



A Documentation of Environmentally Sustainable Mosque in Malaysia

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Abstract: Numerous mosques design in Malaysia disregards the environment which makes the mosque less comfort. For the past 30 years, mosque designs in Malaysia have evolved and are primarily based on the expectations of decision makers and the public (post modernism period). However, there are several mosques in the twenty-first century incorporate sustainability into their design that need to be documented for future research. According to the findings, instead of Masjid Raja Haji Fisabilillah, Cyberjaya, there are 4 more mosques practise sustainable design in Malaysia. These mosques have a good sense of environmental design which gives comfort to the occupants. The study conducted qualitatively from the secondary data source and on field observation. The data is compiled through descriptive analysis of sustainable characteristic implemented in the selected mosques. The propose of this paper is to document sustainable mosques in Malaysia and contribute ideas for future mosque design. This paper will be the reference for the authors to continue detail study of the sustainable mosque in the future.

Keywords: Mosque, sustainable design, Cyberjaya

1. Mosque in Malaysia

Mosque in Malaysia occupy a significant position in the sentiments of Muslims and function as crucial establishments for religious observance and communal engagement. These architectural structures embody the abundant cultural legacy of the nation, simultaneously serving as venues for religious practices, knowledge dissemination and communal involvement [1]. However, the issue of capacity and congestion arises as a result of expanding Muslim population in Malaysia, posing difficulties for certain mosques in handling the rising number of worshippers, particularly during high-demand periods such as Friday prayers and Ramadhan. This scenario may result in a situation of overcrowding and restricted prayer space, hence generating inconvenience and uncomfortable for individuals engaged in worship activities.

The tropical climate in Malaysia poses difficulties in maintaining a comfortable indoor environment within mosques due to elevated temperatures and humidity levels [1], [2]. Insufficient ventilation and air movement can intensify this problem, leading to discomfort among worshippers, particularly during periods of high prayer attendance. It is imperative for mosques to prioritize the implementation of effective ventilation to effectively regulate temperature levels and enhance the overall air quality within the building. Furthermore, not only maintaining the comfort of the

indoor environment, but there is also other characteristic that could improve in the design of the mosque in Malaysia [2].

Mosque in Malaysia play a significant role in the lives of Muslims and the community. When it comes to a sustainable architecture, an environmentally sustainable mosque in Malaysia can have several unique considerations and features. Malaysia has a tropical climate, characterized by high temperatures and humidity. A sustainable mosque design can incorporate climate-responsive design to reduce the need of excessive energy consumption [2].

2. Environmentally Sustainable Mosque

Earlier mosque architectural styles (see figure 2) were comparable to Malay vernacular house, and they progressed with the introduction of the modernist style, which contributed to an increase in energy consumption and the requirement for thermal comfort [1]. It is essential to offer a healthy and comfortable atmosphere for the occupants in any building. According to Nawayai [2], referring to the vernacular Malay house characteristic as shown in Figure 1, the passive designs can be the solution for environmentally friendly designs as a result for a good thermal design. It also can be used to improve the thermal comfort of mosque architecture and passive design strategies. Therefore, these matter needs to be agreed upon by all parties involved especially architects.

