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A TAXONOMY STUDY OF MOSQUE ROOF DESIGN IN KLANG VALLEY, MALAYSIA

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ABSTRACT

Energy is the most important issue to focus on as it contributes to economic development and social growth. Buildings were identified to significantly impact energy usage, where 40% of global energy comes from buildings. Nowadays, many buildings in a tropical climate are equipped with air-conditioners as it is seen as the fastest way to cool down buildings. However, this action impacts the environment. One of the affected buildings that are equipped with air-conditioners is a mosque. However, minimal attention has been given to mosques even though this type of building has a significant total space as other commercial buildings. Furthermore, mosques have a unique pattern of occupancy and energy use. While the major contributor to buildings' energy consumption comes from the roof, scarce information is found regarding roof design and energy consumption for air-conditioned mosques in Malaysia. The study aims at exploring the roof types of mosques in the Klang Valley. The objectives are 1) to identify mosques with air-conditioners in the Klang Valley built between 1998 and 2018, 2) to characterize and classify the specific roof types designed for these identified mosques, and 3) to investigate building energy intensity for mosque buildings in the Klang Valley. This paper presents a taxonomy study to classify roof design for air-conditioned mosques in Klang Valley. The study showed that the flat roof demonstrated high energy consumption and cost. The use of HVLS fans and the association with air-conditioners probably increased the building energy.

KEYWORDS:
Energy Consumption; Energy Efficiency; Air Conditioned; Roof Designed; Malaysia

INTRODUCTION

The growing demand for energy in buildings is increasing due to climate change. Buildings have been widely accepted as a significant energy consumer in many modern cities worldwide. It is estimated that buildings are responsible for over a third of global energy-related carbon dioxide emissions, accounting for approximately 40% of global final energy consumption, as reported by the United Nations Environment Programme [1]. The reasons for the growth of energy consumption in buildings are twofold: 1) the use of heating, ventilation, and air conditioning (HVAC) in response to the growing demand for better thermal comfort and the rising trend of people spending more time indoors [2,3] and 2) the improper estimation of cooling loads and inefficient use of air conditioning [4–6]. It can be argued that the building sector contributes to global warming. The "building envelope", which is defined as the barrier between the indoor and outdoor environments of a building, has a substantial function in building energy consumption. A building envelope consists of walls, roofs, thermal insulation, fenestration, and external shading devices. Studies on improving building envelopes and their impact on building energy consumption have been conducted in tropical countries such as India [7], Sri Lanka [8], and Malaysia [9]. Generally, these studies suggest that advances in building envelope designs can potentially reduce building energy consumption. Out of all the building envelope components, roofs have the greatest effect on a building's energy consumption and thermal comfort because they are highly susceptible to solar radiation and other environmental fluctuations [10,11]. Roofs account for heat loss/gain, particularly in buildings with vast roof areas such as educational buildings, exhibition halls, sports complexes, etc. Moreover, more than 60% of heat transfer occurs through the roof regardless of weather, as buildings' rooftops are often the surface with the highest amount of annual solar radiation per square foot [12].
A significant literature exists on the impact of roof designs (e.g., forms, materials, and component configurations) on the indoor thermal comfort of residential buildings as part of passive cooling strategies [13–19]. However, little attention has been

given to mosque buildings even though their consumption is a significant percentage of the total floor space and energy usage in the commercial sector [20]. A mosque is not a place for prayers only. It is also a place for social and religious activities [21–25]. Lately, this building has been installed with air conditioner for thermal comfort, increasing energy demand in a temperate climate. Beside studies on energy performance, mosque building has been discussed in many aspects, the spatial and zoning, and the influence of façade design as well as thermal comfort in mosque building. Both kinds of research concern on energy consumption [26]. The similarities in Malaysian mosques can be seen in their spatial organization and direction [27]. By contrast, many roofs design for mosques in Malaysia [28]. The influence of roof design is not related to religion but depends on the revolution time or the political impact. Besides, it demonstrates a monumental image such as a state mosque. Dome does not symbolize Islam. The evolution showed many roof design types, from traditional vernacular architecture to modernist revivalism [29,30]. However, the questions are whether these various roof designs influence the energy consumption of a mosque. In Malaysia, with the increment in population by 2020, 309 new mosques are expected to be built [30]. The population will increase in urban areas in the next future, which urges more active development of mosques. Climate change will promote more cooling device installation, especially in urban areas, to achieve thermal comfort. The installation of cooling devices will increase energy consumption. The system is designed for temperature control without any concern regarding energy efficiency. The current trend of using air conditioner as a device to give indoor thermal comfort will impact not only the environment but also the operation cost of the buildings. A mosque is a public building where the operation cost is managed with the public fund, and mostly the fund is for the utility bill of the mosque [32].

