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Sustainable On-Stilt Construction Technology for Mangrove Land in Malaysia

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On-stilt construction is one of the widely used methods worldwide and nevertheless fits the requirements of modern building construction. Nowadays, almost all construction methods cause harm to the environment. Stilt construction, on the other hand, can protect the land and nature as its counterparts in constructing structures; it is a construction method used for long-term sustainability. This research aims to determine which type of on-stilt construction method and material are appropriate for current design and construction in Mangrove land in Malaysia. This paper discusses the principles and techniques of construction in the construction of houses on stilts and how the elements of structure respond to environmental problems as sustainable construction through a process of architectural transformation. The potential and selection of the stilt construction method were thoroughly investigated to explain its relevance as a method in comparison across contemporary techniques. The methodology applied using a qualitative approach with systematic comparative evaluation through precedent study from multiple stilt construction methods and materials. This study also involved the qualitative method by comparing the building case study using materials such as concrete, steel, bamboo, and concrete. Conclusively, the environmental benefits of operating on stilts construction as a construction method outweigh the disadvantages of using another way. As a result, stilt has provided significant environmental benefits as a sustainable technology compared to other construction methods.

Keywords: *Construction Material, Environment, Stilt method, Sustainable Element, Mangrove area.*

1. INTRODUCTION

Stilt buildings have been used for thousands of years as functional regional architecture or as a symbol of history and belief. "On stilt has demonstrated an outstanding variety of features, making it suitable for various purposes." (Friess, 2019). Several elements influence the stilt construction method, such as the location of the building, environmental impact, and climatic conditions. Most of the on-stilt construction was built near the coastal zone. Hence, they are inherently non-sustainable. It led to a highly adverse effect on the mangrove land in Malaysia. As a result, the evolution of construction in Malaysia has impacted the environment along the coastal zone. On-stilt buildings can reduce the environmental impact on the ecology of the mangrove area.

2. LITERATURE REVIEW

As stated by Brand (1995), "Architects must consider the structural properties and aesthetic qualities of materials while constructing the building using the on-stilt method, in addition to its sacred significance of sustainability". The outcome of this study should be an intuitive example to show how the design works, what it will cost, and how adopting it can become a "win-win situation" for human beings and the environment. ("New Possibilities for Stilt Building") Future researchers can use this information to improve the long-term worth of the mangrove ecosystem.

The research description and analysis provide preliminary data for understanding these buildings, which paves the way for future research in this study area and allows for comparative studies of on-stilt buildings in other areas. This research addresses the issue of conserving and improving on-stilt construction worldwide under the dynamic changes related to globalisation. This study urges the importance of on-stilt for mangrove areas. Heraclitus said, "The only thing permanent in life is change." Because of population growth, resource extraction, and urbanisation, ecosystems have changed in many parts of the world.

Furthermore, technical advancements and economic considerations have altered the socio-cultural by creating new wants. The question is what kind of structures are economically viable and can adapt well to the surrounding dings of a mangrove. There are six types of changes that occur in buildings, according to Schmidt et al. (2010): changes in the task or user, space, performance, function, scale, and location. Several changes happened in shearing layers (Brand 1995: 13).

Compared to modern construction methods, the environmental impact of the construction itself, especially the reduction of environmental impact, provides a significant benefit. On stilt has also demonstrated that it may be distinguished by various features, making it suitable for multiple purposes. As a result, several elements influence the use of stilt construction as a construction method. 1) location of the building, 2) Environmental Impact and climatic conditions, and 3) Suitability of land. "Most on-stilt construction is built near the coastal zone," according to Ewell (1998). Malaysia's coastal zone has brought socio-economic benefits to the coastal population and is the centre of economic activity; it is known for its diverse marine ecosystem and can be included in the tourism sector. However, much of the present-day pursuit of economic progress is at the expense of the environment. Hence, they are inherently non-sustainable, leading to a high negative impact on the mangrove land in Malaysia.