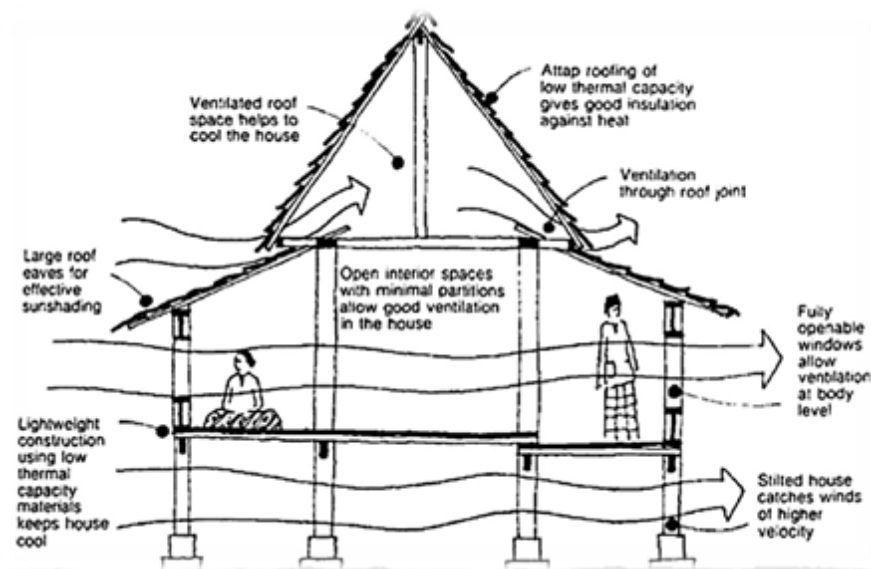


Fig. 1 - The Malay house architectural style [3]



Fig. 2 - The early mosque architectural style [3]

When designing mosques that are sustainable and avant-garde in terms of their architectural expression, architects must take a different approach. For instance, the current architecture of mosques in Malaysia uses and combines architectural references from a variety of past Islamic architectural elements or languages [4]. Various suggestions are still being made to promote a modern approach in the design of many future mosques, including the elimination of unnecessary ornate embellishments that are traditionally employed to express the mosque's grandeur. Therefore, borrowed architectural styles and architectural language or nomenclature have reached a point where they must be evaluated [5] due to their extensive use. Several articles on mosque architecture have brought to attention the fact that elements of traditional architecture from other parts of the world have been borrowed. Whether right or wrong, these elements had somehow become part of our Islamic architectural vocabulary and continue to be applied in the design of mosques in Malaysia and throughout the region to this day. These architects incorporated a variety of Islamic architectural elements on purpose, referring to them as "universal forms of Islamic Mosque architecture." Many Malaysians view these architectural elements as a continuation of Islamic architecture [6] because they are still used in modern mosques. Consequently, the various architectural elements have been combined and incorporated into Malaysian and regional Islamic architectural terminology.

According to Johar [7], when Islam first entered in Malaysia or the Malay Peninsula, mosque architecture was unremarkable compared to that of Middle Eastern nations. Early mosques were vernacular in character and constructed with a variety of common materials. Islam established its presence in the Malay-Indonesian Archipelago in the thirteenth century. During this period, many prior religious and cultural influencing factors were implemented into mosque architecture [6], [7].

It is now essential to redefine this approach to the design of mosques, considering past values, the local environment, and expectations for the future. However, the appearance should not have to be duplicated regarding the traditional design of the mosque, as it has become static and possesses no architectural significance. The environmentally friendly and future mosque design concept can be as Masjid Raja Fi Sabilillah Cyberjaya, where the direction is to keep up with the ever-changing times and ensure the continued relevance of Islamic architecture.

However, architects' unwillingness to take the risks to explore new forms or concepts when designing mosque architectural style is a major cause for concern [7]. In addition, it is essential that the public and decision-makers acknowledge the need to be responsive to and accepting of alternative interpretations of Islamic architecture. All new mosques and other non-religious buildings must adopt a more comprehensive, sustainable, and innovative design. Existing environmental concerns have also resulted in the end of environmental preservation, which aimed to eliminate several negative environmental damaging effects of our daily existence to guarantee that buildings remain energy-efficient and relevant in the future.

