

A REVIEW ON THE IMPACTS OF PLANTS TOWARDS HERITAGE BUILDINGS

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ABSTRACT

Plants have always been as one of the important aspects in human life. Their existence creates ecological and environmental system which beneficial to the human beings. For urban area that highly occupied by concrete buildings, plants could help in filtering dust, reducing noise pollutions, and controlling surrounding temperature. However, in urban area with heritage buildings, plants have been identified to be one of the contributors towards some damages. Such damages would cause these heritage buildings to be easily ruined and not safe to live in not to mention with its age dated to hundreds of years ago. Hence, the purpose of this research is to identify the effects impacted by plants to the heritage buildings. This research is in a qualitative form with an observation and document review method. Based on the research outcomes, the plants do affect the components of the buildings such as its humidity, salt attack and structure damage through roots invasion and attack by pests. Thus, a very careful and detail procedure must be implemented in selecting types of plants so they can be utilizing in a positive way towards the landscape and environment of the heritage buildings. It is not just preventing the old buildings from potential damages and its conservation, but also could contribute to the aesthetic value as well as bring back some of its nostalgia.

Keyword: Plants, heritage buildings, heritage conservation

ABSTRAK

Tumbuhan merupakan salah satu elemen penting dalam kehidupan manusia. Kewujudan tumbuhan berupaya membentuk persekitaran hidup yang sihat kepada manusia. Bagi kawasan perbandaran, tumbuhan bertujuan sebagai penapis habuk, mengurangkan pencemaran bunyi dan mengawal suhu persekitaran yang dipenuhi dengan bangunan konkrit. Namun begitu, di kawasan bandar yang mempunyai bangunan warisan, tumbuhan dikenalpasti menjadi salah satu penyebab kepada kerosakan bangunan tersebut. Kerosakan-kerosakan ini akan menyebabkan bangunan warisan akan mudah rosak dan tidak selamat untuk didiami. Ditambah pula kebanyakan bangunan warisan telah berusia ratusan tahun. Oleh yang demikian, kajian ini adalah untuk mengenalpasti kesan-kesan yang disebabkan oleh tumbuhan terhadap bangunan warisan. Kajian ini adalah berbentuk kualitatif dengan menggunakan kaedah pemerhatian dan kajian literatur. Hasil dari kajian mendapati tumbuhan memberi kesan kepada bangunan seperti kelembapan, serangan garam dan kerosakan struktur melalui serangan akar. Justeru, pemilihan tumbuhan perlu dilakukan dengan teliti supaya tumbuhan dapat dimanfaatkan sebaiknya kepada landskap bangunan warisan dan juga persekitaran. Hal ini bukan hanya dapat menyelamatkan bangunan warisan daripada terus rosak, malah ianya memberi nilai estetika dan mengembalikan nostalgia kepada bangunan tersebut.

Kata kunci: Tumbuh-tumbuhan, bangunan warisan, konservasi bangunan

1.0 INTRODUCTION

Plant is important to human life not just as the food source but also balancing the earth ecosystem. For urban area, it needs plants to reduce the noise pollution, filtering dust, protection against the sunlight's reflection and balancing the surrounding temperature emitted from the nearby buildings. The presence of plants within urban area could create a healthy environment as well as brings out the aesthetic values towards its landscape (Hasan, Othman, & Ahmad, 2016). The significance of plants as the element of urban landscape has been

established in National Physical Plan (NPP) and interpreted by State Structure Plan (SSP), Local Plan (LP), Special Area Plan (SAP), National Urban Policy (NUP) and National Landscape Policy (NLP). The Town & Country Planning Act 1976 (Act 172) stated in the section VA of the Tree Preservation Order (35A to 35H) that the need for the preservation of trees is one of the strategic planning methods for urban and rural areas. Hence, every urban area must implement the plants into their landscapes not just for aesthetic value but also towards a sustainable city.

