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EFFECT OF ADAPTING SUSTAINABLE CONSTRUCTION MATERIALS ON HOUSES IN TROPICAL CLIMATES: CASE STUDY OF S11 HOUSE, SELANGOR, MALAYSIA

Muhammad Zulhelmi bin Maimun[1], Farah Hanna Ahmad Fuad[1*], Murni Zainal[1]

[1]Department of Built Environment Studies and Technology, College of Built Environment, Universiti Teknologi MARA, Perak Branch, 32610, Seri Iskandar, Perak, Malaysia

2019244582@student.uitm.edu.my, *fhanaafuad@uitm.edu.my, murnizainal@uitm.edu.my

ABSTRACT

Practicing sustainability will not only enhance one's quality of life, but also contribute in advancing social, economic, and environmental conditions. Tropical region is associated with year-round lengthy periods of sunshine, high temperatures, high relative humidity, and a lot of solar radiation (Karam M., 2014). These conditions have encouraged the construction industry to adapt sustainable building materials to face such extreme hot and rainy seasons throughout every year. Utilizing sustainable materials in building design will help in reducing a building's life cycle cost and worrying environmental impact (Sahlol, D. G, 2020). The main case study is to focus on the material used by S11 House, which has achieved the highest-level, Platinum rating, of Malaysia's Green Building Index (GBI) award. This research identifies the underlying benefits of incorporating sustainable building materials, especially in tropical climate. The research was accomplished through the analysis of S11 House on related topics, included publications, websites, essays, theses, national and worldwide organisations on the topic, all of which supported the comprehension and articulation of ideas. In response, the study will give further understanding on the right materials to use that suits the weather and condition in tropical region.

Keywords: *S11 House, Sustainable materials, Tropical climates, thermal comfort, Environmental impact*

INTRODUCTION

In all countries, especially in areas with harsh climatic conditions, buildings are major users of energy, and a sizeable portion of that energy is used to heat and cool structures. The right design and selection of the building envelope and its components stand out among the many approaches to reduce the heat and air conditioning load in the buildings (P. K. Latha, 2015). Based on A. Ahmadian (2019), A paradigm shift is necessary to execute a sustainable material procurement approach to minimise the effects across the whole life cycle of a developed facility. The use of sustainable structures, often known as green buildings, is becoming more popular around the world as people become more concerned about the environment. Green design has several benefits, including increased public and tenant health due to improved indoor air quality, less environmental effects, and lower running costs by increasing productivity and using less energy and water. Building materials are affected by the outside temperature and humidity, thus determine the internal thermal comfort (R. Hyde,2000). The usage of sustainable material had widely spread throughout the globe but tropical regions still have low awareness rates and exposure to this new type of construction materials (R Sabar, 2018).

LITERATURE REVIEW

Sustainable Building Materials

In order to be sustainable, managing a balance between maintaining our natural resources and gradually raising our standard of living is important. Resilience is therefore a key element of long-term sustainability. Sustainable building materials are made from resource-efficient processes with low embodied energy content, using locally available and renewable energy sources and contribute fewer amounts of greenhouse gas emissions to the atmosphere (G.K.C Ding, 2014). According to Tebbouche, H., Bouchair, A., & Grimes, S. (2017), sustainable architecture is a tactic with the objectives of controlling the different dynamic relations between external environment and its internal space then harmonize the internal space with the social, natural and architectural surroundings.

One of the most crucial elements of green construction, aside from several other standards, is the use of ecologically friendly building materials. Manufacturers will assert that their products qualify as green materials even if there appears to be a lot of confusion right now about what defines green materials. If a material meets certain review standards, it might be categorised as green (Paresh H. Shah, 2010). Using Recycle materials are also a sustainable step that can be taken towards sustainability. This is because utilizing readily materials can cut down the dependency of virgin resources, lessen production energy, cost, landfill area, and harmful emissions, whilst improving the image and productivity of our construction industry concurrently (Ahmad Fuad, F.H., and Shahdan M.S., 2023).