As a result, the evolution of construction in Malaysia has impacted the environment along the coastal zone. On-stilt building can potentially reduce the environmental impact on the ecology of the mangrove area. Architects must consider the structural properties and aesthetic qualities of materials while constructing the building using the on-stilt method and its sacred significance for sustainability. The findings of this study should be included as an example of how the design works, how much it will cost, and how adopting it can result in a "win-win situation" for humans and the environment. It can be achieved by analysing which type of on-stilt construction material is suitable in mangrove areas in Malaysia.

As there is no specification on which sort of on-stilt building is suitable for Malaysia's mangrove coastal zone area, this study focuses on the on-stilt method and material. As a result, it is critical to identify and comprehend the on-stilt procedure to improve the mangrove region's environmental value by comparing through analysis and assisting in constructing more environmentally friendly structures in the mangrove area. According to Susanto, D., & Lubis, M. S. (2018, March), "In general, there are four types of on-stilt buildings in Mangrove land area: (a) floating building with wooden construction, (b) Wooden stilt house (c) Concrete house, and (d) Brick house. There are seven primary materials used by the buildings: (1) wood, (2) concrete, (3) brick & mortar, (4) stone & mortar, (5) cement board, (6) Zinc metal sheet, And (7) clay tile.

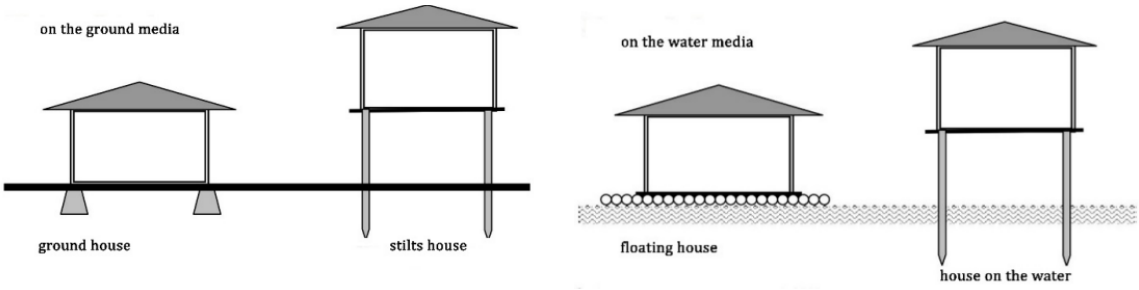

Figure 1: The Designs of Houses in coastal mangrove areas (Adi et al.)

The primary goal of this research is to determine the most appropriate and suitable stilt construction method that is sustainable and does well for the mangrove coastal zone area focused on Malaysia. The research objective: 1) To identify the most suitable option for stilt building in Malaysia's coastal mangrove area, 2) To examine the benefits and limitations of on stilt building method in Malaysian Architecture and lastly, 3) To analyse the human perception of the on-stilt construction. Numerous research questions have been addressed; 1) How the stilt construction methods and materials are significant to the modern coastal mangrove construction in Malaysia? 2) What is the Environmental Impact of using the on-stilt construction? And lastly, 3) How can on-stilt construction benefits the mangrove areas?

3. METHODOLOGY

This paper's research method used the qualitative approach to collect data. The first phase is to identify the issue using a literature review to acquire an overall framework of the topic and to provide the theoretical foundation for the research, especially in formulating the research questions and objectives. The development of the conceptual framework for case studies has been identified. The case study for this study is selected on different primary materials as their substructures, such as timber, steel, concrete, and bamboo. The study focuses on Identifying criteria, and four case studies were selected based on their materials and types of construction. The data collected emphasised the functionality, technical detailing, data stability, advantages, disadvantages, limitations, and implementation.

Lastly, using the comparative analysis method, the four case studies were being comparatively analysed based on the criteria to obtain essential data from the findings and tabulate them to best display their adaptability, strength, and durability, keeping in mind the objective and character of this research. The result of this study should be to compare and identify which of these several examples is the best option for the coastal area as a construction method and material. This dissertation is a structural comparison examination of sustainable technology building in mangrove land, Malaysia, for data stability and how the findings are implemented.

