Improving the thermal performance of mosque buildings with the assistance of passive cooling systems

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Abstract: *The first mosque in Islam was built by the Prophet Muhammad (pbh). It was simple rectangular plan, built with palm trunks and mud bricks. During the next centuries, the mosque construction witnessed tremendous development. Mosque designs varied in different countries and cultures where Muslim live. Most mosque buildings today neglect the positive use of natural environment and consume a lot of energy in order to provide comfortable internal environment for the worshippers. The present paper aims mainly to investigate the great role that passive cooling systems could help in providing thermal comfort for human being and natural lighting in indoor environment of mosques with natural means. Exploratory and descriptive method will be used in this paper research to discover how far passive cooling systems can enhance the internal environment of mosque buildings. The paper also discusses passive cooling systems which could be used in mosque buildings, analysis and defines their positive impact in providing visually and spiritually comfortable indoor milieu for the worshippers. The paper will come out with design recommendations which could be applicable for both existing and new mosque buildings.*

Key words: Mosque, thermal performance, passive cooling, courtyard, wind catchers.

1. INTRODUCTION

Since Allah (SWT) created him, man is in continues search for appropriate shelter for his comfort that will enable him to exercise his different life activities, and protection from natural environmental conditions, particularly the climate changes. The attempts of man to provide this protection developed from imitating the environment in the beginning, to cohabitate with the reality of the natural environment, after acquainting himself with its characteristics, his attempts to adapt to its changes, resist its disadvantages, and to provide conducive climate for his thermal comfort. The climatic condition is a main factor in determining the extent of human feeling of thermal comfort inside and around the building he uses.

The last decades witnessed the emergence of many global trends concerned with natural environment and conserve energy resources, and increase in focusing on the importance of the relationship between buildings and natural environment. These trends with varying names emerged as a reaction to face environmental problems resulting from the constructional development and the recognition of the importance of conserving the natural energy and resources in general.

Mosques in the Muslim world, particularly in the hot regions, consume lot energy in order to achieve thermal comfort for the worshippers inside the mosque buildings. The expectable inconsistency of the traditional sources of energy and the high cost of their production, the direct activation of the use of the passive cooling systems in buildings becomes an important demand for the reduction of the cost of operating buildings.

2. AIMS OF THE PAPER

This study aims at investigating the great role that could be played by passive cooling systems used in mosque buildings in order to provide thermal comfort for the worshippers and natural lighting compatible with the internal environment of mosques with natural means, to find out to what extent these means could enhance the internal environment of mosques by respecting the natural environment. The application of these natural means in mosque buildings will lead to the reduction of energy consumption in the cooling systems as well as the energy used in lighting, particularly during daytime.

3. PAPER METHODOLOGY

Exploratory and descriptive methods will used in this paper whereby the reciprocal influence between construction in general, and natural environment and its resources and ordained us to conserve this resources by balancing our use of natural resources, as they constitute a right for all succeeding human generations. This will be followed by the discussion of mosque construction in Islam in the course of time and determine the degree of its suitability for the natural environment as well as the development of the mosque construction techniques. The paper will also analyze the predominant mosque construction techniques in the present time for the purpose of identifying their disadvantages related to the surrounding natural environment. Discuss the passive cooling methods that could be used in the mosque buildings, then analyze and define their positive impacts in providing thermally, visually and spiritually comfortable interior milieu for the worshippers, as well as its contribution to the conserve of the natural resources. By undertaking a comparative analyze of the predominant techniques and applicable passive cooling systems, one could

come out with design recommendations that could be applied to the buildings of existing mosques as well as those to be built, thus making the mosque buildings become environment friendly, whereby it will benefit from its resources and reduce, as much as possible, its harming it.

4. MOSQUE BUILDINGS IN ISLAM

Mosque is considered the centre of the Islamic urban communities. It has a central role in the Muslim society, as it not only a place of worshipping Allah but a school, an institute of science and technology, Arts, leadership and orientation. Muslim heroes had graduated from the mosque in the arms of their great teacher and educator, Muhammad Bin Abdullah, the prophet (pbh).The first action undertook by the Prophet (pbh) upon his arrival at Madinah was the erection of his mosque, constructed with his blessed hands together with his companions (May Allah be pleased with them). The mosque was constructed with mud bricks and part of the roof was covered with palm leaves whilst the other part was left open.

