Sustainability Assessment of Mosque: A Case Study of Design Proposal in Bandar Bertam Jaya, Penang

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Sustainability Assessment of Mosque: A Case Study of Design Proposal in Bandar Bertam Jaya, Penang

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Abstract. Mosque is a significant building typology for Muslims. Careful consideration on location and capacity should be practiced to increasing accessibility and promote comfort to worshippers. Due to high-density residential development, location of the nearest mosque and sense of unity among Muslims in the area, a local community was proposing a new mosque in Bandar Bertam Jaya, Penang to Majlis Agama Islam Negeri Pulau Pinang. A self-sustained mosque with phased development was proposed by Arkitek ICB Sdn. Bhd. With VELUX Daylighting Simulation and basic ventilation principle, the aim of the research is to study the sustainability of the design comprising daylighting and ventilation aspects respectively and how the proposal can give an impact to energy and resource management. The findings including Average Daylight Factor (ADF), opening sizes, wind speed and direction will also be reflected to Malaysian Standard MS 1525 and MS 2680 to value the sustainability aspect performed by the mosque. The findings of the research can be a reference to the architecture firm and the local community on the performance and sustainability of the proposal.

1. Introduction

Mosque is a sacred typology for Muslims, a hub for significant numbers of activities and functions more than just a place of prayer. Historically, the typology performed as a place for business and commerce, a school for general knowledge learning, and a centre for ruling government. The proposal was designed by Arkitek ICB Sdn. Bhd. for Majlis Agama Islam Negeri Pulau Pinang was to establish a mosque that not just act as a place for worshiping, but a self-sustained mosque that caters all needs of local community. However, the typology primarily facilitates collective ritual worship in the form of daily congregational prayer. Hence, a typical mosque will record approximately hundreds of visitors daily [1]. Careful considerations on design and selection of materials are required to provide comfort to visitors. Thus, the aim of this study is to investigate the building performance and sustainability through daylighting, ventilation, and energy management of the proposal in relation with context and needs from the local community.

Sustainability encompasses several definitions. Sustainable architecture always perceived as technology advancement, energy efficiency and environmentally friendly. However, the terminology covers broad meaning including community contexts relation. These include custom and culture, local materials, and response to the need of local community [2]. The project itself is a perfect representation

of context relation and together with the usage of technology, the building proposed is able to perform sustainably and increase the energy efficiency.

2. Methodology

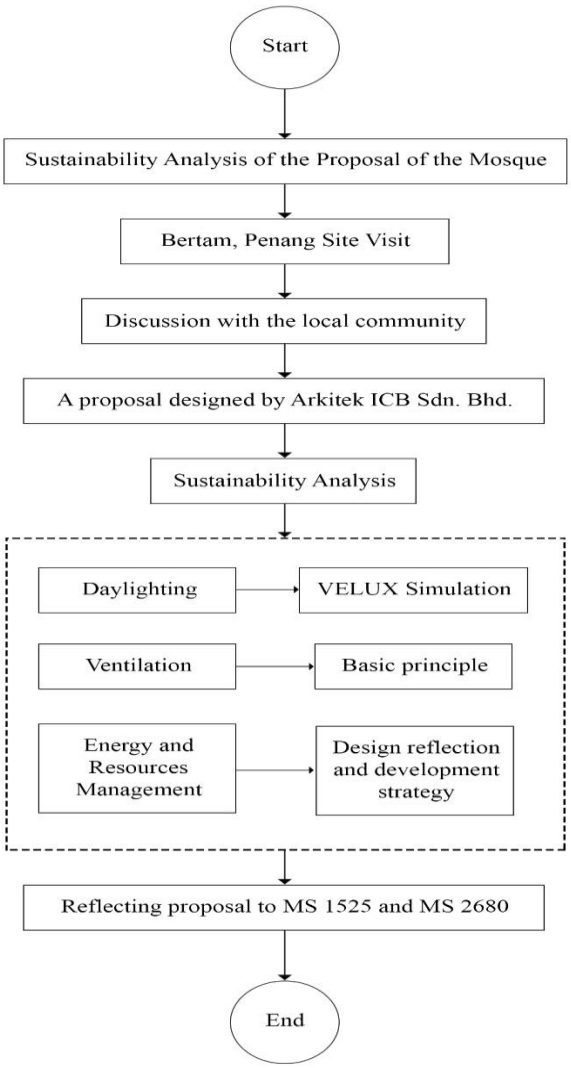


Figure 1. Procedures of conducting the case study.