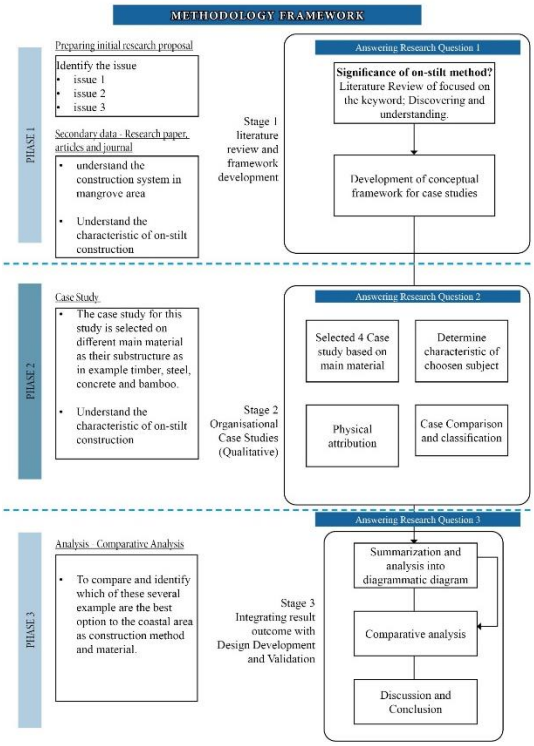

Figure 2: Framework

This research aims to determine how stilt construction methods and materials are essential in modern coastal mangrove construction in Malaysia. Four case studies were chosen as case studies after an empirical observation was made, and qualitative comparative analysis was utilised

to assess the content in response to the study's criteria. The observation parameters were determined based on the literature review findings. Then, content analysis is used to determine whether materials suit on-stilt buildings in the mangrove area.

4. FINDING

This chapter presents the result of the data analysis. The results are structured based on physical attribute factors with several sub-themes under each. The data sources were verified with detailed analysis. The study's objective is (i) To analyse the attribute of the on-stilt construction in mangrove areas. (ii) Identify the most suitable option for stilt building in Malaysia's mangrove coastal area. Attribute factors are as follows:

- Material
- Resistance
- Durability
- Climatic suitability
- Stage of Experience
- Functionality
- Special Properties
- Cost
- Impact
- Stability

4.1 Type of Stilt building according to primary material used

Timber, steel, concrete, bamboo, and other materials are utilised to construct a good and long-lasting stilt house. In some areas, even mud is required to build a stilt house. The stilt houses can be seen along the river in different locations, but these dwellings' modern-day and commercial adaptations are pretty popular. When it comes to classic stilt houses, the verandah extended around those dwellings varies greatly, but it never surrounds a home. The stilt buildings were absorbed to construct the bedrooms when the veranda was modernised, and increased space was used to build the living area. The traditional forms of stilt building are blended with modern architectural characteristics to make stilt houses adaptable and suitable for the current and contemporary lifestyle.

Case Study 1: Timber Stilt house, Sabah, Malaysia

I. **Material:** The material of this building is mainly timber. The dwellings are often built without metal, including nails, using renewable natural materials, including wood and bamboo. Instead, pre-cut holes and grooves are used to fit the timber elements into one another, effectively making it a 'prefabricated house.' ("Malay Houses - Vernacular Architecture"). Although nails had been invented and in later houses were used minimally for non-structural elements (for example, windows or panels), structural flexibility was a benefit which nailing inhibited. Without nails, a timber house could be dismantled and reconstructed in a new location. Most ancient Malay peoples of South-East Asia maintained a form of self-regenerating environmental culture.

II. **Flood resistance:** Timber is one of the flood-resistant materials as it can withstand the water pressure and can withstand direct and prolonged contact with floodwaters without sustaining considerable damage.

III. **Durability**: The stilt structure's competent and technological construction according to its material in terms of endurance. The medium durability of the wood has proven to be one of the most popular on-stilt materials.

IV. **Stage of experience**: The level of expertise necessary to construct a timber stilt house is low. Because it is not as complicated as other construction systems, these structures are prevalent because they are simple to build.

