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VIRTUAL GO GREEN: CONFERENCE AND PUBLICATION

"Rethinking Built Environment: Towards a Sustainable Future"

Organiser:
Research, Industrial Linkages, Community & Alumni Network (PJIM&A)

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Department of Built Environment Studies & Technology (JABT), Faculty of Architecture, Planning & Surveying (FSPU)

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Mosque Energy Efficiency and Designer's Approaches Towards MS1525

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Abstract

Several concepts and approaches have emerged throughout the last decades concerning energy efficiency in buildings, including passive houses, green buildings, and bioclimatic design. Every country begins to consider how to cut energy usage and work toward a carbon-free future. The built environment is one of the most significant contributors to high energy use. New legislation, codes of practice, standards, and incentives have been initiated to enforce energy efficiency in buildings in some nations. This exploratory study will investigate 'passive design methods' in the Malaysian setting, reducing, and minimizing energy consumption to meet the Malaysian Standard MS 1525. In expediting and implementing the MS 1525, the valuable design information on the selection and arrangement of various components in the early building design process is beneficial. It helps implement optimization techniques of passive design strategies that could aid building designers in their decision-making process to achieve optimum thermal performance. Proper treatment of building envelope contributes to the improvement of the building. Therefore, this study will analyse and measure the current building design and materials concerning MS 1525 and focus on the mosque as the case study. Mosques have high working schedules, prayer times, and activities, which require the buildings operation to be working 24/7. The Malaysian Standard MS1525, designers are required to consider energy efficiency and be prudent when constructing buildings, particularly those with large volumes and gross floor areas. Passive design solutions that are effective may help reduce wastage while also reducing energy consumption in a building compared to this benchmark. The outcomes of this research will help determine and measure the success rate of our designers to implement and adopt Malaysian Standard 1525.

Keywords: *Malaysian Standard MS1525, Passive Design Strategies, Mosque Energy Efficiency*

1.0 Introduction

The government is trying very hard to produce energy to meet the capacity needed and subsidize a few sectors to accommodate the demand. Moghimi et al., (2014), "As the economy and population grow, the scarcity of energy supply will become real over time". Aun (2009) mentioned that the Malaysian government's goal is to avoid the need for nuclear energy and any tendency to import electricity or natural resources from other countries. That is why urgency needs to be taken to control minimising the energy consumed in Malaysia. This study highlights the critical aspect of finding, analysing, and synthesizing the passive design strategies for low energy consumption in a mosque. This is because this type of building possesses high importance function and consumes high energy usage, which can be reduced by identifying the best alternatives to minimize the energy usage.

This research focuses on the mosque as a building typology that the government purely subsidizes to sustain. Most federal mosques did not generate income and cash flow to pay for the electrical bill, which unconditionally relies on subsidization by organizations or the government. The study aims to raise designers', architects', and engineers' understanding of the importance of passive design techniques, environmental conservation, and energy-saving challenges. Mosques' administrators, users, and the government or whomever the paymaster of energy usage also benefit when the mosques' energy consumption is reduced.

2.0 Mosque and Energy Consumption

In comparison to other types of structures, mosques have a different operating schedule. "They are usually occupied five intermittent times a day all year round, with occupancy averaging from a fraction of an hour to an hour." (Abdou A. A.-H., 2002). Besides these fixed prayers, there are also occasional prayers that may be performed according to circumstances. The following important function of the mosque is as the centre for religious education. Jaffar et al. (2020) stated that Mosques are buildings with sporadic occupancy, making maintaining thermal comfort during prayer times difficult. Mosques have immense volumes, enormous heights, and gigantic domes, all of which make cooling the prayer room an energy-intensive task. (Yahaya, 2008). However, for our case studies, only PM uses a district conditioning system while TMZAM is mainly naturally ventilated with minimal fans placed at specific locations at the prayer hall. Mosques can play an essential role in advocating these solutions and encouraging Muslim communities to adopt them by their status as iconic structures. The goal of this article was to investigate the energy consumption scheme in-depth and provide energy-saving measures.