To conduct this study, the author has worked closely with Arkitek ICB Sdn. Bhd. and representatives from the local community. Site visit was conducted in April 2021 to scan and view the site as well as understand the problem of the local community and the importance of having a new mosque in the area. From the proposal designed by the architecture firm, a quantitative approach through VELUX simulation is conducted to assess the daylighting aspect of the proposal. Basic principle of natural ventilation supported with wind direction statistical data will be utilised to assess the ventilation aspect around and within the proposed design. The design of the proposal, data, and numbers obtained then will be reflected in Malaysian Standard MS 1525 and MS 2680 and how far the proposal meets the recommendation and requirement set by the standard. From the design and development strategy proposed as well as daylighting and ventilation analysis, how these can affect the energy and resources management. The analysis then can be a reference to Arkitek ICB Sdn. Bhd. and the local community on how the building proposed sustainably performs.

DF (%)	Lighting	Glare	Thermal comfort
> 6.0	Intolerable	Intolerable	Uncomfortable
3.5 - 6.0	Tolerable	Uncomfortable	Tolerable
1.0 - 3.5	Acceptable	Acceptable	Acceptable
< 1.0	Perceptible	Imperceptible	Acceptable

Figure 2. Daylight Factors and Impact outlined in the MS 2680.

3. Project Background

3.1. Issues

Figure 3. Location of the site and relation to context.

The project is located in Bandar Putra Bertam, Kepala Batas, Penang and the design was proposed to local Islamic authority body, which is Majlis Agama Islam Negeri Pulau Pinang. There is a nearby mosque which is Abdullah Fahim Mosque which located 4 km away from the site. The mosque was built in 2012 and can accommodate 6000 worshipers at a time [3]. However, the local community believed the capacity was insufficient to serve Muslims in the area. The issue intensifies when there is a new residential area that will be developed across the site. The new project is developed by Mekarsari and will be covering approximately 40 acres comprising hundreds of new residential units [4]. Other than that, there are also hundreds of segregated kampong houses located on the East of the site. Apart from the residential typology, educational institutions are also situated in the area. There are Kepala Batas Industrial Training Institute, Universiti Sains Malaysia (USM) and Kepala Batas MARA Science College. This typology directly increases the human population in the area. The surrounding site is also equipped with a wide active commercial area which directly promotes a sustainable way of living, especially for families. With a wide range of population demography, the surrounding area surely is congested with people who rent or stay in the residential area around the site. This indicates the needs of a new mosque in the area.

The new mosque seems desperately needed as a centre of unity for the local community. Currently, there are 3 *surau*s around the site: Surau Al Muttaqin, Surau Al Falah and Surau Tok Solomon. In Malaysia, *surau* is still considered as a communal prayer place. However, the building's footprint is typically smaller, and the typology generally serves a smaller number of worshippers compared to the mosque. Without any support from the state government, financial resources through grassroot

operations ensures the continuation of operation of *surau* [5]. With the establishment of the new mosque, segregation can be avoided, and the mosque can be the focal point for the local community.

Figure 4. Proposal of the mosque as a focal point connecting all nearby *surau*s.

3.2. Proposal

A design proposal was prepared by Arkitek ICB Sdn. Bhd. after reflecting characteristics of the site and input from the local community. Area of the site is approximately 5.3 acres and situated next to the main road: Tun Hamdan Sheikh Tahir Road connecting Kepala Batas and Tasek Gelugor. According to Malaysian Law, the site requires a minimum 7 meters one-way local road connecting the site from the main road. Then, there should be a 20 feet setback before the building footprint is allowed to be built. The proposal was aiming to provide a self-sustained mosque with other public amenities. Other than worshipping area, there are five other complement areas proposed:

- Mosque: Worshipping area (main space)
- Multipurpose hall
- Offices
- Commercial spaces
- Playground for children
- Supporting spaces including stores, kitchen, and mortuary management room

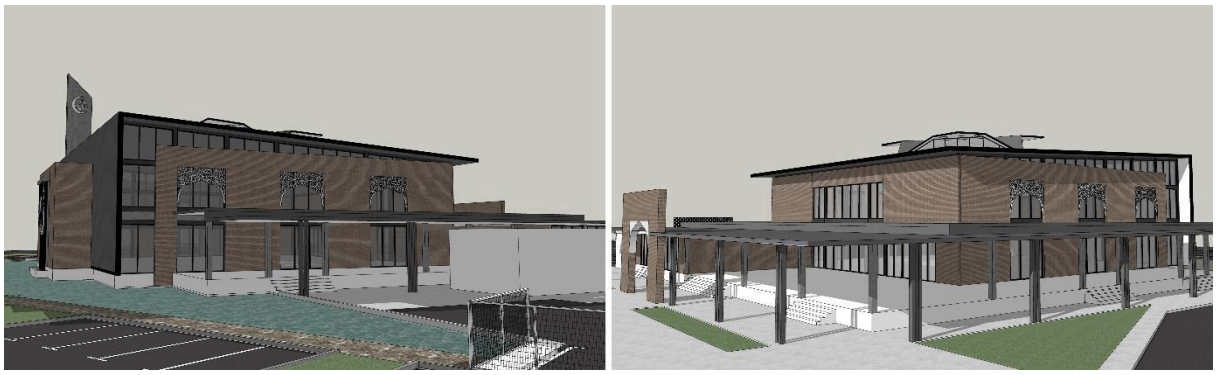
Figure 5. Aerial view of the proposal [6].

