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Types of Damage to Heritage Buildings in Malaysia Caused by Plants: A Comprehensive Investigation

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Abstract

Plants are essential for creating a positive environment and enhancing the aesthetics of heritage buildings' surroundings. However, the presence of plants around historical buildings can jeopardise the integrity of the structures, making them unsafe for habitation. The objective of this research is to identify in detail the types of damage caused by plants to heritage buildings. This study employs a qualitative approach and relies on observations of 112 heritage masonry buildings recognised by the National Heritage Department (JWN). The types of plants in this study include plants that grow around buildings and epiphytic plants that grow on buildings. In-depth interviews were conducted with eight registered conservators who possess extensive experience in conserving heritage buildings. The collected data was analysed to form themes of damage to buildings caused by plants. The study identified seven categories of plant-caused damage to heritage buildings, offering crucial insights for conservators, local authorities, and building owners to take preservation actions.

Keywords: Building conservation; epiphytic plants; heritage building damages; landscape plants

Introduction

According to the National Heritage Act of 2005, heritage buildings are defined as buildings that exist in a group, separate or connected state and possess architectural characteristics and universal values that stand out from the standpoint of history, art, or science. These buildings—railway stations, mosques, prisons, schools, palaces, traditional Malay houses, Indian temples, Chinese shop houses, churches, clock towers, institutional buildings, and monuments—are valuable assets to the country, particularly in the tourism sector, and need to be preserved earnestly (Sodangi et al., 2014). As of 2020, the

National Heritage Department (JWN) has designated a total of 185 buildings as heritage buildings. Out of that total, 64 buildings have been designated as National Heritage Sites, while 120 have been designated as Heritage Sites. There are 173 masonry buildings listed, compared to 10 timber buildings and 2 mixed stone and wood structures. Most of these buildings are still in use as shops, workplaces, hotels, and museums. These heritage buildings have developed into tourist hotspots and given advantage to the country in attracting both local and foreign visitors due to the distinctiveness of their architectures and their historical significance. As a result, many of these structures are restored and preserved to ensure they remain in good condition and can continue to be used. However, there are numerous dangers to historic structures that will impair their functionality. Plants pose one of the threats to historic structures, but they are also a vital component of landscaping that improves the appearance and ambiance of a space. Involving plant experts such as landscape architects and arborists in building conservation work can prevent damage, reduce maintenance costs of heritage buildings, and simultaneously enhance the surrounding environment's aesthetics.

Literature Review

Damage to buildings can be divided into two categories: structural damage and non-structural damage. Structural damage refers to damage to components of the main structure such as load-bearing walls, columns, beams, and flat slabs. Non-structural damage refers to damage that does not affect the stability of a building such as damage to brickwork, moisture, and peeling plaster (Bakri & Mydin, 2014). Common building damages include damage to roofs, walls, floors, ceilings, toilets, doors, and windows (Hanafi et al., 2018, 2019). Previous studies have shown that plants can have an impact on heritage buildings, such as blockages in drainage channels caused by fallen leaves and branches (Ahmad, 2018; Ahmad & Rahman, 2010), peeling paint due to moisture (Bakri & Mydin, 2014), moss and lichen growth due to shaded moisture (Ahmad, 2018; Bakri & Mydin, 2014; Kayan, 2006), structural cracks due to root penetration (Ahmad, 2004, 2018; Caneva et al., 2009; Halwatura et al., 2013; Jim, 2013, 2018; Kayan, 2006; Lakshmipriya, 2008; Satriani et al., 2010; Uchida et al., 2015; Yadav, 2015), termite infestations where plants serve as habitats and food sources (Awang et al., 2020, 2021, 2023; Noirot & Darlington, 2000), and damage to heritage buildings caused by inefficient maintenance and lack of repair work (Baharuddin et al., 2022). However, research on plant invasions affecting heritage buildings is still limited, stemming from the lack of direct involvement of plant experts in

the conservation of heritage buildings in Malaysia (Ahmad, 1994; Kamal et al., 2010; Tan et al., 2016). The conservation of heritage buildings requires sustainable planning so that the value of heritage lasts longer and can be enjoyed by future generations (Abd Rahim et al., 2022).

