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Evaluating the Impact of Vernacular Façade Design on Indoor Thermal Performance in Malaysia's Modern Masjids

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Abstract – Accessing buildings for evaluation on architectural concerns are raised as some designers create the call to revive indigenous architecture when a trend of adopting foreign or international architectural style is widely spreading. The quests for cultural identity in Malaysia towards sustainable contemporary buildings require research of past achievements. Vernacular masjid is known to adhere to principles of passive design as the key to thermal comfort. Researchers posed questions on the extent of flexibility in vernacular architectural concepts, concerning design adaptation on modern masjids for optimal thermal performance. This experimental research aimed to evaluate the outcome of modern masjid façades designed with the vernacular concept in Malaysia. In the literature, research brings together variables such as building height, façade shading, *serambi* openings, as well as materials and construction details. A quantitative analysis led this investigation through observation and field survey on stratified random samples of modern vernacular masjids in Malaysia. Air temperature and relative humidity were recorded using a MIC-98583 sensor with ±0.6 °C accuracy in temperature and ± 3 % accuracy in relative humidity. Wind speed was measured using an AVM-305 sensor with ± 0.2 m/s accuracy. The empirical finding highlights *serambi* opening-to-wall design as the most significant element of vernacular architecture found in building façade that influences indoor thermal performance in modern vernacular masjids. The result could become an extremely useful guideline for designers to create the sustainable design in the future.

Keywords: *façade design, masjid,* serambi *thermal, vernacular architecture.*

I. INTRODUCTION

High demand for additional infrastructure and increased population in urban areas have specifically created challenges for the design and architecture of masjids. Consequently, a problem emerged which is the low quality of indoor thermal performance. Construction of buildings that are not well organized and systematic will easily contribute to discomfort in internal and external spaces through the current situation of global warming. The growing need for responsible architecture and human footprint on the environment sees the necessity of vernacular practices in the days of modernism and globalization. Ali (1983) defined vernacular architectural style as the state of tradition and environment using local materials or situated at a local place. The main characteristics of vernacular style include the flexibility of space layout and construction materials as well as elevated floors. Lim (1987) and Rashid et al., (2021) added on the construction of vernacular buildings that incorporate occupants' culture and reflect a good understanding of nature and the environment. Moreover, Roche (2001) suggested that designers study the importance of thermal comfort and energy-saving concepts before designing a climate-responsive building. Hussin et al. (2018) mentioned that buildings with natural ventilation systems have higher occupant satisfaction and lower operating costs than those with mechanical ventilation systems like air conditioners.

ASHRAE Standard 55 specifies conditions for acceptable thermal environments and is intended for use in the design, operation, and commissioning of buildings and other occupied spaces (ASHRAE & ANSI, 2004). Thermal comfort can be defined as the satisfaction level of the human thermal sense responding to the surrounding environment. Lim (1987) listed solar radiation, temperature, and humidity as the three factors that determine thermal comfort. It is also important for designers to consider the type of building materials and shading design on the building façade, keeping in mind that the main source of heat is direct solar radiation. Moreover, better living conditions can be achieved in hot and humid climactic regions by designing buildings with sufficient airflow to ensure good natural ventilation (Lim, 1987). However, the local climatic conditions and energy conservation possibilities have not been considered in the most recent building designs. As masjid's designs are modernized, the use of modern construction materials often compromises the passive climate-responsive measures. Motealleh et al., (2018) illustrate conceptual diagrams of vernacular architecture from some scholars' points of view. However, this research was absent on the relationship between vernacular concepts and thermal performance.

Malaysia features masjids built in a variety of cultural and architectural styles. It blends elements unique to the region, whether it is in the east or west of Malaysia, the available materials, and the dominant architectural style of the time, reflecting the influences of various civilizations both within and outside. Moreover, the essence of vernacular architecture in Malaysia has always centered on a good design and construction process. The practice takes into consideration the materials and resources used, indoor environmental quality, energy efficiency, as well as sustainable site planning.

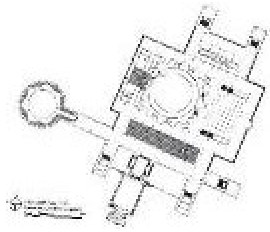
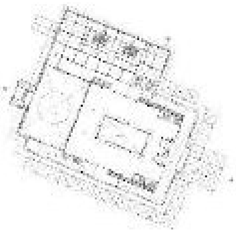
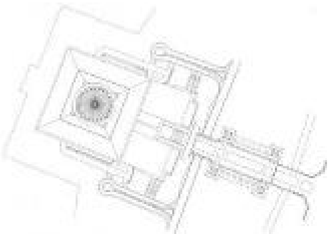
A. Problem Statement

Due to the current state of global warming, poorly planned and managed masjid construction will easily contribute to discomfort in interior areas. In Malaysia, it has become the customary practice for masjids to have air conditioning systems installed for cooling and thermal comfort. Humans grew more dependent on mechanical equipment as a result of the construction development and phases of architecture than they were on natural resources. 34% of the annual power used in a building is used to run air conditioning and other interior cooling systems (Birkha Mohd Ali et al., 2021). Nevertheless, masjids have a very high energy usage as the same energy-intensive system is operated even during minimal occupancy profiles. It may be possible to adapt vernacular masjid characteristics to make it more climate-appropriate while using less energy. Designs that use traditional building materials like timber might seem unworkable in the context of expanding urban developments. A small number of masjids that were constructed after Malaysia gained its independence show how vernacular architecture in Malaysia has changed over time. This investigation is guided by identifying the significant element of vernacular architecture for indoor thermal performance found in modern masjid façades in Malaysia.