However, for some urban cities which possess hundred years old buildings such as in Perak, Pulau Pinang, Kuala

Lumpur, Malacca and Sarawak, the plants surrounded the heritage buildings are proved to give bad impact to the buildings' structure. Plants not just endanger the urban surroundings but also affect the buildings maintenance (Sim, 2015). Generally, cities not just consist of new buildings and towers but also occupied by old ones which most of it have been a starting point in the development of the cities. Maintenance works for the heritage and old buildings are quite different from the new one because such buildings are not subjected to the current Building Code. Its construction and evaluation must based on the standards set up during its time of construction and conservation (Bakri & Mydin, 2014).

Old buildings possess high historical virtues with its own architectural details which need to be preserve continuously to keep their values of heritage, architectural, aesthetic, archaeological, spiritual, social, political and economical on (Kamal & Harun, 2002). Hence, heritage buildings need to be preserved and protected to increase their durability (Idrus, Khamidi, & Sodangi, 2010). Some damages on the buildings resulted from the plant impacts have been part of problems in preserving and conserving the historical heritage. Plus, the preservation efforts for the heritage buildings due to plants impact are not taken seriously by the conservators. This is because the solution for those problems are always through cutting off the trees and plants that already there and reducing activity of replantation at the surrounding area after the conversation works are done (Ahmad, 2018). In efforts of conserving the heritage buildings, any kind of threats should be avoided to preserve its durability and prolong its lifespan for the future generations.

2.0 OBJECTIVE AND METHODOLOGY

Based on those issues, this research aims to identify effects caused by plants towards the heritage buildings. This research will be conducted in qualitative mode through observations method and document reviews. The observations method was conducted in Pulau Pinang at Rumah Teh Bunga (Floral Tea Mansion) at Hutton Lane, Historical City of Malacca and Kampung Gadong mosque at Rembau, Negeri Sembilan. The observation was also being conducted in Cambodia at the one of Angkor temples namely Ta Prohm Temple (the location for Tomb Raider film). The selection of the temple is because it is the only one of the major temples in Angkor region severely threatened by plants. Meanwhile, the document reviews method was handled based on secondary sources such as articles, journals, theses, slides and websites. Half of the documents are from 2010 to 2020. Documents that are over 10 years are also used as supported data as it still in line with the latest documents. Finally, the data was analysed by using image analysis and text analysis.

3.0 HERITAGE BUILDING IN MALAYSIA

Based on National Heritage Act 2005, heritage buildings are defined as a type of building that exist either in cluster, singular or terrace due to its architectural characteristics, homogeneity, landscape, that possess remarkable universal values from the perspectives of history, art or science. The heritage buildings in Malaysia are also defined as historical buildings with four categories of main architectural values which are Moorish, Tudor and Neo-classical (Ahmad, 2002). Besides, the heritage buildings exhibit architectural and historical values influenced by some architectural elements from Traditional Malay, Portuguese, Dutch and British (Salleh & Ahmad, 2009). Heritage buildings have their own authentic heritage and historical evidence which need to be preserved properly (Harun, 2011; Mitra, Grover, & Sing, 2013).

Furthermore, heritage buildings have potential to serve as tourism attractions through their historical values such as railway stations, mosques, prisons, schools, palaces, traditional Malay houses, Indian temples, Chinese shop houses, churches, clock towers, institutional buildings, monuments etc. (Sodangi, Khamdi, Idrus, Hammad, & AhmedUmar, 2014). This is because the heritage buildings represent the invisible cultures for particular local community (S. Y. Tan, Olanrewaju, & Lee, 2016). The heritage buildings are also defined as building that lost its original function and practicing reuse concept in order to preserve its heritage and identity for the future generation (Benhamou, 2003; Mısırlısoy & Günçe, 2016).