Studies regarding roof and energy performance have shown a relationship with energy reduction strategy [32], [33]. The Gable roof design for residential buildings in the USA identified that the heating load increases with the roof pitch depending on the type of attic, whether it is sealed or ventilated. Another factor influencing energy consumption is using a skylight on the roof [34]. Still, an innovative roofing system uniform natural light from the roof with 2.1 degrees reduced temperature of the heat gain [35]. In Australia, the application of the cool roof technique showed a reduction in energy consumption for warehouse buildings [36]. The studies are about thermal comfort in a mosque for pitch roof and dome design. His research showed no direct relation between roof design and thermal comfort, but thermal comfort is significant with air temperature [37]. However, he highlighted significant differences in the duration taken by the space to cool down, where a pitched roof mosque heats and cools faster than a domed roof mosque. The roof contributes more heat energy to the interior space than other building elements. Many studies regarding energy consumption in buildings showed a relation between roof design and the energy performance of a building. Early design consideration is important for designers and construction players to optimize energy use, in this case, to design a practical roof and fit for function. It will recommend the best roof configuration for cooling loads energy consumption. The outcome of this research can be used as guidelines for the next generation of mosque design and retrofitting of an existing mosque. Therefore, there is a need for this research to investigate roof design in relation with energy consumption of air-conditioned loads for mosque in Malaysia.

Most of the energy demand for buildings comes from the air-conditioner, where the need for air-conditioners is thermal comfort [4]. Additionally, the improper operation of an air-conditioning system where under or over-cooling is frequently practiced in many mosques may greatly impact the worshippers' spiritual experience and physical comfort. However, the impact that roofs have on energy is often overlooked despite many studies showing that roof design can help in the energy performance of a building [38]. Investigations on the applied cool roofing membrane have been conducted to have the potential to reduce the temperature [42, 43]. The substantial innovative experiments on the material of roofs will improve the energy efficiency of the buildings [41].

This paper aims at exploring the various roof designs for air-conditioned mosques in Klang Valley with the following objectives, 1) to identify air-conditioned mosques built in the Klang Valley between 1998 to 2018, 2) to characterize and classify the specific roof types designed for these identified mosques, and 3) to investigate building energy intensity for mosque building in Klang Valley. This study contributes to a better understanding of the classifications of mosque roof designs in Malaysia, hence, providing the basis for further research to help improving the energy efficiency of mosque buildings in Malaysia. Therefore, this study is crucial to ensure the design of future buildings that can address the important elements of the building envelopes, specifically, the roof design and appropriate strategy to improve energy efficiency besides avoiding energy waste of cooling loads in mosque buildings. The rest of this paper is organized as follows. First, the paper explains the background of mosque design, followed by an explanation of the methods used for the study. Then, the study results are presented and discussed before concluding with several recommendations for future research.

