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Tropical Sustainable Architecture:

Passive Design Strategies in Green Building

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Abstract

Green building, or sustainable design, is the practice of increasing the efficiency of the building with which buildings and their sites use energy, water, and materials. It also reducing building impacts on human health and the environment over the entire life cycle of the building. Green Building Index (GBI) is one of a rating tools for building grading system developed by construction industry professionals in order to promote sustainability in the built environment and raise awareness about environmental issues. A variety of active and passive design strategies can be integrated in order to increase the energy efficiency of a building. Active design strategies usually consist of heating and cooling systems like electricity or natural gas to keep the building comfortable. For instance, forced-air HVAC systems, heat pumps, radiant panels or chilled beams, and electric lights. Most building in tropical climate usually depend on mechanical means by using fans or air conditioning systems to maintain the indoor temperature within the comfort level. The dependence on a mechanical ventilation system could lead to additional costs for its installation, operation and maintenance. However passive design strategies use ambient energy sources which include daylighting, natural ventilation, and solar energy. It is achieved by appropriately orientating your building on its site and carefully designing the building envelope (roof, walls, windows and floors of a home). Passive architecture design strategies in tropical sustainable architecture aim to avoid heat from the sun, promote natural cross ventilation from the prevailing wind and ensure daylight into the building. This paper aims to introduce the natural climatic strategies for coping with local climate. These strategies include architectural development of the climate responsive design process. For instance, orientation, ventilation, thermal zoning, building form and typology, building envelope and optimize daylight access, building envelope design, materials selection and landscaping. Finally, it focuses on lessons that we can learn from our past experiences to improve our energy consumption patterns in tropical sustainable architecture.

Key-word: - Green Building; Tropical Climate; Passive Architecture.

1. Introduction

Sustainability is the most vital issue and central challenge of our time. Numerous studies and policies executed and other sustainable development efforts have been implementing due to the emergence of environmental problems throughout the world. The efforts cover in a wide range of field such as transportation, construction and industry. In construction area, the green building practices is highlighted as an application of sustainable design including the recycling of resources, application of energy-efficient designs and utilization of natural energy. Hence, many countries around the world have been applying various green building certification standards such as BREEAM (UK), LEED (USA), Green Star (Australia), Green Mark (Singapore), GREENSHIP (Indonesia) and GBI (Malaysia). The reason of different rating tools developed among other countries because each regions has different kind of characteristics such as distinctive climatic conditions, unique cultures and traditions, diverse building types and ages, or wide-ranging environmental, economic and social priorities. All of this dissimilarities will create a unique shape for their approach to green building.

However, generally the purpose of this building grading system is to promote sustainability in the built environment and raise awareness about environmental issues. For example, in Malaysia, the government, recognizes green buildings which contribute to sustainable development and efficient utilization of resources. In line with the effort to encourage the usage of green technology, incentives have been introduced by the Malaysia government for a person obtaining Green Building Index Certificate for buildings.

1.1 Green Buildings Characteristics

Green buildings are also known as a sustainable or high performance building, whether it is classified as residential or non-residential building such as an office, a school, a hospital, a community center, or any other type of structures. The green buildings have less impact on the environment compare to conventional buildings in terms of site planning and development, indoor environmental quality, material resources, energy efficiency and water efficiency. In addition, the expected output of a green building is that it will use less energy, less water, produce less waste and create a more live able environment for its habitants and surrounding community, throughout the building's lifetime. It is working towards zero fossil fuel use, zero greenhouse gas emissions, zero potable water use and zero sanitary waste entering municipal systems. Figure 1 shows the conceptual drawings indicating components of green building, illustrated by F Çiner and N Doan-Salamtimur (2019).