4.0 GENERAL ISSUES IN CONSERVING HERITAGE BUILDINGS

Heritage buildings in Malaysia have been facing damage issue in their structure due to poor maintenance practice and its old condition with hundreds of years of age. The damages in Malaysia buildings often caused by poor handling in maintenance work (Wee, 1992), lack of knowledge in building conservation (Ahmad, 1994; ICOMOS, 2000) that lead the conservators to unable to identify proper method in solving the conservational issue (S. Y. Tan et al., 2016). Because of that, many heritage buildings in Malaysia do not have proper management and are left out unattended. Damages not just occurred to old buildings but also new ones. The difference is, the new buildings are subjected to its own building code and etiquette but old buildings do not tied to any standard during its construction and only require to do some maintenance works (Bakri & Mydin, 2014). Therefore, the fact that heritage buildings have been existing for such a long period of time exposed themselves to more problems including damages caused by the presence of plants. Such condition attracted some plants to grow attach to the buildings as they serve as perfect support especially to crawling plants (Jim, 2018).

Numbers of researches show that the age of building could also contribute to the damage of the heritage buildings. Most of the heritage buildings dated back to hundreds years ago that vulnerable to more damages (Bakri & Mydin, 2014; Idrus et al., 2010). This factor also shows that the heritage buildings are fragile and less resilient for long period of time and requires continuous maintenance. This is because most heritage buildings were constructed and built with porous and brittle materials such as soil, wood, lime, mortar and fired clay (Clim, Groll, & Diaconu, 2017; Halim & Halim, 2010). Such materials contain minerals that able to absorb any moisture hence providing required nutrients for the plants to attach their roots on (Jim, 2013). With these materials as the basic foundation of the buildings, frequent survey and maintenance need to be run towards any detected damages to prevent collapse in a short-term effect.

Humidity problem always happening to the heritage buildings due to tropical climate that caused dampness as well as lack of sunlight exposure resulted from being covered underneath the plant canopies and then lead to moss production (Giulia Caneva et al., 2015). The humidity problem also caused by some methods and techniques applied in the construction work of the heritage buildings. Most of the heritage buildings with the colonial architectural style built before earlier 1900s didn't use Damp-Proof Course (DPC) to prevent direct moisture absorption to the floor and upper part of the buildings (Young, 2008). The high humidity level that happen continuously on the wall surface could cause greenish stains to build up on the external parts of the building (Jim, 2018). The dampness on the external surface not just causes high humidity on the internal walls as well but also bring salt together with it that will lead to porous masonry due to salt crystallization process (Ahmad & Rahman, 2010).

5.0 PLANT PROBLEMS TOWARDS THE HERITAGE BUILDINGS

Some issues faced by most heritage buildings in Malaysia are related to its surrounding plants and trees. The hitchhiking plants are tend to grow and attach to old buildings such as palaces, forts, cemetery, ritual places, and archeological locations (Giulia Caneva et al., 2015; Giulia Caneva, De Marco, Dinelli, & Vinci, 1992; Giulia Caneva, De Marco, & Pontrandolfi, 1993; G Caneva, Galotta, Cancellieri, & Savo, 2009). Not just that, plants that grow on the land could also affecting the heritage buildings.

Climate also plays a major role in causing damage to heritage buildings. The tropical climate gives an advantage to the plants to grow effectively at different types of locations including walls and joints of stone blocks on the building (Jim, 1998, 2010, 2013, 2018). Therefore, problem regarding plants' invasive nature toward the heritage buildings in the tropical climate area need to be focused in order to conserve and preserve the buildings.

Some of the effects can be attributed to the destruction caused by the existence of plants in heritage buildings such as increase in humidity and salt in buildings, impacts of the building and landscape maintenance, cracks in the building components, growth area of hitchhiking plants, tree as pest host, plants management by the conservator and plant management by conservators.