MOSQUE DESIGN IN MALAYSIA

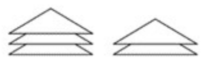
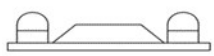
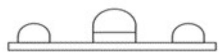
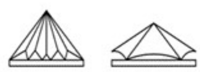
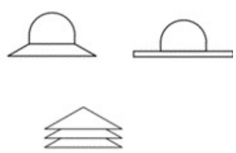
The mosque is a unique building where the operation schedule depends on the prayer times compared to other buildings. The similarity in mosques' design is their building orientation, where they face the Qiblah (the direction of the Kaaba). The difference in mosque design worldwide is the mosque's architecture [42]. Mosques in Muslim countries are influenced by the local culture, traditions, and colonialism [43]. The revolution of Islamic architecture in Malaysia has been divided into three stages, namely, Vernacular, Colonial, and Modern [44]. Later, M. Tajuddin, 2007 highlighted the seven typologies of mosque architecture classified according to the style and influence within the timeline. Baharuddin and Ismail [24] highlight that mosque architecture is more related to political agenda. Mosques are very important buildings for the 61.5% Muslim population in Malaysia. According to JAKIM, the total number of mosques in Malaysia is 6347, and 331 are in the Klang Valley. The increased number of mosques being built aligns with the Muslim population in urban areas [30]. Nowadays, a mosque is not only a religious center, but the function has widely expanded as a place for community development and society programs such as religious classes and cafés [23]. The Malaysia Standard 2577:2018 had published the general planning of a mosque where it highlighted that the function and general planning could be standardized, as in MS2577:2014 [45]. Malaysian mosques have evolved through their shape and form [27]. It is influenced by colonialism without maintaining the original function of the mosque itself. The revolution significantly transformed the styles and identities applied to designing the mosques.

ROOF DESIGN IN MOSQUE ARCHITECTURE

One of the most notable Islamic features of the mosque is the roof design. In Malaysia, domes had generally become a notable thing in designing mosques during the British era [46]. Roof forms of Malaysian mosques are differentiated by their geographical context and the influence of the origin era over time [47]. History has shown the revolution of mosque architecture in Malaysia. Currently, the architecture is moving away from contemporary styles where the focus is emphasized on sustainable features in the design [48].

The roof becomes an important building envelope because it contributes most of the heat gains in the building. The impact that roofs have on energy is often overlooked, which can be significant. Many studies showed that roof design could help in the energy performance of a building [41]. Heat gain through building surfaces is essential in determining the building's cooling loads. The more solar radiation received in a building's roofing surface area, the more heat gains will be produced. [38]. The difference between many mosques in Malaysia has been identified through their roof designs. The roof design revolution can be seen before the Malaysian independence and after the independence [24]. In Malaysia, the mosque's roof design had many influences from the historical time and the revolution of the form that had the history behind it [49]. Based on seven typologies classified by M.Rasdi [28] (refer to Table 1), this table (which is an interpretation that has been done by this paper's authors based on Mohamed Tajuddin's work) shows the development of roof form. With the current trends, architects are developing design concepts not only for architectural form but also to provide a more functional and sustainable building. Previous Islamic monuments became innovative, and advances were applied to the buildings [46]. The potential of a mosque design aiming toward the building's performance is important in addressing a sustainable building, especially for urban mosques [30]. Generally, the roof typology for mosques in Malaysia can be grouped into both a single form and a mix form. Single roof form consists of flat, pitch and circular, while the mix form is a combination of the single forms such as dome on pitch or dome on flat roof [50].

Table 1. The mosque's roof form style ccording to the classification [28]

Images	Era	Style
	Traditional Vernacular Style	Two tier pyramidical roof/ gable
	Sino Electic Style	Two and three tiers
	European Classical Style	Hipped gable roof
	North Indian Style	Multiple Dome
	Modern Vernacular Style	Gabled roof with a dome (Small size)
	Modernistic Style	Gabled roof
	Post Modern Revivalism	Hybrid (big scale)

Understanding the factors affecting buildings' energy consumption and the influence of roof design is necessary for producing energy-efficient buildings. The taxonomy study on the roof design of mosques is a classification that systematically describes the roof preference built-in Klang Valley, Malaysia.

It is concerned with observing two descriptions: the formal and functional. The formal description includes images of the mosque: depicting the building as a system of spatial and material parts. The functional description explains the rules and the criteria of the mosque design that should be met in order to achieve the desired quality of performance aspects such as energy efficiency, thermal comfort, indoor air quality, and daylight.

