster	Earthquake	√	√
	Tsunami	√	√
	Flooding	√	√
	Landslide	√	√
	Firestorm	√	√

The table above summarizes the main agents that can cause defects in materials and their effects on material changes. These agents can have significant impacts on the composition, condition, structure, form, shape, size, weight, and appearance of materials, including colour.

Mechanical agents such as forces applied, ground pressure, dynamic loads, vibration, wind, and water can cause changes in the structure, form, and shape of materials. These changes can result in deformation, cracks, fractures, and failure of the material.

In summary, understanding the main agents that can cause defects in materials and their effects on material changes is crucial for designing materials that can withstand various environmental conditions and protect against the effects of external factors.

Building Defects Near the Coast

In general, a number of factors, such as the relation to environmental conditions that prevail close to the coast, the building materials used in coastal structures, and the proximity of these structures to water, contribute to building problems along the coast (Sangiorgio et al., 2019). Coastal areas are often exposed to high levels of humidity, salt, and wind, which can cause wear and tear on building materials over time. While wind can harm roofs and create other structural damage, the salt and humidity can corrode metal parts and cause wood to rot. In addition, coastal buildings are often built on unstable soils that can shift and cause foundation problems. The proximity of these buildings to the water can increase their vulnerability to flooding, which can cause further damage to the structure.

The surrounding environment of the building will also have an effect on it. This is because Malaysia is a hot weather country with a high amount of rainfall near the end of the year and strong UV rays that can seriously damage the building surface and structure (Chin Hang, 2016). Furthermore, the effect will accelerate the rate at which building defects occur. The surface of buildings built at different locations will be exposed to different temperature changes, and the structures affected will not be the same. Since many residential buildings in coastal areas are exposed to saltwater. Corrosion and deterioration of building elements such as the rebar, window frame, door, and others are possible defects caused by seawater (Mackenzie et al., 2018).

According to FEMA, (2013a), corrosion is influenced by a variety of elements, with the presence of salt spray being the most significant difference between coastal and non-coastal areas. Metal corrodes five times quicker in salt water than in freshwater, while metal corrodes ten times faster in salty, humid ocean air than in air with normal humidity. When exposed to air, iron begins to corrode due to the presence of oxygen. Oxygen reacts with the iron to form iron oxide, also known as rust. Rust is a reddish-brown material that is much weaker than the original iron.

As more rust forms, it can cause the iron to become weak and brittle, and eventually lead to failure. Bacteria in ocean water also devour iron, and their excretions rust (Bailey Rodriguez, 2018). This is because one of the factors that influence the corrosion rate in this

location is the wind speed and direction (salt air) in the coastal area. Salt-laden, moist air can corrode exposed metal surfaces and seep into any gap in the structure (FEMA, 2013b). Salt air may impact metals more than 50 miles inland, according to studies by the Poma (2018) in the United States, and the graphic below shows how corrosion rates vary in various areas. One of the most common causes of concrete structure degradation in coastal environments is reinforcing steel corrosion. A map of salt air deposition rates near the sea is shown in Figure 1.