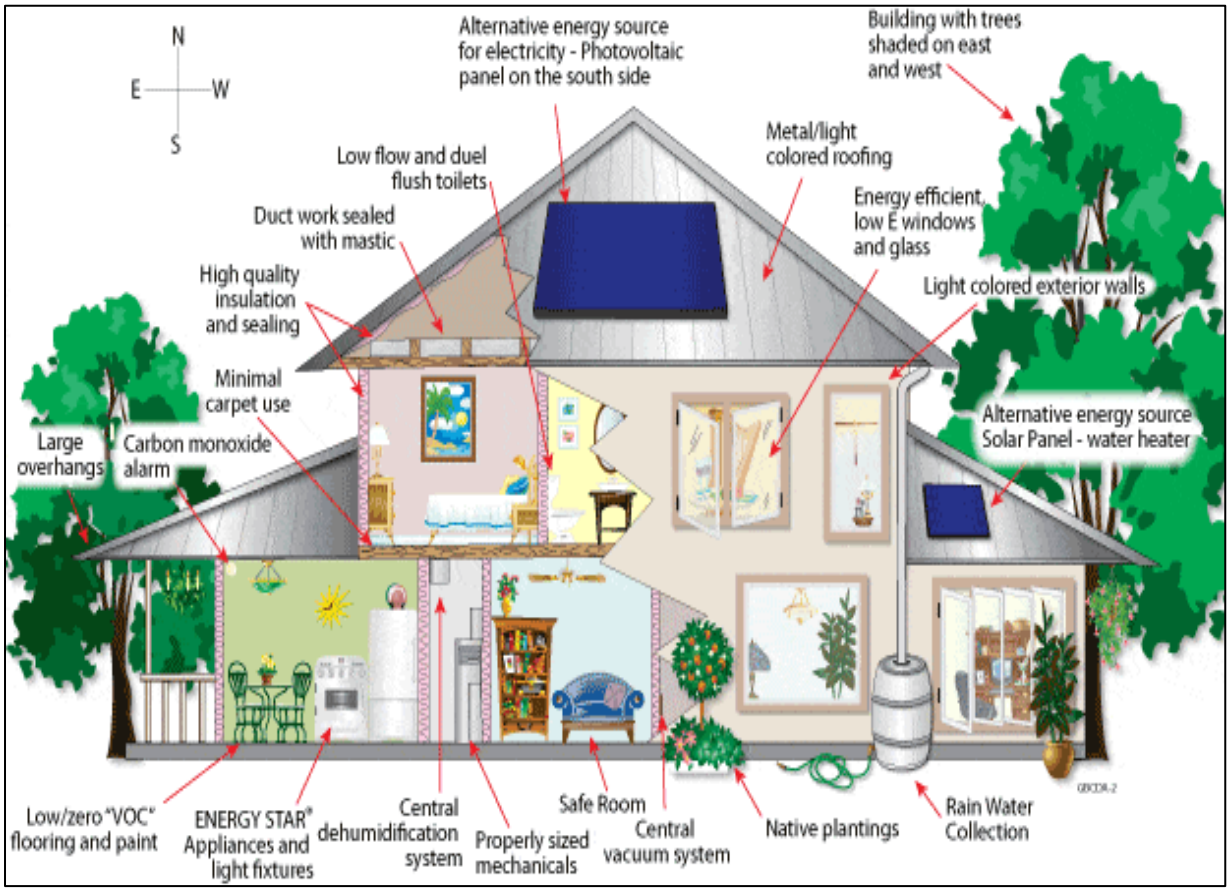

Figure 1
Conceptual drawings indicating components of green building
(F Çiner and N Doan-Salamtimur, 2019)

Many benefits can be obtained by adopting green building strategies especially if the design and construction team takes an integrated approach from the earliest stages of a building project apart from renovation and deconstruction stage. A green building may cost more up front, but saves through lower operating costs over the life of the building. The financial benefits of green buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. Thus, design strategies in the initial stages of a building project are crucial to maximize both economic and environmental performance.

The Green Building Index (GBI) rating system for new constructions evaluates the overall performance of a building by the following criteria (GBI, 2009);

- Energy efficiency (35 points): Energy efficient design of the building envelope, heating and cooling systems
- Indoor environmental quality (21 points): Reduction of exposure to pollutants in order to improve indoor air quality.
- Sustainable site planning and management (16 points): Minimization of the negative impacts of the project on the site
- Materials and resources (11 points): Selection of environmentally friendly materials, efficient use of materials, minimization of construction waste
- Water efficiency (10 points): Measures to enhance efficient usage of water
- Innovation and design process (7 points): Special design methods, and excellent performance levels

1.2 Passive Design

There are two types of design strategies in order to increase the energy efficiency of a green building, the active and passive design. Active design strategies usually consist of heating and cooling systems like electricity or natural gas to keep the building comfortable. For instance, forced-air HVAC systems, heat pumps, radiant panels or chilled beams, and electric lights. Most building in tropical climate usually depend on mechanical means by using fans or air conditioning systems to maintain the indoor temperature within the comfort level.