METHOD

FIRST STAGE: ROOF CLASSIFICATION

For this study, mosques that are located in Klang Valley are identified. The Klang Valley covers the area of Kuala Lumpur, Gombak, Petaling, Hulu Langat, Klang and Sepang. This area was selected due to its high number of mosques built in the past 20 years and is considered to be a highly populated urban area. Therefore, it is suitable to be chosen as the study area. The following three stages of data collection were conducted to fulfill the objectives of this study.

IDENTIFICATION OF AIR-CONDITIONED MOSQUE IN THE KLANG VALLEY

Mosques were identified from the following six primary sources:

- Department of Islamic Development Malaysia (JAKIM): JAKIM coordinates the standardization of the administration of Islamic affairs in all states. The list of mosques in the Klang Valley was extracted from JAKIM's website, which lists all mosques nationwide [51].
- Selangor Islamic Religion Department (JAIS): This department is responsible for administering the religion of Islam in Selangor state. The mosque management division in JAIS ensures all mosques in Selangor are in good condition and conducive for the worshippers. Data were obtained from *e-masjid* JAIS, a comprehensive database on mosques in Selangor. Some information available in the *e-masjid* consist of essential details, such as the year built, building capacity, and the buildings' images. An official application was made to the Buildings Department of JAIS to seek approval for the data collection [52].
- Department of Federal Territory Islamic Affairs (JAWI): This department is a leading organization promoting Islamic Affairs at the Federal territory level. One of its missions is to supervise the maintenance of mosques under the federal territory and carefully observe the activities conducted in the mosques. Data on mosques in the Federal Territory of Kuala Lumpur were obtained from JAWI's website. However, the web provides only the list of mosques without any other details. Hence, an official visit to the JAWI's Buildings Department was conducted to obtain more data [53]
- Malaysia Administrative Modernisation and Management Planning Unit (MAMPU): MAMPU is one of the government agencies in Malaysia that is responsible for modernizing and reforming the public sector. MAMPU developed the Public Sector Open Data Portal, an online one-service-center to access and download open government data. Additional data on mosques in Kuala Lumpur and Selangor were also requested using this platform [54].
- mymasjid.net.my: This web was established in 2011 as a platform for the Muslim community to share information on mosque activities. It also provides a detailed list of mosques in Malaysia [55].
- Book: Additional information was obtained from a book titled 'Masjid-Masjid di Kuala Lumpur,' published by JAWI in 2014 [56].

There were 6446—mosques in Malaysia, as revealed from the list of mosques by JAKIM. The list was narrowed down to those in the Klang Valley only, giving 467 mosques, of which 71 were in Kuala Lumpur and 396 were in Gombak, Petaling, Hulu Langat, Klang, and Sepang, which are a part of Selangor. Mosques in Kuala Lumpur were listed according to their six zones. In contrast, mosques in Selangor were listed by district.

IDENTIFICATION OF MOSQUES THAT MEET THE RESEARCH PARAMETERS

All of the mosques that were identified are located in the Klang Valley. It was further investigated to identify mosques that meet the research parameter where mosques should be equipped with air-conditioners, built in the range of 1998 to 2018 [57][58] and the capacity is within 1000 to 3500 people [59] [60]. Methods used to achieve this are:

- Mosque individual website: Many mosques have their websites, especially through their Facebook accounts.
- Google search: The fastest way to get the description about the year where they were built. The images also eased the mosques' selection for those equipped with air conditioners.

An internet search was carried out to overview the mosques in Klang Valley. Furthermore, to confirm the mosques are air-conditioned and built within the parameter years, phone calls were made to each mosque administration.

IDENTIFICATION OF THE MOSQUES' ROOF TYPES

A site visit was conducted for each identified mosque in Klang Valley. The purpose of the site visit is to identify roof types and other parameters that have been listed. Observations were made, and relevant photos were taken. In addition, interviews with the mosque administration were conducted to further describe usage duration for air conditioners and the information on mosque drawings.

SECOND STAGE: SELECTION SAMPLE FOR CASE STUDY

The roof group samples were selected after the roofs were classified according to their typology. The sample should represent ordinally seen design to compare in the group. The case study also should provide five years of electric bills and area of cooling areas. Further investigation of detail of the sample buildings was carried out. Actual annual energy usage had been obtained from the mosque records and a local electric provider Tenaga Nasional Berhad (TNB). The utility bills requested for each mosque should state records of electric consumption and the cost from January until December. These data were used to calculate the sample's Building Energy Index (BEI).