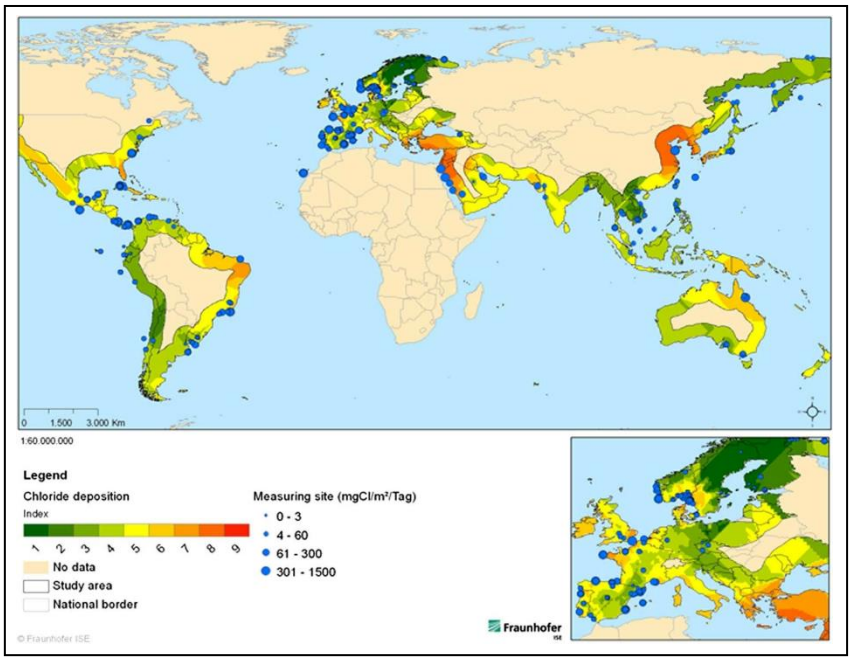

Figure 1 Coastal Map shows salt air or chloride deposit rates of inland area (Poma, 2018)

The next defect that may occur from the saltwater is the decay of timber or also known as timber rot of building in coastal areas. Decay will happen when the timber is exposed to moisture or water and termites attack. Next is the strong wave in the coastal area. This is due to high wind, especially during a monsoon season and it may occur an erosion problem. This factor may affect the natural coastal processes which are also sometimes subject to severe damage by erosion and flooding (Persson, 2015).

The erosion problem is capable of threatening a coastal residential building such as big damage to the structures such as cracked, because of the destroying erosion control devices and breaching low-lying coastal barrier islands exposing structures on the mainland to increased flood and wave effects (FEMA, 2013a). Besides, this also can make a building collapse if it did not control and monitored earlier. Furthermore, due to excessive rains and water flow, concrete constructions will be harmed during the monsoon season. This will effect on the structure, particularly its strength and life cycle.

According to Ekekezie (2022), there are a few impacts or defects that can arise as a result of rainwater, such as water entering through seepage or leaking damaging the internal structure through corrosion. It will decrease the structural strength of the structure. Then, due to the increased dampness, fungal growth will appear on the walls, causing a variety of health problems.

Methodology

The investigation of building defects can involve a variety of different processes, depending on the nature of the defect and the type of building. Generally, the process involves an initial assessment of the defect to determine its scope and severity, followed by a detailed investigation to determine the cause. This can involve visual inspections, interviewing witnesses, testing equipment's, and potentially engaging experts in the field. Once the cause has been identified, the defect can be rectified and appropriate steps taken to prevent a similar problem in the future.

The case study was observed and both qualitative and quantitative methods were used. These were carried out at four different residences along the coast in order to obtain photographic evidence. This approach's data was used to analyse the most common problems encountered during the research investigation. An interview with the building's owner was also conducted to gather additional information. The surveys were distributed to three locations, each with four case studies: Batu Rakit beach, Seberang Takir beach, Kelulut beach, and Tok Jembal beach. The location was chosen because the homes were near the sea. All of the respondents had adequate local experience.

The questions began with general topics such as the age of the building and progressed to specific issues concerning the defects that had occurred at the building. As a result, they are well-versed in the coastal environment and the common problems that affect coastal homes. 50 respondents were given questionnaires, and they were all delivered during the research investigation. Furthermore, this method necessitates the use of data collection instruments such as a digital calliper, moisture metre, measuring tape, hygrometer, and anemometer by the researcher.

Douglas and Ransom (2013) conducted a chronological study that assisted in the research process as shown in Figure 2. The building's chronology will begin with a source of error that has happened at the structure, which then leads to a cause, which leads to a defect, which manifests as an anomaly or symptom, then failure, and eventually loss or damage (Douglas & Ransom, 2013). The inquiry, on the other hand, will begin with the building damage or failure and work its way to the cause of the defect.

This chronology might assist the researcher in determining the causes and types of defects that developed in the structure. The researcher can also determine what the most serious defect is based on this information. The major purpose of this investigation is to get all necessary information without incurring excessive costs. Additionally, a well-informed decision can be made concerning any recommendations or additional steps that must be taken. This decision should be based on the collected data as well as any potential risks and benefits that may arise.