2.1 MS1525

MS 1525 is a Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings is created to deliver the best practice in building energy efficiency. This standard is beneficial as it provides minimum standards for designing new, existing buildings and methods of determining their compliance. A parameter that measures the Energy Efficiency of the Aun (2009) mentioned that building without inhibiting the design options and creativity of the architect is used that are RTTV and OTTV. The Sun, Heat, and High Humidity are the key elements. Architects must deal with the Malaysian climate. A low RTTV and OTTV mean overall a lower heat gain into the building and therefore a lower air conditioning load and fewer hours of operation. Passive design strategies are one part of MS1525. It is a method of maintaining consistent indoor temperatures and occupant comfort that avoids using mechanical systems for cooling, lighting, and even heating in some areas (MS1525). As the phrase implies, 'passive buildings' must have a closer relationship with their surroundings to achieve a comfortable internal environment with minimum resource use. The critical factors that should be considered include: -

i. building location and orientation
ii. building envelope/ shape
iii. volume/ floor to floor height
iv. natural lighting
v. natural ventilation
vi. landscaping.

Most of the previous research and data collected only refer to residential, offices, and commercial typologies but lack mosques. The studies on passive design strategies of a mosque concerning energy consumption are yet to be established, lack information, and should be further discussed with detailed analysis and studies. This research aims to identify the passive design strategies that can help reduce and minimise the energy consumption concerning Malaysian Standard MS 1525:2007/2019. The energy efficiency measures should be considered in all buildings by getting to know the attributes of energy consumptions. Attributes of energy consumption for a building can be subdivided into a few causes, but one category that can be structured as preventive measures is the building design and shape.

3.0 Methodology

Figure 1. Putra Mosque from the lake view.

Figure 2. Tuanku Mizan Zainal Abidin Mosque from the lake view.

Two federal mosques were selected to review as case studies. This research is limited to a 'Federal Mosque' in Putrajaya, Putra Mosque (PM) as per figure 1 and Tuanku Mizan Zainal Abidin Mosque (TMZAM) in figure 2. Table 1 shows the criteria of mosques selection and the essential data of the two case studies. Public information regarding selected cases was gathered through books, journals, and the internet, while semi-structured and qualitative interviews with architects were employed to obtain specific unpublished material. Field studies and inspections are also being conducted to observe the issues on site, monitor the human comfort at the praying area by collecting data on RH and temperature, and capture images as evidence. Finally, the collected data were analysed, and a comparison between two case studies was highlighted. The architectural firm Kumpulan Senireka Sdn. Bhd, who designed both mosques, provided most of the plans and details. For OTTV and RTTV, the drawings are also helpful in determining volume, mass, façade surfaces, and roof finishes.

Table 1. An overview of crucial information concerning the two mosques.

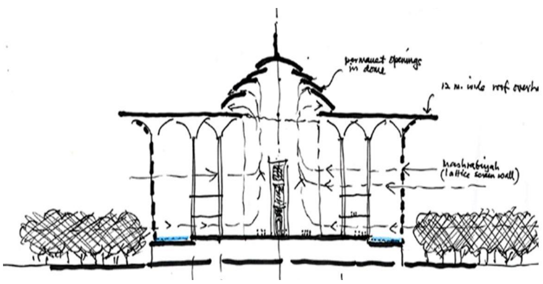
No	Factors	Putra Mosque (PM), Putrajaya	Tuanku Mizan Zainal Abidin Mosque (TMZAM), Putrajaya
1	**Construction Date**	1997 - 1999	2004 -2009
2	**Capacity**	10,000 worshippers at any one time (not including 5000 worshippers at courtyard)	20,000 worshippers at any one time (not including the Qiblat Walk
3	**Location**	Landmark of Putrajaya, surrounded by lakes and next to Perdana Putra Building	2nd Landmark of Putrajaya, surrounded by lakes and opposite to the Palace of Justice
4	**Spaces Provided**	Main functional areas – the prayer hall, the Sahn, or courtyard, various learning facilities and function rooms	Main functional areas – the prayer hall, the Qiblat Walk (Courtyar) and various learning facilities, banquet hall and function rooms
5	**Presence of Commerce**	Yes, Souq and Bazaar surround the adjacent area of the mosque	Yes, have convenient shops and kiosk at the ground level of the mosque
6	**Opening Time**	5am – 10pm (during prayers time & occasions)	5am – 10pm (during prayers time & occasions)
7	**Cooling Systems at Main Prayer Hall**	District Cooling System	Natural Ventilated and minimal fans
10	**Stylistic Architecture**	Persian & Moorish Islamic architecture With Malay Styles as internal carvings	Modern Architecture Style (Borrowed from German and Chinese Influence)