Methodology

The objective of this research is to identify in detail the types of damage caused by plants to heritage buildings. This research focuses on masonry buildings and buildings of mixed types that have been designated as Heritage Buildings by JWN. Only 110 masonry and two mixed type buildings from a total of 175 heritage buildings were studied due to limitations in gathering information on-site caused by the Covid-19 pandemic. Masonry buildings were chosen because they are the oldest structures in Malaysia and frequently face threats from various factors including plants. This study employs a qualitative approach and uses on-site observation methods and in-depth interviews with experts for data collection. This method of observation employs equipment such as measuring tapes, cameras, and drones, inventory forms to record the types of damage to the buildings. The form was drawn up based on the heritage building dilapidation report template outlined by JWN. Meanwhile, the interview session was conducted using open-ended questions concerning the effects of plants on heritage buildings in Malaysia. Eight registered conservators recognized by JWN were chosen as respondents. The respondents have at least 15 years of experience and are actively involved in heritage building conservation in Malaysia. The criteria for selecting respondents are expertise, knowledge, experience, and having extensive reference sources related to conservation practices and issues. To comply with research ethics, the consultation sessions were conducted via phone, and after agreement was reached, an official letter was sent to each respondent through email. Participants also needed to complete a hardcopy consent form as proof of agreement to join the study. The conservators were labelled as K1 to K8 to protect their identities. The interview sessions lasted between 35 minutes to 1 ½ hours, depending on the respondents' replies and elaborations. To counter the risk of Covid-19, the interviews were conducted online via Google Meet. The interviews were also recorded on video to aid in transcription and data analysis. Following that, data from on-site observations and interviews were combined and analysed using thematic analysis methods to determine the types and causes of heritage building damage. As a result of this research, a comprehensive table detailing the types and causes of damage to heritage buildings in Malaysia was produced.

Findings and Discussion

Findings from the interview sessions and observations reveal that there are seven (7) types of damage to heritage buildings caused by plants.

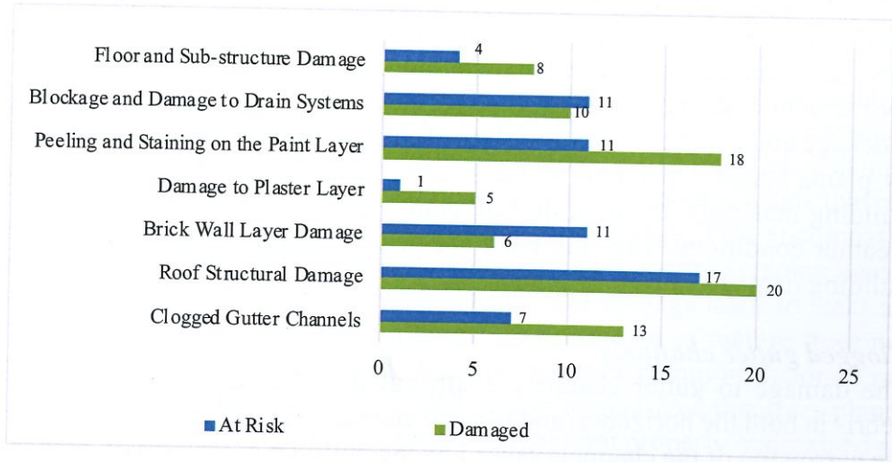

Figure 1: The number of heritage buildings in Malaysia at risk of plant damage

Table 1 Types of damage to heritage buildings in Malaysia

DATA COLLECTION METHOD		TYPES OF BUILDING DAMAGE CAUSED BY PLANTS						
		Clogged Gutter Channels	Roof Structural Damage	Floor and Sub-structure Damage	Brick Wall Layer Damage	Damage to Plaster Layer	Peeling and Staining on the Wall Paint	Blockage & Damage to Drain Systems
CONSERVATOR	K1	/	/	/	/	/	/	/
	K2	/	/	/	/	/	/	/
	K3	/	/	/	/	/	/	
	K4	/	/	/	/	/	/	
	K5	/		/	/		/	
	K6	/	/	/	/	/	/	
	K7	/	/	/	/		/	
	K8	/		/			/	

The observations showed that roof structural damage is the most encountered, followed by peeling and staining on the painted wall, blockage and damage to drain systems, clogged gutter channels, brick wall layer damage, floor and sub-structure damage and damage to plaster layer (Figure 1). The interview sessions revealed that the most common forms of damage encountered during conservation work are clogged gutter channels, floor and sub-structure damage and peeling and staining on the painted wall followed by roof structural damage, brick wall layer damage, damage to plaster layer and blockage and damage to drain system (Table 1). Each type of damage caused by plants varies depending on the situation such as the building's location, building materials, building design, plant types, environmental factors, and weather conditions. The following are details regarding the seven types of building damage caused by plants:

