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The Potentiality of Domes on Provision of Daylight in Mosques

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Abstract

Natural light in building represent an attractive component of interior life. It is a phenomenal link between interior and exterior spaces. In addition, it improves the human psychological comfort. Moreover, it plays an essential economical role in saving energy during windows. However, it does not operate efficiently in deep spaces. This is also more acute where there are not enough light controlling devices to help in increasing the penetrated light level on the external envelope. The mosques are one of the clear example where this lighting problem occur. Therefore, such architectural spaces need to be installed with skylight through to insure sufficient natural light in the central zone. However, the question is whether the light is enough especially with such space of large volume and height. This paper intends to identify light contribution through the dome as one of the devices that are usually used in mosques. This will be explored using a survey study and experimental process.

INTRODUCTION

Natural light is one of the most influencing environmental factors in building interiors [1-5]. This will be guaranteed if efficiently controlled sunlight contributes in saving energy consumption and visual performance [1-3]. Daylight is one of the most environmental parameters that contribute towards the human comfort in buildings for its visual performance and the energy load of electricity bills. The controlled daylight systems reduce heating load that affect the air-conditioning system. Although the light contribution through top openings is very low, Architects intend to use these devices particularly in deep spaces as penetration of fenestration light is very limited [1, 2]. However, controlled devices may help to control the light distribution. Dome is one of the most distinctive components that had been used in many mosques. Therefore, skylight devices such as domes, monitors were provided in most of mosques now days [6, 7].

In the recent decades, the development of architectural design theory and structural systems has obviously affected mosque design [6, 7]. Although, many necessary design requirements still to be considered, like orienting towards Mecca, the argument regarding the necessity of other elements, like dome and minaret, still experienced [5, 8]. Dome is considered to be an essential environmental control device in buildings as thermal, lighting, and acoustical controllers [5]. Recently; Artificial Intelligence (AI) algorithms were widely used for solving difficult problems, such as information retrieval and patterns recognition [9-20], image segmentations [21-29], nurse rostering problem [30], medical image analysis [31-35] and river flow forecasting [36-38], furthermore many researchers employed AI algorithms in mosque architectural design and development [39-41] and architectural design of other buildings [42-45].

THE DEFINITION OF THE PROBLEM

It is crucial to express the Islamic identity of the Muslim societies across the world. Preservation of mosque historical typology even in recent modern ones represent the most obvious building type to ensure this expression. One way of achieving this target is to explore the environmental potential architectural elements of mosques [5, 6].

Domes had become an essential architectural symbols in mosques that had been traced through the different Islamic civilizations in various geometries [46, 47]. Recently, this component had been used intensively in mosques to identify its location besides the minaret. Among the 34 selected mosques to be nominated for the mosques' prize of Alfouzan during its first period (2014), 23 mosques contain domes on the roof of the prayer area [48].

Due to mosque dimensions, side windows may not be efficient for satisfactory light. Therefore, skylight devices such as domes, contributes positively in various environmental parameters. It was considered to be an essential environmental control device in buildings as thermal, lighting, and acoustical controllers in most of mosques now days [49].

Many researches had been conducted the investigation of the Environmental performance of domes in mosques. Daylight contribution through such component is one of them. Thus; most of these studies using a software investigation models that had been implemented in specific case studies. However, deep investigation of the openings' configurations contained in the dome itself is not sufficiently explored, especially in modern mosques [50, 51]. Therefore, the aim of the paper is to investigate the optimization of the use of the dome according to its different openings' configuration in the provision of daylight.

THE PRESENCE OF DOMES IN THE MOSQUE

Domes had been known earlier in Mesopotamia and rural areas. It also had been found in Nineueh as a conical shape to cover the roof of houses. In Egyptian architecture, domes had been built over the tombs. The pantheon, Rome, represent the use of the dome during the Roman age. The Byzantines developed the dome with ornaments such as [52].

As an important symbol in Islam, a mosque is built with architectural grandeur. Among the characteristics is its high ceiling and typical spherical dome shape. Dome had been used specifically as a structural system to support the large spans; supported by either circular and/or square base [46, 53].

During the Islamic period, the dome design had been characterized by different shapes depending on their local culture such as pyramidal, as found in mosques in Malacca, Malaysia [54]. Dome of the Rock in Jerusalem is the earliest example in Ommiad period (661 – 750), where it contains octagonal base of 95.2. m and a height of 31.5 m. It has a nick where 16 arched windows installed for daylight. Ottoman period represent one of the most flourishing ages in the use of domed mosques where mostly supported by stalactites (mogarnas).

Modern Domes in Mosques

Recently, the dome had been used for other building types rather than religious buildings. They had been used in office buildings, commercial complexes and governmental buildings. In the recent decades, the development of architectural design theory and structural systems has obviously affected mosque design [54].

It is crucial to preserve mosque historical typology in order to keep this building type linked to the Islamic history, and to express the Islamic identity of the Muslim societies across the world. This means that even when mosque design is intended to be modern, it should reflect the historical architectural identity [7, 54].

In Turkey, as a large Islamic country with a rich Islamic heritage of Ottoman mosques, many architectural designs expressed the trend of modernism [55]. As shown in Figure 1, domes of contemporary mosques had been built in various geometries. Traditional domes have been built in the center of the prayer hall in different configuration of the opening at the base of the dome. Moreover, dome had been built covering the prayer hall.