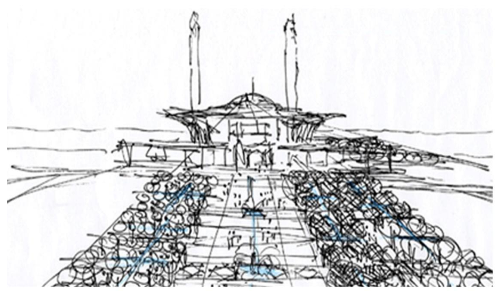
Sources: Kumpulan Senireka Sdn. Bhd. (KSSB - architects and designers of both mosques)

4.0 Results and Findings

4.1 Interviewed with Architects and Designers

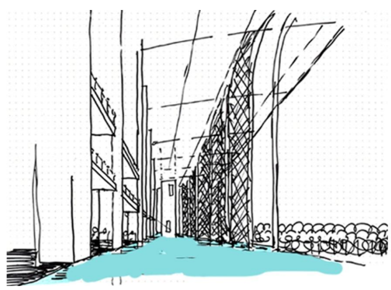
From the interviews conducted with the architects, Dato' Nik Mohamad highlighted the importance for end-users to feel comfortable and habitable in the mosque, especially when doing ibadah. The design should be responsive to the environments, adding up the landscaping area, water elements (refer to figure 3), enhancing the cross-ventilation, and minimising energy usage by providing ample natural lighting to the building (refer to figure 4). Ar. Nik Arshad stated that the large overhangs, high ceilings (refer to figure 5), and shading devices (as per figure 6) could be the aided values to achieve passive design for such an enormous volume of building without neglecting the stylistic characters and enhanced the physical look.





(Sources: KSSB)
Figure 3. Sketches from the Architect show the huge ample spaces allocated from landscaping and water elements.

(Sources: KSSB)
Figure 4. Sketches from the Architect show the design to provide cross ventilation and ample natural lighting to the buildings.



(Sources: KSSB)
Figure 5. Concept of height ceiling, openness, natural light, and air. Double to triple volume should have good cross ventilation and be less dependable on electrical lighting and cooling appliances.
(Sources: KSSB)
Figure 6. Concept of shading devices and evaporative cooling effect from the water, filter the hot air from coming into the prayer hall.

4.2 Comparative Analysis

Below in Table 2 are the comparative analysis of both case studies based on passive design strategies as required in MS1525. The table shows some similarities of ratio and proportion, especially on the floor to ceiling height and the room depth. The physical look from the external portrays contrast stylistic characters but carries significant passive strategies that we can learn.

Table 2. Factors of Passive Design Strategy of Putra Mosque (PM) and Tuanku Mizan Zainal Abidin Mosque (TMZAM) *as per MS1525

No	Factors	Putra Mosque (PM), Putrajaya	Tuanku Mizan Zainal Abidin Mosque (TMZAM), Putrajaya
1	**Building Orientation**	Front Elevation (Main Entrance) – South East Rear Elevation (Qiblat Wall) – North West Side Elevation (To the Lake) – South West Side Elevation (To PMM) – North East	Front Elevation (From Qiblat Walk) – South East Rear Elevation (Facing the Lake) – North West Side Elevation (To the Park) – South West Side Elevation (Iconic Monument) – North East
2	**Building Location**	Located at Dataran Putra, the focal point of Putrajaya Surrounded by the Putrajaya lake- Floating image No high building in the surrounding area – Breezy and tranquil	Located at the central Boulevard of Putrajaya Next to the Putrajaya Lake – Breezy and tranquil Got high building at the surrounding area
3	**Effective Room Depth**	Transition area/ known as corridors/'Ruang limpahan Protects occupants from rains and enhances natural lighting Ventilation. 24metres away from the main prayer wall	Transition area – water features as the cooling factors Protects occupants from rains and enhances natural lighting Ventilation. 21metres away from the main prayer wall
4	**Floor to Ceiling Height**	24.1 metres to the roof's ceiling (female prayer area) and 68.4 metres to the highest nitch of the internal dome surface	22.1 metres to the flat roof's ceiling (female prayer hall) and 40.6 metres to the highest nitch of the internal dome surface