The dependence on a mechanical ventilation system could lead to additional costs for its installation, operation and maintenance. Most Malaysia building nowadays neglect the passive design features by relying on air conditioners and using electrical lighting to keep the building cool and bright. This is the result of blind copying of foreign designs (influence of Modernist architecture) and inattention to our architectural heritage. According to Kubota (2006), 62% of Malaysia houses possess at least one air conditioner. This proving that Malaysian building are lacking of a conscious approach to energy conservation in the design of the built environment.

However passive design strategies use ambient energy sources which include daylighting, natural ventilation, and solar energy. It is achieved by appropriately orientating your building on its site and carefully designing the building envelope (roof, walls, windows and floors of a home). Majority of studies undertaken for the purpose of developing the means for conserving energy in relation to green buildings concentrated on the development of technologies for environmental facilities through the application of active designs. And, to date, there is little suggestion on the passive design strategies proposed to be implemented in the green building.

1.3 Tropical Climate Responsive Design

In Southeast Asia, the climate allows for specific responses different from those in temperate environment. Hence, climate had a major effect on the performance of the traditional building architecture and its energy consumption. Southeast Asia has developed its own unique identity and a rich diversity of built – forms. Architecturally, the countries shared many characteristics in the built-forms of the region such as the intense sun-shine, heavy rainfall, prevailing winds, high humidity and calm temperatures. This region includes Indo-Chinese Peninsula, the Philippines, vast archipelago of Indonesia, Brunei, Malaysia and Singapore.

This paper aims to determine the natural climatic strategies for coping with local climate in the Southeast Asia region. These strategies include seven architectural development of the climate responsive design process which is the orientation, ventilation, thermal zoning, building form and typology, building envelope design, materials selection and landscaping (Amira Mersal, 2017). Finally, it focuses on lessons that we can learn from our past experiences to improve our energy consumption patterns in tropical sustainable architecture.

Figure 2
Architectural development of the climate responsive design process
(Amira Mersal, 2017)

Referring to figure 2, according to Amira Mersal (2017) the passive design approach consist of different climate responsive strategies, mainly to avoid heat transfer through the building envelope, promote natural cross ventilation from the prevailing wind and ensure daylight into the building.:

- Orientation: minimize solar radiation on the building envelope.
- Ventilation: use airflow to release heat and humidity.
- Thermal zoning: allocate functions related to time of use and solar gain.
- Building form and typology: minimize the solar radiation on the building envelope, optimize daylight access and heavy rainfall.
- Building envelope design: provide the minimum required daylight access, together with a minimal heat gain and maximal external reflection.
- Materials selection: to minimize heat transfer to the indoor space.
- Landscaping: provide shade on the building, reducing the heat gain, and to create pleasant outdoor space.

2.0 Tropical Architecture Issues

In Southeast Asia, many architects advocated an approach based on using elements from vernacular tropes and combining them in new ways. In many ways, the use of vernacular forms was an implicit critique of modernity. Elements of the past have been recombined with those from another traditional source outside its cultural context. Architectural traditional forms evolved, diffused, hybridized, and in the process, synergized (Tan, Hock Beng, 2001). They have always been hybrids of indigenous and imported types. For instance, the lessons from traditional Malay house in Malaysia and Singapore has been imported to the colonial houses to adapt the local context. Hence, traditions are always contested, transformed, resisted and invented.

Malaysian architect, Jimmy Lim's unique architecture on series of distinctive houses which captures the sense of Malaysian Indigenous architectural types reflects his sincere effort to develop critical vernacular and regional forms that relate to the Malaysia's context. He believes that "architecture in Malaysia would have to be developed from observation of our environment, life-style, climate and more of what and who we are. The respond to the environment and the climate is crucial (Tan, Hock Beng, 2001).