THIRD STAGE: MOSQUE ENERGY INTENSITY CASE STUDY

After selecting the case study, the building energy intensity was evaluated. A few mosques were chosen to evaluate the building energy index for the case study. The formula derived to obtain BEI is the total annual energy usage of a building in kWh to the cooling floor area (m^2) as referred to in Azman et al. [56]. Malaysian Standard MS1525:2019 had developed a standard BEI for an office building of about 200kWh/Year/m^2, and a study from Moghimi showed BEI reference for a hospital is 245kWh/year/m^2 [57]. So far, Sheik Saidur (2009) and Azman et al. have studied BEI references for a mosque. The summarized study regarding BEI is in Table 2, and the study for the BEI mosque is in Table 3. The average BEI of the case study was analyzed using SPSS. The value of building energy intensity between the selected mosque was discussed.

Table 2. Studied Building Energy Index

Description	kWh/yr	Cooling Area	BEI (kWh/ m^2)
Moghimi,2014 (Hospital)	60,562,548	13563 / 247384 (overall area)	245
M.Saidur,2009	127752000	983000	130
MS1525:2019 (Office)			200
EPU Unit ,2017			140

Table 3. Studied Building Energy Index for Mosque

Description	kWh/yr/m^2	Cooling Area	BEI
(Abdou, Al-homoud, and Budaiwi 2005)	72721	-	194
	35559	-	195
	124213	-	179
	111431	-	88
	168603	-	197
Azman et.al (2019)	21457	159	135
	38978	314	124
	63419	577	110
	44100	632	70
	942003	2920	323

RESULTS

FIRST STAGE: ROOF TYPOLOGY

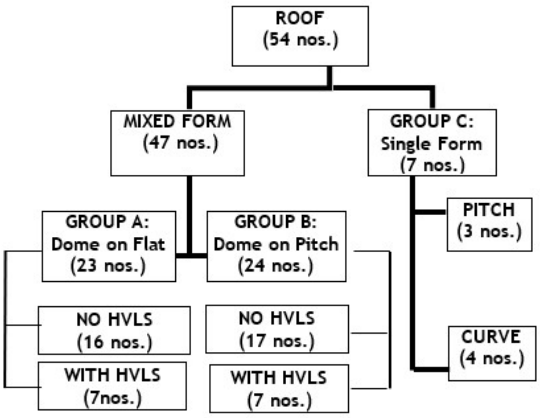
Fifty-four mosques had been identified in the Klang Valley, all equipped with air conditioners and built between 1998 and 2018 with a capacity between 1000 and 3500 people. From the roof observation carried out, the mosques were categorized as illustrated in Figure 1 below.

Two groups of roof typologies were found during the site visit and observation. The groups are either the single form or mixed forms used for mosques in the Klang Valley. The mixed form of roof design category was divided into two groups: roofs consisting of domes on flat roofs were named Group A, and mosques with domes on pitch roofs as Group B. The single-roof form was labeled Group C. Group C is essentially not associated with a dome design. From the site visit, the total number of buildings in Group A is 23 and Group B is 24, while Group C is 7.

FEATURES OBSERVED IN THE MOSQUES

All the roofs have a clerestory of either under the dome or the dome's perimeter. The observation revealed the usage of HVLS fans as part of the additional ventilation used in both Groups A and B. Some mosques have installed exhaust fans at the perimeter of the roof. In order to improve the ventilation system in the mosque, wall-fans are installed. This is due to the high ceiling height that made it difficult to install a ceiling fan. The wall fans are installed on the column or pillars erected to mount the fan. On top of that, stand-fans are put as part of the additional ventilation system.

Most interior lighting systems used fluorescent lights, down-lights, and spotlights. Thus far, according to the interview with the officers of mosques, energy-efficient lighting was regarded with little priority. The efficient lighting was not taken much into accord as there is less awareness of low energy consumption due to efficient luminaire. Perimeter fence lighting for the mosques will mostly switch on at 7 pm and switch off at 7 am. The duration generally takes 12 hours. The fence lighting were normally used. Generally, all lighting had been arranged according to zones to navigate the light easily.