(Sources: Information by KSSB- extracted and analysed by author)

4.3 Passive Design Strategies and Analysis

4.3.1 Solar Heat Gain Minimisation Strategies

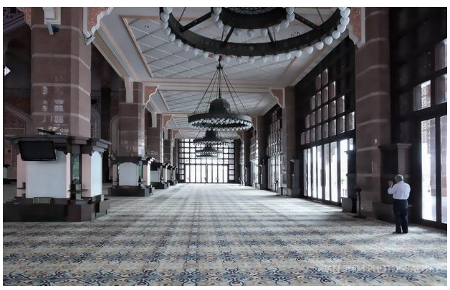
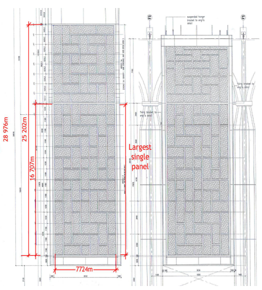
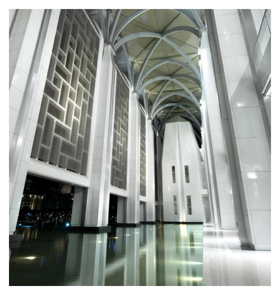


Figure 7. 998m² - Shape and Size of Glazing of Putra Mosque with glazing technologies.





Figures 8 and 9. The aluminium panels were adopted from German's technology in TMZAM.

Solar heat gain minimisation is gained through the glazing technologies (tinted) (refer to figure 7), the external shading devices of mashrabiya and aluminium panel as screening (as per figure 8 and 9). All of the criteria used in both mosques (as per table 2) identified the essential strategies to prevent glare and increase the deep daylight penetration. The energy efficiency of the mosques can be achieved where the electrical and mechanical systems are only used in a particular dedicated area when needed. The big openings and 'modern mashrabiya' concepts found in TMZAM with the surrounded water elements create an airy and breezy praying hall, tranquil space and meet the thermal comforts of the occupants. Materials usage and selected colours of the interior carries a significant impact too. Moghimi et al. (2014) stated that light colours reflect the heat while dark colours absorb heat.

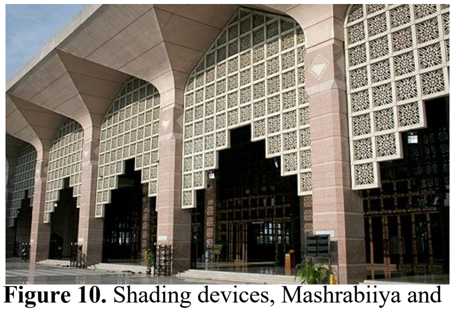
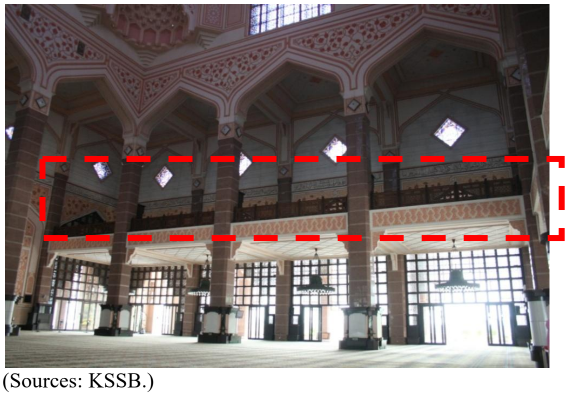