V. **Functionality:** The purpose of timber stilt houses is typically seen as small to medium-sized residences because the materials are easier to assemble in small to medium-sized structures. Unfortunately, lumber is not generally used in larger systems because it cannot bear high-pressure loads.

VI. **Properties:** The unique features of a timber stilt house are that it is raised and has floating structures to support the system.

VII. **Cost**: Depending on the size of the house, additional charges to build a new home on stilts will range from RM 83689.96 to RM 251069.87, according to HomeAdvisor (NASDAQ: ANGI). Compared to other materials. Timber can be considered as medium costs, and usually, very low-income people are living in the timber stilt house

VIII. **Impact on the Surrounding**: The structure will also be examined in terms of how it reflects its

surroundings. The timber stilt building has a minimal environmental impact as its material comes from nature. The most significant component is the sustainable elements, as it is necessary to conserve and protect the mangrove area, which is a sensitive portion of the site.

IX. **Stability**: The timber stilt houses are an excellent option for building a home on shaky ground. Because the house is raised above the ground, the stilts provide stability rather than the environment beneath it ("Harden Custom Homes, 2019"). This material enables the construction of buildings in otherwise unstable areas.

Case Study 2: Tinbeerwah steel stilt house, Australia

I. **Material**: Natural calamities, such as fires, floods, storms, and earthquakes, are naturally more resistant to steel. Steel is resistant to mildew and the feared termite danger, costing the real estate industry millions of dollars annually. It does increase the weight strain faced by material movers and constructors ("Midwest Steel," 2017). However, the weight difference can readily be made up in long-term costs. Best of all, steel construction poses little to no environmental risk because it does not necessitate the felling of trees and forests. Steel is quickly becoming the preferred building material for many development companies for all of these reasons.

II. **Resistance to flood**: The steel commonly is solid to resist the flood and earthquakes as its material can withstand high pressure

III. **Durability**: Steel buildings that are professionally designed and constructed provide long-term durability. Barrier coatings (such as paint) can be applied to the steel surface to protect it from water and oxygen. Steel cannot corrode without water and oxygen ("Durability - Build Using Steel," 2020). When further protection is required, zinc coatings (such as galvanised) can be used to provide both sacrificial and barrier protection. When the base metal of zinc-coated steel is exposed, such as by a cut or scratch, cathodic protection is provided by sacrificial corrosion of the zinc coating around it.

IV. **Stage of experience**: The level of expertise necessary to construct a steel stilt house is high. Because it is complicated to compare construction systems, these structures are prevalent because they are hard to build.

V. **Functionality**: Most steel stilts are medium to generous building size as their material can stand and form a large structure.

VI. **Properties**: The specific qualities stated are used to investigate the case studies' unique physical appearance. For instance, raised housing, high-strength prefabrication, and so on.

VII. **Cost**: The cost of the structure may vary depending on the materials used. Steel, for example, maybe more expensive than wood or bamboo. It also has an impact on the life cycle cost of the building.

VIII. **Stability**: Steel structures have a long-term record of reliability. Steel does not expand or shrink in response to moisture. Steel does not develop or shrink in response to humidity. When materials are employed in mid-rise construction, dimensional stability considerations are increased. Although the material may be successful in low-rise buildings, it cannot be expected that the same construction procedures will be appropriate for larger ones.

Case Study 3: Concrete Stilt house, Kerala, India

I. Material: For concrete panels, employed prefabricated, pre-stressed technology, which is 30 times stronger than standard construction materials." They will be able to withstand any natural disaster," S. stated. Apart from two more houses being built on Mundrothuruthu island, TKM Engineering College's 'infill houses,' low-cost, eco-friendly buildings, would be made in the worst affected Pandanoor and Buthanoor villages in Alapuzha district. ("Flood-resistant housing attracts attention in Kerala").