B. Study Area

A finding by Mohd Sojak (2019) narrows the typology of modern vernacular masjids in Malaysia by its design approach factors. This paper aims to investigate how effectively the vernacular design approach can be re-adapted to benefit thermal performance in Malaysia's modern masjids. This study generates a population of twelve (12) modern vernacular masjids which were constructed in Malaysia from 1965 to 2017. To answer the research objective, it is doubtful to be able to collect data from all masjids. Thus, there is a need to select a sample. A stratified random sampling is implemented to the population of modern vernacular masjids to identify the final sampling used for the façade design inventory. It leads to three (3) samples being selected based on their vernacular design approach (Table 1). Experiments were conducted at Malaysia National Masjid (Kuala Lumpur), Sultan Tuanku Mizan Zainal Abidin Masjid (Putrajaya), and Raja Haji Fisabilillah Masjid (Cyberjaya). Elements such as the architectural approach, construction materials, as well as structural and non-structural components are discussed in this paper. Determining the significance of these vernacular elements in façade design is crucial to assess their impact on indoor thermal performance.

Table 1. Stratified Random Sampling of Modern Masjids with Vernacular Design Concept for Experimental Research Design

Masjid	Building Facade	Building Layout	Main Prayer Hall
Malaysia National Masjid, Kuala Lumpur.			
Raja Haji Fisabilillah Masjid, Cyberjaya.			
Sultan Zainal Abidin Masjid, Putrajaya			

Source: Authors (2023)

II. METHODOLOGY

The field survey was carried out by using the data logger HOBOware E348-U12-011, which allowed the measurement of thermal parameters in air temperature and relative humidity. Air velocities are measured using Multifunction Air Velocity Meter PCE-VA 20. Data on each masjid was taken four times a day (according to prayer times) for five consecutive days. Each instrument is located at predetermined points inside the main prayer hall and *serambi* areas. The logged data were downloaded and transferred into Microsoft Excel. Building measurements for detail drawings are collected using Laser Levels Infrared Laser Level Cross Line Measure Tape Multifunction. During the data collection period in each masjid, outside climatic data were obtained from the local meteorological office. This research collects outdoor data because it usually gives a direct impact on indoor thermal comfort.

Through site observation, the researcher can also validate the secondary in desk review. The collection of primary data in the actual environment on site requires in-situ observation, which is of utmost importance. The investigation is conducted at the actual building as well as the areas immediately surrounding it. Its objective is partially exploratory, and the knowledge that is essential to defining a strategic approach for the building of masjids that would achieve high interior thermal efficiency is the observations that are made. As a consequence of the research, the primary data gathering that took place on-site is shown and documented in great detail, along with drawings of the floor plan, sections of the building, and elevations. These drawings are backed by pictures.

The validity of a research instrument describes the degree to which an instrument accurately represents the variables that are being investigated. Because the purpose of this study is to evaluate the relationships between vernacular façade design, which will serve as the independent variable, and indoor thermal comfort, which will serve as the dependent variable, the quantitative approach through field experiment has a higher ecological validity than any lab experiment could ever have since it takes place in its natural surroundings (Balbis-Morejón et al., 2020). This means that the behavior seen in a field experiment is more likely to mirror actual life. The modern vernacular masjid facade design (MVM) is the mediator that links independent and dependent variables.

III. Elements of Vernacular Architecture at Masjid Façade That Influence Indoor Thermal Performance

Mohd Nawayai et al. (2020) provide a comparative study on the criteria of both old and modern vernacular masjids. Taking the importance of vernacular architecture, several elements connected façade design strategies in modern vernacular to associate with the old vernacular approach. Despite the variation of distinctive approaches in old vernacular design through the evolution process, some elements are considered dominant in the construction of modern masjid buildings. The modern design evolution is based on the essential elements in façade design strategies to create an optimum indoor thermal performance towards sustainable development. Vernacular architecture act as an independent variable and indoor thermal performance is considered the dependent variable in this research mechanism. The elements are classified as building form and architectural layout, building height, *serambi* as façade shading, ventilation panels and building material. This literature study will assist experimental data to identify the most significant element of façade design that contribute to optimum thermal performance on modern masjids.

A. Building Form and Architectural Layout

The shape of a building is an essential feature of the external surface area, which determines the energy balance and thus, the cooling load. Rectangular open plans allow air passage for cross ventilation. Minimal interior partitions also encourage air movement in the masjid. The open plan concept has advantages, such as the prevention of heat gain from the East and West side of the building, and hindrance to solar radiation in the design of rectangular building plans with lengths facing the North and South (Halwatura & Jayasinghe, 2007; Konya, 1980; Tombazis & Preuss, 2001).

B. Building Height

Wind velocity is higher at a higher altitude, thus height is a crucial factor. Stilts are a prominent and unique feature of traditional vernacular masjids in Malaysia, which is inspired by the design of traditional Malay houses as in Fig. 1 (Lim, 1987). This building feature was introduced for safety, thermal and functional aspects. In addition, the elevated floor helps the building to capture higher velocity winds. The raised floor captures high wind velocity. It also provides an excellent under-floor ventilation system. This is particularly vital in areas with plants covering the grounds that may restrict air movements. The use of timber planks for the floor with gaps in-between directs air into the inner space under the floor.