Figure 10. Shading devices, Mashrabiiya and overhang roof of PM

Figure 11. Shading devices, Mashrabiiya and overhang roof of TMZAM

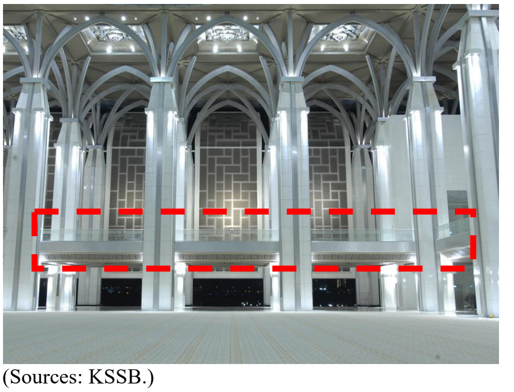
Both mosques featured external shadings to control heat gain (as shown in figures 10 and 11) and were constructed to endure a lifetime. Fouih et al. (2020) specified that the external shades are more effective than internal shades because they block the solar radiation before entering the building. The internal shadings such as curtains and blinds are not installed in both mosques' main prayer hall to increase the visual quality of the inside out. The shading devices found in TMZAM are made of woven stainless steel or 'Architectural Wire Mesh' act as the perimeter wall of the building (as per figure 11). The materials have unique features of high transparency, visibility and promote a higher rate of cross ventilation.

4.3.2 Natural Lighting Strategies



(Sources: KSSB.)

Figure 12. Daylighting penetrates the main prayer hall, PM's internal area through the glass wall and doors (Ground Floor Level), stained glasses at the First Floor, upper floor and dome neck windows.



(Sources: KSSB.)

Figure 13. Daylighting penetrates the internal arca of the main prayer hall, TMZAM, through the woven stainless steel mesh (mashrabiya), the skylight at the roof level and the air gap space at the dome

A tropical climate ideal for daylight harvesting can help get the most out of daylight and give back to the mosque's everyday use. Glare discomfort, excessive heat gain, increased thermal discomfort, and high energy consumption in buildings can all be caused by improper daylight harvesting design. The "quality" of the daylight harvested is just as important as the "amount" of sunshine captured. The 1st floor level of both palaces, placed above the prayer hall at the perimeter wall (as per Figures 12 and 13), act as the internal light shelves. It helps to reduce internal light levels near the façade and reduce the brightness contrasts in the main prayer hall. The natural lighting penetration gives a pleasant ambience for the occupants. The overhanging roof acted as the external light shelves and carried the advantages of capturing more daylight from outside and deflecting it more profound, as shown in Figures 14 and 15. El-Darwish & El-Gendy(2016) quantified that the light coloured interior fit-outs deflect the harvested daylight more profound into the building.

Figure 14. The material used for finishes and Floor Surfaces Properties is found in PM.

Figure 15. The material used for finishes, Internal Ceiling Wall, and Floor Surfaces of TMZAM.

4.4 Daylighting Analysis

Data was collected using Heavy Duty Light Meter (Extech Instruments) Series – 407026 for the external and internal surroundings. The data collected is in 3 different times (9.00 am, 1.00 pm and 5.00 pm) but exact locations (internal and external). The data shown below is the calibrated data taken three times within the same range (morning, afternoon and evening). Table 3 shows the sound distribution of lux in the internal spaces of the main prayer hall and external area (*Ruang limpahan*) in both mosques. The results are mostly good and fair.

$$DF = \frac{E_{\text{internal}}}{E_{\text{external}}} \times 100\%$$

Table 3. Daylight factors and distributions

ZONE	Day Lighting Factor (%)	DISTRIBUTION
Very Bright	> 6	Very large with thermal and glare problems
Bright	3 – 6	Good
Average	1 – 3	Fair
Dark	0 – 1	Poor