3. Role of Sustainable Architecture

The purpose of sustainable architecture is to reduce environmental impact of buildings that use inefficient materials, energy, expansion space, and eco-systems in general [8]. The design of the built environment is also intended to conserve resources and the environment. Long-term, the purpose of sustainable practices or environmental design is to limit our universal well-being or make it impossible to obtain resources for other uses [9]. Through furthermore to being compatible with the local climate, tradition, culture, and environment, a sustainable building can preserve or improve the quality of life. Recycling conserves energy, resources, and materials, which can decrease the quantity of pollutants to which humans and other organisms were indeed (or may be) affected in the local and global ecosystem throughout the building's life cycle. In order to reduce a building's negative impacts on the environment and energy consumption, as well as improve the health and productivity of its occupants, a comprehensive design process is essential [10].

4. Sustainable Design Characteristic

Providing comfortable and healthy environments for human activities is among the main goals of sustainable building [11]. To meet these fundamental human needs, the building must not be harmful to its occupants or the environment, and it must fulfil specific needs, such as the building's energy consumption. Having good natural ventilation, as in Malay traditional house designs, for instance, provides a comfortable space and safeguards health in the indoor environment.

A healthy building recognises the importance of human health and comfort. Numerous architects have prioritised aesthetics and form-making over environmental quality and human pleasure in the built environment. Poor ventilation, poor indoor air quality, pollutants from indoor or outdoor sources, having felt too cold or too hot, traffic noise, and poor lighting affect occupant comfort and productivity [11]. A study of the relevant literature highlighted the importance of (but not limited to) the following strategies for better coexistence between the environment, buildings, and their occupants: (see fig. 3). The following design methods should be considered to facilitate and enhance human adaptation.