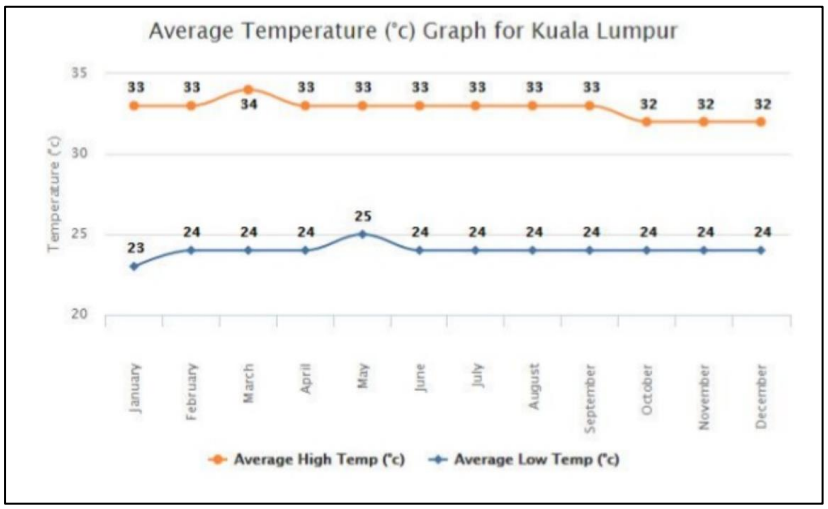

Figure 3
Average temperature of Kuala Lumpur throughout the year (worldweatheronline, n.d)

Based on Figure 3, Malaysia capital city, Kuala Lumpur experiences a hot and humid weather all year long with average temperature is ranging from 23°C to 34°C. Located in the equatorial region, Malaysia also experiences at least an average of one rainfall per week. Hence, the people living in the tropics receives plenty of sunlight, rain and wind to provide comfort and do not require much effort to survive. However, most building nowadays neglect the passive design features by relying on air conditioners and using electrical lighting to keep our house cool and bright. This is the result of blind copying of foreign designs (influence of Modernist architecture) and inattention to our architectural heritage. According to Kubota 2006, 62% of Malaysia terrace houses possess at least one air conditioner. This proving that Malaysian houses are lacking of a conscious approach to energy conservation in the design of the built environment. The main issues of architecture in tropical climate can be classified into four major problems (table 4).

Main Issues in Tropical Architecture	Description
Lack of natural ventilation	Completely rely on Mechanical cooling systems that contributes to the urban heat island effect by releasing greenhouse gases into the atmosphere, making them harmful to the environment.
Lack of natural lighting	Modern house such as the terrace house is enclosed in between the two houses of the same row. Roof is usually enclosed hence no skylight penetration into the interior space.
Unsuitable materials	Typically use relatively heavy materials such as concrete, steel and masonry which have high heat capacities and store plenty of heat which released during night time, making houses hot within.
Mimicking of modern western design	Focus on minimal appearance, aesthetics and economical profit neglects passive design, resulting in unsustainable building design.

Table 4
Main issues of architecture in Tropical climate

3.0 Passive design strategies in tropics

3.1 Building Orientation and Site Context

Building must be designed and rotate its position according to the wind direction to maximize the cooling system and minimize the shading and high temperature of sun path. Therefore, building that is going to be built should be planned in the early stage to minimize heat gain from sun. sufficient shading devices can be installed in the building if site location cannot be compromised. Building can be built above the ground level to reduce the impact on land and environment. Minimization of the negative impacts of the project on the site is crucial and parts of the green building criteria for most of the country to promote sustainable site planning and management.

The sun provides the daylight in two ways which is direct and diffused sunlight. Part of the sun's energy reaches the earth's surface is called direct sunlight. The direct sunlight may cause excessive brightness which will contribute to visual discomfort or what we call glare. While some of the other part is scattered by the atmosphere and produces the blue sky is called diffused sunlight.
In Malaysia, east and west facing windows get direct absorption of heat into the building. Thus, most building windows face north or south. It is also recommended that maximum windows to wall ratios for Malaysian buildings (Figure 4) are always high for south and north facades but lower for east and west facades in order to minimize solar radiation on the building envelope (A. M.R. Aminuddin, et, 2012). Clerestory window can allow optimum sunlight enter the building to reduce usage of electricity during the day.

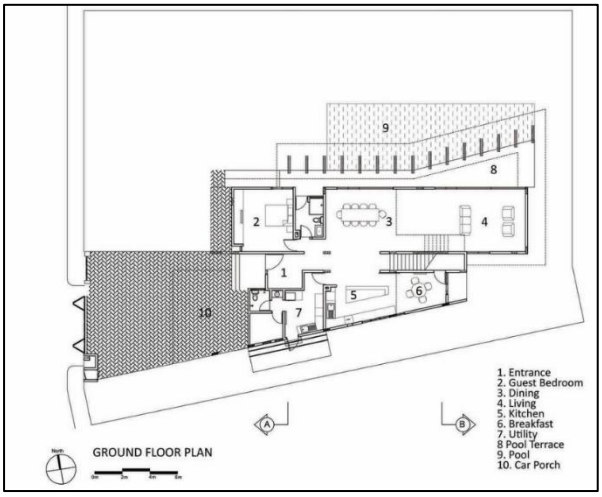

Figure 5 Sepang house facing most of the façade towards north and south direction, designed by Eleena Jamil Architect (2015).