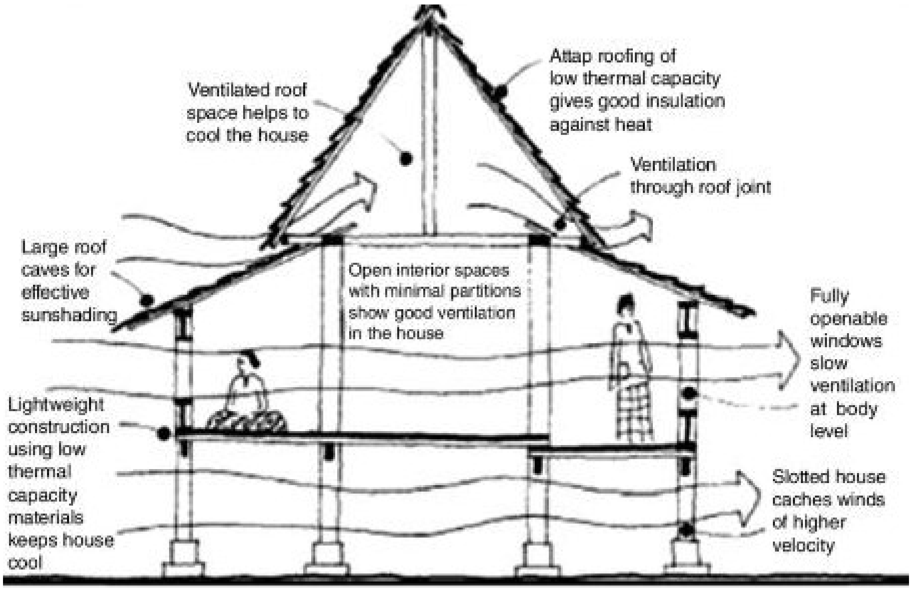


Fig. 1. Climatic Design of the Malay House
Source: Authors (2023)

C. Building Material

Vernacular masjids in Malaysia constitute the expression of the practical and cultural needs of each community. A complex balance between material, shape, and natural context resulted in vernacular architecture being the most integrated architectural form in communion with the environment. According to Shah et al. (2014), a study of building materials is organized based on its main constituent components, stone and minerals, concrete and clay, metal, glass and plastics, as well as composite building materials. Construction technology can be analyzed based on specific parts of a masjid such as a floor, walls, and roof construction system. However, this research tends to only focus on ventilation panels at the main prayer hall that is designed to manipulate indoor thermal performance.

D. Serambi *as Façade Shadings*

Sufficient daylight, reduced glare, and controlled solar heat gained in interior spaces can be ensured via a proper shading design. *Serambi* is one of the basic features of regional vernacular masjids because of its cultural diversity. The design of the regional vernacular masjid includes *serambi* as one of its important components. Serambi is always introduced as an outdoor shaded space to cool off before entering the building. It acts as the transitional space between the entrance and the remaining parts of the masjid (Fig. 2). *Serambi* is also known as a semi-open or semi-enclosed space without a solid wall. Openings are a very significant physical characteristic that can be seen at *serambi* (Anuwar & Abas, 2019). Apart from offering protection against rain, *serambi* is a form of good shading which also allow openings for ventilation to remain open most of the time. In addition, the amount of light and glare entering a masjid can be controlled with the incorporation of overhangs on top of the *serambi*.

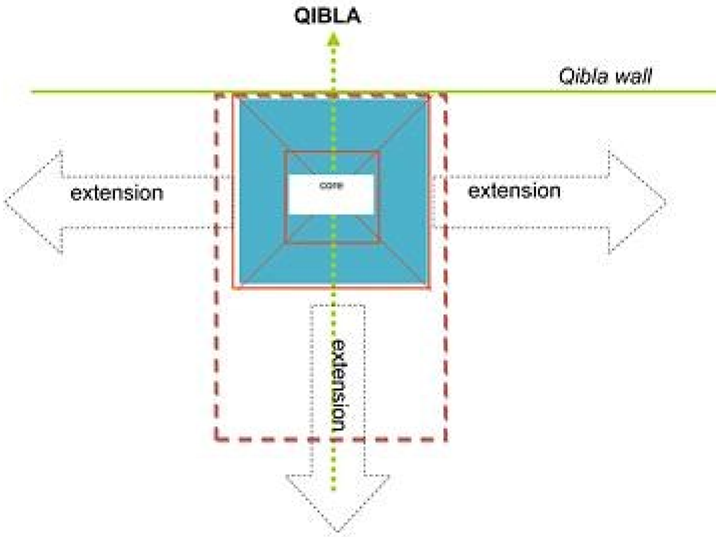


Fig. 2. *Serambi* Usually Surrounds Three Parts of the Vernacular Masjid Plan Except in the Qibla Direction
Source: Authors (2023)

E. Ventilation Panels

Vernacular masjids in Malaysia portray a high level of craftsmanship. Hassan and Ramli (2010) elaborated that a large number of windows and openings aided by ornamentation at perimeter walls of the vernacular masjids contributed to the cross-ventilation process. The non-structural components such as louvered windows, fanlights, carving wall panels and fascia boards at floors, walls, stairs, and roofs are fitted between frames to allow natural cross ventilation of air.