The proposal outlines two development phases where the first phase focusing on development of the mosque and all complement spaces will be completed in the second phase.

(a) **(b)**

Figure 6. Site Plan of the development phases of the mosque. (a) Development Phase 1; (b) Development Phase 2 [6].

The worshipping area will be the main agenda of the development. Footprint of the space comprises other sub-spaces that are crucial in the typology: covered prayer space for women, library for children, and a room for *imam* (leader in a congregational prayer). The mosque can accommodate 2500 visitors at a time. However, the capacity can be increased with provision of the multipurpose hall. The hall can be used as a worshipping space, especially on Friday congregational prayer as well as sports and social activities. The second phase of the development also provides a food court and commercial spaces for rent. This business model can be an income generator to the mosque and allow the mosque to be a self-sustained typology even without financial assistance from the state government. The commercial spaces that are located next to the main road make it traffic convenience and hence increase the possibility of being noticed and visited [7].



(a) **(b)**

Figure 7. External perspectives of the mosque. (a) South-West perspective; (b) North-East perspective [6].

Table 1. Schedule of Accommodation (SOA) of the Mosque

No.	Space	Area (m^2)
1	Main prayer hall	760
2	Prayer hall for women	179
3	Opened prayer space	644

4	Mihrab		12
5	Mimbar		12
6	Technical room		12
7	Room for Imam		12
8	Meeting room		12
9	Library for children		60
10	Minaret		14
11	Utility room		90
		TOTAL	1807

4. Analysis

4.1. Daylighting Analysis

In the analysis, the focus will be scaled down to the worshipping area. The area includes the main prayer hall, prayer hall for women and opened prayer space. Main prayer hall comprises small sub-spaces: mimbar, mihrab, technical room, room for Imam and meeting room. The hall is a closed space bounded with a brick wall and glazing façade. According to Section 39 of UBBL 1984, every space should be provided with natural daylighting through window(s) with a total area of not less than 10% of the clear floor area [8]. Referring to Table 1, floor area for main prayer hall is 760 m², thus, minimum area for glazing façade required to support natural daylighting is 76 m². However, the space was designed with approximately 380 m² of glazing façade which is equivalent to 50% of floor area to glazing façade area ratio. Reflecting the ratio to Window-to-Floor Ratio (WFR) shown in Malaysian Standard (MS 2680), higher percentage of WFR is required when room depth is increasing [9]. Thus, the percentage indicates a sufficient natural daylighting throughout the main prayer hall.

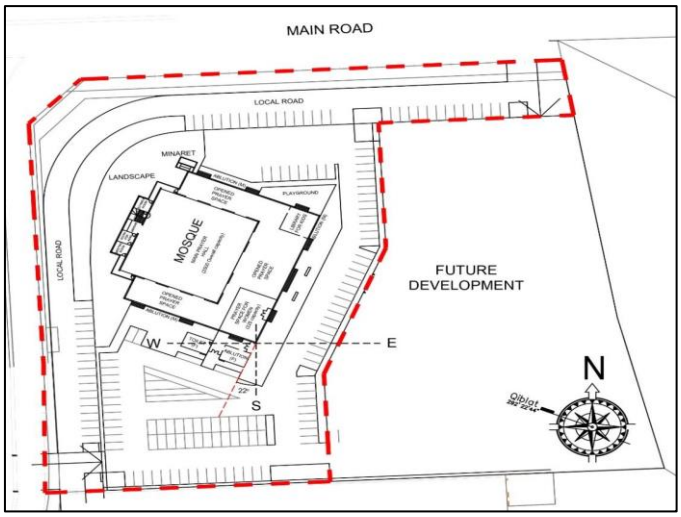


Figure 8. Ground floor plan of the proposal [6].

However, the large amount of glazing façade also increases the risk of sun glare and direct hit gain which can increase the temperature inside of the building and thus reduce the thermal comfort of the visitors. Orientation of the building can be a major strategy to control the amount of sunlight penetration and amount of direct hit gain [10]. Sunny sky causes critical situations on East and West where East and West façade-oriented buildings encounter excessive daylight in the morning and afternoon, respectively [10]. To provide natural shading to a building, glazing façade should be oriented 45º due South [9]. Referring to Figure 8, the mosque is 22º oriented from the South without any direct exposure to the East

and West. With a large overhang roof facing the East, this can further reduce the sunlight penetration into the main prayer hall.