Clogged gutter channels

The damage to gutter channels is attributed to the accumulation of plant debris in both the horizontal and vertical channels. This damage occurs due to the narrowing of the channels caused by the build-up of dry leaves, branches, and other similar debris. As per K7's observations, gutter blockages result in the slowing down of rainwater flow from the channels to the collector drains, leading to an overflow of water from the drainage channels. The overflow of rainwater onto building walls leads to dampness, damage to wooden components, paint damage, and the growth of moss and other plants. Based on the interview sessions conducted, all respondents cited dry leaves as the most common plant debris that causes blockages in gutter channels. Additionally, K2, K4, and K6 also stated that dry branches and fallen fruits can also accumulate in the channels. Furthermore, K4 mentioned that fallen flowers can contribute to the blockage of gutter channels, although this situation rarely occurs. Observations revealed that 20 buildings were facing problems related to gutter channels. The most significant problems were found at the Seremban Railway Station in Negeri Sembilan, PULAPOL Kuala Lumpur, the Pejabat Ugama Melaka, and the King Edward VII Secondary School building in Perak. In addition, K3 stated that blockages in gutter channels can also occur due to invasion by plant roots that grow in the channel, causing it to narrow. K8 stated that these plants come from seeds that were not cleared away. They were deposited by birds and later grew to a size large enough to cause damage. Furthermore, K3 also mentioned that overgrown plants that grow on buildings will cause the entire channel to be clogged, leading to water overflow in the channel during rainfall. Observations showed that four (4) buildings were covered with parasitic plants, causing rainwater

overflow from the drainage channel. These buildings are the Johor Bahru Railway Station in Johor, the Kangar State Secretary Building in Perlis, the PULAPOL Sports Building (JKR 2076), and the PULAPOL Central Weapon and Armoury Workshop (JKR 2005) at PULAPOL.

Roof structural damage

Observations revealed two types of roof designs in heritage buildings in Malaysia: steep and flat roofs. Out of 37 buildings studied, 17 were found to have varying degrees of damage, while 20 were deemed to be at risk of damage due to visible signs of deterioration. Interviews with experts indicate that roof damage is primarily caused by trees near the buildings. This encompasses three situations: falling branches, fallen trees, and branches scraping against the roof. K1, K2, K6, and K7 explained that roof damage leads to leaks and increased humidity inside the buildings. The presence of mature trees near the buildings is identified by K1, K2, and K3 as a common factor in roof damage caused by falling branches. K7 further emphasized that trees planted near buildings pose a high risk of roof damage if not properly maintained and controlled. Serious damage resulting from falling branches was observed in three buildings at PULAPOL, where woody plants were planted too close to the structures without adequate control measures. Another instance of roof damage was observed at King George V Secondary School in Negeri Sembilan, where there is a herb garden containing large woody plants reaching the height of over 15 meters with a crown spread of 17 meters. The extent of roof damage depends on the size and weight of the branches, as well as the resilience and materials used in the roof construction. Apart from falling branches, roof damage was also attributed to fallen trees by K3, K4, K6, and K7. An incident at Kuala Dal Mosque was recounted where a durian tree with rotting branches was cut down as it leaned onto the building's column. Several nearby trees were also removed due to their susceptibility to breakage during storms. Observations demonstrated that fallen trees can cause severe damage to buildings, as evident at Kellie's Castle in Perak and the Sekolah Kebangsaan Tunku Putra in Kedah, where roof structures collapsed, necessitating costly repairs. Furthermore, observations indicated that fruit-bearing plants pose a risk to building roofs. Surau Jamhuriah in Kuala Besut, Terengganu, serves as an example, where jackfruit (Artocarpus heterophyllus) fruits fall onto the roof, fence, and surrounding areas. Although no damage has been reported thus far, this situation is considered a potential threat to this heritage building if not addressed and the tree properly maintained.