IV. Governing Parameters on Indoor Thermal Comfort Related to the Façade of Modern Vernacular Masjid in Malaysia

Understanding the parameters that contribute to thermal comfort in outdoor and semi-outdoor settings has recently seen an uptick in research since it has the potential to cut down on energy use in inhabited buildings and turn unused areas into liveable ones (Potchter et al., 2018; Huang et al., 2019; Zhang et al., 2020; de Dear et al., 2020; Wu et al., 2021). In terms of importance and significance, the climate should be an aspect that needs to be highlighted in the design of a building. It is the deciding factor in the types of materials utilized, the construction time frame, and the sustainability of the constructed building. To achieve thermal comfort and energy savings, the design operation of a building's envelope also might be impacted by climatic circumstances. In Malaysia, buildings with mechanical cooling systems adopted the 2014 Malaysian Standard (MS) 1525 Code of Practice, referencing the ASHRAE Handbook (ASHRAE & ANSI, 2004). The purpose of these regulations is to specify various combinations of indoor thermal environmental factors as well as personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within a space. The thermal comfort within a building is affected by physical parameters of air temperature, air velocity, and relative humidity.

A. Air Temperature (Ta)

Air temperature (Ta) is the mean temperature of the air around an inhabitant at a given time and place. Degrees Fahrenheit and degrees Celsius are the standard units of temperature measurement. According to ASHRAE Standard 55, the comfort range for air temperature varies depending upon the air velocity inside an enclosed space; generally, a variation between 21℃ to 26℃ is acceptable (ASHRAE & ANSI, 2004). Meanwhile, the Department of Standards Malaysia developed guidelines for a standard indoor environment design for the climate of Malaysia in 2007, which propose a temperature of 23°C to 26°C. The estimation of indoor air temperature is essential for the evaluation of thermal performance.

B. Air Velocity (Va)

Ventilation is the intentional introduction of outdoor air into a space. Indoor air quality is managed primarily via the use of ventilation systems, which dilute and displace indoor contaminants. The ventilation of a building significantly affects its thermal efficiency. Air Velocity (Va) is expressed in the unit of m/s. (meter/second). ASHRAE Standard 55 specifies a velocity range of 0.10-0.25 m/s as optimal for equable cutaneous heat loss (ASHRAE & ANSI, 2004). Gamero-Salinas et al. (2021) suggested that building opening features that allow an increase in air velocity contribute to greater thermal comfort in semi-outdoor settings. They discovered that various building forms and environmental characteristics (height-to-depth ratio, open space ratio, and green plot ratio) all contributed to varying degrees of thermal comfort in these semi-outdoor spaces (such as air temperature, mean radiant temperature, relative humidity, and air velocity). Even though the study evaluates five (5) types of semi-outdoor space in tall buildings in Singapore, their finding is comparable to the subject of this research. Both studies investigate air velocity as an environmental parameter to the opening ratio of semi-outdoor space design for thermal comfort.

C. Relative Humidity (RH)

Humidity and temperature are interrelated. According to ASHRAE Standard 55, relative humidity (RH) is the air's moisture content (i.e., water vapor) expressed as a percentage of the quantity of water that can be held by the air (moisture-holding capacity) at a particular temperature and pressure without condensing. When the temperature rises or falls, so does the relative humidity, and vice versa. At higher temperatures, relative humidity (RH) drops, whereas at lower temperatures, RH rises (RH increases). Percentage (%) is the standard unit of measurement for relative humidity. Humidity levels are measured with higher numbers indicating a more watery air-water combination. The importance to measure relative humidity is related to the elements of vernacular architecture found in building façades that influence indoor thermal comfort in old vernacular masjids. Humidity may have a detrimental and costly effect on construction materials such as building metals like iron and steel which are subject to rust. Other material such as wood remains permeable to moisture even when dried. Moisture is a prime weakness for paint and adhesive. When temperature and relative humidity are low, the evaporation of water is sluggish. When relative humidity hits 100%, condensation can form on surfaces. It can cause difficulties at mould, create corrosion, decay, and other damage caused by moisture. Mold and wood rot can be fostered by condensation, which potentially poses a safety problem. This may result in architectural flaws and prevent the structure from being sustainable. In building automation systems that prioritize human comfort, relative humidity is considered as one of the significant aspects. The ability to detect and adjust relative humidity not only helps to maintain a comfortable climate within a structure but also helps to maximize the efficiency of HVAC systems.

V. RESULTS AND DISCUSSION

In this true experiment research, elements of vernacular architecture at the masjid façade are manipulated to determine the effect on thermal performance as the dependent variable. To answer the research objective, masjids are grouped according to characteristics they share and stratified randomly assigned. Three (3) masjids were shortlisted to represent ranges of modern vernacular masjid variations currently existing in this country. National Masjid represents the birth of Modernism architecture, Sultan Zainal Abidin Masjid was the first sustainable masjid design, and Masjid Raja Haji Fisabilillah is awarded a Platinum rating of the Green Building Index (GBI) standard. Referring to ASHRAE Standard 55, there are three primary parameters to measure indoor thermal performance impacting from building façade of a modern vernacular masjid in a hot and humid climate. They are namely the temperature, air velocity, and relative humidity. Data were taken at a few identified points to calculate the mean measurement for each zone.