However, according to the BREEAM Guideline, there are other criteria that should be assessed under the daylighting aspect which is Average Daylighting Factor (ADF) and Average Illuminance level [11]. A simulation generated by VELUX Daylight Software was used to identify the value and then it will be reflected to standard. The daylight factor is a metric that is expressed as a percentage of the amount of available daylight inside a room and is limited to overcast sky condition [9]. It can be divided into three components: the direct skylight, the external reflected component and internal reflected component [11]. In the analysis, the average daylight factor will be assessed only in the main prayer hall because it is a closed space, and the space is primarily used by visitors. Figure below shows a simulation generated by the VELUX.

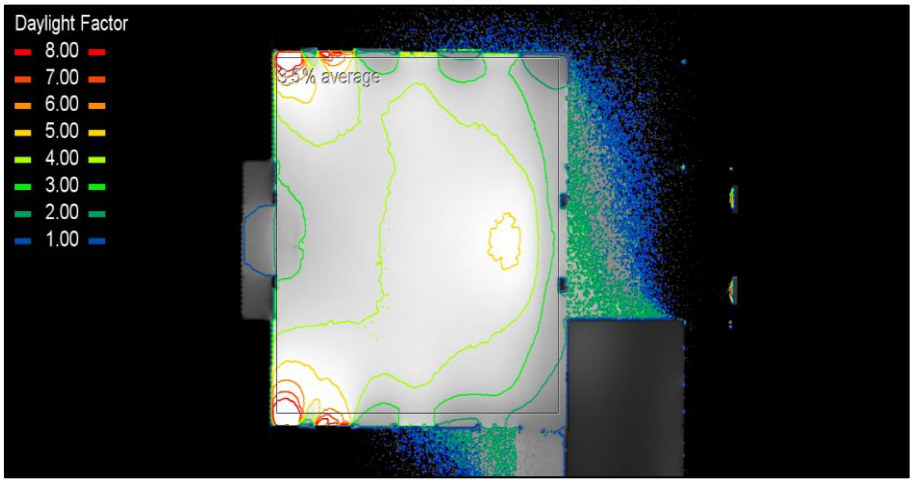
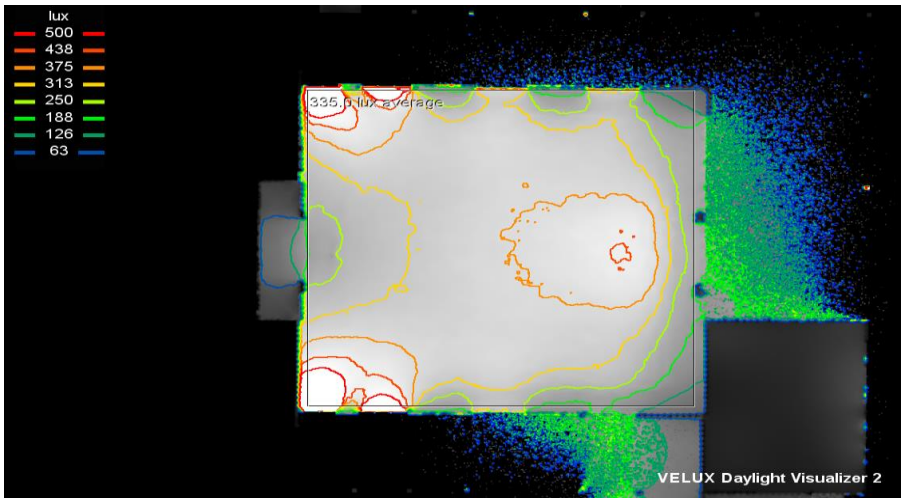
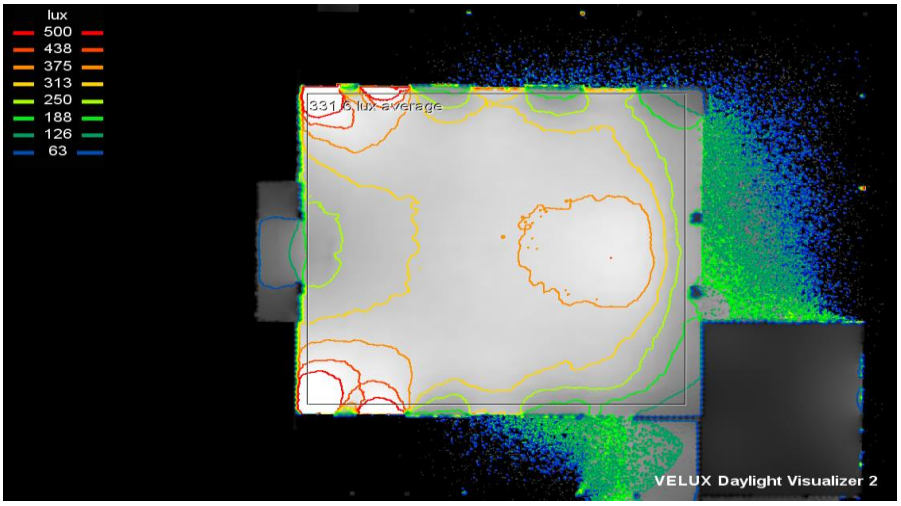