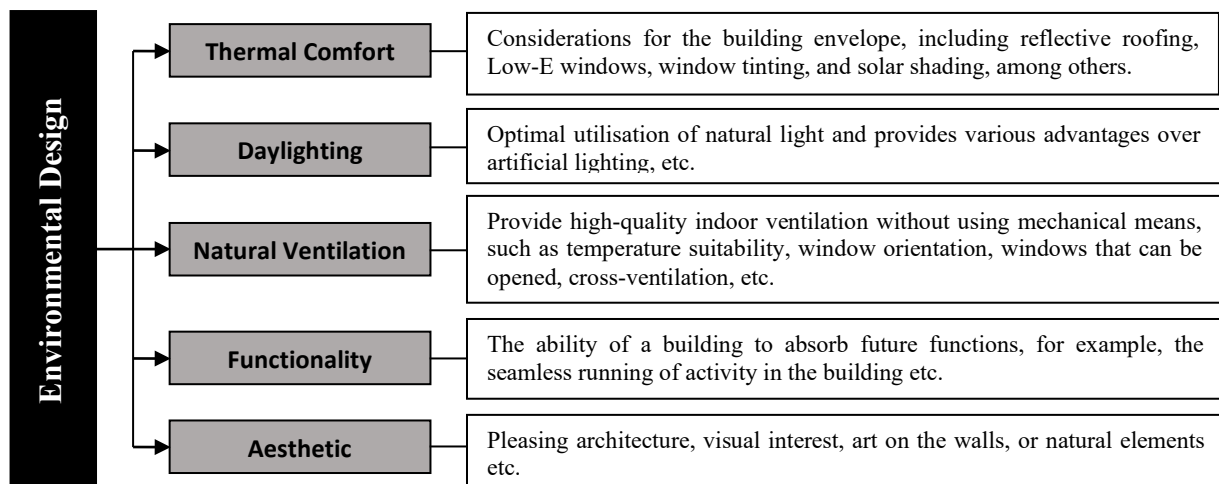


Fig. 3 - Environmental design characteristic

4.1 Thermal Comfort

The consideration of thermal comfort holds significant importance in the realm of building design, since it possesses a direct influence on the physical and mental well-being, as well as the productivity, of individuals occupying such spaces. Architects endeavour to design environments that uphold the highest standards of thermal comfort. One potential strategy for accomplishing this objective is considering the architectural enclosure, encompassing a range of components such as reflective roofing materials which have been specifically engineered to effectively reflect a substantial proportion of solar radiation, thereby mitigating heat absorption and minimising the transmission of heat into the structure; low-emissivity (low-E) windows which are equipped with a thin, transparent coating that effectively absorbs thermal radiation while permitting the transmission of visible light. The use of this coating serves to mitigate the ingress of heat during periods of high temperatures and the egress of heat during colder seasons, thereby enhancing thermal comfort; window tinting as additional efficacious approach for managing the accumulation of heat. Tinted windows serve to mitigate the ingress of solar radiation into a structure, so diminishing the thermal burden and upholding a more agreeable indoor climate; and solar shade which encompasses the utilisation of external shade mechanisms, such as overhangs, louvres, or awnings, with the purpose of obstructing direct sunlight from penetrating the building. These shading devices serve the purpose of mitigating solar heat gain, minimising glare, and promoting a consistently comfortable indoor thermal environment [12].

Furthermore, architects consider the general orientation of the structure and carefully choose suitable materials in addition to implementing these specific steps. The optimal orientation of a building can effectively manage solar exposure, either by maximising or minimising it, depending on the prevailing climate conditions and desired objectives. Architects could enhance natural ventilation and daylighting by carefully placing windows and openings, so minimising the reliance on mechanical cooling systems and artificial lighting.

In addition, the selection of building envelope materials significantly influences thermal comfort. Insulation, as an illustrative example, serves the purpose of mitigating heat movement between walls and roofs, hence facilitating the maintenance of a consistent indoor temperature. Architects could enhance thermal comfort by opting for materials that possess low thermal conductivity, hence reducing heat gain and loss.

Architects place a high emphasis on achieving thermal comfort by a comprehensive evaluation of the building envelope. This evaluation encompasses several key elements such as reflective roofing, Low-E windows, window tinting, sun shading, and appropriate structure orientation. The tactics are designed with the objective of minimising heat gain, managing solar radiation, and maximising natural ventilation, so establishing an interior atmosphere that is both energy-efficient and conducive to comfort as shown in Figure 3.



Fig. 4 - Basic building design for internal thermal comfort [12]

4.2 Daylighting

Daylighting is the technique of constructing buildings to make the best use of natural light, which has several advantages over artificial lighting. It is thought to improve both health and well-being [13]. Maximising the amount of natural light in a home is an important consideration. Good daylight refers to daylight levels that allow for proper vision without excessive brightness or contrast. Overexposure to direct sunlight, particularly on reflecting surfaces, can induce pain and disease [13].

Daylighting is an architectural strategy that prioritises the utilisation of natural light to illuminate interior spaces, presenting a multitude of benefits in comparison to the usage of artificial lighting. The incorporation of aesthetic elements in a structure not only serves to enhance its visual appeal, but also yields good impacts on the health and well-being of its occupants [13]. One of the key advantages of incorporating daylighting is its capacity to enhance the overall light quality within a given area. The dynamic and ever-changing nature of natural light renders it a visually engaging setting in contrast to the static nature of artificial lighting. The utilisation of this technique serves to unveil the authentic hues of various entities, heightens the clarity of visual perception, and fosters a profound sense of affinity with the surrounding natural surroundings [13]. The association between exposure to natural light and favourable impacts on health and well-being has been established. The circadian rhythm, which governs sleep patterns, mood, and physiological functioning, can be regulated by it. Sufficient exposure to natural light during daylight hours has been found to have a positive impact on individuals' ability to regulate their sleep-wake cycle, as well as enhance their mood and productivity levels. In addition, daylighting presents advantages in terms of energy conservation. By employing efficient strategies to harness natural light, the reliance on artificial lighting during daylight hours can be substantially diminished or eradicated (See Fig. 5). As a result, there is a reduction in energy use and the corresponding expenses. Furthermore, the increased dependence on natural light can significantly enhance the sustainability and ecological soundness of architectural designs.