A. Air Temperature (Ta)

Table 2. Average Temperature in Prayer Hall Areas From 7th – 11th October 2019 at Malaysia National Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ornamentation (Concrete)
6.00 am	25.28	25.20	24.69	25.28	25.34
2.00 pm	25.08	29.42	31.09	25.92	25.86
5.00 pm	22.44	26.94	27.67	22.06	22.96
8.00 pm	22.54	26.86	26.9	22.94	23.08

Source: Authors (2023)

Table 3. Average Temperature in Prayer Hall Areas From 7th – 11th October 2019 at Raja Haji Fisabilillah Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ornamentation (Glass)	Ornamentation (Timber)
6.00 am	23.36	23.8	25.42	23.5	25.38	25.38
2.00 pm	27.28	28.26	31.24	28.32	31.28	31.28
5.00 pm	25.92	26.44	29.1	26.02	29.26	29.26
8.00 pm	23.2	24.46	26.58	24.4	26.54	26.54

Source: Authors (2023)

Table 4. Average Temperature in Prayer Hall Areas From 7th – 11th October 2019 at Sultan Zainal Abidin Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ventilated Ornamentation (Metal)
6.00 am	25.6	25.76	25.9	26	25.82
2.00 pm	29.76	31.18	31.34	29.36	31.28
5.00 pm	28.58	28.6	28.68	28.62	29.34
8.00 pm	26.66	26.8	26.86	26.14	27.16

Source: Authors (2023)

According to Table 2-4, the temperature in prayer halls at all masjids during the daytime range from 22.44-29.76°C. The highest indoor prayer hall temperature was during Zuhur prayer time. Recorded data find *serambi* areas located at both sides of these prayer halls were always higher than the indoor temperature (range from 24.69-31.34°C), but lower than the ambient outdoor temperature in Fig. 3 (range from 25-32.8°C). This finding justifies the function of *serambi* which successfully acted as a transitional space between the outdoor and indoor of the masjids. It could be due to the application of shading devices that create a semi-open space and efficiently reduce solar penetration into the main prayer hall. As a result, the indoor temperature is consistently lower than the temperature in *serambi* area. At these three masjids, the external shading devices include overhangs, *mashrabiya* and screens to improve thermal performance for masjid users. The construction of the overhang allows rain to flow down and outwards from the masjid facade as well as giving plentiful shades for the users. Data in Table 2-4 also show that concrete material is not affected by changes in its ambient temperature at the National

Masjid. Glass and timber material displayed the same surface temperature at Raja Haji Fisabilillah Masjid probably due to the application of an air conditioning system. As for the ventilated metal mesh at Sultan Zainal Abidin Masjid, the material exhibits a similar temperature to its surrounding ambiance.

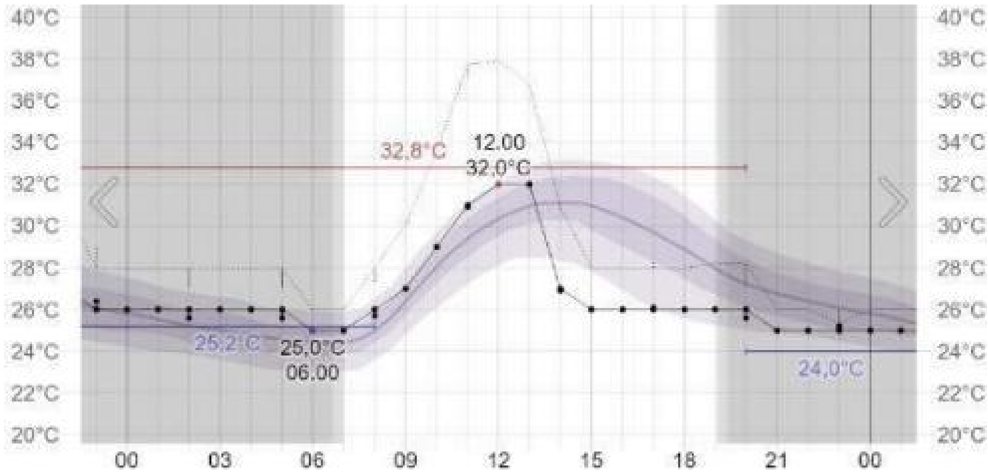


Fig. 3. Average Temperature in October 2019, Malaysia.
Source: World Weather and Climate Information. (n.d.).

B. Air Velocity (Va)

Table 5. Average Air Velocity in Prayer Hall Areas From 7th – 11th October 2019 at the Malaysia National Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ornamentation (Concrete)
6.00 am	0	0	1.05	0	0
2.00 pm	0	0.08	1.55	0	0.08
5.00 pm	0	0.06	1.35	0	0
8.00 pm	0	0.6	0.75	0.14	0

Source: Authors (2023)

Table 6. Average Air Velocity in Prayer Hall Areas From 7th – 11th October 2019 at Raja Haji Fisabilillah Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ornamentation (Glass)	Ornamentation (Timber)
6.00 am	0	0	0.5	0	0	0.1
2.00 pm	0	0.2	0.38	0	0	0.28
5.00 pm	0	0.16	0.42	0.06	0.06	0.5
8.00 pm	0	0	0.2	0	0	0.26

Source: Authors (2023)

Table 7. Average Air Velocity in Prayer Hall Areas From 7th – 11th October 2019 at Sultan Zainal Abidin Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ventilated Ornamentation (Metal)
6.00 am	0.62	0.78	1.68	0.5	0.56
2.00 pm	1.12	1.32	1.72	0.5	1.58
5.00 pm	0.54	0.58	1.6	0.76	0.54
8.00 pm	0.58	0.76	0.9	0.56	0.66