3.2 Ventilation

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The wind orientation is important to increase natural ventilation. The natural ventilation needs to make use of the prevailing wind direction. It is recommended that building in tropics should be designed by raised up the stilts to minimized the wall and partition to provide open space that can allow cross ventilation. Stilts also functioning to catch winds of high velocity. It uses airflow to release heat and humidity. Large overhang and low exposed vertical areas provide good shading and solar radiation control. Large overhang also provides protection against falling rain and allow opening to be left open for ventilation. Elongated open plans also allow easy passage of air and good cross ventilation part from broad verandahs and lots of openings.

Buildings in tropics must have a large number of huge openings to encourage maximum amount of cross ventilation. The location of the opening can be within the ceiling or between two planes. In the traditional Malay house (Figure 5), the windows are usually full-length and are fully operable, extending all the way down to the floor level. Some windows have adjustable louvres or shutters which allow ventilation even when the windows are closed. Designing the facade with more openings between two building blocks, big openings at facade, ample size and number of windows and sufficient ventilation louvres may assist in cross-ventilation. High ceilings also encourage the free flow of air.

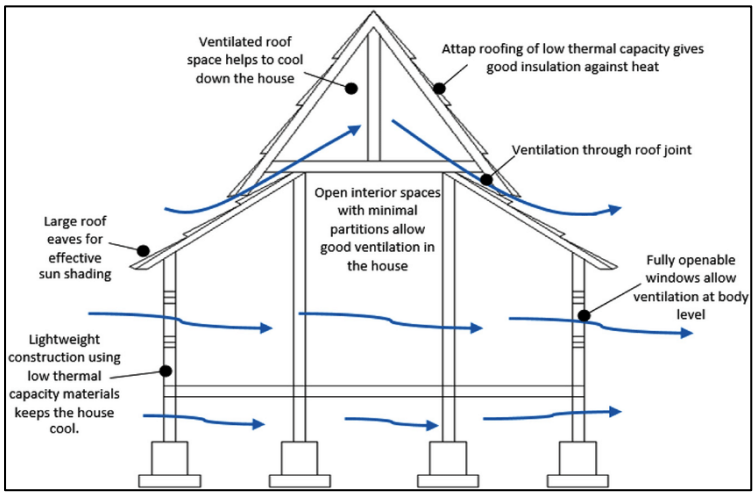

Figure 6 Air movement in Traditional Malay House
Lim, J.Y., (1987)

3.3 Thermal Zoning

The external heat gains into the building are mainly from the external sources (solar radiation). The external heat gets into the building through conduction and convection from the building envelopes i.e. wall and windows. While the heat gains from internal sources such as occupants, electric lights and equipment also provide heat inside the building as they are actively operated. A building design should firstly understand how climate response can influence its façade performance. Tropical climate buildings would require a facade that is able to keep the building cool however cold countries would prefer to keep the building warm. Windows may influence occupant thermal comfort by heat gain or heat loss through the glass, which either raises or lowers the room air temperature, and by radiation exchange between occupants and the glass and other surroundings. Semi-permeable walls with a light-weight benefit, maximize the interface between the interior and the surroundings. Instead of excluding the weather and isolating the occupants from the external environment, it also offers immediate and direct contact with the surroundings.

The transition spaces or in-between realms is vital and essential link between architecture and landscape in Southeast Asia passive design. It includes a variety of architectural element such as loggia, verandah, balcony, patio, terrace, colonnade, pergola, pavilion, passageway and external staircase. Verandah for example, serve as an outdoor room and provide sense of shelter from the heat. Deep overhangs provide physical shelter from the heat and torrential downpour. Non-air conditioned public spaces do not require enclosing walls to keep out the rain and heat.

Courtyard is predominant in the indigenous urban settlements of Southeast Asia. The courtyard, opened to the sky space brings daylight, rain, natural ventilation and a feeling of openness to the interiors. It is efficient in the utilization of space and provides private outdoor space. It provides light and ventilation through central air wells for high density housing and the long narrow buildings of the traditional shop house in Singapore and Malaysia.

3.4 Building Form and Typology

Building form and typology for topics aim to minimize the solar radiation on the building envelope, optimize daylight access and heavy rainfall. Steeply pitched roofs wide eaves and deep overhangs like the shape of umbrella are some of building form in tropics to adapt with the context. A building shape, form and orientation may determine the receipt of solar radiation. It was found that a spherical building consumes less energy. Roofs as part from dominant element of architectural composition and it provides the quickest visual impression of a distinctly regional flavor. Studies have shown that the roof is an important symbol of a shelter and security.