Brick wall layer damage

Loose brick bonds were found to occur due to plant root attacks that penetrate the brick bond layer. There are two ways in which roots can attack buildings, namely, plant roots growing on the building and nearby plant root intrusion. The interview results showed that respondents K1, K2, K3, K4, and K8 stated that root entanglement causes the loosening of the brick bond due to penetration and enlargement of tree roots over a long period. According to K4, the fine root structures of the plant entanglement would seek out soft spaces or mortar joints to penetrate, and then the roots would grow larger and push against the bricks. K1 explained that brick damage occurs when roots are left unremoved, allowing the plant to remain alive, and its roots will continue to grow and eventually cause structural damage to the building over a long period. K4 also stated that tree roots crawling and climbing on building walls can cause the same problem. Almost all the heritage buildings studied had plants entangled in their structure. The extent and condition of plant entanglement on a building depend on the building's maintenance management. Observations also showed that plant entanglement easily expands in high, hard-to-reach places and gaps in brick structures such as roofs, parapets, walls, and aprons. All respondents also stated that nearby plant root intrusion damages the main structure of a building, including the building walls. K1, K2, K3, K5, and K7 explained that wall damage is caused by roots growing beneath the building; enlarging and lifting the building structure, and thus damaging the walls. Observations showed 17 heritage buildings were threatened by root intrusion on their walls. Of the 17 buildings, five were seen to have significant damage, including cracked bricks on the walls of Kellie's Castle in Perak, elongated cracks on the walls of SMK King George V in Negeri Sembilan, cracked and broken walls of Pejabat Ugama Melaka and position changes as well as loose brick bonds on the walls of Gereja Christ and Muzium Yang Di-Pertua Negeri Melaka. Meanwhile, the walls of 12 buildings were found to be at risk of damage due to the large number of root circles around them and in the apron gaps of the buildings.

Floor and substructure damage

All respondents stated that root invasion results in serious damage to the main substructure underground. According to K1, there was a case where tree roots had lifted the floor structure, causing damage to the building's walls. Meanwhile, K2 recounted that tree roots near Fort Cornwallis were pruned and a retaining wall was built because they had attacked the foundation of the fortress. K7 explained that root intrusion in the sub-structure occurs due to a

lack of proper planning during tree planting. Trees that are planted too close to a building can cause cracks in the foundation and allow water in the soil to attack the structure of the building. This is concerning for the stability of the building as this type of attack cannot be seen by the naked eye. Therefore, root attacks in the soil can only be detected when the damage to the building becomes serious, such as cracks in the walls, lifted aprons, pillars that are increasingly distanced from the walls, and cracked or raised floors. Root attacks can be more clearly seen when conservation work is carried out, where investigations into damage are conducted in more detail. Observations found that 17 heritage buildings were threatened by root attacks on the substructure of the building. Four of them were found to be expected to be damaged based on serious damage to aprons, drains and walls. These buildings are Kellie's Castle in Perak, SMK King George V in Negeri Sembilan, Bangunan Pejabat Ugama Melaka (Muzium Islam Melaka), Gereja Christ Melaka, and Muzium Yang Di-Pertua Negeri Melaka. Meanwhile, 12 buildings were found to be at risk of damage due to large circles of roots around the buildings and tree branches that pass over and cover the buildings.

Damage to plaster layer

All respondents stated that plants affect the plaster layer of heritage buildings due to moisture under the shade of trees over a long period. Observations found that the most significant damage occurs on walls made of limestone, where the plaster would crumble and peel due to moisture absorbed over a long period. According to K2, to ensure that buildings receive adequate sunlight, it is recommended to trim large tree branches that are near the building or avoid planting large trees nearby. For instance, at the Sultan Abdul Samad Building, some plants were removed because of the high moisture level on the lower surface of the building walls. K2 also emphasized the importance of considering the growth of trees in the next 10 years when planning to plant them. K1, K2, K3, K4, K6 and K8 stated that damage to the plaster layer is also identified due to the attack by plant roots penetrating the layer. K1 stated that damage commonly occurs to the plaster layer of limestone due to the overgrowth of tree roots on a building. K6 added that root attacks will push the brick walls, which eventually causes the plaster layer to peel off. In addition, K4 also stated that climbing plants attached to walls cause damage to the plaster layer on building walls. On-site studies found that several species of climbing landscape plants were deliberately planted to cover certain building walls for decorative purposes. This caused the covered area to become constantly damp, and moss damage occurred on the plaster layer due to the penetration of tree roots.

Peeling and staining on the paint layer

Damage to the paint on heritage buildings was identified in two situations: peeling and contamination with stain. A total of 29 buildings were identified with paint damage. K7 explained that the existing moisture disrupts the paint adhesive, which is closely related to tropical weather, such as consistent rain and heat throughout the year. K1 also supported that moisture in buildings caused by shade trees results in paint damage on heritage buildings in Melaka. Observations found that heritage building walls shaded by plants are always cool and damp. The colour difference on damp walls results in uneven, faded, and easily removable surfaces when touched. It was also observed that uncleaned plant debris on the ground causes environmental and building dampness. This situation was also supported by K1, who said landscape plants often shed leaves in Melaka city, causing the entire building area to become damp, damaging the paint. K1 further explained that paint damage occurs due to the invasion of plant roots on buildings. K4 added that climbing plant roots attached to walls cause the lime to dry and chip off. Stain from moss formation on buildings occurs when a building is shaded for a long period. This was supported by K2, K4, K5, K6, and K7, who corroborated that plants shading heritage buildings and their surroundings cause buildings to remain damp, facilitating moss growth. Observations showed that morning and evening sunlight are key factors in moss growth on buildings. This happens at locations like the Perpustakaan Awam Taiping, Masjid Ampang Pecah, King Edward V Secondary School, and Suluh Budiman Building, where dense canopy plants are planted around the structures, keeping the vicinity cool even in midday heat. K2 stated that moss formation changes the wall colour to green even after cleaning, requiring repainting.