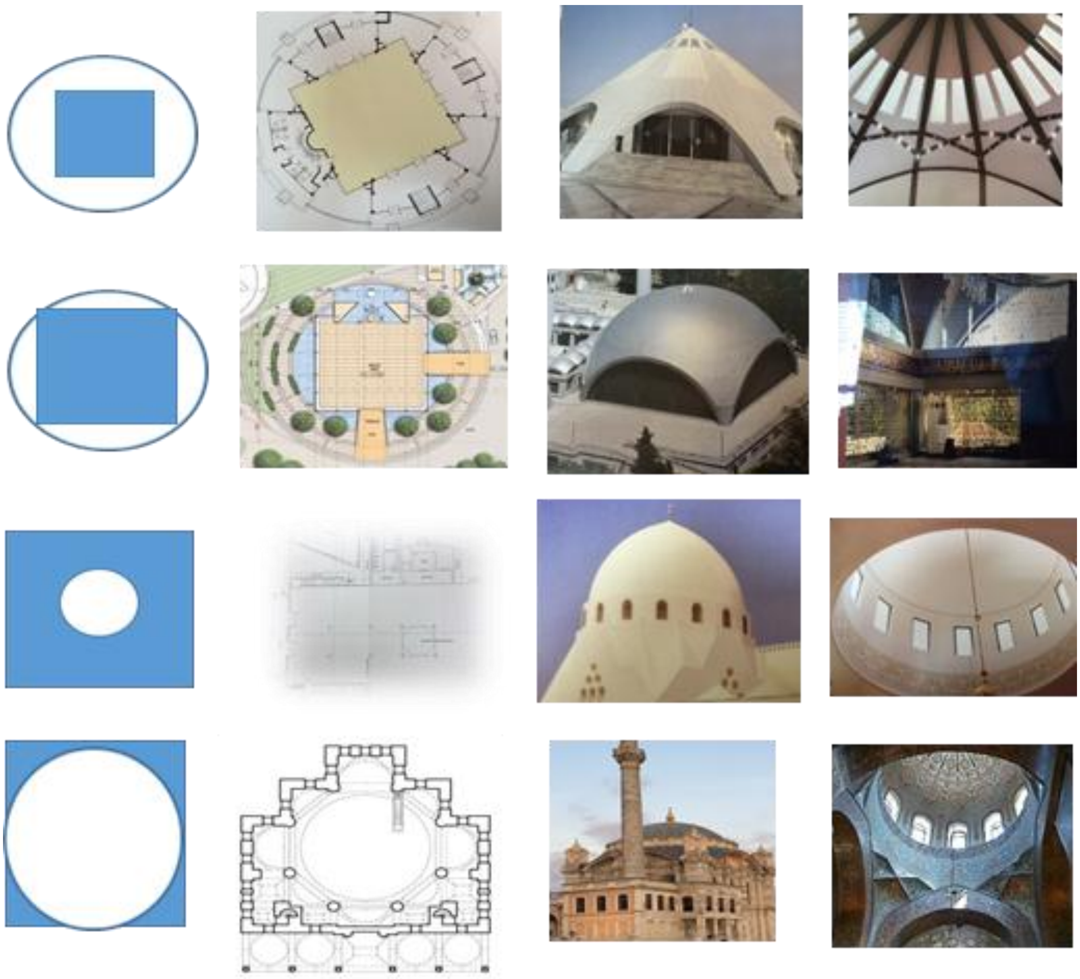

Figure 1: Domes of contemporary mosques has been built in various geometries.

ENVIRONMENTAL CHARACTERISTICS

The dome as one of the most characterized architectural features of mosques that could be used as a potential environmental element for acoustical, light and thermal treatment [56]. This is briefly stated in the following paragraphs.

Thermal Contribution

Dome remains the distinguished architectural feature due to its ability of large area coverage and favorable thermal performance [52]. On this account, the current research studies investigated the role of shape in roofs towards energy loss, specifically throughout a day or year to achieve an optimized form. The results show that the dome with lower rise has a more acceptable thermal performance since it has the least surface area; the result shows that the more external area is the rate of heating load and consequently the rate of heat transfer flux will be more. The thermal performance is better than the building with flat roof, particularly when the dome covered with glazed tiles [57]. In addition to their aesthetic values, they have thermal benefits of keeping the inside air of these buildings relatively cool during the summer. Moreover, openings in domes cause passive air flow across the interior space. The average monthly utilization of energy in 5 selected mosques indicated that air conditioning to cool the space utilized 73% of the electrical consumption while lighting system utilized 22% [58]. The average annual energy use index for a typical mosque is around 182 KWh/ Cm2-yr [58]. This means that energy conservation measures should be applied in mosques. If controlled daylight devices are considered in such buildings, this will help to cut off the energy cost by 22%. One such technique could be the use of domes with windows. A case study was conducted in six air conditioned mosques in Kuwait during the summer [59]. An analysis of prayer hall thermal comfort sensation indicated that the neutral temperature of the prayer was found to be 26.1 C [59].

Acoustical Contribution

The acoustics treatments in mosque considered to be one of the important environmental issues. Many mosque activities cannot perform without it; such as individual and/or group Quran reading, especially during the holy Ramadan. In addition to the Friday sermon and the other sermons made occasionally [60].

A number of researches had been conducted for the acoustical treatment and in particular, the effected architectural components such as walls, windows and their properties of materials. A research was aimed to investigate the acoustical characteristics of typical constructed mosques without domes [61]. The study conducted into two most common geometries of prayer halls in the absence of concrete frame systems. Those are the rectangular and the square geometries. It had been concluded that the square geometry shows the positive impression of uniform typical sound distribution in all rows of prayer hall [62]. However, the rectangular layout indicates a negative impacted sound field in the front rows [63]. Another study conducted mosque prayer halls of five different geometries that represent the most common ones used in such type of building. These geometries are rectangle, trapezoid, square, Hexagon and octagon. Preferred ranges of RT values at mid-frequencies for a variety of activities are well established. Despite the fact that no major differences were found, the square mosque showed the merits of uniform spatial distribution.

Light Contribution

Daylight is one of the environmental parameters that contribute towards the human comfort in buildings. Besides its visual performance, daylight affects the energy load of electricity. The controlled daylight systems reduce the heating load which affects the air-conditioning system. Electrical lighting can add as much as 16% to the cooling energy bill [64]. Daylight alone can reduce total energy use by 25 -30% [65].