5.1 Increase in Humidity and Salt in Buildings

The presence of plants surrounding the building area could cause dampness and high humidity on the wall surface and internal parts that then activates moss and green stain production (Ahmad, 2018; Kayan, 2006). Such cases can be observed on Angkor temples in Cambodia which the plant canopies are appear to prevent the sunlight to reach the building surface and created moss, shady and damp area (Giulia Caneva et al., 2015). This situation also occurs in the temple of Ta Prohm where high humidity due to plant canopies covering the temple floor promote fungi, algae and moss growth. Besides, moss and fungi that grow there could emit spores into the air that can lead to harmful threat and endanger the occupants' health (Bakri & Mydin, 2014).

Trees or plants that grow around the heritage buildings will also clog the drainage system on the roof area due to the trapped twigs and leaves in it. This situation not just increase the humidity level in the building but also decomposing the salt because of the rotten leaves and twigs in that drainage system. If the minerals are absorbed by the clay masonry-type of building, their structures will be porous due to a long-term salt crystallization process (Ahmad, 2018; Ahmad & Rahman, 2010). Moisture and salts are interconnected and need to be addressed to ensure the building remains standing.



Figure 1. Dampness level on the walls of Ta Prohm temple, Cambodia causing moss and green stains due to plant or tree canopy blocking the sunlight from reaching the lower part.

5.2 Impacts of the Building and Landscape Maintenance

Based on the current landscape maintenance in the heritage building area, plants watering and fertilizing should be reduced to prevent the increase in humidity and salt absorption levels (Young, 2008). This also causes stunt growth in ornamental plants that will produce such poor

landscape view visually. Besides, lower level of nutrients and water on the other hand will force the roots to move further towards the buildings to get nutrient and water source. Furthermore, the bricks manufacturing process requires some important elements such as Fe, Mn, Zn, Cu, SO₂ and NO₂ where these elements are macro nutrients for plants' growth (Sikder, Begum, Parveen, & Hossain, 2016). Therefore, bricks could also act as a good plantation medium especially for crawling, climbing, and hitchhiking-types of plant. Damp soil can activate mineral salt to be absorbed through the building structure. Fertilization practice also provide source of salt to the plant medium (Young, 2008). Both practices not just making the plant to grow better but also providing salt to the heritage buildings which already in poor condition.



Figure 2. Picture of before and after the presence of ornamental plants at the both sides of of St. Paul & Santiago Gate/A' Famosa's entrance, Jalan Kota Melaka, the word 'Melaka already diminished from the building. (Source: website ntqt.com.my)

5.3 Cracks in the Building Components

Research also identifies that the plant roots could also cause damages to the heritage buildings. Plant roots capable in causing some cracks to the building structures especially on walls and pavement (Ahmad, 2004, 2018; G Caneva et al., 2009; Halwatura, Jayawardena, & Somarathna, 2013; Kayan, 2006; Satriani, Loperte, Proto, & Bavusi, 2010; Yadav, 2000). For masonry building with non-mortar materials in seam components, the roots can protrude easily (Uchida et al., 2015). This situation often happens in a tropical climate area where the roots can be more invasive compared to area with smooth surface (Jim, 2018).

Buildings and pavement area facilitate the growth of the plants either from local or exotic species with the support of pollination activities through wind, animals, and human as their spreading agents (Jim, 2013). Besides, roots of crawling type of plant such as ivy can cause some cracks on the walls of the heritage buildings as well as contributing to water leaking through the structures (Ahmad, 2004; Hollis, 2005; Kayan, 2006). This condition creates dampness not only on the external part but also the internal part of the buildings.



Figure 3. Picture shows before and after the component damage of the building due to plant invasion in Kg. Gadong mosque, Rembau Negeri Sembilan. (Source: website ntqt.com.my)

5.4 Growth Area of Hitchhiking Plants

Plant likes fig (*Ficus* sp.) that always been a popular choice for urban landscape are actually threatening the heritage buildings because they are epiphytic in nature and also belong to some type of hitchhiking plants (Jim, 2010, 2018). Trees that are *Ficus* species possess aerial roots that capable to tie up or hang onto nearby buildings. For example, *Ficus benghalensis* tied or choked up the steel railing that has been built since 1860s in Old Brisbane Botanic Gardens, Alice Street boundary (Sim, 2015).