Source: Authors (2023)

Table 5-7 demonstrates that air velocity at *serambi* areas ranged from 0.2m/s to 1.72m/s. The air velocity comes from natural ventilation that was created by a full-height *mashrabiya*. Surrounding pools at masjid samples provides airy and coolness to the atmosphere. The indoor main prayer hall at Malaysia

National Masjid and Raja Haji Fisabilillah Masjid is assisted by an air conditioning system which is only activated during prayer time through a sensor timer device (12-9 pm). Since all openings are closed when the air conditioning system is activated, data was not collected at the main prayer area during this period. Wall screens at Sultan Zainal Abidin Masjid primarily serve as a feature wall that would allow maximum cross ventilation. At the same time, it also prevents heat gain from its surroundings. This design allows Sultan Zainal Abidin masjid to not rely solely on mechanical ventilation such as fans or air-conditioning. Data recorded a range of 0.9-1.72m/s of air velocity at *serambi* area, reduced into a range of 0.54-1.58m/s after passing through the metal mesh wall screens. When reached the middle of the main prayer hall, the range of air velocity is 0.54-1.12m/s. So, the inconsistencies implied that although *serambi* provide a significant impact in manipulating the indoor thermal performance, other variables around the *serambi* area also give impacts the data survey.

C. Relative Humidity (RH)

Table 8. Average Relative Humidity in Prayer Hall Areas From 7th – 11th October 2019 at Malaysia National Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ornamentation (Concrete)
6.00 am	67.92	69.64	76.14	66.16	65.92
2.00 pm	51.72	55.96	56.74	51.28	45.90
5.00 pm	61.72	65.86	67.51	61.60	61.34
8.00 pm	61.32	64.40	68.62	60.96	61.14

Source: Authors (2023)

Table 9. Average Relative Humidity in Prayer Hall Areas From 7th – 11th October 2019 at Raja Haji Fisabilillah Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ornamentation (Glass)	Ornamentation (Timber)
6.00 am	64.48	64.76	76.96	64.8	64.8	76.04
2.00 pm	54.92	55.22	55.3	54.16	56.16	56.28
5.00 pm	59.48	62.00	65.74	60.22	62.22	63.10
8.00 pm	56.26	66.22	76.46	56.52	72.52	76.66

Source: Authors (2023)

Table 10. Average Relative Humidity in Prayer Hall Areas From 7th – 11th October 2019 at Raja Haji Fisabilillah Masjid.

Time	Middle Of Main Prayer Hall	Entrance Of Main Prayer Hall	Veranda / Serambi	Mimbar	Ventilated Ornamentation (Metal)
6.00 am	69	69.56	69.62	65.1	68.32
2.00 pm	53.46	53.82	53.18	53.78	53.36
5.00 pm	61.36	61.04	60.98	60	60.84
8.00 pm	68.4	68.4	68.4	66.5	67.92

Source: Authors (2023)

Fig. 4. Average relative humidity in Malaysia in 2019
Source: World Weather and Climate Information, (n.d.).

The range of indoor relative humidity as presented in Table 8-10 is from 51.28%-69.64%. Timber material displays the highest relative humidity level compared to concrete, glass, timber, and metal. Referring to Fig. 4 by Malaysia Meteorological Department, the average annual percentage of humidity in Malaysia is 81%. Even though the American Society of Heating, Refrigerating and Air- Conditioning Engineers (ASHRAE) recommended an indoor relative humidity (RH) at 40-60%, the result from these parameters was in line with Sapian et. al (2001) mentioned, naturally ventilated building in a hot and humid climate such as Malaysia achieves thermal comfort when the indoor air temperature is within 26-29.9°C and indoor air velocity is within 0.5-1.0m/s. In such conditions, relative humidity must not exceed 90% to sustain the level of comfort. Based on the results obtained in this field survey, the element of *serambi* contributed a very significant role in thermal performance in this experimental study. Airflow properties at the *serambi* opening-to-wall design provide the main prayer hall with natural climate control to provide an optimum thermal environment for occupants. *Serambi* opening-to-wall design also serves as a feature wall that screen and shield *serambi* from direct sunlight, as well as allows a controlled quality of light into the prayer hall.

D. Adaptation of Serambi in Modern Context

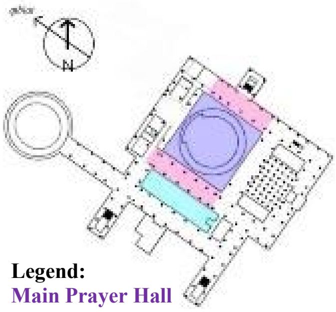
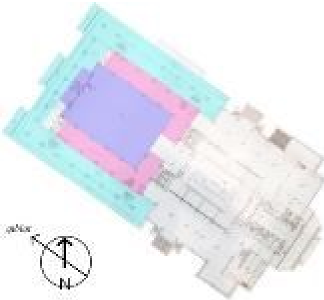
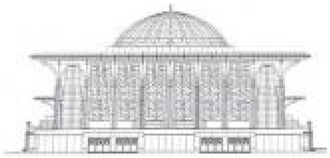
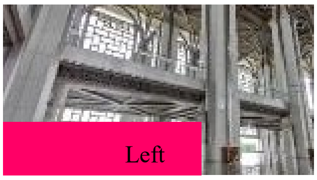
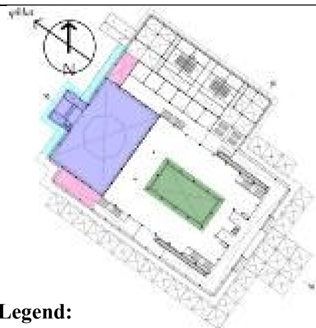
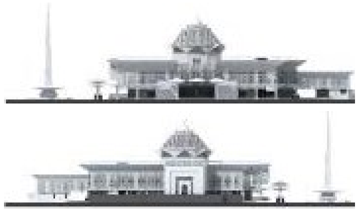
The vernacular architecture involved meanings related to the occupant's unique customs, traditions, beliefs, and philosophy which constitutes the surrounding environment. In response to the rapid expansion of Islam over the Malay Peninsula, local architectural styles began to be appropriated and reinterpreted to conform to Islamic terminology and usage. As a result, Malaysian identity for indigenous masjid architecture began to develop. The existence of *serambi* is commonly known to be built in old vernacular masjids. However, the adaptation and effectiveness of *serambi* in a modern context are less acknowledged although it is a very significant architectural element that plays roles in cultural and environmental aspects.