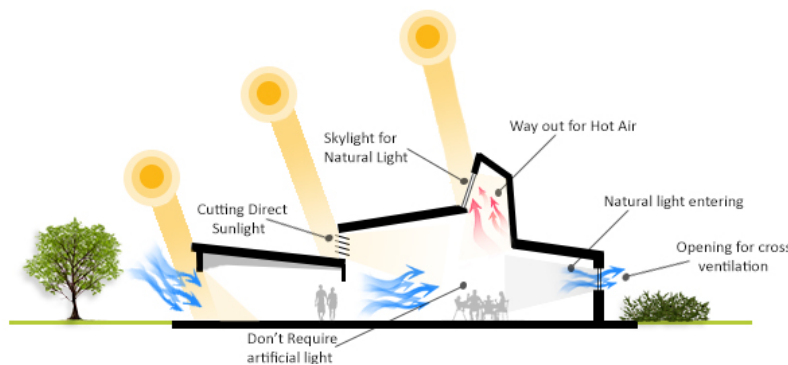


Fig. 5 - Example of daylighting design to maximize the natural light in a building [17]

4.3 Natural Ventilation

Natural ventilation is the process of having to replace air in any space without the use of mechanical means to maintain high indoor air quality [12]. It is the process of controlling and circulating natural wind flow within the confines of a comfortable built environment. Wind velocity and intensity are affected by the building's mass and site layout. The direction and placement of openings in a building's envelope impact the rate and flow of air around occupied spaces. Cross ventilation design allows energy-saving strategies in humid climatic zones.

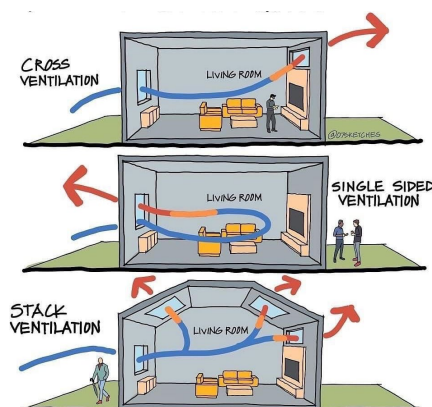


Fig. 6 - Types of ventilation that gives the impact on the comfort thermal in a building [18]

The ventilation conditions within a space have an immediate impact on the health, comfort, and well-being of the users. In addition, it can be used to provide fresh air, eliminate smells and pollutants, and dissipate heat from spaces, people, and masses (see fig. 6) [13]. The main aspects for natural ventilation are climate compatibility, window orientation, and operable windows. Examples include to provide cross-ventilation to utilise air chimneys to induce stack ventilation and implementing water evaporation systems in hot, dry climates to induce airflow. Opening a window, sitting in the sun or shade, and engaging with nature appear to be the fundamental design of sustainable building [14].

4.4 Functionality

The concept of building functionality pertains to the capacity of a structure to efficiently enable and facilitate the intended activities and objectives for which it has been specifically designed. In the process of architectural design, it is imperative to consider the manner in which the arrangement, characteristics, and systems of a structure can maximise the efficiency and effectiveness of the area [15]. It is crucial to consider the anticipation of future requirements and potential expansions during the architectural design process of a structure. Assessing the building's ability to accommodate future purposes from the outset can potentially mitigate expenses related to subsequent construction and material disposal. By integrating flexibility into the architectural design, using flexible spaces or modular components, the building can effectively accommodate evolving requirements and demands over an extended period. Besides, the consideration of the extended-term maintenance and longevity of construction materials is crucial for ensuring optimal operation. Although it may not be readily evident, the careful selection of low-maintenance and durable materials can have a substantial influence on the operational efficiency and cost-effectiveness of a building. Durable materials exhibit a decreased need for frequent repairs or replacements, hence resulting in reduced maintenance expenses and mitigated interruptions to the operational efficiency of the building [15].