The pollination process of such plants is easy because some of their fruits are food source to the birds. Just like in Ta Prohm's temple, Cambodia. The seeds that fall onto the temple surface eventually grow due to the nutrient source that available there. When the plants continue to grow bigger, their roots then keep expanding and causing the bricks to move apart from each other thus damaging the temple's walls (Lakshmipriya, 2008). The presence of this type of plants should be considered as serious threat towards heritage buildings because their capability to cause intense damages to the structures.



Figure 4. Domination of the plant's roots damaging the structures of Ta Prohm's temple, Cambodia.

5.5 Tree as Pest Host

Plants are one of the habitats that support the termite and carpenter ants. Termites are identified to live in the dead wood or dead components of tree such as logs and stumps where it require moisture to build nest (Noirot & Darlington, 2000). This could cause the trees to break down and fall

when exposed to strong wind that also endangers the nearby surrounding area (Conquer Termites, 2020). This directly will harm and threaten the occupants and nearby buildings. Termites exist and inhabit tropical and subtropical regions either in damp or dry conditions including countries in Africa, South America, and South East Asia (Verma, Verma, & Sharma, 2018). Termites are one of the main enemies for buildings constructed by using woods as their materials. Termites are so hard to detect and trace due to their nature in invading and inhabiting the internal components of the dead wood and could survive within the cracks of the concrete buildings. The termites of the subterranean type (*Coptotermes curvignathus*) bring damage to the timber structure as well as the concrete foundation of the building (M. Tan, 2009). For the buildings constructed with bricks and concrete materials, the wood components are usually located at the roof area which is difficult to reach due to its high position from the ground. Because of that, any inspection and maintenance on the structural damages is hard to carry out. Fragile plants are not a suitable material to be used because it will attract more termites to build their colony. Termites can be found in the building area surrounded by plants and trees because this insect usually builds their nest in the form of arboreal nest, tree trunk nest, tree stump nest, mound nest and embedded nest in landscape timber (Conquer Termites, 2020). The probability for the termite colonies to move from one place to another is high if there are trees and plants located near the buildings.

Besides termites, carpenter ants (*Camponotus ferrugineus*) also threaten heritage buildings. Although these ants do not eat wood, they damage the wood structure to build colonies (Johar, Ahmad, Che-Ani, Tawil, & Usman, 2011). Compared with termites, carpenter ants attack was not so severe, but it is necessary to avoid the existence of this colony because the same life pattern with termites inhabiting a fragile and dead plant. Plants of such nature should be avoided so that these pests do not migrate to heritage buildings.

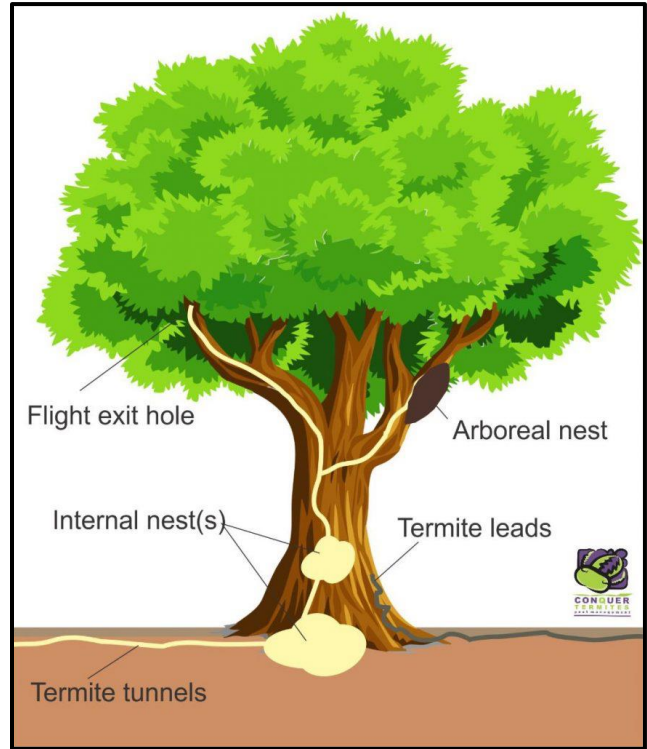


Figure 5. The condition of the tree after was attacked by the termite. Source: website conquertermites.com.au)