In tropics, the traditional pitched roofs remove the heavy downpour quickly and efficiently. It also provides lavish space to the interior in which the high ceiling is ideal for inducing air movement and cross-ventilation (Figure 5). In Peninsular Malaysia, each state has its unique roof form like the ‘Minangkabau’ house, the ‘Kelantan’ house, etc. The most highly developed of these roofs and simplest design is *bumbung panjang*, a gable roof supported by king posts. The gable ends usually has ventilation grilles or a motif that allows for efficient cross-ventilation.

3.5 Building envelope

The building envelope which is consisting of roof, walls, windows, doors, construction details and ground surfaces, is a main component of any facility since it protects the building occupants and plays a major role in regulating the indoor environment. It can be considered as the selective pathway for a building to work with the climate- responding to the needs of heating, cooling, ventilating, and natural lighting. The design of building envelope for passive design strategies in tropics may include several purposes including to provide the minimum required daylight access, together with a minimal heat gain and maximal external reflection.

Reflective materials and light colors for roofing can reduce solar heat in the building since the roof is exposed to the sun for the whole day. Wall shading can minimize solar heat gain significantly using roof overhangs, window shades, awnings, a canopy of mature trees, or other vegetative plantings. Buildings in tropics must have a large number of huge windows and doors to encourage maximum amount of cross ventilation and allow daylighting. For example, in Malaysia office buildings which are mainly glazed facade buildings, the work stations should be located along the building perimeter to encourage the full use of daylight and good views. The function of shading devices is to prevent direct sunlight, for good visual and thermal comfort. A punch-hole window with light shelves is best for shading direct radiation, and also bounces natural light deeper into building interiors. The adjustable louvres with shading fins are widely used at most of the building windows.

3.6 Materials selection

Materials selected for building in tropics must minimize heat transfer to the indoor space. The use of timber as a building material is sensible as it is abundant, locally available and has a low thermal mass. Apart from that, other insulation material is essential to act as a barrier from heat transferring in and out of the building. There are few commonly available insulating materials in Malaysia such as aerated concrete, mineral wool and low-e double glazing. Buildings should also be well insulated by installing layers with high u-value such as timber or fiber glass insulation.

3.7 Landscaping

Landscape and gardens can provide shade on the building, reducing the heat gain, and to create pleasant outdoor space. In the tropics, buildings are not mere objects in the landscape. Shaded gardens provide great relief in the hot climate while plants soften hard building edges. There are several advantages of plants in architecture. For instance, to define space, provide privacy, frame views, create exciting spatial sequences, acting as absorbent materials, reducing heat, glare and airborne noise in micro-climate effect of the surrounding. Trees planted strategically provide efficient shade and act as wind barriers not only visually pleasing. Green roof, green wall and water features may lower the surrounding air temperature and provide more moisture in the air. Trees also function as good shading devices to protect glazing from direct sunlight, and lower the indoor air temperature. Besides trees, water features play an important role in tropical architecture in Southeast Asia and as one of the essential component of the landscape. Vegetation surrounding and pool could create a cool micro-climate system to the building

4.0 Conclusion

There are still a lot of other factors that may contribute in enhancing the passive design strategies for green building in tropics. Different setting and location of the building may also require different approach in providing a good thermal condition of the building, thus opening an ample room of researches and studies in this field. Architects need to decide which principles are still best appropriated with modern building in order to incorporate with the requirements todays and current construction methods.

As a conclusion, the passive design strategies in the tropics, can be categorized into three main aspects; heat regulation, natural lighting and response to tropical context. In term of heat regulation, designers can apply the air well, vegetation, green roof, jack roof, openings, less partitions between spaces and maximize openings like louvres, casement or awning windows to allow natural ventilation. While in order to maximize natural lighting, the application of air well, openings, clerestory windows, inner courtyard and the orientation of the building can be part of the strategies to promote energy efficiency. Response to the tropical context also can be seen in the use lightweight materials, locally available materials, materials of low u-Value, abundance of tropical greenery and levelling of floor. All these strategies actually can be learnt from our indigenous architecture design. Finally, we should learn from our past experiences to improve our energy consumption patterns in tropical sustainable architecture and therefore could fulfill the green building criteria.

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