Figure 9. A Daylight Factor (DF) generated by VELUX.

Referring to the simulation, high intensity of light can be seen around the window. The Daylight Factor (DF) is decreasing as the distance from the window increases [9]. Generally, the upper half space which is space near the mimbar records higher Average DF which is 3.9% due to unobstructed light penetrating through the windows. Due to the large overhang roof on the South-East façade, the amount of light penetration has significantly reduced and hence resulting in low ADF on the lower half of the main prayer hall. However, the space records 3.5% on ADF which is considered as 'acceptable' in terms of lighting, glare and thermal comfort set by Malaysian Standard [9]. The simulator also indicates a sufficient amount of average illuminance inside the mosque as shown in Figure 10.



(a)



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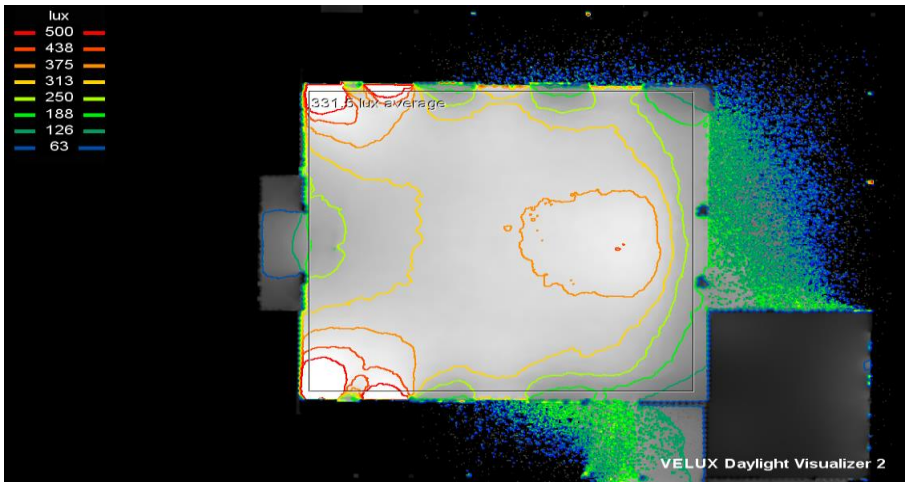


(c)

Figure 10. Average Illuminance level (AI) generated by VELUX. (a) AI in March; (b) AI in June; (c) AI in December.

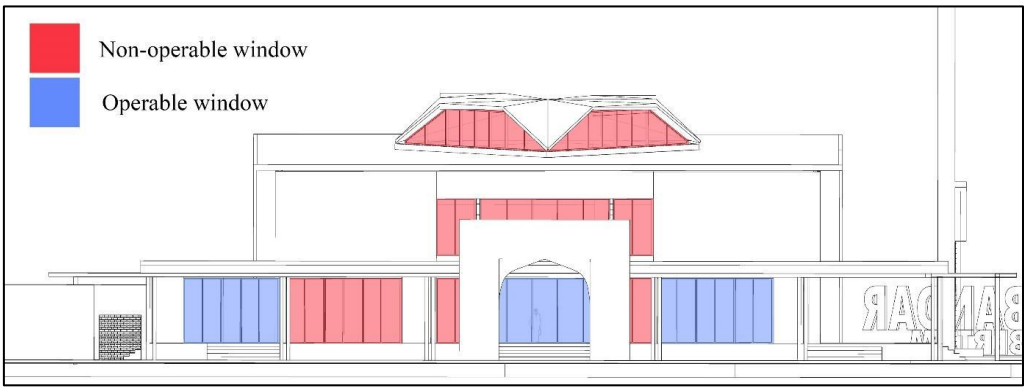
To assess the average illuminance level, two variables are maintained. The results are obtained under the same sky condition which is standard overcast (5000 – 20,000 lux). It is defined as the sun not visible and covered with thick and milky white clouds [9]. The condition is chosen in order to obtain a parallel and consistent result between Average Daylight Factor (ADF) and the Average Illuminance level. The time is also fixed which is in 1300 where the highest level of illuminance occurs at this particular time. According to the simulation, it can be seen that the mihrab area including mimbar, technical room, room for imam and meeting room are relatively dark. This can be reflected to the façade design of the spaces where there is no single window provided for the space. Furthermore, the spaces are not for public use and only mosque committee members are using the spaces. Referring to MS 2680, maximum average hourly illuminance (AHI) occurs in March, and minimum AHI is recorded in December. This information also can be reflected to the AI simulated in the VELUX. Referring to Figure 10, AI recorded in March is 335.0 lux, 331.6 lux (June) and 331.5 lux (December). This value corresponds to the recommended average illuminance level set by MS 1525, which is 300 – 400 [13].