Note: The figures are average daylight factors for windows without glazing

				Lux		DF (%)	
No.	**Mosque**	**Date**	**Time**	**External**	**Internal**	**DayLighting Factor**	**Distributio**
1	**Putra**	9th June 2012	9.00 am	5500	150	3	Fair
	Mosque	Thursday	1.00 pm	8500	280	3	Good
	(PM)	Cloudy & Overcast	5.00 pm	6500	220	3	Good
		11th June 2012	9.00 am	7500	200	3	Fair
		Saturday	1.00 pm	25000	480	2	Fair
		Bright & Sunny	5.00 pm	12000	220	2	Fair
		17th June 2012	9.00 am	10000	250	3	Fair
		Friday	1.00 pm	28000	520	2	Fair
		Bright & Sunny	5.00 pm	15000	350	2	Fair
2	**Sultan**	9th June 2012	9.00 am	7500	180	2	Fair
	Mizan	Thursday	1.00 pm	10500	280	3	Good
	Zainal	Cloudy & Overcast	5.00 pm	6500	220	3	Good
	Abidin	11th June 2012	9.00 am	8500	220	3	Good
	Mosque	Saturday	1.00 pm	26500	750	3	Good
	TMZAM	Bright & Sunny	5.00 pm	12000	320	3	Good
		17th June 2012	9.00 am	10000	300	3	Fair
		Friday	1.00 pm	28000	550	2	Fair
		Bright & Sunny	5.00 pm	15000	250	2	Fair

4.4.1 Natural Ventilation Strategies

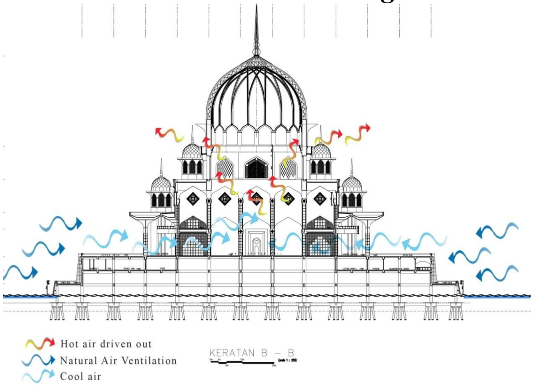


Figure 16. Natural Ventilation; Cross ventilation at PM

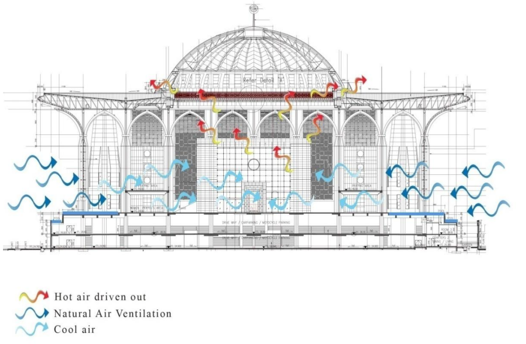


Figure 17. Natural Ventilation; Cross ventilation and Stack effect diagram at TMZAM

It is critical to understand how fresh air moves throughout a structure, around people within, and through its openings, to determine how to increase cooling and air quality. When the wind blows into the building's sides, different amounts of pressure are applied to each side. The building section of PM in figure 16 and TMZAM in figure 17 show the cross-ventilation and stack effect strategies applied in the mosques. Water elements' evaporative cooling was aided to cool up the air and promote natural ventilation.