Tropical Climates

According to Kellman and Tackaberry (1997), tropical climate has a predictable temperature trend with little seasonal change and extremely varied precipitation regimes from year to year. On a sunny day, the difference between the daily temperature range and the seasonal fluctuation between the warmest and coldest months is much larger and the daily temperature variation in hilly areas may reach 20 °C. The Asian monsoon is characterised by a change in wind direction, bringing in warm, humid air in the summer and sending out cold, dry air in the winter. Based on Kim Rutledge (2022) Average temperatures in the tropics range from 25 to 28 degrees Celsius all year round (77 to 82 degrees Fahrenheit). This is because the tropics has experienced the increased of sun exposure. The tropics do not have the same kind of seasons as the rest of the Earth because of all the sun. The wet season and the dry season are the only two seasons that occur in the tropics.

Near the equator, there are often two alternating seasons, dry and rainy with each lasting up until three months. When the sun is in the opposite hemisphere, one dry season lengthens. As one advances farther from the equator, whereas the other shortens or vanishes. Because there can be brief rainless intervals during the rainy season or sporadic showers during the dry season, rainfall regimes are rarely straightforward or predictable. The equatorial climate had high monthly precipitation, usually no less than 60 mm, and hot average temperatures throughout the year, with yearly precipitation normally tending to be over 2000 mm. The difference between the daily and annual temperature ranges is higher. The high levels of soil moisture and rainfall interception by the dense vegetation cover, which results in transpiration, in combination with low pressure convectional processes caused by the high altitude of the sun (ITCZ), account for this consistent climate. This feedback creates a recurring pattern of weather that includes hot, muggy air, foggy mornings, late-afternoon downpours, and convectional storms.

Thermal comfort

Temperature, humidity, and air movement are the main determinants of thermal comfort since it is one of the aspects in the indoor environment that affects health and human performance. Thermal comfort is a concept that is influenced by social norms and expectations since it refers to a comfortable, stress-free thermal environment in buildings. The idea of what is comfortable has undoubtedly evolved over time, space, and season (Chappells & Shove, 2005). For buildings, thermal comfort is crucial, particularly in hot climates where intense cooling capacity is required. The thermos-physical characteristics of the building materials, building orientation, ventilation, the use of the building's space, and the integration of passive energy and contemporary technologies are some of the factors that affect a building's thermal comfort in addition to its ability to conserve energy. Ventilation is one of the important aspects in improving thermal comfort, whether or not using cutting-edge construction materials. Poor ventilation in building envelopes would trap heat inside, perhaps making it worse for occupants' thermal comfort. Study by Syed Fadzil (2004) have

demonstrated that the key to an energy-efficient design that could affect how well the building uses energy inside its envelope to keep its occupants comfortable is its orientation. Y.W. Fung (2014) further explained Research demonstrates that natural ventilation enhances thermal comfort in buildings in hot and humid areas in addition to building orientation. Natural ventilation can be integrated into the building envelope by adding any one of the ventilation components listed below, including the wind scoop, wind tower, chimney, double façade, atrium, ventilation chamber, embedded duct, and/or ventilation opening in the facade. According to Hamza's (2011) research, A dome with openings at the top is a successful architectural design used in Persian buildings that helped with natural ventilation of interior spaces. It was claimed that the dome's curved shape caused pressure differentials that affected air flow from the outside to the inside, providing direct cooling to the interiors.

Due to energy demands, there is increased interest in the use of natural ventilation in buildings as buildings with mechanical ventilation are linked to issues with interior air quality and the environment. Study by P.O Fanger (2002) have reported that human thermal sensitivity is significantly better in a naturally ventilated atmosphere than in a mechanically regulated thermal environment. This idea is supported in clean-environment buildings. Building materials may be the next simple and sustainable choice to use in many businesses where the orientation of the building and ensuing natural ventilation may not be an option due to industrial zoning, spacing concerns, or other regulatory reasons. According to research by Energy Consumption Guide (ECG 19) from 1993, a naturally ventilated structure uses 40 percent less energy overall than an air-conditioned building, which makes natural ventilation a more sustainable solution to the problem of thermal comfort with added energy-saving benefits. Even if there is only a few research in the tropics, humidity control in the provided fresh air and the resulting humidity gradient in the building must be considered as an alternative for energy effective cooling and thermal comfort of residents, according to R. Kosonen (2001).