4.5 Aesthetic

The significance of aesthetics is of utmost importance in the creation of a visually appealing and psychologically comforting work and home environment. When engaging in the process of architectural design, the consideration of aesthetic considerations extends beyond simply practicality, encompassing components that contribute to the overall visual appeal and mood of the built environment [16]. One facet of aesthetics pertains to the aesthetic appeal exhibited by a structure. This pertains to the holistic aesthetic quality and visual allure of the building, design, and arrangement. Architecturally pleasing structures have the capacity to elicit favourable emotional responses, instil a feeling of satisfaction, and enhance the overall ambiance, so fostering a more gratifying and stimulating milieu. The incorporation of visually captivating architectural characteristics, distinctive design components, and meticulous attention to detail collectively enhance the aesthetic appeal of a structure.

In conjunction with architectural design, the integration of wall art can further augment the visual appeal of a given environment. The incorporation of artwork, murals, or ornamental wall treatments into interior spaces can enhance the visual appeal by introducing brilliant colours, varied textures, and captivating elements. This infusion of artistic elements contributes to the creation of a more dynamic and immersive environment, fostering a heightened sense of engagement and interest. Wall art can additionally serve as a means of expressing the identity, culture, or values of the individuals inhabiting a particular area, thereby promoting a sense of connection and personalization within that environment [16]. The inclusion of natural features in a building can make a substantial contribution to its aesthetic appeal. The inclusion of features such as ponds, plants, or aquariums can foster a feeling of serenity, biophilic affinity, and a connection to the natural world [15]. These ingredients have the capacity to not only increase visual aesthetics but also to potentially ameliorate air quality, mitigate stress levels, and foster overall well-being. Although quantifying the impact of aesthetics on the entire experience of a building may present challenges, it is commonly acknowledged as a crucial element in the creation of sustainable and enjoyable spaces. The presence of visually appealing surroundings has the potential to exert a favourable impact on an individual's emotional state, level of efficiency, and overall sense of contentment [16]. In addition, aesthetically pleasing and well-designed areas have the potential to enhance the durability and worth of a structure, as they are often perceived as more attractive and in-demand.

In brief, aesthetics in the realm of building design encompasses several aspects such as visual appeal, architectural attractiveness, the integration of wall art, and the inclusion of natural elements. The consideration of aesthetics serves to foster psychological well-being, elevate the overall experiential quality, and contribute to the creation of sustainable and pleasurable work and living environments. Architects could design rooms that are both useful and visually appealing, as well as motivating and conducive to well-being, by integrating visually striking design elements, wall art, and natural features.

5. Methodology

This research utilised a qualitative methodology to examine the sustainable design characteristics present in the mosques that were chosen for analysis. The justification behind the selection of these mosques originated in the acknowledgment they garnered from multiple parties for their sustainable architectural features. Furthermore, the

author reviewed secondary data sources to verify the sustainable attributes of the mosques in question. In order to collect data, the author undertook firsthand observation, relying on their sense and grasp of the overall description of the field. The application of this methodology enhanced the quality of the gathered data by offering direct observations and perspectives on the sustainable design elements found within the chosen mosques.

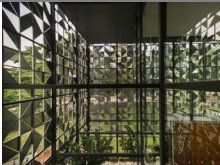
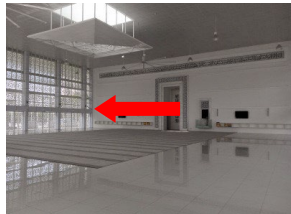
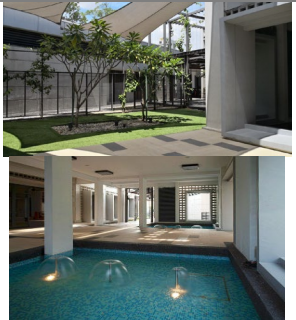
The objective of this study was to offer a comprehensive analysis of the presented facts, facilitating a deeper knowledge of sustainable mosque design concepts in Malaysia. This study also offers a comprehensive depiction of the sustainable attributes observed in these mosques. The information holds significant potential as a valuable resource for future students, architects, and researchers.