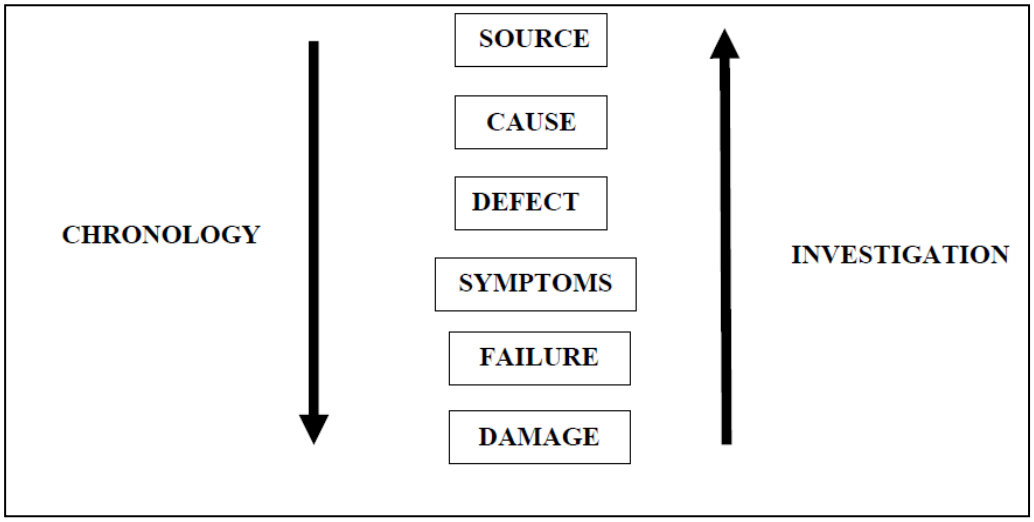

Figure 2 The chronology of investigation (Douglas & Ransom, 2013)

Results

Visual investigations were conducted at various dwellings in three separate case studies in Terengganu, all of which are located near the shore as shown in Table 2. This section has been divided into 5 part which is roof, window, door, wall and external. It easier for the researcher to analyse the defects that have been occurred in the building in the coastal area. By focusing on each individual part, the researcher can identify any issues that may have been caused by the specific environmental conditions of the coastal area.

Table 2
Buildings Information

Building	Age	Beach Area	Distance from Beach	Building type	Building Material
1	Over 5 years	Batu Rakit Beach	300 m	One storey/Bungalow	Mix
2	Over 50 years	Batu Rakit Beach	5m	One storey/Bungalow	Timber
3	Over 30 years	Seberang Takir Beach	70m	Two-Storey	Mix
4	Over 70 years	Tok Jembal Beach	50m	One Storey/Bungalow	Concrete

The research study is being conducted in Kuala Terengganu, Malaysia, and residential areas near beaches are the study's target population. The climate in Malaysia is tropical, with temperatures ranging between 28^{o}C and 32^{o}C during the day. Furthermore, due to exposure to the annually occurring northeast monsoon, the coastlines of eastern Peninsular Malaysia are directly exposed to the South China Sea's strong winds and dynamic coastal processes, and coastal vegetation acts as a first line of protection against physical elements of wind and wave, Raza (2016) remarked that, in comparison to the other east coast states, Terengganu has the longest coast. The evidence that has been taken during the observation also will be discussed in this paper. Because the researcher would immerse herself in the environment

where her respondents are, while taking notes and/or recording as proof or information, the observation data collecting approach is categorised as a participatory study. As a result, the researcher conducted a semi-structured interview and took notes while doing the observation. This will assist the researcher in analysing the data gathering and conducting a study discussion.

The observation was carried out in a coastal area ranging 5m to 300m from the beach. Most of this house's metal components are rusted. Upon closer inspection of these four homes, it became apparent that decay, rust, stickiness, and dampness were prevalent problems seen in coastal residences. Rusty at the metal component or material, however, was the most frequent defect. A major contributing factor to rusting residential buildings along the seaside is the reaction from the sea salt and also an improper material choice and careless maintenance. All of these homes revealed the same rust issue, with rust appearing at the hinge, doorknob, electrical components, lockset, and windows. Next, a common problem that the owner faced was sticky due to salt water. Their building will be sticky, particularly on windy days. It will be sticky inside the building, especially on its furnishings. In these four homes, salt water caused the floor, table, and sofa to be damp and sticky throughout the inspection. This can be the factor that causes rust at home because salt always occurs in the building. Figure 3 showed the sample outcomes and an explanation of the observation. The results indicated that salt is the main contributor to the rusting process, and that it accelerates the corrosion rate of metal.