5.6 Plants Management by the Conservator

Due to the serious damages done by the plants onto the heritage building, there are two measures taken by the conservators to help dealing with such problems; - cut off the nearby trees and minimize the number of plants after completing the conservation project. The cutting off process usually will be carried out after the building inventory works before the conservation. Besides reducing the maintenance works on the heritage building, some landscape plants are not being planted anymore or reducing its number after completing the conservation work (Ahmad, 2018). Based on projects handled by NTQT, only turf grass and red palm (*Cyrtostachys renda*) is planted on the frontyard area of Rumah Teh Bunga in Pulau Pinang. While, the mango tree (*Mangifera indica*) at the side of Ayer Barok mosque had been removed after conservation work. This situation could certainly save the buildings but it effects the spirit and nostalgia values of the place compared to the atmosphere before the conservation work. This was driven by lack of scientific understanding and nature of plants is often a problem in preserving old buildings (Jim, 2010). In addition, the lack of knowledge in building conservation has led to poor and inadequate solution methods (Ahmad, 1994; S. Y. Tan et al., 2016).



Figure 6. Photo of Rumah Teh Bunga, Pulau Pinang before the presence of surrounding plants and the house after the conservation work taken place showing only turf grass and red palms (*Cyrtostachys renda*) as the landscape main elements. (Source: website ntqt.com.my)



Figure 7. Conservation work in Ayer Barok mosque, Malacca showing the presence of mango tree (*Mangifera indica*) at the side of the mosque. (Source: website ntqt.com.my)

6.0 CONCLUSION

As a conclusion, plants capable in causing damages to the heritage buildings. The damages caused by the plants can be observed in a long-term effect which this situation often unnoticed by the building owner. This is because it is plants nature to keep growing bigger continuously from time to time. If the people who responsible for tree planting ignoring its physical maturity, the building occupants may be affected

in the future. The plant morphology also needs to be acknowledged because specific plant requires specific nutrient obtained through its own physiological process.

However, not all plants can bring damage to the heritage building and it depends on what type of plants selected to be planted nearby the buildings. Therefore, it is compulsory to study the characteristic and nature of plants scientifically to understand the level of damage they can bring to the building as well as to identify plants that are compatible with the heritage building. Before taking step to do a plantation project, the selected plants should be studied in term of its traits and morphologies to ensure no damage and harm can be done to the heritage buildings that already in a poor condition. In effort to comply with the regulations and policies towards sustainable nation, research on plants is significant since it can be considered as one of the elements needed to realize the mission. The historical buildings also in need of detail and careful conservation and preservation to create a country with identity.

References

- Ahmad, A. G. (1994). *Conservation of British colonial buildings built between 1800 and 1930 in Malaysia*. University of Sheffield,
- Ahmad, A. G. (2002). *Challenges of Colonial Heritage Buildings in Malaysia*. Paper presented at the Proceedings of the International Conference on the Politics of World Heritage, The University of North London, UK.
- Ahmad, A. G. (2004). Understanding common building defects: the dilapidation survey report. *Majalah Arkitek*, 16(1), 19-21.
- Ahmad, A. G. (2018). *Treatment of Rising Damp and Salt Attack in Heritage Building*. GTWHI Heritage & Conservation Workshop.
- Ahmad, A. G., & Rahman, H. F. A. (2010). Treatment of salt attack and rising damp in heritage buildings in Penang, Malaysia. *Journal of Construction in Developing Countries*, 15(1), 93-113.
- Bakri, N. N. O., & Mydin, M. A. O. (2014). General building defects: causes, symptoms and remedial work. *European Journal of Technology and Design*(1), 4-17.
- Benhamou, F. (2003). *Heritage* (1840643382). Retrieved from
- Caneva, G., Bartoli, F., Ceschin, S., Salvadori, O., Futagami, Y., & Salvati, L. (2015). Exploring ecological relationships in the biodeterioration patterns of Angkor temples (Cambodia) along a forest canopy gradient. *Journal of Cultural Heritage*, 16(5), 728-735.
- Caneva, G., De Marco, G., Dinelli, A., & Vinci, M. (1992). The wall vegetation of the roman archaeological areas. *Science and technology for cultural heritage*, 1, 217-226.