Congregational prayer is thought to have more social and spiritual benefits in Islamic doctrine than praying alone. With the expansion of ritual obligations like *salat* from being a solitary act to a communal activity, masjid developed from being merely a place for prostration to becoming the center in which the community gathers, and activities were performed on the communal ground. Congregational prayers are performed with an imam standing in the central space near the qibla wall, while the *ma'mum* stands behind him in perpendicular rows (*saf*) to qibla axis. This arrangement requires the prayer hall to accommodate for expansion of *saf* in linear directions by providing ample space either parallel to the *saf* lines (i.e., expansion in length of the *saf*) or parallel to the qibla axis (i.e., expansion in direction of the qibla axis). As the *ma'mum* are expected to stand in uninterrupted rows without any gaps in between them (where possible), the prayer hall is expected to have only minimum physical obstructions that will break the *saf*. *Saf* regulations alone demand that the prayer hall should have certain key features, including an efficient size floor plan, a minimally obstructed open plan layout, and convertible spaces that adapt to various socio-religious functions.

Serambi design has been used as an extension to the main prayer space in old vernacular masjids to solve these design problems. When applied to masjids in modern settings, *serambi* adaption satisfies the demand for accommodation of socio-religious activities such as religious celebrations, socialising, resting places for users, as well as other activities which are related to the socio-cultural needs of the community (see Table 11). Located on each side of the prayer hall, the flexibility is owing to its architectural configuration. The *serambi* opening-to-wall design provides the main prayer hall with natural temperature management to ensure that occupants have the best possible thermal environment.

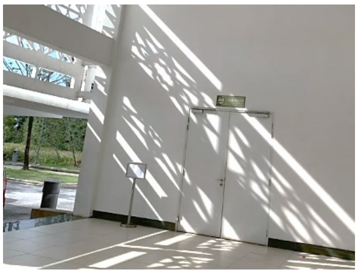
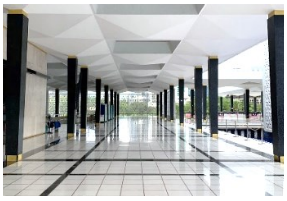
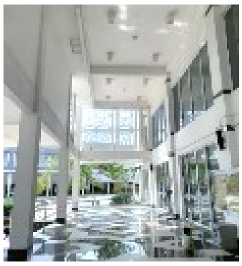
Modern vernacular masjids in urban contexts require spatial arrangements to provide for a larger community in comparison to old vernacular masjids. Each *serambi* is usually designed along the sides of the main prayer hall, with the main entrance placed opposite the qibla axis. This layout is to create a thermally comfortable system for *ma'mum* to stand in uninterrupted rows while others expand the *saf*. Visually, *serambi* design provides character to the building facade without rivalling the fundamental functions of a masjid. Although the functions of the masjid have remained unchanged, its architectural form, space, construction system, and building materials have evolved. They have developed to a significant and variable extent in different periods of vernacular architecture, influenced by many factors in Malaysia. From this perspective, the spatial arrangement offered by modern vernacular masjid seems to imply its function inspired by the conceptual idea of the old vernacular masjid.

Table 11. Adaptation of *Serambi* in the Façade Design of Modern Vernacular Masjid in Malaysia

Building Parts	National Masjid	Sultan Mizan Zainal Abidin Masjid	Masjid Raja Haji Fi Sabilillah
Location Of The *Serambi*	 **Legend:** **Main Prayer Hall** ***Serambi*** **Water feature** **Vegetation** • No other masjid to date has open space larger than the loosely enclosed spaced under the umbrella-like roof (prayer hall). • Both sides of the main prayer hall are attached with *serambi* area to provide ample daylighting and passive cooling to the masjid. • It blocks out direct sunlight and provides shade for prayers and keeps the masjid at a comfortable temperature. • The *serambi* serves its function as a walkway which connects all other spaces in the National Masjid as it was designed to envelop the prayer hall and accommodate additional worshippers during Friday prayers or special occasions. It is also used as a place for informal religious classes or a meeting place for informal discussion sometimes. • It also functions as a transitional space between the outdoor area (entrance) and the indoor area (prayer hall).   	 **Legend:** **Main Prayer Hall** ***Serambi*** **Water feature**  • The sophisticated façade cladding, comprising 4,300 m² of stainless-steel spiral mesh, not only connects the building's rectangular openings architecturally, but it also performs important functions: climate control, solar and weather protection.  • The *serambi* acts as a shaded space to cool off before entering the prayer hall.  	 **Legend:** **Main Prayer Hall** ***Serambi*** **Water feature** **Vegetation**   