The choice of building materials has a significant impact on both the building's energy use and level of thermal comfort. When compared to some more sophisticated materials, some conventional materials have higher thermal conductivities and diffusivities, which increases heat transmission at the expense of energy efficiency and thermal comfort. According to Arun Kumar (2013), It has been proposed that improving some conventional materials through modification and adoption of a better composition, design, and/or integration of technology can address future energy needs while also providing enhanced thermal comfort as a side benefit. As stated by Givoni (1976) the envelope of a building also acts as an external layer that protects from climatic elements affecting the building directly rather than just a separator from the external environment. Further supported by R. Hyde (2000) The qualities of the building materials chosen, which are impacted by the outside temperature and humidity, determine the internal thermal comfort. Windows and transparent or translucent materials allow heat and cold to enter the building, and the hermetic-physical characteristics of the materials have an impact on the inside climate. O Meral (2011) said in his research that compared to the materials with high thermal conductivity It has been demonstrated that materials with lower thermal diffusivity, absorptivity, and conductivity have less temperature swing on the inside surface of the walls. Nylon, polystyrene foam, and polyurethane foam are examples of building materials with low thermal conductivity that may not offer the best thermal comfort,

particularly when used for flooring in hot and humid climates. However, these materials could be incorporated into other parts of the building to achieve the desired thermal comfort.

METHODOLOGY

After getting the characteristics of the materials involved, an analysis of the data to find connection between the characteristics to its benefits will be made and decision will be made whether the sustainable components used are improving thermal comfort. The analysis will be made by referring to the recommendations and guidelines from the experts. Once the analysis is made, conclusions and recommendations will be made regarding the benefits of sustainable materials to be used in tropical region.

Case Study

Figure 1: S11 House (Low Yen Yeing, 2021)

A case study conducted on S11 House to identify the material used in the construction. This data is collected from the official website of S11 House for the type and detailed information about the sustainable materials used in the house. The data required are the type of sustainable materials used, benefits and limitation of the materials. The research was supported by the analysis of S11 House on other publications, websites, essays, theses, national and worldwide organisations on the topic to re-enact the articulation of ideas.

Result and Discussion

Case Study: S11 House

The architect Dr. Tan Loke Mun is the owner and designer of S11 House, a noteworthy green building in Malaysia that is situated in the older suburban neighbourhood of Petaling Jaya. The aim behind this structure was to use a sizable canopy as an envelope for the inner areas, offering a unique viewpoint and sensations from the inside. The majority of the site's original elements and features were remained such as the on-site vegetation was preserved and used to provide shade for the house and components from the destruction were also used to build S11 House in the future. With the abundant use of local materials like bricks and hardwood, the local architectural essences of this structure were brought out and enriched in a whole new and significantly more intriguing way. The space arrangement had also been modified by the spatial planning and design in accordance with the details discovered in a nearby Malay house, which has high spatial significance and hierarchy of spaces.

S11 House has distinguished itself from the customary direct application of material in planning and building a space with its intriguing new interpretation of common materials into a conventional vernacular spatial design. The conventional adaption of the contextual climatic building design works well with the well-proportioned and balanced integration of materials by taking into account their qualities (Inhabitat, 2013). S11 House was the first structure in Malaysia to be recognised as Platinum by the Green Building Index (GBI), and all of these additions helped it win the Tropical Building Category of the Asean Energy Awards in 2013 (S11 House, 2015).

Materials are the fundamental elements used in building construction as they have an impact on the functionality and use of a space. Materials have a variety of different properties, and one of these is thermal mass, which is relevant for regulating the heat acquired into a building and has an impact on the comfort of the occupants. More readily obtainable local materials were employed in the construction of S11 House. Although they are the most fundamental materials in a structure, their performance could be greatly enhanced with careful planning and spatial design. Following that, the various materials are enumerated and grouped according to their thermal masses. Thermal mass is the capacity of a material to absorb heat; typically, a considerably higher heat is required to raise the temperature of high thermal mass materials, such as concrete and bricks. This has an impact on how long it takes a material to heat up or cool down. These materials may have been used in a thoughtful and effective way to provide cooling and reduce heat in a place (Chris Reardon, 2013).