** HVLS – High Volume Low-Speed fan*

Figure 1. Roof Findings

Another finding during the site visit was the additional usage of HVLS fans for some mosques in Group A and B. Based on the interview with the mosque administration, most of the the installation of the fan was initiated in the previous two years. However, none of the mosques in Group C had this additional fan.

SECOND STAGE: SELECTION OF CASE STUDY

Samples of the mosque selected to represent Group A, B, and C are listed in Table 4. The selection of the mosque is based on the ordinally seen design so that it can represent all groups. Observation during the site visit and mosque features as well as its description was recorded in the survey form. Table 5 briefly explains the general description and observation of the roof designs for Groups A, B, and C. From the observation, the mosque in Group A and C had perimeter clerestory under the roof, and the mosque for Group B had three fixed glass on all sides of the roof. The glass uses standard floating glass that is 6mm thick. So far, the clerestory enhances lighting in the main prayer hall. The air conditioner operation schedule follows five times prayers for mosques selected to represent Group A, B, and C.

THIRD STAGE: MOSQUE ENERGY INTENSITY AND COST

In this stage, at least one sample of mosques had been selected to represent Group A, B, and C. Energy bills for five years and drawings were requested from the selected mosques. The Building Energy Index (BEI) and cost for the sample mosque for Group A, B, and C were calculated. Since the electric bills were collected for five years, there are five BEIs for each mosque. Next, the data of BEI were analyzed using SPSS to obtain the average BEI for each mosque. Previous studies regarding building energy intensity are summarized in Table 2, and previous studies regarding mosque energy intensity are depicted in Table 3. Based on the result, the mosque that consumed the highest energy is Mosque UTM, from Group A. Mosque that used the least energy is Mosque Hidayah from Group C, followed by mosque K.D. from Group B. Mosque Hidayah noted less energy cost for cost consumption, and mosque UTM from group A noted high energy cost. The summaries of the result are presented in Table 6.

Table 4. Selection Of Mosque to Represent Roof Group

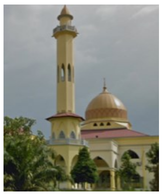
GROUP A	GROUP B	GROUP C
		
Mosque UTM , Jalan Semarak, Kuala Lumpur	Mosque Kota Damansara (K.D.) Petaling, Sel	Mosque Hidayah, Sg Penchala, Kuala Lumpur

Table 5. General description selection of case study

I.D.		Group A The dome on the Flat Roof	Group B The dome on Pitch Roof	Group C No dome
Mosques Name		UTM Mosque	Kota Damansara Mosque	Hidayah Mosque
Descriptions	Built Year	2010	2008	2008
	Clerestory	/	/	/
	Floors	1 ½	1 ½	1 ½
	Capacity	3500	2000	3000
	AC Area (m^2)	919	1122	784
	Wall Fan	/	/	/
	Stand Fan	/	/	/

Table 6. BEI Using Five Years Bill

Mosque Name	Roof Design	Average BEI (year/kWh/m2)	Average annual cost (R.M.)
Masjid Hidayah	C	125	62,625
Masjid KD	B	188	71,300
Masjid UTM	A	222	103,877

DISCUSSION

ROOF TYPOLOGY

The roof plays an important role in building energy where it is the top-most part of the building [5]. The potential of a mosque design for the building's performance is important in addressing a sustainable building, especially for urban mosques [30]. Many studies showed that roof design could help in the energy performance of a building [41]. Studies regarding roof and energy performance have influenced energy reduction strategy [33, 34].1. The result showed the group of mosques with the dome on the flat roof; 23 mosques fell under this category and were named Group A. 24 mosques with a dome on the pitch roof were labeled Group B. The single roof form with no associated dome mosques in Klang Valley was marked as Group C. Group B was the foremost choice in designing the roof form. However, it is slightly more as compared to Group A.