- Caneva, G., De Marco, G., & Pontrandolfi, M. (1993). *Plant communities on the walls of Venosa Castle (Basilicata, Italy) as biodeteriogens and bioindicators*. Paper presented at the Conservation of stone and other materials. Vol. One: causes of disorders and diagnosis. Vol. Two: prevention and treatments. Proceedings of the international RILEM/UNESCO congress... Paris, June 29-July 1, 1993.
- Caneva, G., Galotta, G., Cancellieri, L., & Savo, V. (2009). Tree roots and damages in the Jewish catacombs of Villa Torlonia (Roma). *Journal of Cultural Heritage, 10*(1), 53-62.
- Clim, D.-A., Groll, L., & Diaconu, L.-I. (2017). Moisture—the Main Cause of the Degradation of Historic Buildings. *Buletinul Institutului Politehnic din Iasi. Sectia Constructii, Arhitectura, 63*(3), 65-78.
- Conquer Termites. (2020). HOW TO TREAT TERMITES IN A TREE OR STUMP. Retrieved from <https://conquertermites.com.au/services/found-termites-in-a-tree-stump-what-should-i-do/>
- Halim, A.-H. A., & Halim, A. Z. A. (2010). An Analysis of Dampness Study on Heritage Building: A Case Study Ipoh Old Post Office Building and Suluh Budiman Building, UPSI, Perak, Malaysia. *Journal of Sustainable Development, 3*(4), 171.
- Halwatura, R., Jayawardena, V., & Somarathna, H. (2013). Identification of damages to building structures due to roots of trees.
- Harun, S. (2011). Heritage building conservation in Malaysia: Experience and challenges. *Procedia Engineering, 20*, 41-53.
- Hasan, R., Othman, N., & Ahmad, R. (2016). Tree Preservation Order and its role in enhancing the quality of life. *Procedia-Social and Behavioral Sciences, 222*, 493-501.
- Hollis, M. (2005). *Surveying buildings*: Royal Institution of Chartered Surveyors.
- ICOMOS. (2000). ICOMOS World Report 2000 on Monuments and Sites in Danger. Retrieved from https://www.icomos.org/risk/world_report/2000/tr_ends_eng.htm
- Idrus, A., Khamidi, F., & Sodangi, M. (2010). Maintenance management framework for conservation of heritage buildings in Malaysia. *Modern Applied Science, 4*(11), 66.
- Jim, C. Y. (1998). Old stone walls as an ecological habitat for urban trees in Hong Kong. *Landscape and Urban Planning, 42*(1), 29-43.
- Jim, C. Y. (2010). Old masonry walls as ruderal habitats for biodiversity conservation and enhancement in urban Hong Kong. *Urban biodiversity and design. Blackwell, Oxford, 323-347*.
- Jim, C. Y. (2013). Drivers for colonization and sustainable management of tree-dominated stonewall ecosystems. *Ecological engineering, 57*, 324-335.
- Jim, C. Y. (2018). Epiphytic strangler trees colonizing extreme habitats of building envelopes in Hong Kong. *Landscape and urban planning, 178*, 281-291.
- Johar, S., Ahmad, A. G., Che-Ani, A. I., Tawil, N. M., & Usman, I. M. S. (2011). Analisa kajian lapangan ke atas kecacatan pada bangunan masjid lama di Malaysia. *Journal Of Design+ Built*(2).
- Kamal, S., & Harun, S. (2002). *Building research methodology in the conservation of the historic buildings in Malaysia*. Paper presented at the Proceedings of the International Symposium Building Research and the Sustainability of the Built Environment in the Tropics, University Tarumanagara, Jakarta, Indonesia.
- Kayan, B. (2006). Building maintenance in old buildings conservation approach: an overview of related problems. *Journal of Design and Built Environment, 2*(1).
- LakshmiPriya, T. (2008). *Conservation and restoration of Ta Prohm temple*. Paper presented at the Proc. of VI International Conference on Structural Analysis of Historic Construction, D'Ayala, D. and Fodde (Eds).
- Malaysia. (2005). *Town and Country Planning Act 1976 (Act 172): as at 10th August 2005*: International Law Book Services.
- Mısırlısoy, D., & Günçe, K. (2016). Adaptive reuse strategies for heritage buildings: A holistic approach. *Sustainable Cities and Society, 26*, 91-98.
- Mitra, S., Grover, A., & Sing, R. (2013). Handbook of conservation of heritage buildings. *Nirman Bhawan, New Delhi: Directorate General, Central Public Works Department, 101*.
- Noirot, C., & Darlington, J. P. (2000). Termite nests: architecture, regulation and defence. In *Termites: evolution, sociality, symbioses, ecology* (pp. 121-139): Springer.
- Salleh, N., & Ahmad, A. (2009). *Fire safety management in heritage buildings: The current scenario in Malaysia*. Paper presented at the 22nd CIPA Symposium.
- Satriani, A., Loperte, A., Proto, M., & Bavusi, M. (2010). Building damage caused by tree roots: laboratory experiments of GPR and ERT surveys. *Advances in Geosciences, 24*, 133-137.
- Sikder, A. H. F., Begum, K., Parveen, Z., & Hossain, M. F. (2016). Assessment of macro and micro nutrients around brick kilns agricultural environment. *Information Processing in Agriculture, 3*(1), 61-68.
- Sim, J. (2015). *Planting Design Sourcebook*. Queensland University of Technology.
- Sodangi, M., Khamdi, M. F., Idrus, A., Hammad, D. B., & AhmedUmar, A. (2014). Best practice criteria for sustainable maintenance management of heritage