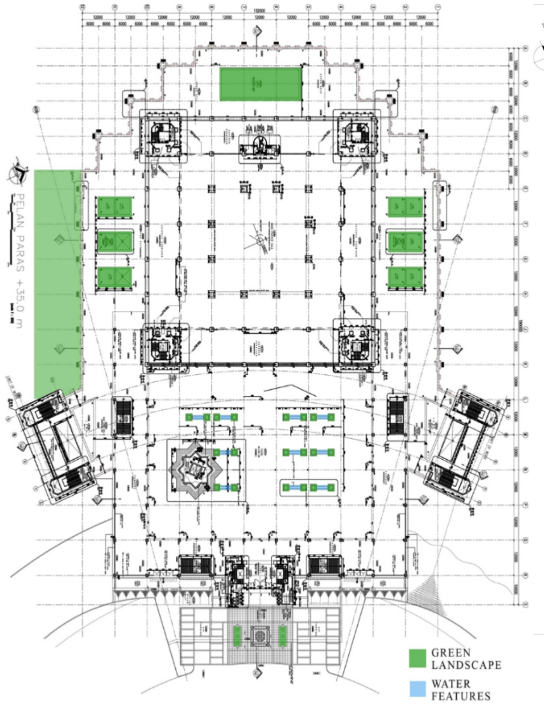


Figure 18. Landscaping area – green and water features at PM

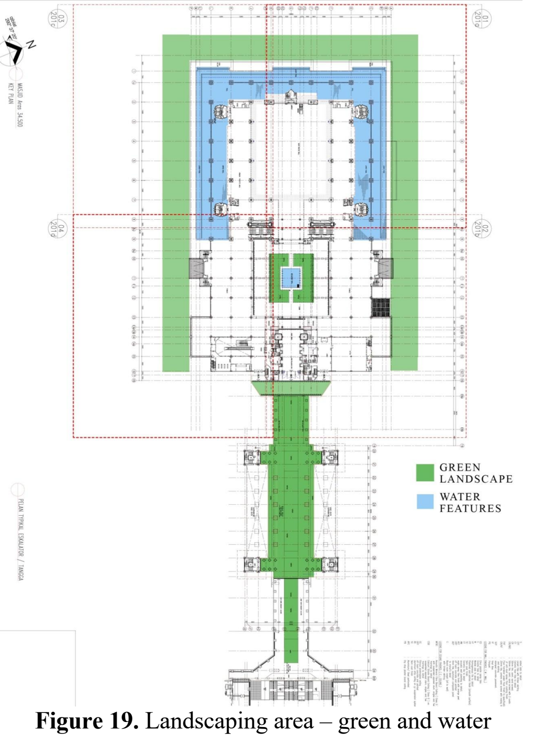


Figure 19. Landscaping area – green and water features at TMZAM

Evaporation and heat absorption help to chill an area. Water bodies and greeneries can also aid space cooling. Chang (2016) mentioned that gardens, roof gardens and planters on windows and shades could reduce heat gain. If water bodies can be integrated, that too would be beneficial. Further, shaded courtyards would lead to lower air temperatures. Besides the soft-scape features and green area requested in the MS 1525, the designers invented the aquascape around the mosque area to cool down the external temperature, as shown in Figures 18 and 19 above.

4.4.2 Building Shape, Envelope and Selection of Material's Strategies

The shape and exterior structure of a building play significant roles in determining its energy efficiency and the comfort of occupants' (Salwana et al., 2020). The shape comprises the building's height, width, and depth, also known as the footprint. The exterior structure, which is the building envelope includes the walls, roof, windows, doors, and cladding. The footprint and envelope of the building can either enhance efficiency or contribute to more energy consumption. Azmi & Kandar (2019) identified that the more the surface area, the more heat will be absorbed and affect the interior condition. Building materials come with different properties, qualities, looks and functions. Some are excellent to carry the load, have latent heat, porosity, and others. Selection materials are essential for architectural and structural purposes and give thermal comforts to the occupants.

4.4.3 OTTV Calculations

The building envelope's overall thermal transfer value is used to calculate its heat conduction (OTTV). The OTTV requirement aims to achieve the design of an adequately insulated building envelope to cut down external heat gain and reduce the cooling load of the air-conditioning system. It helps to measure heat gain into the building through the building envelope. It also acts as an index for comparing the thermal performance of buildings.

> "Certain design modifications can be brought in at an early design stage to ensure reduction of OTTV. For wall orientations with a high OTTV, altering walling material and glazing type must be explored early in the design process. Such precautions would limit heat gain and, as a result, the burden on the air conditioner." (Vijayalaxmi, 2010)

4.4.4 OTTV Concept

- OTTV is a measure of the average heat gain into a building through the building envelope and has three components:
  a) Heat conduction through the opaque wall, Q_{wc}
  b) Heat conduction through window glass, Q_{gc}
  c) Solar radiation through window glass, Q_{gs}