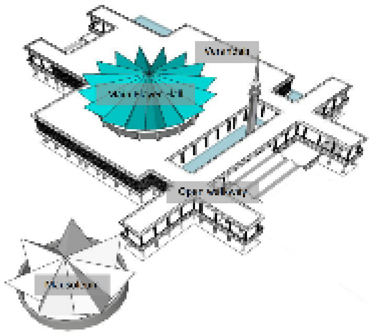
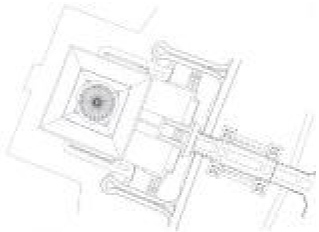
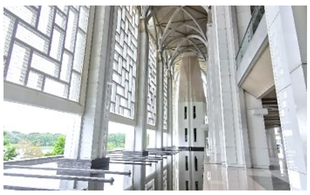
Source: Authors (2023)

Table 11. Continued

Building Parts	National Masjid	Sultan Mizan Zainal Abidin Masjid	Masjid Raja Haji Fi Sabilillah
Building Height From Ground Level	 • Generous floating *serambi* form a horizontal lane from a raised platform with high ceilings and large fenestration for ventilation.	 • The stainless-steel spiral mesh allows the enclosure to appear visually seamless and brings the impressive height of the building façade and its windows to the fore.  • The water pool acts without the need to build a high fence which in turn can block the view around Putrajaya. • The masjid is covered by a composite dome structure sitting on a concrete base.	  
Shading	  • The design of roof at National Masjid's *serambi* area allows natural lighting to enter the space. • The *serambi* acts as a shaded space to cool off before entering the prayer hall.	 • Puristic structural steel work with ornamentation typical of this country characterizes the 24m high façade as a modern interpretation of Islamic architecture. • Rather than glass windows, a woven skin acts as a protecting membrane. The tropical climate in this region places high demands on the materials used. The 'Escale 7x1' spiral mesh from GKD is resistant to corrosion and heat, low maintenance, non-combustible, resistant to mechanical influences and extremely durable.	 
Aisle Design	 • The wide-open design of the *serambi* accommodates Malaysia's tropical weather as it is not fully enclosed and cool air is allowed to pass through the *serambi* space 	 	 

Source: Authors (2023)

Table 11. Continued

Building Parts	National Masjid	Sultan Mizan Zainal Abidin Masjid	Masjid Raja Haji Fi Sabilillah
Opening Design	 • *Serambi* by prayer hall sides is treated like an open gallery. • *Serambi* was designed to envelop the prayer Hall and accommodate additional worshippers during Friday prayers or special occasions. It is also used as a place for informal religious classes or a meeting place for informal discussion sometimes. • A pattern of *mashrabiya* along the *serambi* area act as screening that provides shading while allowing entry of a sufficient amount of daylight. • It also does not hinder ventilation, keeping the area at an acceptable temperature and maintaining a constant flow of ventilation.  	 • Under the open concept, it is surrounded by the interesting scenery of Putrajaya. • The airflow properties of the stainless-steel mesh provide the main prayer hall with natural climate control. • The woven façade shell not only offers protection from drafts, but it also allows the right amount of cooling air to pass through. • Wind blows into *serambi* from the semi-open opening that is according to the human height scale.  • Depending on where the viewer is standing/sitting and the incidence of light, the stainless-steel spiral mesh façade cladding appears semi-transparent or opaque, with a shimmering metallic effect or simply pale grey. At night, illumination brings the transparency of the woven façade shell into the limelight. • The semi-transparent spiral mesh offers visitors reliable solar protection and protects them from driving rain. 	   • The *serambi* does not only screen and shield from direct sunlight, but also allows a controlled quality of light into the prayer hall.

Source: Authors (2023)

VI. CONCLUSION

Serambi has been applied traditionally in Malay vernacular houses and regional vernacular masjid in this tropical region. It provides a sustainable lifestyle and moderates the negative impact on the environment. Serambi has played a significant role in creating conducive social and environmental control. Several physical attributes contribute to the physical characteristics of *serambi*. However, it should not be ignored that some of the characteristics of *serambi* as a vernacular approach might no longer function properly because of changes in cultural and environmental conditions. In this context, the challenge is whether knowledge, skills and experience gained from *serambi* design are still relevant to be applied as an effective tool for thermal comfort in the modern masjid context. The implication is designers will probably have to accept the fact that some of the theories held for so long are no longer applicable in modern living. The main concern is to guide designers to use vernacular architecture technology and design buildings working well in parallel with changes in lifestyle and construction developments. A conceptual framework can be constructed as a new guideline for the study of thermal performance in vernacular architecture, thus contributing to subsequent studies in related studies. Hopefully, the findings from this research can be expanded beyond the scope of masjid architecture and create a space for future research such as in other community organizations and residential developments issues related to this area. Better architecture or building design can improve ambient air quality and protect natural resources as well as minimize the adverse impact on the surrounding environment. Lower operation and building maintenance costs lead to minimizing energy consumption will help in economic aspects, thus improving the occupant's productivity and advance of life-cycle achievement in the category of potential social benefits.

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