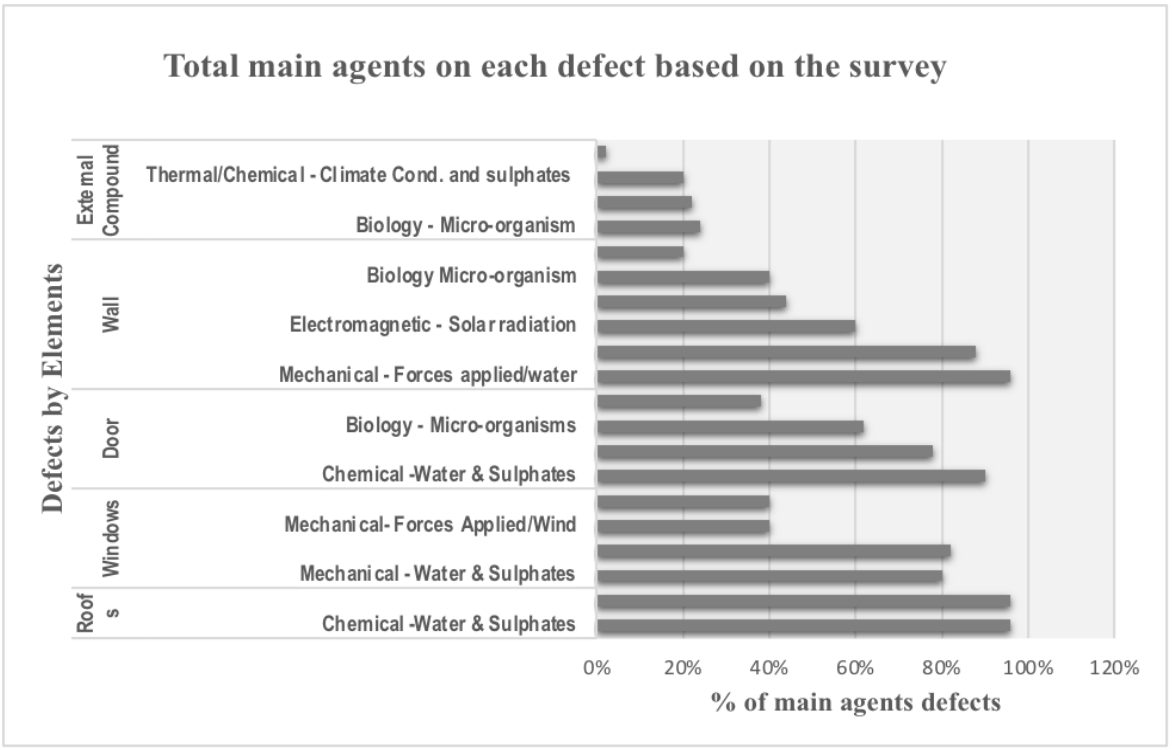

Figure 3 An assessment of the questionnaire survey on building defects and significant factors *affecting coastal environments*