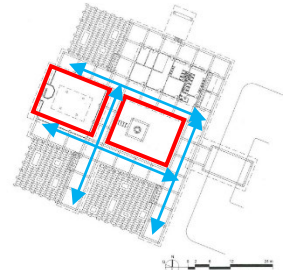
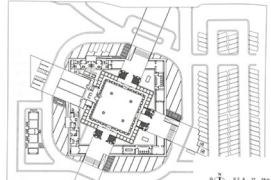
This study sought to provide significant insights into the sustainable design practises used by selected mosques in Malaysia by utilising a qualitative technique and integrating direct observation with secondary data sources. The results of this study have the potential to enhance the current understanding of sustainable mosque design and serve as a source of inspiration for future architectural undertakings aimed at developing environmentally conscious and comfortable spaces for worshippers.

6. Analysis of Selected Mosque

In the contemporary age of Malaysia, a number of mosques have adopted sustainable design principles, making them deserve of additional scholarly investigation and documentation. In addition to Masjid Raja Haji Fisabilillah in Cyberjaya, there exist five other mosques in Malaysia that adhere to sustainable design principles. The analysis of the selected mosque is as shown in Table 1. The design of these mosques has effectively integrated environmental factors, leading to a pleasant and comfortable experience for their occupants. The subsequent mosques serve as illustrations of environmentally sustainable architecture within the context of Malaysia.

Table 1 - Analysis of environmentally sustainable design characteristic (SDC) in selected mosque

SDC	Masjid Daing Abdul Rahman	Masjid Cyberjaya 10	Masjid Ara Damansara	Masjid Al-Ikhlash Naza
Thermal Comfort	 the mosque is surrounding greeneries, brick wall with steel panel design which allow the ventilation to flow to indoor spaces.	 -the use of timber, brick and concrete material brings down the indoor temperature. -Implementing layered roof design to flow hot air outside the building -a water pool that serves as a rain catchment area at the same time helps control the temperature inside the mosque.	 -the interior part of the prayer hall surrounded by a lattice concrete wall design that protect the interior from outside and allowing for natural ventilation throughout the space which will bring comfort to the interior spaces.it also have landscape around the building which can cool the interior spaces. -there is also a hole at the centre of the prayer hall to flow hot air outside the building.	 -the application of ventilation blocks on the wall of the mosque allows the ventilation to enter the spaces inside and give comfort to the user. -the landscape around the mosque also makes the spaces cool and yet bring comfort to the users. -there is also water element inside the mosque that can bring coolness in the interior spaces.

Daylighting	 the main prayer hall is clear glazed on three sides as the skin façade to filter direct sunlight.	 -no solid wall, the open plan of the mosque surrounded by glass sliding door and greeneries which allows the daylight to enter to the prayer hall.	 -by having a lattice screen concrete wall design, it allows the natural lighting inside the main prayer hall spaces.	 -the natural ventilation blocks not only allow the ventilation go through inside the building but it also allows the daylight into the interior spaces.
Natural Ventilation	 naturally ventilated prayer hall with wide overhangs and freestanding brick walls	 The main prayer hall is surrounded by a sliding door and open veranda which maximize natural ventilation flow inside.	 -The natural ventilation flow through the lattice concrete and cool the interior area especially the main prayer hall	 -the ventilation blocks wall applies on the surrounding of the main prayer hall which makes the wind flow into the interior spaces
Functionality	 The space at the exterior part can be used for Friday prayer if the occupant can't fit in the prayer hall.	 -in a peak season, the prayer hall can be extended to other spaces around. A 'spill over and open court', corridor, veranda and main prayer hall can fit in until 3680 occupants during seasons.	 -the sapce of main prayer hall can extend to the veranda and the landscape area. It also have a playground area for the children to play around while their parents is praying which can attract more children to enter the mosque.	 -the shape of plan is a rotated geometric which allows the usage of the main prayer hall to extend and fit in more users during seasons.
Aesthetic	-the mosque is 2000m2 three-storey cube of glass, brick, and steel as a screen of faceting galvanised steel panel. -the design of this mosaue is similar to industrial architecture & eco-friendly.	-this mosque applied the design of Malay vernacular architecture in modern way by using steel and brick material. -it also looks like a minimalist architecture where there is no decoration, just a simple shape and -minimalist architecture	-the use of lattice concrete wall and a modern design of the roof makes the mosque looks contemporary and attract the users to enter the mosque. -added the playground area can attract not only adults but also children to come to the mosque.	-this mosque plan consists of 2 simple geometries which are 1st layered and then rotated. (Refer ground floor plan) -the shape of the mosque is simple geometric shape which give a different view from the outside added with a steel structure to filter the direct sunlight. It also has water element inside which looks modern to cool the interior spaces