Daylight devices had been found in various types of the building components. Some are side lighting systems and others are top lighting systems. Depending on the climatic characteristics, the suitable system will be selected as part of the building design parameters. In hot climates, where the illuminance level at the horizon is more sufficient than the azimuth, the vertical openings such as glass panels and windows are more practical. However, the excessive openings reduce the visual performance inside the space due to the brightness difference between outside and inside. Rawshan screens cut off 50% of direct sunlight while maintaining standard light level for reading purpose [66]. Although the light contribution through top openings is very low, architects intend to use these devices particularly in deep spaces as fenestration light is very limited; because layout configuration is high (ratio of width to length). However, controlled devices may help to control the light penetration. Religious buildings are well known as a buildings using natural light through domes and large windows. Dome as one of the most distinctive features in mosques, will be investigated as natural lighting device. In addition, it improves the users' mode towards the outside environment. However, due to mosque dimensions, side windows may not be efficient for satisfactory light. Therefore, skylight devices such as domes and clerestory windows were provided in most of mosques now days.

Investigation of Daylight Contribution in Domed Mosques

The researcher conducted a pilot field investigation of daylight performance through domes for more than 10 domes mosques in the Eastern province of Saudi Arabia. The area of their prayer zone ranges between 225- 400 m2. All selected domes contain side openings with different dimension and shape configurations. The light measurement investigation carried out on the floor plane; parallel to the Qibla wall, across the dome zone where there is no contribution from side openings. The field investigation carried out using portable light meter. The result indicated in Figure 2 concluded that all light level contributed through the central dome for most of the selected cases indicated lower level than the standard level of 500 lux for reading purposes [66]. However, there are a few cases where the light level indicated higher reading up to 1000 lux. This is due to the penetration of direct sun patches. The light level during the period of 1-4 PM, the most occupied period in the mosque during the day, is between 350 – 500 lux. However, the dome according to the specification of the selected cases was not efficient enough to reduce electric consumption as supplementary artificial sky needed.

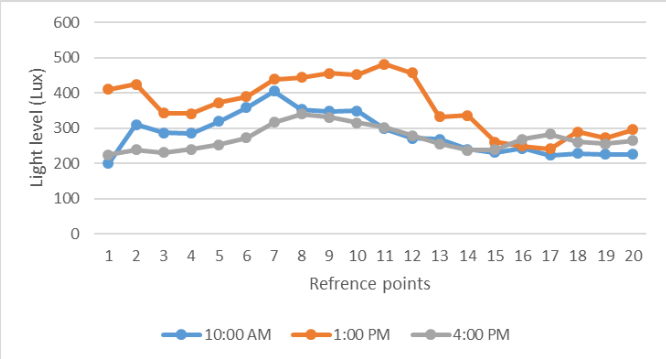

Figure 2: Pilot study to investigate natural light level across the prayer area.

The Daylight Investigation of Selected Case Study

The pilot study made in the last paragraph for the chosen mosques indicates the positive contribution of light through the domes. However, the investigation had been made only in one section through the domes' zones. Moreover, the results recorded as an average of the ten cases. Therefore, one of these case studies was selected for more detailed investigation.

Alarfaj mosque in Alkhobar was chosen for this investigation because of its architectural style is similar to the Ottoman period style; Figure 3 shows the external views of the selected mosques.

Figure 3: External views of the selected mosques.

The light introduced in this mosque through two vertical openings of (1.2 m 6.65m) each on both ends. In Addition, there are two large tinted 10 mm glass panels of (7.40 x 8) each on both north and south walls. The dome on the roof is the other device that light introduced through its 28 side openings of 0.97 m by .60 m. Figure 4 shows the sections through the mosques indicating the opening through the central dome.

The Light Contribution Analysis

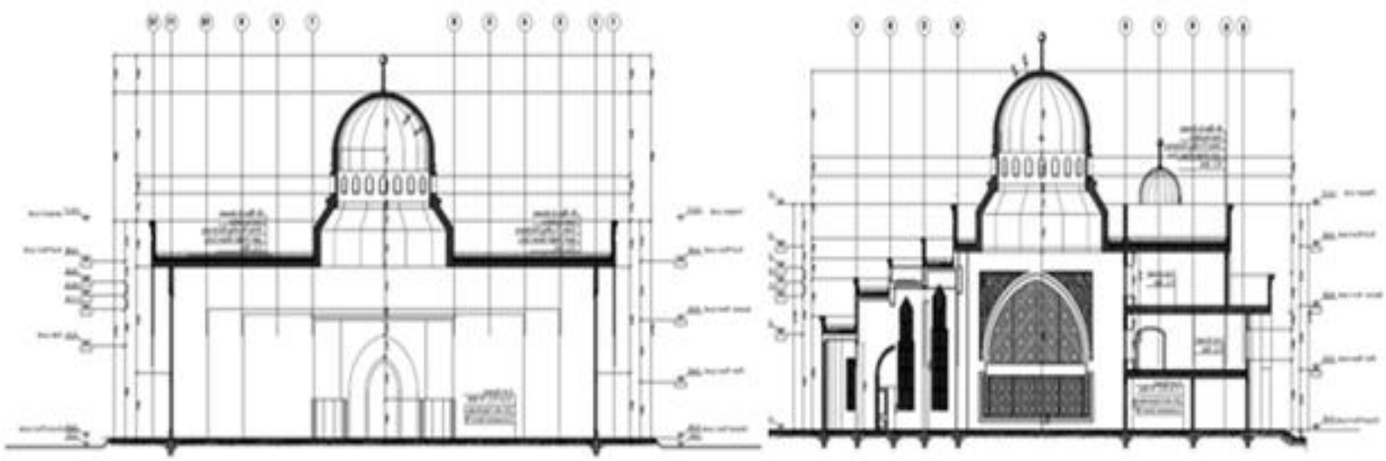

Figure 4: Sections through the mosques indicating the opening through the central dome.

The light level performance contributed through the dome in this mosque had been measured using portable measured tool, Figure 5 reads in a range of 0 -100000 lux of 1 lux resolution up to 32000 lux and 10 lux resolution up to 100000 lux.

Figure 5: The portable light meter used for measurements [67].