Observations found that lower walls, floor edges, and drains are most susceptible to moss due to the presence of planter boxes, shrubs, and pots. Building stain also occurs due to bird droppings, bat faeces, bat food waste, and rotten fruit. According to K2, K3, K4, K5, and K8, bats often leave fruit waste and droppings on buildings. K8 stated that this happens on unoccupied heritage buildings. K2 mentioned bats in Penang heritage buildings that damage newly painted walls with their droppings and waste, affecting the buildings' aesthetics. K4 added that bats invite pests which could cause health issues for inhabitants. Additionally, K8 mentioned that bird droppings cause damage and stains on window louvres at the Jugra tower. K4 also stated that birds perching on trees leave droppings on heritage buildings. Observations showed that birds use large trees next to buildings as perches at night, like at the Municipal building in Penang. The effect of droppings on

buildings is evident on white walls. Observations also found that fallen fruits on walls, floors, aprons, and drains dirty the building. However, this situation does not cause serious damage but only damages the paint on walls, aprons, barriers, and drains.

Blockage and damage to drainage systems

Blockage of drainage systems is identified as caused by the accumulation of plant debris over a long period. This condition is found to impede the flow of water, which along with the decaying plant debris, leaves sediment behind. These remnants provide a medium for the growth of weeds. This is often found to occur in poorly maintained buildings that are not cleaned regularly. According to K1, drainage blockage caused by dried leaves is due to the presence of tree branches that extend over the building roof. Meanwhile, K2 stated that drainage channels are less susceptible to plant infestation because maintenance work is often carried out and is easily accessible compared to the roof. K1 added that the problem with drainage systems is closely related to maintenance weaknesses, such as not managing plant debris like leaves, which makes building damage worse. In addition to dry leaves, observations showed that fallen flowers and fruits also accumulate in the drainage systems. The locations involved include the Jamhuriah Surau in Kuala Besut, King George V Secondary School in Seremban, the State Secretary Building in Perlis and the Leboh Acheh Malay Mosque in Penang. The presence of fruits and flowers is not as much as dried leaves, but it is also seen to contribute to the increase in debris in the drainage system. However, if these remnants are not cleaned, they can accumulate daily and become substantial. There is a situation where damage to the drainage system is caused by tree roots planted near buildings. This can be seen at the King George V Secondary School in Seremban, where the drainage channel becomes narrow and uneven from being pushed by tree roots under the building. It can also be observed at the Big School of the MCKK building in Perak, the Municipal building in Penang, the Ipoh Court, the Land Survey Office in Negeri Sembilan and the State Secretary Building in Perlis, all of which experience cracks in their drainage structures due to the penetration of nearby tree roots.

Conclusion

In conclusion, plants have an impact on the structural integrity of buildings, whether it is damage to structural or non-structural components. Remnants of plants such as leaves, fruits, flowers, and branches are major contributors to damage in heritage buildings, such as blockage of drainage channels, roof

damage, blockage of gutter channels, and damage to paint layers. However, these plant remnants mostly only cause damage to non-structural components such as roof tiles, drainage channels, gutters, plaster layers, and paint layers. In contrast, in root attacks, even though the attacks are focused on the foundation of a building due to strangulation by plant roots, the level of damage caused by roots is highly serious because it attacks the structural components of the building. The stability of the building is more threatened by root attacks compared to the effects of plant debris. Underground root attacks are difficult to detect because they target the foundation of the building, which cannot be seen by the naked eye. Cracked floors or walls serve as a warning that the foundation of the building may have been attacked. Confirmation of damage requires further studies such as excavation work to be carried out. Therefore, plant attacks need to be given attention to in order to prevent more serious damage in the future. It must be noted that the presence of plants is necessary for the beautification of a heritage building's environment, making it more attractive, especially to support the heritage tourism industry. Thus, these findings are crucial for further studies in the future because not all plants harm heritage buildings. Each plant has its characteristics, and a study of plant traits can determine, which plants are suitable for use in the landscapes of heritage buildings in Malaysia, ensuring that they do not pose a threat or cause damage to heritage buildings in the long run.

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