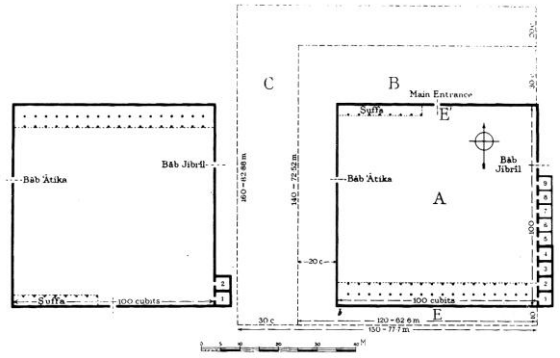

Figure 1: showing the plan of the Prophet's mosque, based on historical narratives [Creswell,1940].

Afterwards, Muslims followed this model to build up many mosques like the Basra Mosque built in the year 14 AH considered the second mosque to be built after the Mosque of the Prophet, and then the Mosque of Kufa built in the year 17 AH. Also, Amr Ibn Al-A'ss followed this in the same model in building his mosque in Fustat town of Egypt in the year 21 AH.

With the spread of the mosque buildings in the Islamic history in consonance with the geographical spread of Muslims in different part of the globe whereby the civilization mission of the mosque is linked to the faith in Allah (SWT) and their worshipping of Him. Mosque buildings are considered an expression of "cultural identity" for the Muslims nation, distinguishing it from other nations, religions and peoples, in terms of civilization and culture.

In the ancient Islamic architecture many natural building materials available in local environment were used in the construction of many mosques, in the past. Also architectural designs which help provide shadow in daytime and store cool air in the night were used, wind catchers were used, as well, for indirect ventilation. The wooden bars were also used for the façade to break the direct sunshine. All these construction elements and others helped, in the past and are still capable of giving the building of the mosque either old or modern a high degree of harmony with its environmental surrounding in terms of economizing the energy consumption and providing thermal comfort to the worshippers with natural techniques.

Many mosques, nowadays, particularly in hot regions, suffer from problem that contributed, to a large extent, to the increase of the rate of electricity consumption. These problems include constructing mosques without using thermal insulators, exaggeration of size of mosques, flaunting in the use of electricity lamps beyond necessity and sometimes extending the base of the mosques without corresponding number of worshippers, fixing air-conditioning equipment beyond the required limit, lack of appropriate way of operating the air-conditioning equipment and use of the artificial lighting.

In the recent times many Muslim communities carried out awareness programmes on the consumption of electricity and mosque buildings for consistency with the general global trend of reducing dependence on the traditional energy in operating and constructing mosques.

The government of the Kingdom of Saudi Arabia has, in the past ten years, carried out awareness campaigns on electricity consumption in most of the government buildings and those of the private sectors. The Ministry of Islamic Affairs, Endowment, Da'wah and Guidance issued a circular to all Imams of mosques to enlighten worshippers on the consumption of electricity [Ministry of Industry and Electricity, 1995].

5. PASSIVE COOLING SYSTEMS

The concern of Human being had been to make sure that his place of abode contains two principal elements: projection from the weather and provision of interior human thermal comfort. Building design and its forms had been reflected, throughout history, by the desire, through different solutions appropriate with each epoch, to achieve this goal. In hot regions the passive cooling systems depend on basic factors: first controlling the intrusion of sunshine into the building, whereby the protection from the sunshine if need arises will lead to the reduction of the interior temperature and natural lighting in Summer, while the exposure to the hot sunshine, if need arises, will lead to the increase of temperature and natural lighting of the interior during winter. Second, positive use of the natural movement of the air to provide certain degree of interior natural ventilation if need be and the protection from unwanted or sandy winds either by tree plantation or

harmonization elements of the location or orientation of the buildings and the external openings.

As a result of the unlimited use of mechanical means to achieve thermal comfort of human beings in built environment, the present energy problems emerged in the field of urban development. For this reason, a serious effort was made to return to the renewable energy like solar energy and wind energy, and their use through passive cooling systems or the combination of passive and active techniques to achieve human thermal comfort (Fig. 2).

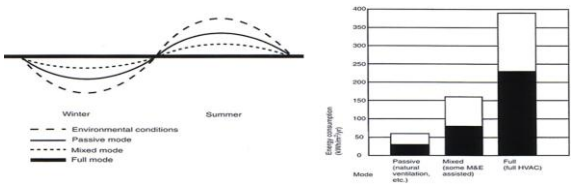

Figure 2: comparison of the amount of energy consumption when depending or automated system or natural or combined [Yeang, 1999].

The decrease of energy consumption in mosque buildings could be achieved by adopting a number of approaches at the during early design stage. In the next part, the paper will discuss the possibility of achieving micro climatic environment of built environment suitable for achieving the human thermal comfort in mosque. This is in order to minimizing the dependence on mechanical means which require energy consumption.