Table 1: Materials Used in S11 House Thermal Mass Classification

Materials Used	Weight	Density	Heat store Capacity	Absorb/release heat rate	Low/High thermal mass
Crushed Concrete	Heavyweight	High	High	Slow	High
Recycled Clay Brick	Heavyweight	High	High	Slow	High
Recycled Plywood	Lightweight	Low	Low	Fast	Low
Recycled chengal	Lightweight	Low	Low	Fast	Low
Insulated aerated light- weight concrete block	Lightweight	Low	Low	Fast	Low

By taking into account the position and side surroundings of a particular space, the architect in S11 House had collaborated materials with both high and low thermal mass into the external as well as interior spaces. Aerated concrete blocks are used as the exterior façade or building envelope in place of most high thermal mass materials like traditional heavy weight concrete because of Malaysia's hot and humid climate (S11 House, 2015). More crucially, these materials are either shaded by the building canopy or naturally occurring flora, or they are both insulated. These is because, these thermal materials react to the climatic condition by containing the significant quantity of heat that is absorbed by the structure during the day, the building doesn't overheat. Old clay bricks are also stacked differently than they were originally to accommodate the country's changing climate. The house also avoids using high thermal mass materials such as glass. The glass is primarily on the north and south sides of the building, away from direct sunlight to avoid glaring and accumulation of heat in the house. The interior areas use low thermal materials much more frequently, such as timber because in hot and humid climates like Malaysia, lightweight materials with low thermal mass would benefit with their quick release of heat as well as their prompt response to cooling breezes. It has a significant impact on how effectively the interior spaces are kept cool during the day. The family room and sundeck are two examples of public spaces with timber flooring.

Table 2: Findings of Sustainable Materials in S11 House

Materials	Application	Advantages	Disadvantages
Old Crushed Concrete	The roof tiles from the previous homes were recycled, and now this material is used for stonework projects like toilet, driveways, and ground-floor living spaces.	• Low cost of building • Conserve its resources • faster construction process due to readily supply • Low CO^2 emission	• low tensile strength
Old Clay Brick	These bricks, which were cleaned from project rejects or outdated fragments, were used for the interior spaces' accent walls and walls.	• fire resistance • good insulator • thermal insulation • High compressive strength.	• Not uniform compressive strength
Old Recycled Waste Plywood	These salvaged plywood cut-offs from project rejects were used to construct the modular bookshelves in the home.	• to avoid cutting down of trees • good strength • Affordable	• quality is uncertain • high maintenance
Old Recycled Chengal	The wood is utilised for the timber decking on the ground floor. This wood is categorised as a heavyweight tropical hardwood with excellent endurance, durability, sturdiness, and	• less trees will be damaged • Raw aesthetics provided • low thermal mass	• The supply search takes more time.

	termite resistance.		
Insulated Aerated Lightweight Concrete Block	On the east and west walls, these lightweight concrete blocks were used and built.	• good thermal insulation • lightweight • practical in usage • easy to use and handled.	• high maintenance quality

CONCLUSION

The lack of research on the benefits and the limitation of sustainable usage in tropical architecture has led to the unexplored parts of the architecture that could be better than the current state and could solve the sustainability issues. This research has proven that the usage of sustainable materials could help tropical region architecture to solve their main problems regarding heat gain and humidity as the sustainable materials come with many benefits. Each sustainable materials have its own properties that differs from the others. In this research paper context, S11 House by Dr. Tan Loke Mun uses sustainable materials which are mostly recycled such as old crushed concrete, old clay bricks, waste plywood and chengal wood which helps lower the cost of the projects and to move towards green practices. There are also non-recycled materials which is AAC block used in the case study. Some of these materials have low thermal mass characteristics that could help lower down the indoor temperature and blocking the hot tropical climate from affecting the indoor environment other than lowering the dependency of virgin resources, production energy, cost, and harmful emissions. Although there are also some limitations related to handling and maintenance along the way but it is worth the try as they are less harmful to our planet. The recommendation for the future implementation of sustainable building materials is that the material need to be deeply studied before replacing it with the conventional material. A comparison study on specific characteristics of the sustainable materials is highly recommended to obtain accurate data and results.

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