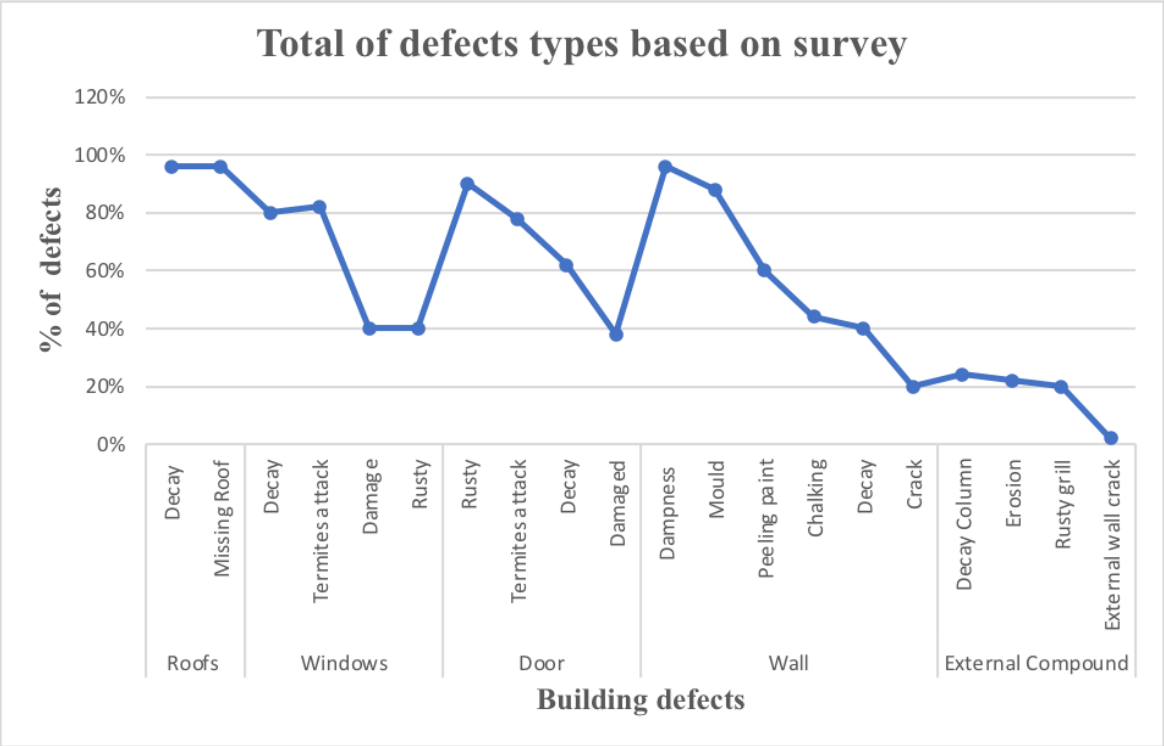

Figure 4 Total of defect based on the survey for coastal environment

Figure 3 and 4 shows the finding of a qualitative survey on building defects and agents that cause them. The finding on the different types of damages that can affect various building components, such as roofs, windows, doors, walls, and external compounds. For roofs, the most common causes of damage are chemical exposure to water and sulphates (96%) and mechanical forces such as wind (96%). Windows are also susceptible to chemical exposure (water and sulphates at 80%), biological damage from micro-organisms (82%), and mechanical forces such as wind (40%). Doors are prone to chemical exposure (water and sulphates at 90%), biological damage from micro-organisms (78% and 62%), and mechanical forces such as wind (38%). Walls can suffer from mechanical forces such as water (96%), biological damage from water and micro-organisms (88%), electromagnetic solar radiation (60%), and thermal climatic conditions (44%). External compounds are mostly affected by biological damage from micro-organisms (24%) and mechanical forces (22%), while thermal/chemical damage from climate conditions and sulphates (20%) is also a factor.

Overall, the table highlights the importance of considering different types of damage when selecting building materials and designing buildings that can withstand the specific environmental conditions they will be exposed to. It is also important to regularly maintain and repair building components to prevent further damage and ensure the longevity of the building.

Figure 5
Building at a Coastal Environment: Finishing Material Condition and Defects

Building 1	
Louver windows that have corroded	The door hinge is corroded.



Building 2

Electricity equipment and door hinge corrosion

Wooden wall decay and sticky surfaces on the walls (sea salt).


Building 3	
Paint peeling as a result of a damp and sticky surface (sea salt)	Louver windows that have corroded
	 

Building 4	
The metal part is rusted.	Wooden structure deterioration and crack
	 

Discussion and Analysis

Based on the analysis, it appears that all four buildings are facing issues related to the corrosive effects of a coastal environment. The high levels of salt in the air, along with the moisture and humidity, can cause significant damage to building materials over time.

For building 1, the corrosion of louver windows and door hinges in buildings built near the seaside are subject to seawater intrusion. This is a result of the coastal area's wind direction and speed (salt air) affecting the building. The corrosion may have weakened the structural integrity of the affected parts, potentially compromising the safety and security of the building. It is recommended to replace the corroded parts with materials that are more resistant to corrosion in a coastal environment.