The readings were taken at three sections of the prayer hall at an interval of 1m as shown Figure 6. The position of reading points had been made at three sections where about 24 -26 points were recorded in each section. Section A-A was in the front part of the prayer hall, parallel to the Qibla wall. The light contributed of this zone were influenced on both ends with vertical windows of (m2) facing North -East and South -west. Section B-B in the middle part of the prayer hall is crossing through the zone under the dome. Major daylight contribution was gained through large glazing panels through both ends Section C -C was in the back zone of the prayer hall near the main entrance. There is no side light contribution in this section. The results and analysis of light contribution will be stated in the following:

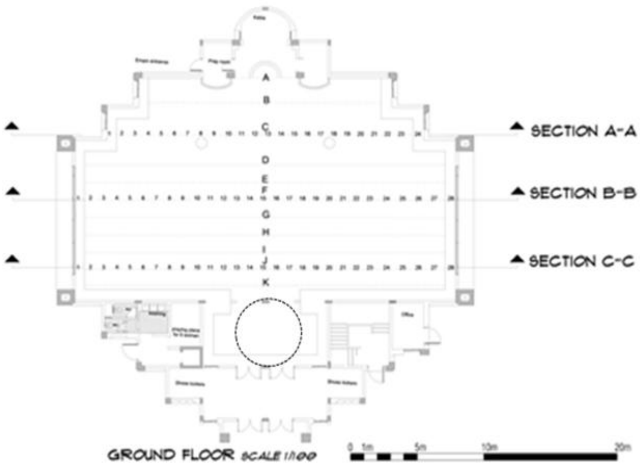

Figure 6: Plan of the tested mosques illustrating the points of readings.

Section A-A:

The section located near the front zone of the prayer area where the light was penetrated only through small vertical windows on both sides facing North-East and south – West. There is no clear evidence of any light contribution through the opening of the dome in this section; Figure 7 indicates that the maximum light level of 580 lux near the windows was at 8:00 AM. The light level is below 250 lux during the period between 10: 00 AM and 4:00 PM. The central part of this zone measured a very low level of 180 lux during the whole period.

Light level recorded as low as 50 lux up to 370 lux through all the day hours. However, light level recorded up to 650 Lux at 8:00 AM near the vertical window. The central zone indicates very low light level of less than 160 Lux.

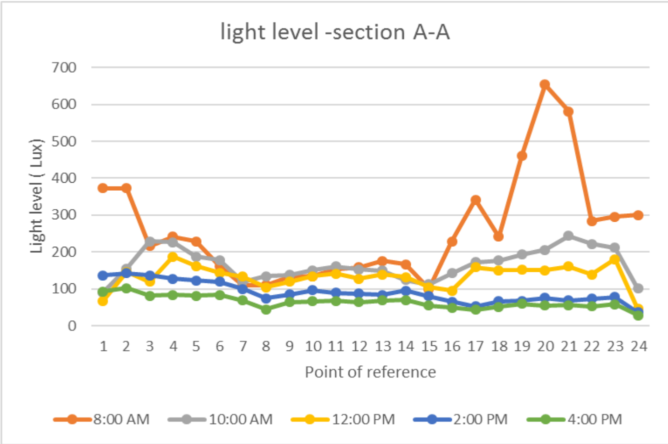

Figure 7: Measured light level at section A-A

Section B-B:

This section located across the middle part of the prayer hall where the light is contributed through the dome openings as well as through the large glass panel on both sides of North-East and South -East walls. Regardless of the high recorded light level up to 8 m on both ends near the large glass panel, the light level at the central zone is between 100 – 300 lux maximum as shown in figure 8. The light level near the glass wall panel on the north- east side was recorded very high between 1000 – 8800 lux during the morning period within the first 8 meters. These results were omitted from the analysis since it was not during the normal prayer time period. Moreover, the aim of this study is to investigate the light contributed through the dome only. The maximum light under the dome on both ends was recorded as 480 lux while it was much reduced under the dome of up to a maximum of 180 – 200 lux.

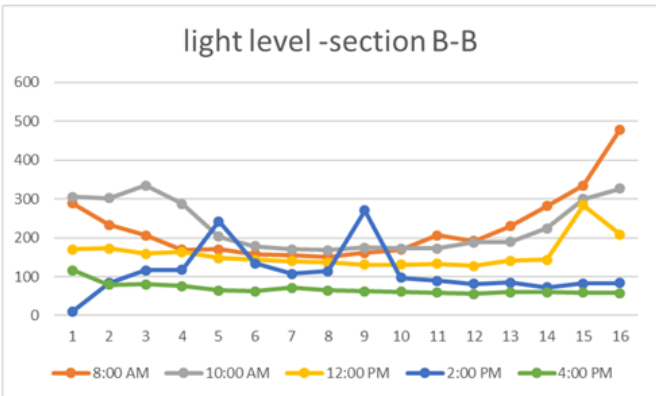

Figure 8: Measured light level at the Section B-B.

Section C-C:

The light level contributed at this zone is very low (100 -250 Lux) through all the section. However, a Light level at 370 Lux recorded at 3- points in one end which is due to light beam penetrated through the dome opening at 12:00 PM as shown in Figure 9.

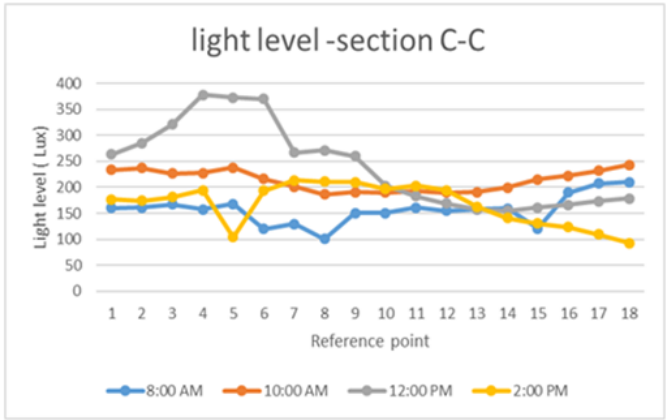

Figure 9: Measured light level at the section C-C.

The Conclusion of the Field Study

The field measurements of the above case study indicate that high light level contribution through the side opening, whatever the area of the glazed panel is limited to the adjacent zone to these opening of up to 8 M. Moreover, the light contributed through the dome with side opening is still inefficient. This may be due to the limited glazed area within the dome. In addition, this may be a result of the direction of the beam penetrated through those opening which only affect a specific reference point on the floor. This means that controlling devices needed to be adapted to the opening to redirect the light beam in the inner ceiling of the dome or the interior vertical walls.