Masjid Daing Abdul Rahman showcases sustainable design elements through the integration of energy-efficient lighting systems, implementation of natural ventilation measures, and use of sustainable building materials. These characteristics contribute to the creation of a comfortable and ecologically sustainable environment for individuals engaged in religious worship.

Masjid Cyberjaya 10 exemplifies sustainable design principles by including solar panels to generate energy, implementing rainwater harvesting systems to conserve water, and integrating green spaces inside the mosque premises. The incorporation of sustainable features within the mosque contributes to the improvement of occupant comfort and well-being.

Masjid Ara Damansara showcases sustainable design principles through the integration of passive cooling strategies, including the utilisation of natural ventilation and shading mechanisms, to minimise the dependence on air conditioning systems. Furthermore, the mosque employs sustainable materials and implements water conservation measures by utilising efficient plumbing systems.

Masjid Al Ikhlas Naza mosque exemplifies sustainable design concepts through the integration of energy-efficient lighting systems, solar panels for the generation of renewable energy, and rainwater collection systems. The characteristics lead to the establishment of an environment that is both sustainable and conducive to the comfort of individuals engaged in worship.

The examination of these specific mosques demonstrates a prioritisation of sustainable design attributes, leading to the creation of modern mosque designs. These mosques exhibit a dedication to establishing pleasant and environmentally sustainable environments for their inhabitants through the integration of energy-efficient systems, utilisation of renewable energy sources, implementation of water conservation measures, and incorporation of green spaces. In general, the incorporation of sustainable design concepts in these mosques exemplifies the promise for modern mosque design in Malaysia, where environmental concerns are accorded equal significance alongside aesthetics and usefulness.

7. Conclusion

Malaysia possesses a notable number of mosques that frequently seek renovation in order to improve the overall comfort experienced by their worshippers. Typically, these upgrades entail the incorporation of facilities such as air conditioning and additional area designated for prayer. Nevertheless, numerous mosque designs have undergone modifications influenced by the preferences of those in positions of authority, frequently disregarding the need of establishing a conducive atmosphere and prioritising aesthetic appeal exclusively.

There is currently an increasing recognition of the significance of sustainability in mosque design. The adoption of sustainable design principles has demonstrated its efficacy in enhancing the comfort levels experienced by individuals within mosque environments. An instance of a mosque that integrates sustainable design concepts may be observed at Masjid Fi Sabilillah located in Cyberjaya. By incorporating sustainable design features, mosques may not only enhance the comfort of their occupants but also secure the longevity of their design in the face of changing times. This approach addresses the impacts on the environment associated with the mosque and endeavours to establish an integrated balance of visual appeal, practicality, and environmental responsibility. The acknowledgment of the necessity for renovations in Malaysian mosques to improve comfort, combined with the increasing focus on sustainable design, presents a prospect to develop mosques that are aesthetically appealing, environmentally conscious, and user-friendly.

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