- The heat transfer through the building envelope can be expressed as:

$$OTTV = \frac{Q}{A}$$

where Q = total heat transfer through the envelope (W)
A = gross area of building envelope (m^2)

OTTV calculation, energy consumption and the effect of the building parameters on energy consumption have been investigated. The applied formula above,

$$OTTV = 15 \times \alpha \times (1-WWR) \times Uw + 6(WWR)U_f (222 \times CF \times WWR \times SHGC)$$

Where,

WWR	is the window to gross wall area ratio for the orientation under consideration;
α	is the solar absorptive of an opaque wall;
Uw	is the thermal transmittance of opaque wall (W/m^2K);
Uf	is the thermal transmittance of fenestration system wall (W/m^2K);
CF	is the solar correction factor as in MS1525:2007, Table 4
SHGC	is the shading coefficient of the fenestration system

$$\text{TOTAL OTTV} = \frac{(Ai\,1 \times OTTV\,1) + (Ai\,2 \times OTTV\,2) + (Ai\,3 \times OTTV\,3) + (Ai\,4 \times OTTV\,4)}{Ai\,1 + Ai\,2 + Ai\,3 + Ai\,4}$$

Table 4. Total OTTV Calculation for Putra Mosque (PM)

Parameter	North-West	South-West	South-East	North-East
α	0.650	0.650	0.650	0.650
Uw	2.024	2.024	2.024	2.024
Uf	4.525	4.525	4.525	4.525
CF	0.900	0.900	1.130	1.090
SC	0.234	0.234	0.234	0.234
wwr	0.140	0.350	0.350	0.350
OTTV	26.492	36.629	40.284	39.647
OTTV average				**36**

Table 5. Total OTTV Calculation for Tuanku Mizan Zainal Abidin Mosque (TMZAM)

Parameter	North-East	South-East	South-West	North-West
α	0.140	0.140	0.140	0.140
Uw	5.211	5.211	5.211	5.211
Uf	6.074	6.074	6.074	6.074
CF	1.090	1.130	0.900	0.900
SC	0.145	0.145	0.145	0.145
wwr	0.221	0.569	0.442	0.569
OTTV	23.355	43.540	33.405	39.850
OTTV average				**35**

The overall OTTV calculation of both case studies above shows that the PM is estimated at 36 W/m2. In comparison, TMZAM is estimated at 35 W/m2, which is far less compared to the maximum permissible 0TTV specified in clause 5.2: MS 1525 - it should not exceed 50 W/m2. This study showed that the significant factor for lowering the building energy consumption is the building envelope. The least amount of glazing was installed at the East and West to limit the direct sun exposure. These calculations of OTTV can help the designer estimate energy reduction based on the facade design. From the table above, we can justify the value of OTTV is higher at the Southeast façade of PM and TMZAM as itemised in Tables 4 and 5. The first aspect that significantly impacts energy consumption and mosque's sustainability is its design and architecture. This is even more important when considering that design decisions are made during the early stage of the construction and are difficult to change after.

5.0 Conclusion

Building energy efficiency is such a pressing issue that collaboration among all stakeholders in the construction industry, including architects, engineers, interior designers, and academics, is critical. These professionals who typically work in isolation and sometimes have contradicting views now have to sit together, discuss, and reach a consensus. Their thoughts and ideas must be moulded into one collective force to bring about the creation of energy-efficient buildings. Saving energy use in buildings requires cooperation. Everyone from architects, engineers, interior designers, and researchers play essential roles in moulding ideas into creating energy-efficient buildings. A combined architectural, engineering, site planning, and landscaping (multidisciplinary) approach to designing an energy-efficient building would optimize energy efficiency, especially when employing combined passive and active devices (Azmi & Kandar, 2019). Optimisation results showed that valuable design information on the selection and arrangement of various components of mosques could be obtained in the early phases of the building design process by implementing optimisation techniques of passive design strategies, as demonstrated in this analysis. Such information could aid building designers in their decision-making process to achieve building design with optimum thermal performance. Proper treatment of building envelope contributes to the improvement of the thermal performance of mosques. Therefore, optimization in the design of buildings and the selection of envelope components are highly recommended.

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