Meanwhile for Building 2, the corrosion of electrical equipment and door hinges is caused by the exposure of saltwater to electrical appliances in the building. This form of corrosion occurs when two different metals with physical or electrical contact are immersed in a common electrolyte (such as salt water) or when a metal is exposed to different concentrations of electrolyte. When saltwater comes into contact with electrical equipment and door hinges, it can accelerate the corrosion process due to the presence of chloride ions. The seawater that condenses on building elements will finally evaporate, but the salt in the water will remain. This also results in the decay of the timber wall and its surface to be sticky. The sticky surfaces may be due to the salt in the air, which can accumulate on surfaces and make them difficult to clean. It is recommended to repair or replace the affected parts and use materials that are more resistant to corrosion and decay.

Next, building 3, is subject to seawater intrusion. The peeling of the paint due to dampness, sticky surface, and the corrosion of louvers windows are the symptoms that can be found in building 3. When salt water evaporates, it leaves behind a residue of salt crystals, which can make surfaces sticky. This is because the salt crystals attract and hold onto moisture from the surrounding air, creating a damp surface that can trap dirt and other particles. This is a result of the coastal area's wind direction and speed (salt air). The speed and the direction of the wind is determined by the weather of the area. The high levels of salt in the air can cause paint to peel and flake off, making the building look unsightly and potentially exposing the underlying material to further damage. It is recommended to remove the peeling paint, repair any underlying damage, and use paint that is designed to resist the effects of a coastal environment.

Rust on the metal component and decay of timber structure can be found in Building 4. In the coastal area, the quantity of moisture present in the air is higher than in the deserts. Hence, rusting of iron objects is faster. Biological damage to above-water parts of waterfront structures is caused directly or indirectly by the activity of fungi and insects that utilize wood for food or nesting material. The rust on the metal part can compromise its strength and structural integrity, while the deterioration and crack on the wooden structure may be a result of rot and decay caused by the high levels of humidity and moisture in the air. It is recommended to replace the rusted metal part with a more resistant material and repair or replace the deteriorated wooden structure to ensure the safety and stability of the building.

Epidemiologic evidence from primary studies and qualitative method analyses shows evidence of factors and main agents consistently associated to the defects found on the building at the Coastal Environmental. The examination of the data from the research study observational and qualitative methods reveals that there are essential parts that contributed to the building's defects. According to the type of defects that were discovered during the research study and data from the surveys, termite infestation, decay, rust, dampness, missing roofs, cracks, erosion, and mould growth were among the most common concerns at the buildings (Evans, 2005). Other building defects, such as chalking, honeycombing, and peeling paint occur often. Another defect found is the sticky condition on the walls surface. This is an uncommon defect as this defect only occur in coastal area buildings due the seawater intrusion. Both the observation and survey findings show similar defects found when analysing the data above.

Conclusion

The result interpretation has been laid out in this paper to confirm the contributing factors and main agents affecting building defects in the coastal environment of Malaysia from a case study. Based on observations and questionnaires, the prevention offered for coastal defects to limit future difficulties was investigated. Defects found in the coastal building area come in a variety of agents and types, as found by several researchers (Hanafi et al., 2018; Mydin et al., 2012). Saltwater and strong winds are huge problems for buildings near the sea (Mackenzie et al., 2018). The agents or consequences of moisture in the building will damage the element, causing a variety of defects such as rust (Bailey Rodriguez, 2018), decay, sticking, and mould growth. While mechanical causes result in damaged windows, doors, and missing roof parts. However, to prevent any major issues in the future, building owners need to maintain their buildings' safety and good condition. This study's findings suggest that building owners in the coastal area should consider materials that are stable against significant wind vibrations and can survive the reaction of the sea salt content.

Furthermore, the building owner is responsible for doing routine maintenance at their building by performing planned maintenance. For instance, by doing monthly and yearly scheduled maintenance. As a result of its ability to inspect the building and monitor its performance, it may also contribute to reducing building defects. Regular maintenance can help prevent costly repairs and extend the lifespan of building components. Additionally, it can improve energy efficiency and occupant comfort.

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