THE EXPERIMENTAL PROCESS

The field investigation of the selected case study indicates that the light level penetrated through the dome need to be increased as it was below the standard (500 lux). The increase in area of glazed opening on the dome could help to reach this objective. Therefore, an experimental investigation using a physical model of the same case was considered. A physical model was made for the prayer hall in the model making labs at the Imam Abdurrahman Bin Faisal University. It was setup according to the site orientation of the real location. As shown in Figure 10; four movable domes were prepared for this investigation with different glazing area of 25, 50, 75, and 100%. The light level was measured using the Megatron light meter available in the light lab at the Imam Abdurrahman Bin Faisal University for 5 hours through the day. The readings were recorded at 7 points at the central zone under the dome. The light contribution represented only through the dome with the windows completely blocked.

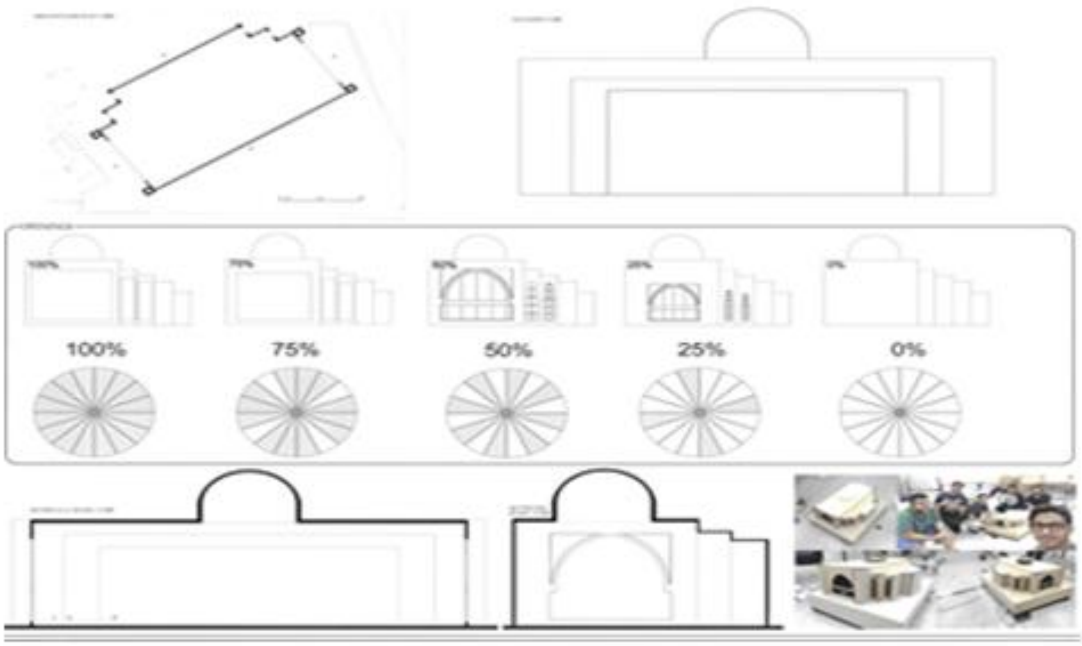

Figure 10: The physical model used for the experiment.

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Results and Analysis

Light level found was lower than the standard level for reading purposes (500 lux) in all types of tested domes through the day. There was an indication of very high level (650 – 2500 Lux) at point 5 and 6 only in all types of domes as shown in Figure 11. This means that sun patches were falling on these points at the hours between 10 Am -2 PM. However, light level during these hours on those two points was lower with the dome of 25% of openings (650 Lux) and higher with the 100% of openings (2500 Lux).

The light that penetrated through the dome was not enough for reading purpose in the mosque, where most of light depend on the side windows. This was due to the fact that luminance level at the zenith of the sky dome in hot climate area is very low [68]. In order to get benefit of light from the dome, further treatments could be investigated. Controlling devices could improve light distribution over the central zone of the prayer hall. Another treatment is to increase the reflectivity of the roof area around the external part of the dome to reflect the light beam at the inner ceiling of the dome of a reflective material. The calligraphy belt with gold or white colors usually found at the bottom of the dome could act as a reflective material to distribute light further into the other parts of the central zone. Moreover, light sensors could be installed around the base of the dome to reorient the light beam.