4.2. Ventilation Analysis

Ventilation is an important aspect in order to control indoor air quality, replace warm indoor air with outside cool air, and comfort the building inhabitants [14]. Natural ventilation on the other hand can

effectively reduce humidity and lower the temperature without using any energy resources. This can reduce dependency on resources, cut down environmental pollution and support sustainability agenda [15]. The analysis will investigate air circulation that occurs inside of the building and how the design of the context and wind speed can affect the interior air circulation. Referring to the same law (Section 39 of UBBL 1984), every space should be equipped with openings of not less than 5% of such floor area to allow uninterrupted air circulation. The law indicates that the minimum opening required to allow natural ventilation in the mosque is 38 m². From the proposal, the glazing façades designed are equipped with fixed glass and operable windows where only less than half of the glazing façades are sliding windows. However, the proposal is designed with minimum 98.5 m² of opening through sliding window and thus, it's already enough to comply with the minimum requirement set by law.

(a)



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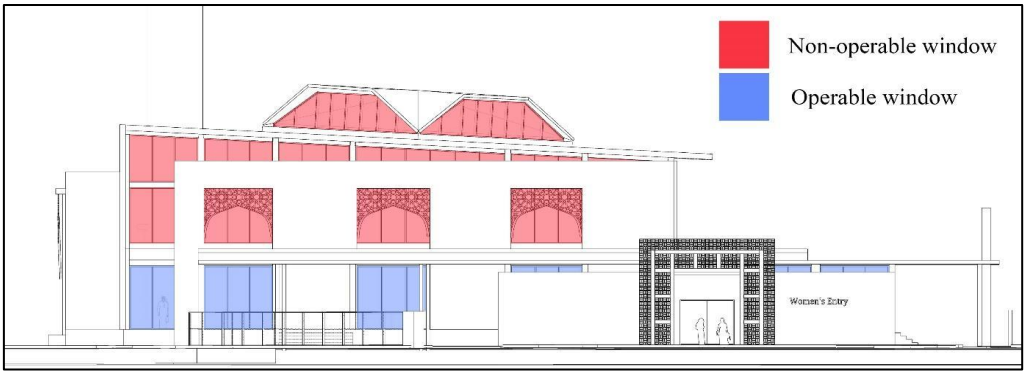

(c)

Figure 11. Elevation views of the proposal. Red hatch indicates non-operable window and blue hatch indicates operable window. (a) North-East façade; (b) South-East façade; (c) South-West façade.

Wind speed and direction are aspects that significantly influence the ventilation aspect on the site and within the building [16]. Orientation and materiality of the building should be considered carefully as the aspects can provide opportunity for maximum natural ventilation [12] [16]. The building and its opening should be positioned in a way that is able to take advantage of natural breezes and prevailing wind. Figure 12 shows data of annual wind speed and direction that take place in Penang. From the data, it reveals that the wind predominantly blows from the North-East and South-West. The proposal provides big glazing façades towards both directions and thus maximising natural ventilation to run inside the building. However, the typology should fundamentally face the Kaaba with an angle of 292º22'44". From Malaysia, all mosques and *surau*s should be facing roughly to the North-West to perform the purpose of the typology. These aspects are coincidentally met, and the ventilation aspect can be carried out maximumly and effortlessly. Provision of naturally ventilated corridors are also encouraged for smoke venting of the spaces in the event of fire [9]. The design provides a large corridor on the building perimeter as opened prayer spaces and indirectly complies with the requirement set by the fire authorities.