Despite the unpredictability of the environment, tourists continue to Mundrothuruthu. However, the situation in the low-lying areas does not look promising. The continual rattling of saline wind is the villain, as the walls of the buildings here, most of which are owned by fishers, appear to be socked. In fact, amid the ruins, on the bank of a torrent, stands the 67-year-old little but remarkable bungalow (S. Gopikrishna Warrier, 2019).

II. **Flood resistance**: Concrete is naturally water-resistant, making it one of the most excellent materials for construction in flood-prone areas. Waterproof and water-resistant concrete are two different types of concrete. Waterproof concrete is impervious to water ("Concrete Utilization for Flood Safety - Best Concrete Mix Corp.," 2019).

This form of concrete is utilised to construct long-lasting, watertight structures. Best Concrete Mix Corp. and other top-rated concrete suppliers can also combine concrete mixtures with improving permeability.

III. **Durability**: A competence and expertise in the technical construction of stilt structures is a must. Low, medium, and high are the three categories in this area. It can be concluded that for a concrete stilt house to withstand flash flooding effectively, the main structure needs to be reinforced.

IV. **Stage of experience**: The experience level necessary to construct a concrete stilt house is medium. Because it is not complicated compared to steel construction systems, these structures are prevalent because they are hard to build.

V. **Properties**: The specific qualities stated are used to investigate the case studies' unique physical appearance. For instance, raised housing, high-strength prefabrication, and so on.

VI. **Stability**: The building's impact on the environment will also be investigated. The most significant component is the sustainable elements because the mangrove region must be conserved and cared for because it is a delicate part of the environment.

VII. "Cost-effective houses are not just for the poor": For spearheading the awareness campaign, a model house has been highlighted at the Police Guest House in Thiruvananthapuram. It is a 495-sqft of three-storied house. Its architecture, pillaring, plastering, etc., have been meticulously done to withstand natural disasters. Materials such as treated bamboo, mud, and concrete were used to build the pillars. Mud, coconut shells, and treated bamboo were used for the plastering. This small but pretty house has two bedrooms, a living area, a kitchen, and a bathroom.

VIII. **Impact on the Surrounding**: The structure will also be examined in terms of how it reflects its surroundings. The most significant component is the sustainable elements, as it is necessary to conserve and protect the mangrove area, which is a sensitive portion of the site.

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Case Study 4: Bamboo Stilt house, Shan, Myanmar

I. **Material**: In 2017, Sham was hit by one of the most severe floods in its history. The community banded together, with local assistance, to bring the property back to life. One of the first things they did was build bamboo stilt dwellings. Stilt bamboo houses are most widely observed in Myanmar, where they are most suited for flood-prone locations. It is found that the most suitable materials for this area are the combination of new technology and indigenous knowledge of creating bamboo stilt dwellings. Bamboo is one of the available materials that can give mass supply and infrastructure in commercial quantities.

It is a short-rotation plant that is renewable. Bamboo takes around a year to reach its maximum growth. The plant will need another two or three years to gain its full strength. Even on deteriorated terrain, bamboo can be planted. Bamboo construction components should be treated to ensure their lifetime. The use of high-energy materials such as cement and steel is reduced. As a result, using bamboo for house construction helps protect the environment.

II. **Resistance**: Protective precautions are required due to their low resilience to physical assault and fire.

III. **Stability**: These specially made split-bamboo piles were used in stabilising the soft compressible subsoil of an actual construction site which consisted of a top layer of about 2 m thick, mild to medium-stiff sandy, clayey silt underlain by a layer of about 6 m expansive, incredibly soft silty clay which was again underlain by a layer of medium dense silty clayey sand. The split-bamboo piles, each about 8 m long, 80 to 90 mm in diameter, are driven by a drop hammer at 2 m spacing in a square grid. After installing the piles, the entire area was covered with about 2 m surcharges of sandy materials (Bibl. 20.01).

IV. **Stage of experience**: The experience step determines how skilled and technical it is to build a stilt construction using the given resources. When compared to timber, the bamboo building is more accessible.

V. **Functionality**: Bamboo is one of the most extensively utilised building materials as a support for concrete, especially in areas where it is abundant due to its great compressive strength and low weight. Bamboo is operated in the

construction of scaffolding, bridges, and buildings, as well as residences.