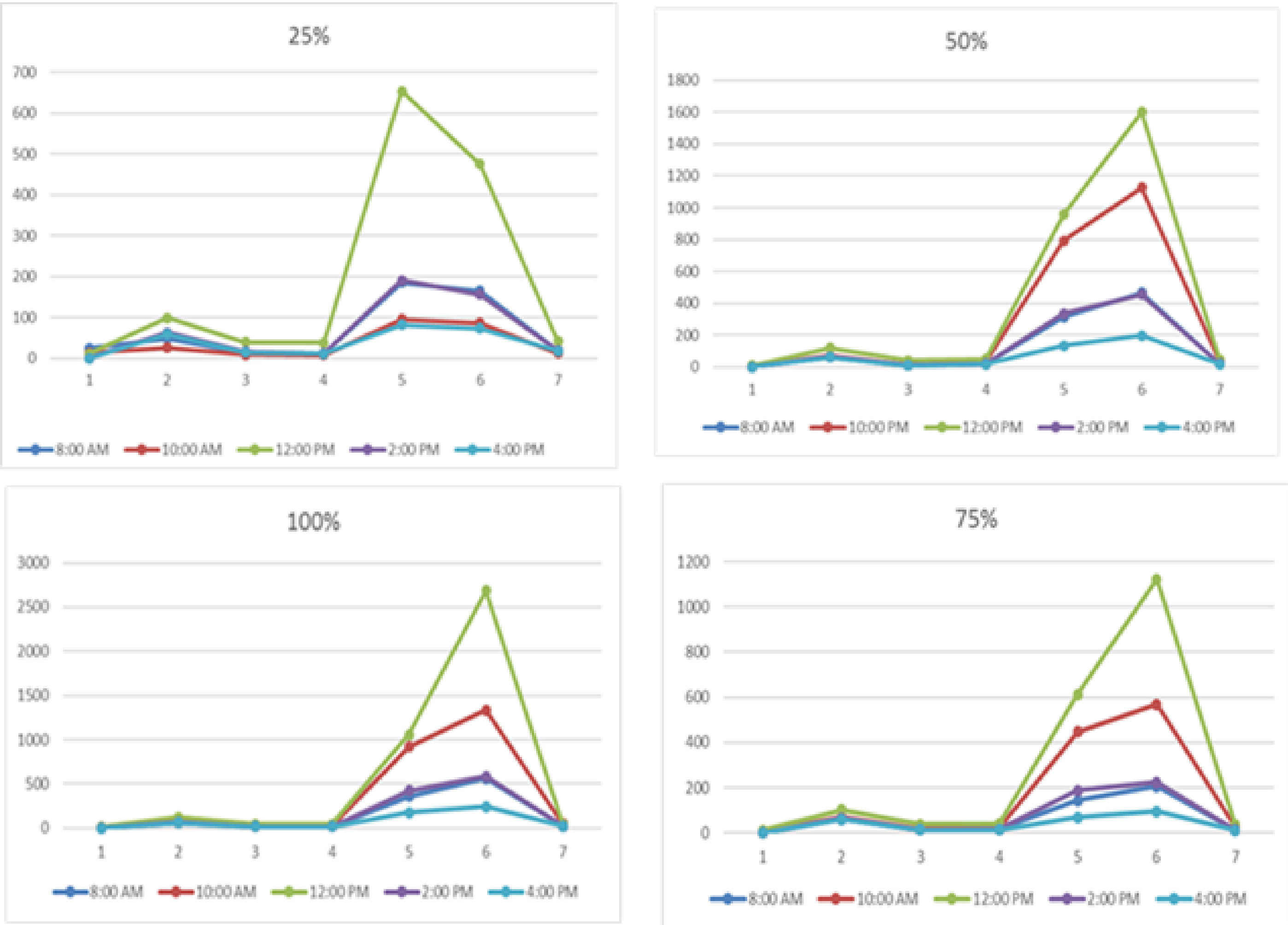

Figure 11: Measured light level in the physical model at various areas of openings.

CONCLUSION

Natural light in building represent a vital component of interior life. It is a phenomenon that link interior and exterior spaces. The utilization of natural light in building through side opening and window does not penetrate into in deep spaces. This also becomes worse where there is not enough light controlling devices to help in increasing the penetrated light level on the external envelope. The mosques are clear examples where this lighting problem occurs. Therefore, such architectural spaces need to be designed with skylight to insure sufficient natural light in the central zone. However, the question is whether the light is enough especially with such space of large volume and height. The purpose of this paper is to identify light contribution of the dome as one of the roof devices that positively contributes in various environmental parameters. This will be explored using a survey study and experimental process. The researcher conducted a pilot field investigation of daylight performance through domes for more than 10 domes mosques in the Eastern province of Saudi Arabia. In all cases, light level is higher at the central zone than near the side opening zones. The light level during the period of 1-4 PM, the most occupied period in the mosque, is between 350 – 500 lux. However, the investigation had been made only in one section through the domes' zones. Therefore, one of these case studies was selected for more detailed investigation. The field measurements of the above case study indicate that high light level contribution through the side opening, whatever the area of the glazed panel is limited to the adjacent zone to these opening of up to 8 M. Four movable domes were prepared for this investigation at different glazing area of 25, 50, 75, and 100%. Therefore, an experimental investigation using a physical model of the same case was considered. The light penetrated through the dome is not enough for reading purpose in the mosque, where most of light depend on the side windows. In order to get benefit from the dome as light concerned, further treatments could be investigated. Controlling devices could improve light distribution over the central zone of the prayer hall. Another treatment is to increase the reflectivity of the roof area around the external part of the dome.

REFERENCES

[1] Shishegar N and Boubekri M. Natural light and productivity: Analyzing the impacts of daylighting on students' and workers' health and alertness. In Proceedings of the International Conference on "Health, Biological and Life Science"(HBLS-16), Istanbul, Turkey, pp. 18-19.

[2] El-Ghobashy S and Mosaad G. Nature Influences on Architecture Interior Designs. Procedia Environmental Sciences, 2016, 34: 573-581.

[3] Al-Obaidi K M, Ismail M and Rahman A M A. A study of the impact of environmental loads that penetrate a passive skylight roofing system in Malaysian buildings. Frontiers of Architectural Research, 2014, 3(2): 178-191.

[4] Hassan Y A S. Daylight Performance of Single Pedentive Dome Mosque Design During Winter Solstice. American Journal of Environmental Science, 2013, 9(1): 25-32.

[5] Asfour O S. Bridging the Gap Between the Past and the Present: a Reconsideration of Mosque Architectural Elements. Journal of Islamic Architecture, 2016, 4(2): 77-85.

[6] Mustafa F A and Hassan A S. Mosque layout design: An analytical study of mosque layouts in the early Ottoman period. Frontiers of Architectural Research, 2013, 2(4): 445-456.

[7] Farrag E. Architecture of mosques and Islamic centers in Non-Muslim context. Alexandria Engineering Journal, 2017, 56(4): 613-620.

[8] Asfour O S. Effect of Mosque Architectural Style on Its Thermal Performance. The Islamic University Journal (Series of Natural Studies and Engineering), 2009, 17(2): 61-74.

[9] Al Smadi A M, Alsmadi M K, Al Bazar H, Alrashed S and Al Smadi B S. Accessing Social Network Sites Using Work Smartphone for Face Recognition and Authentication. Research Journal of Applied Sciences, Engineering and Technology, 2015, 11(1): 56-62.

[10] Alsmadi M. Facial recognition under expression variations. Int. Arab J. Inf. Technol., 2016, 13(1A): 133-141.

[11] Alsmadi M and Omar K. Fish Classification: Fish Classification Using Memetic Algorithms with Back Propagation Classifier. 2012.