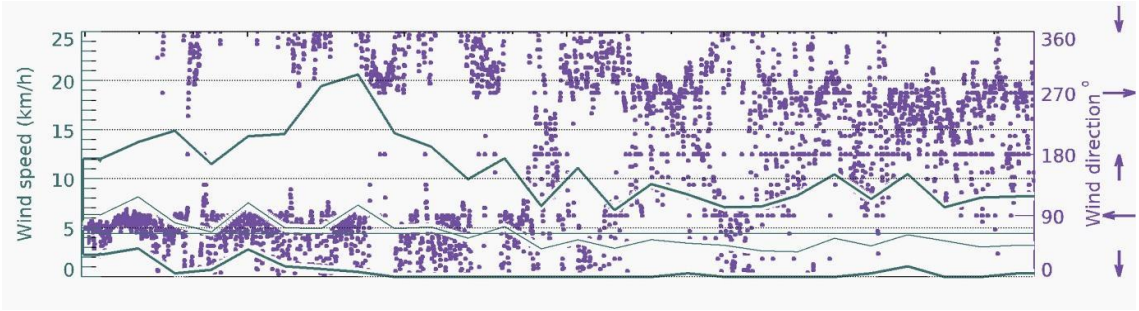

Figure 12. Data on wind speed and wind direction in Penang [17].

Water is an element which is commonly associated with utilitarian, symbolic, therapeutic, leisure or visual context. In fact, throughout history, Islamic architecture, especially mosques, was equipped with the feature for irrigation, display, and sound effects [18]. In the design proposal, Arkitek ICB Sdn. Bhd. also proposing a landscape which consists of water features and green vegetation. The water feature was designed on the North-West of the site to celebrate the mimbar of the mosque as well as enliven the main road junction. The feature is crucial to attract the attention of people from the main road and create an awareness of the presence of the mosque. This can be a vital component in supporting commercial spaces that will be built in the future. Other than the landscape purpose, the water feature also acts as a retention pond to reduce risk of flash flood during heavy rain on the site. The water feature also functions as a supporting tool in the ventilation aspect. From the data on Figure 12, the wind is primarily blowing from the North-East and South-West. The outside air can be cooled down with the presence of the water feature and circulation of cool air can occur inside of the mosque.

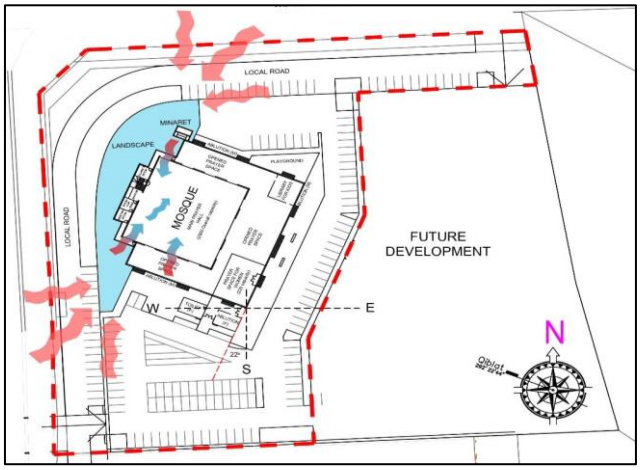

Figure 13. Ventilation diagram that takes place inside the mosque

Generally, there are three passive ventilation types that can take place inside a building, which are cross ventilation, single-sided ventilation, and stack effect. Passive strategy is important to reduce our dependence on mechanical aid. This can effectively reduce the operation cost and provide comfort to visitors. The design of the mosque allows natural ventilation to circulate effectively inside the building. Referring to Figure 13 above and Figure 14 below, glazing façade facing North-East and South-West receive maximum prevailing wind and thus stimulate the natural ventilation to take place inside the building. 1- Cool outside air penetrating the mosque through the opening and slit of the window. 2 – The exchange of air occurs inside of the mosque. 3 – Warm air moves upward due to pressure of air. 4 – Warm air pushed out of the building through opening and slit of window on top of the building.

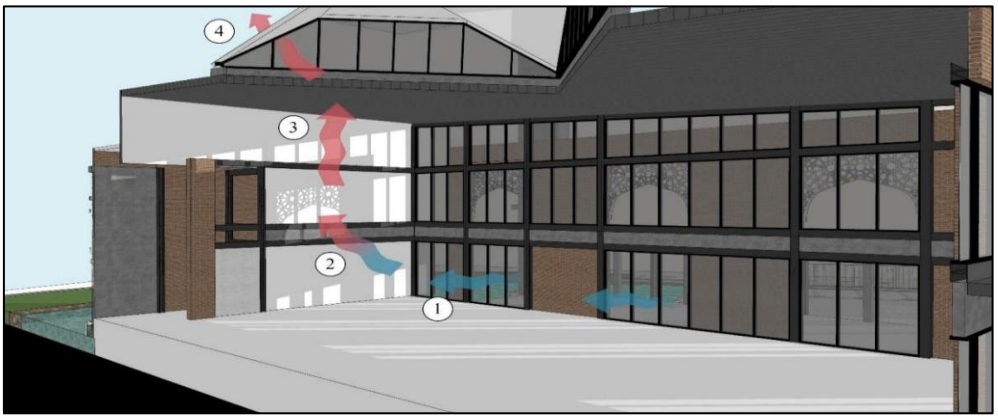

Figure 14. Three-dimensional (3D) cross section model with natural ventilation diagram.