VI. Properties: Bamboos are one of the fastest-growing plants on the planet, growing three times faster than most other plant species thanks to a unique rhizome-dependent structure. They are a renewable and incredibly adaptable material that can be used for various purposes. Among the many applications of bamboo, housing is one of the most important, especially in light of global housing shortages. Bamboo is traditionally connected with the Southeast Asian and South American regions, where the climate is most conducive to its growth. Bamboo is used in many countries to support suspension bridges or to construct homes.

VII. **Cost**: The low-cost housing project is in a flood-prone area with severe year-round temperatures. The building will be erected utilising minimal components and bamboo module units to suit the basic residential needs of a residential house. The construction will be sturdy enough to float in floods if it is fastened with anchors, ties, and solid connections. The project mixes traditional architectural traits to define the outside fabric, using local materials such as bamboo, leaves, and recycled oil drums. The concept, which costs slightly about RM8373.00 per unit, enables mass production and the opportunity for communities to construct their structures.

VIII. **Impact on the Surrounding**: Bamboo stilt houses are a good option for sustainable living because they do not produce as much garbage as other building materials. Besides, bamboo is lightweight, durable, earthquake-resistant and recyclable, thus becoming an excellent choice for home construction

Attribute	Sabah, Malaysia	Tinbeerwah, Australia	Kerala, India	Shan, Myanmar
				
Material	Timber	Steel	Concrete	Bamboo
Resistance	Medium	High	High	Medium
Life term / Durability	High	High	High	Medium
Climatic suitability	Warm Humid climates	All except very warm humid climates	All except very hot dry climates	Warm humid climates
Stage of Experience	Traditional and experimental	Experimental	Experimental	Traditional
Functionality	Small to medium house	All type of house	Small house to large house	Small house to medium house
Special properties	Elevated houses and floating structures	High strength, Prefabrication system, quick assembly	Prefabrication system, quick assembly	High strength, flexibility, numerous designs possible
Cost	Medium costs	High Costs	Medium to high costs	Low to medium costs
Impact to the surrounding	Low	High	Medium	Low
Stability	High	High	High	Medium

Figure 2: The Comparative Analysis table result (Author)

5. DISCUSSION

The case studies mentioned above are typical stilt houses with varying building technologies and materials. Floating villages can be found across Sabah, Malaysia, and have existed for millennia. Local fishers live on the islands. Their homes appear to be elevated above the sea, with wooden foundations and construction techniques based on traditional knowledge. The Tinbeerwah house in Australia is an example of steel stilt construction. Steel stilt houses are now commonly used all over the world. On the other hand, the concrete stilt home can be found in Kerala, India. The floods have hit this site practically every year.

As a result, the residents are constructing concrete houses to protect their homes from water damage. Finally, in Shan, Myanmar, you can find a bamboo stilt house. Because the reeds at the bottom of the building are rapidly decaying, they replace them every three months to maintain the tower's continuity. Several floating villages populated by fishers may be found in Myanmar. The floating houses are made out of jerry cans and are bamboo-based. From a technological standpoint, the precedents reveal that the majority

of floating building types are made of natural materials and erected using conventional methods

6. CONCLUSION

The data demonstrated that the qualities of timber and bamboo stilt houses are more sustainable than those of concrete and steel after this study. Despite this, in strength and longevity, concrete and steel are significantly more compatible than timber and bamboo. The need to minimise the environmental impact of buildings must be emphasised by emphasising the relevance of the mangrove region. As observed, timber and bamboo are the most environmentally friendly materials for stilt construction in mangrove areas.

Concrete and steel have the advantage of lasting longer than timber and bamboo. More structures will be developed as a result of this. Concrete and steel, on the other hand, are significantly more costly than timber and bamboo. As a result, this study suggests that the stilted building can be expanded in various ways depending on its intended use. As indicated by the findings, which suggest that timber and bamboo are the most significant possibilities for mangrove areas, this study aims to establish which materials are ideal for mangrove environments.

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