[12] Alsmadi M, Omar K, Noah S and Almarashdeh I. A hybrid memetic algorithm with back-propagation classifier for fish classification based on robust features extraction from PLGF and shape measurements. Information Technology Journal, 2011, 10(5): 944-954.

[13] Alsmadi M, Omar K B, Noah S A and Almarashdeh I. Fish Recognition Based on Robust Features Extraction from Size and Shape Measurements Using Neural Network Journal of Computer Science, 2010, 6(10): 1088-1094.

[14] Alsmadi M K. An efficient similarity measure for content based image retrieval using memetic algorithm. Egyptian Journal of Basic and Applied Sciences.

[15] Alsmadi M K. Query-sensitive similarity measure for content-based image retrieval using meta-heuristic algorithm. Journal of King Saud University - Computer and Information Sciences.

[16] Alsmadi M K, Hamed A Y, Badawi U A, Almarashdeh I, Salah A, Farag T H, Hassan W, Jaradat G, Alomari Y M and Alsmadi H M. FACE IMAGE RECOGNITION BASED ON PARTIAL FACE MATCHING USING GENETIC ALGORITHM. SUST Journal of Engineering and Computer Sciences (JECS), 2017, 18(1): 51-61.

[17] Alsmadi M K, Omar K B, Noah S A and Almarashdeh I. Fish recognition based on robust features extraction from color texture measurements using back-propagation classifier. Journal of Theoritical and Applied Information Technology, 2010, 18(1).

[18] Badawi U A and Alsmadi M K. A GENERAL FISH CLASSIFICATION METHODOLOGY USING META-HEURISTIC ALGORITHM WITH BACK

PROPAGATION CLASSIFIER. Journal of Theoretical & Applied Information Technology, 2014, 66(3).

[19] Yousuf M, Mehmood Z, Habib H A, Mahmood T, Saba T, Rehman A and Rashid M. A Novel Technique Based on Visual Words Fusion Analysis of Sparse Features for Effective Content-Based Image Retrieval. Mathematical Problems in Engineering, 2018, 2018.

[20] Saritha R R, Paul V and Kumar P G. Content based image retrieval using deep learning process. Cluster Computing, 2018: 1-14.

[21] Farag T H, Hassan W A, Ayad H A, AlBahussain A S, Badawi U A and Alsmadi M K. Extended Absolute Fuzzy Connectedness Segmentation Algorithm Utilizing Region and Boundary-Based Information. Arabian Journal for Science and Engineering, 2017: 1-11.

[22] Thalji Z and Alsmadi M. Iris Recognition using robust algorithm for eyelid, eyelash and shadow avoiding. World Applied Sciences Journal, 2013, 25(6): 858-865.

[23] Alsmadi M K. A hybrid Fuzzy C-Means and Neutrosophic for jaw lesions segmentation. Ain Shams Engineering Journal.

[24] Badawi U A and Alsmadi M K S. A Hybrid Memetic Algorithm (Genetic Algorithm and Great Deluge Local Search) With Back-Propagation Classifier for Fish Recognition International Journal of Computer Science Issues, 2013, 10(2): 348-356.

[25] M A, K O and S N. Back Propagation Algorithm : The Best Algorithm Among the Multi-layer Perceptron Algorithm. International Journal of Computer Science and Network Security, 2009, 9(9): 378-383.

[26] Alsmadi M k, Omar K B, Noah S A and Almarashdah I. Performance Comparison of Multi-layer Perceptron (Back Propagation, Delta Rule and Perceptron) algorithms in Neural Networks. In 2009 IEEE International Advance Computing Conference, 6-7 March 2009, pp. 296-299.

[27] Alsmadi M k, Omar K B and Noah S A. Proposed method to decide the appropriate feature set for fish classification tasks using Artificial Neural Network and Decision Tree. IJCSNS 2009, 9(3): 297-301.

[28] Sharma M, Purohit G and Mukherjee S. Information Retrieves from Brain MRI Images for Tumor Detection Using Hybrid Technique K-means and Artificial Neural Network (KMANN). Networking Communication and Data Knowledge Engineering. Springer, 2018, pp. 145-157.

[29] Gao Y, Li X, Dong M and Li H-p. An enhanced artificial bee colony optimizer and its application to multi-level threshold image segmentation. Journal of Central South University, 2018, 25(1): 107-120.

[30] Jaradat G M, Al-Badareen A, Ayob M, Al-Smadi M, Al-Marashdeh I, Ash-Shuqran M and Al-Odat E. Hybrid Elitist-Ant System for Nurse-Rostering Problem. Journal of King Saud University-Computer and Information Sciences, 2018.

[31] Alsmadi M K. A hybrid firefly algorithm with fuzzy-C mean algorithm for MRI brain segmentation. American Journal of Applied Sciences, 2014, 11(9): 1676-1691.

[32] Alsmadi M K. MRI brain segmentation using a hybrid artificial bee colony algorithm with fuzzy-c mean algorithm. Journal of Applied Sciences, 2015, 15(1): 100.

[33] Alsmadi M K. A hybrid Fuzzy C-Means and Neutrosophic for jaw lesions segmentation. Ain Shams Engineering Journal, 2017.

[34] Park S H and Han K. Methodologic Guide for Evaluating Clinical Performance and Effect of Artificial Intelligence Technology for Medical Diagnosis and Prediction. Radiology, 2018: 171920.

[35] Kermany D S, Goldbaum M, Cai W, Valentim C C, Liang H, Baxter S L, McKeown A, Yang G, Wu X and Yan F. Identifying Medical Diagnoses and Treatable Diseases by Image-Based Deep Learning. Cell, 2018, 172(5): 1122-1131. e1129.

[36] Alsmadi M K. Forecasting River Flow in the USA Using a Hybrid Metaheuristic Algorithm with Back-Propagation Algorithm. Scientific Journal of King Faisal University (Basic and Applied Sciences), 2017, 18(1): 13-24.