It is because the pitch is the foremost choice in a tropical country. Based on the study [37], a pitched roof tends to cool faster than a dome roof. However, the dome had been widely mistaken as a symbol of religion [30]. Therefore, the combination has shown the dome functions as the foremost choice in mosque buildings. The mixed form of the roof design was mostly chosen over the single form roof design. In groups A and B, the dome was integrated as part of the roof design. From the observation during the site visit, the clerestory on the roof impacts the interior luminaries. The clerestory is fixed and cannot be opened. Some mosques have an exhaust fan on the roof. The dome design also varies in radius. Some had an onion shape, and some had a very shallow form that marked the architectural style difference [58]. Flat roofs seem easy to cater to a larger area. However, a pitched roof will create more area in the upper space of the roof. A flat roof has more penetration than a pitch and dome in terms of heat gain. The Dome roof demonstrated more heat gain penetration than the pitched roof [17].

SELECTION OF CASE STUDY

Next, after classifying mosques according to their roof group, the selected sample of the mosque as a case study was carried out. Although it is less built, the roofs in Group C, most of the mosques in this group, are new. On the other hand, group A and Group B have integrated the dome design, and this roof type has been the foremost choice for mosques in the Klang Valley. The reason for being the foremost choice is because the designer assumes the dome as a symbol of religion to be reflected in the design of mosques. Therefore, current trends are likely to have no dome for mosques.

Most of the interior lighting systems used in the mosques were fluorescent lights, down-lights, and spotlights. However, according to the mosque administrative officers, energy-efficient lighting was of little priority due to a lack of awareness. Typically, electric lighting was arranged and controlled according to zones.

Observations during the site visits revealed that some mosques were installed with a hybrid ventilation system, i.e., using both A.C. systems and HVLS fans. Using HVLS fans in mosques started two years ago [65]. However, this trend was not observed in the selected case study.

BUILDING ENERGY INTENSITY (BEI)

Further analysis of the Building Energy Index derived from the three sampled mosques from each roof design revealed mosque from Group A, which is the dome on a flat roof, notes the highest BEI compared with groups B and C using a five-year bill. Previous studies regarding building energy index were carried out for hospital and office buildings.

The mosque in group B possessed a minor energy consumption. Studies by Abdel Abdou and Budaiwi [4] revealed that the average BEI for mosque buildings is 167 kWh/year/m2. Azman et al. [56] identified that the highest BEI is from state mosques where it used AHU for the buildings. However, from the study, the mosque that used split type air-conditioned is the urban mosque with an average BEI123 kWh/yr/m2. The statistical analysis showed that the mosque with the highest BEI and high cost using five years of energy bills is Mosque UTM from Group A. This high energy possibility is from the heat penetration to the inside area, where it takes more energy to cool down the main prayer hall. Previous studies showed that heat penetration is higher for the flat roof and less heat penetration for pitch and is followed by dome roof [17]. Roof from Group B noted second-highest in energy cost and consumption. Although this is the foremost choice in mosque design at Klang Valley, it is more efficient than Group A. Pitch roof showed less heat transfer and is adaptive to tropical climates [59]. Maarof [37] identified that the pitched roof is easier to cool down. The impact on solar penetration for pitch roofs is based on the different angles constructed [19]. The mosque that has the least energy consumption and cost from the five years bills is Group C. It showed that no dome roof type significantly affects the energy cost and consumption. The new era of group C showed less energy consumption and cost.

CONCLUSION AND RECOMMENDATION

The study revealed that most of the roof design is Group B but it is slightly different from Group A. Since Groups A and B are the foremost chosen roof form, it can be concluded that the mixed form roof has been mostly designed for mosques in the Klang Valley. This type of roof is associated with the dome for mosque design. It showed the influence of domes on mosque architecture in the Klang Valley. However, the dome design will create a larger space on the rooftop. The flat roof demonstrated high energy consumption and cost from Group A. The use of HVLS fans and the association with air-conditioners probably increased the building energy. A further recommendation is to investigate the effect of HVLS on building energy consumption. Observation during the site visit also showed that few mosques had facility managers who regularly looked into the maintenance of these mosques.

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