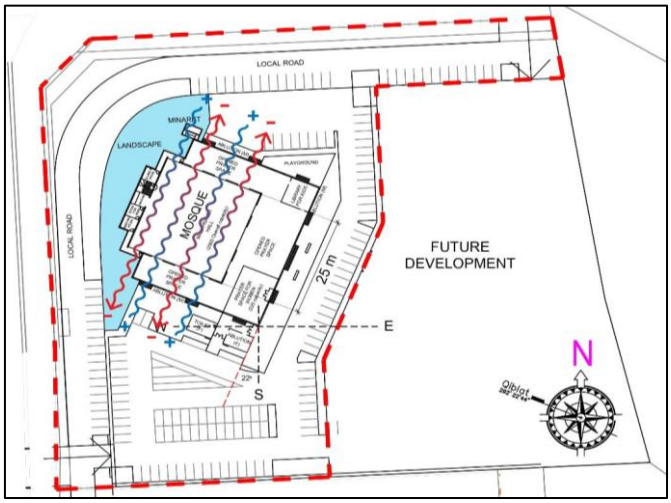

Figure 15. Cross ventilation diagram of the proposal.

To carry out maximum cross ventilation effect, there are few design criteria that should be considered [9]. Other than orienting the building to maximise exposure to prevailing wind, the proposal also provides openings on opposite walls for optimum ventilation. Equal inlets and outlets areas between North-East façade and South-West façade have maximised the airflow throughout the mosque. Without any obstruction between the inlet and outlet, cross ventilation can occur efficiently. It is also suggested that effective room depth for cross ventilation to take place is equal or less than 12 meters [9]. Referring to **Figure 15**, with 25 meters space depth, the proposal seems unfit to possess the two-sided ventilation. However, both opposite façades are facing to the windward side (pressure zone), and it will allow maximum air circulation to occur inside the mosque.

4.3. Energy and Resources Management

The phased development proposed by Arkitek ICB Sdn. Bhd. promotes a sustainable monetary circulation, especially for the government and specifically for Majlis Agama Islam Pulau Pinang. The design which also provides commercial lots next to the main road ensures maximum publicity and promotes a self-sustained ability to the mosque. A design which is equipped with adequate daylighting and natural ventilation can efficiently reduce the dependency on energy as well as reducing carbon impact to the environment. Arkitek ICB Sdn. Bhd. proposes a design which comprises two main spaces which are closed and opened spaces. After discussing with the local community, it is essential to provide an air-conditioned space inside the mosque to provide comfort to the visitors. Thus, it is important to provide a closed space to ensure the cool air generated by the air conditioner units is trapped and circulated just inside the space. The design of the closed main prayer hall is bounded with a wall and operable glazing façade allowing the electricity used to generate air-conditioner units to be minimised and reducing operational cost as much as possible.

The proposal also provides a design with a large glazing façade on every side of the mosque. This aspect can be an important point for building sustainability. With large amounts of sunlight penetration into the mosque, less dependency on mechanical lighting will occur and thus, reducing the energy usage of the building. In Malaysia, even though mosques are managed by the state government including financing mosque's staff and operational cost [19], energy saving should be practiced in a way to promote building sustainability as mentioned in the United Nations: Sustainable Development Goals.

5. Conclusions

Daylighting and ventilation should be considered in the designing phase to promote building sustainability. To design a habitable environment for visitors, a holistic architectural, site planning and landscaping have been used by Arkitek ICB Sdn. Bhd. The proposal manages to provide a design solution that achieves indoor environmental quality (IEQ) and ultimately, deliver sustainability aspects in the design of the mosque. More specific conclusions of this study include:

- The proposal achieves 3.5% of Average Daylight Factor (ADF), which is considered acceptable in terms of lighting, glare, and thermal comfort according to the Malaysian Standard.
- Average Illuminance level of the proposed mosque is 331.5 – 335.0, which is aligned with the recommended average illuminance level set by MS 1525.
- Position of windows and glazing façade facing directly to prevailing wind encourage natural ventilation to take place inside the mosque.
- The design of the water feature and landscape near the mosque provides cool and fresh air to be blown into the mosque.
- Air-conditioned main prayer hall was designed as a closed space to ensure the cool conditioned air trapped and thus, reducing the energy and electricity bill.

Even though the obtained results showed a prospect of a sustainability, the materiality of the building also plays an important role to determine the aspect. Ability to obtain U-value of materials used would be extremely helpful to identify the level of sustainability that could be achieved in the building.

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