[37] Adeyemo J, Oyebode O and Stretch D. River Flow Forecasting Using an Improved Artificial Neural Network. EVOLVE-A Bridge between Probability, Set Oriented Numerics, and Evolutionary Computation VI. Springer, 2018, pp. 179-193.

[38] Ahani A, Shourian M and Rad P R. Performance Assessment of the Linear, Nonlinear and Nonparametric Data Driven Models in River Flow Forecasting. Water Resources Management, 2018: 1-17.

[39] Şener S M and Görgül E. A shape grammar algorithm and educational software to analyze classic Ottoman mosques. A| Z ITU Journal of the Faculty of Architecture, 2008, 5(1): 12-30.

[40] Bukhari F, Frazer J H and Drogemuller R. Evolutionary algorithms for sustainable building design. In Proceedings of the 2nd International Conference on Sustainable Architecture and Urban Development, pp. 363-378.

[41] Mosque design breaks the shackles of the past, https://www.mysalaam.com/en/story/mosque-design-

breaks-the-shackles-of-the-past/SALAAM25052017081917.

[42] Bhatt M, Suchan J, Schultz C P, Kondyli V and Goyal S. Artificial Intelligence for Predictive and Evidence Based Architecture Design. In AAAI, pp. 4349-4350.

[43] Gero J S. Artificial intelligence in design'91. 2014.

[44] Bhatt M, Suchan J, Schultz C, Kondyli V and Goyal S. Artificial Intelligence for Predictive and Evidence Based Architecture Design∗. In Proceedings of the Thirtieth AAAI Conference on Artificial Intelligence (AAAI-16).

[45] Gilan S S and Dilkina B. Sustainable Building Design: A Challenge at the Intersection of Machine Learning and Design Optimization. In Computational Sustainability: Papers from the 2015 AAAI Workshop, pp. 101-106.

[46] Jamil R. Role of a Dome-Less Mosque in Conserving the Religious and Traditional Values of Muslims: An Innovative Architecture of Shah Faisal Mosque, Islamabad. International Journal of Architecture, Engineering and Construction, 2017, 6(2): 40-45.

[47] Kassim D H, Putra A, Nor M J M and Muhammad N S. EFFECT OF PYRAMIDAL DOME GEOMETRY ON THE ACOUSTICAL CHARACTERISTICS IN A MOSQUE. Journal of Mechanical Engineering and Science, 2014, 7: 1127-1133.

[48] First Cycle of the Abdullatif Al Fozan Award for Mosque Architecture, http://www.alfozan.com/media-center/news/first-cycle-abdullatif-al-fozan-award-mosque-architecture-1435-h-2014.

[49] Baglivo C, Bonomolo M, Beccali M and Congedo P M. Sizing analysis of interior lighting using tubular daylighting devices. Energy Procedia, 2017, 126: 179-186.

[50] Arab Y and Hassan A S. Daylight Performance of Single Pedentive Dome Mosque Design During Winter Solstice American Journal of Environmental Science, 2013, 9(1): 25-32.

[51] Din N C, Adzahan Z and Abdullah Z. ACOUSTICAL PERFORMANCE OF MOSQUES: AN OVERVIEW OF CURRENT RESEARCH IN MALAYSIA. In ICSV24, London, pp. 1-7.

[52] Mahdavinejad M, Badri N, Fakhari M and Haqshenas M. Thermal Behavior of Domed Roofs, Case Study: Historical Dome-Shaped Roofs of Isfahan. Armanshahr Architecture & Urban Development, 2013, 6(10): 67-76.

[53] Jamil E R. CONSERVING THE RELIGIOUS AND TRADITIONAL VALUES OF MUSLIMS WITH A DOME-LESS MOSQUE ARCHITECTURE: A CASE STUDY OF SHAH FAISAL MOSQUE, ISLAMABAD.

[54] Baharudin N A and Ismail A S. Architectural Style of Da'wah Mosque in Malaysia: from Vernacular to Modern Structures. International Journal of Built Environment and Sustainability, 2016, 3(2).

[55] Turan İ A. CreatIng new from the old:COMp ARISON BET wEEN MODERN AND OTTOMAN ARCHITECTURAL DESIGNS IN TURKISH MOSqUES AND DwELLINGS. 2014: 201-218.

[56] Ismail M R and Eldaly H. Acoustic of monolithic dome structures. Frontiers of Architectural Research, 2018, 7(1): 56-66.

[57] Faghih A K and Bahadori M N. Thermal performance evaluation of domed roofs. Energy and Buildings, 2011, 43(6): 1254-1263.

[58] Budaiwi I M, Abdou A A and Al-Homoud M S. Envelope retrofit and air-conditioning operational strategies for reduced energy consumption in mosques in hot climates. In Building Simulation, pp. 33-50.

[59] Al-ajmi F F. Thermal comfort in air-conditioned mosques in the dry desert climate. Building and Environment, 2010, 45(11): 2407-2413.

[60] Importance of mosques for imparting proper Islamic worship and knowledge, http://foreignpolicynews.org/2016/06/27/importance-mosques-imparting-proper-islamic-worship-knowledge/.

[61] Eldien H H and Farghaly Y. The Effect of Domes Shape on the Acoustics of Mosques. 2013.

[62] Abdou A A. Comparison of the acoustical performance of mosque geometry using computer model studies. In Eighth International IBPSA Conference.

[63] Lam Y W. Acoustics in the built environment. Constructing the Future: ND Modelling, 2006: 142.

[64] Gago E J, Muneer T, Knez M and Köster H. Natural light controls and guides in buildings. Energy saving for electrical lighting, reduction of cooling load. Renewable and Sustainable Energy Reviews, 2015, 41: 1-13.

[65] Köster H. Daylighting Controls, Performance, and Global Impacts. Encyclopedia of Sustainability Science and Technology, 2015: 1-53.

[66] Abdelazeez M K, Hammad R N and Mustafa A A. Acoustics of King Abdullah Mosque. The Journal of the Acoustical Society of America, 1991, 90(3): 1441-1445.

[67] Instrumentos de medición testo, http://www.linlabrioja.com/_pdf/catalogo_testo.pdf.

[68] Butcher K. CIBSE guide F–Energy efficiency in buildings. 2012.