- buildings in Malaysia. *Procedia Engineering*, 77, 11-19.
- Tan, M. (2009). Perfection for Timber Flooring: Installation Method, Seminar on Timber Talk Series. In: Organised by Malaysian Timber Council.
- Tan, S. Y., Olanrewaju, A., & Lee, L. T. (2016). *Maintenance of Heritage Building: A Case Study from Ipoh, Malaysia*. Paper presented at the MATEC Web of Conferences.
- Uchida, T., Furuno, M., Minami, T., Yamashita, S., Uchiyama, T., Arase, T., & Hayasaka, D. (2015). Ecological significance of masonry revetments in plant biodiversity. *Int. J. of GEOMATE*, 9(1), 1353-1359.
- Undang-undang, L. P. (2006). National Heritage Act 2005 (Act 645). *Kuala Lumpur: International Law Book Services*.
- Verma, M., Verma, S., & Sharma, S. (2018). Eco-Friendly Termite Management in Tropical Conditions. In *Termites and Sustainable Management* (pp. 137-164): Springer.
- Wee, Y. (1992). The occurrence of *Ficus* spp. on high-rise buildings in Singapore. *International Biodeterioration & Biodegradation*, 29(1), 53-59.
- Yadav, O. P. (2000). Eradication of Plants and Trees from Historic Buildings and Monuments. *Ancient Nepal*, 5.
- Young, D. (2008). *Salt attack and rising damp: a guide to salt damp in historic and older buildings*.