This goal can be achieved through two levels: first at the level of urban design level and second at the level of architectural design of the mosque buildings. In fact it is difficult to achieve thermal comfort for the worshippers in the mosque at all the times, and then it will be difficult to dispense with the use of mechanical means. Accordingly, the inclination of designers and executers of mosques towards the positive use of renewable sources of energy instead of mechanical ones would be useful in minimizing ecological damages resulting from the use of traditional energy and in avoiding infringement of the right of the future generations to clean and healthy sources of energy and earth environment suitable for human life.

6. URBAN DESIGN

The urban fabric has, like any product among the modern industrial civilization products, provided in the present time, rather more easy and comfortable life, but it now causes, in most cases, a lot of damages to the natural environment. The spread of buildings and distancing between them will lead to increase in the initial cost of the infrastructures in terms of the road networks and their likes as well as an increase in the cost of operating these infrastructures in addition to the increase in convection resulting from the increased exposure to direct sunshine. The Compact Urban Fabric in some hot regions was successful to a larger extent in tackling the disadvantages of the natural environment.

Figure 3: proposal for developing the urban fabric around the Prophet's Mosque in Madinah Al-Munawwarah with techniques that are suitable for hot areas.[Bianca,Stefano,2000].

The choice of an appropriate location is one of the most important phases for the construction of new mosque. The more the chosen location possess the potentials for self-reliance economically and provision of services, the less the need for using means of transportation and their negative effects on the energy consumption and environmental pollution. Also the choice of the location for constructing mosque would have bigger impact on the need for energy consumption. Therefore, the design which takes the movement of the sun into consideration on the location and the effects of the nature which determine the characteristics of the local climate of the location could provide thermal comfort for the worshippers with lesser need for energy consumption.

The choice of location of the mosque could help achieve efficiency in the energy consumption if executed in an easily accessible location or in a place where public transport system is available to reach it, particularly that which uses clean energy, or the possibility of reaching it by foot or by using light means of transport, could contribute, to a large extent, in reducing the need for energy used for reaching the mosque.

Tight and tortuous roads are always shade and cool during the daytime and warm in the night, and reduce the effect of dusty and sandy winds. Also the green spaces which ornate the areas of the city and its distribution system could effectively contribute to the enhancing of ventilation around buildings in general and mosque building in particular thus reducing the need for air conditioning inside mosque and other buildings, as it also contribute to the elimination of air pollution.

7. ARCHITECTURAL DESIGN

The mosque buildings have religious and functional worshipping peculiarities which led to the unification of its basic architectural factors which achieve the functional purpose of the mosque. The unification of these factors will not prevent variation in the external forms or the architectural design or difference of materials or means of construction from environment to another. The first architectural model that combines all the basic elements of the Mosque is the Prophet Mosque model. The Prophet Mosque in Madinah Al-Munawwarah was built on a simple rectangular form with an open courtyard surrounded from four the sides by covered corridors, the bigger one usually facing the Qiblah.

Islam and Muslims reached different parts of the world with varying cultures and environments accompanied with varying means and forms of construction of mosques while maintaining the basic elements of the mosques based on the Prophet Mosque model in Madinah Al-Munawwarah.Also, the architectural approaches of the mosque building elements varied to reflect the local mosque building environments to enable the building to achieve thermal comfort for the worshippers in and around the mosque. Some architectural approaches that help enhance thermal performance, most important among which are the open courtyard, wind catchers, walls and openings design, roof design and harmonization elements of the location.

7.1. Open Courtyard

The open space of the mosque is what is termed courtyard of the mosque. Its shapes and areas vary in accordance with the climatic condition of the location of the mosque. It represents the main source of natural lighting and ventilation of the prayer areas. In accordance with the climatic conditions the courtyard is used for prayer whenever this is suitable for the thermal comfort of the worshippers and when the number of the worshippers increases. The courtyard is less and inexistent in cold or very hot regions. The courtyard increases whenever the climatic conditions allow this whereby it receives cold air in the night and store it during the daytime to face the very hot temperature in the daytime in hot and dry regions.

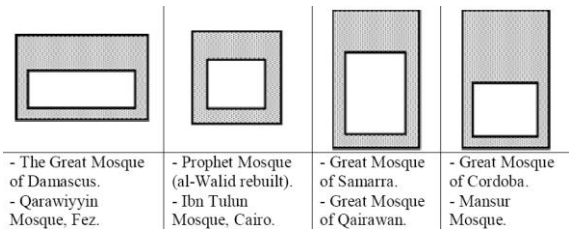

Figure 4: Different forms of shapes mosque courtyards [Ashour,2009].

The courtyard of the mosques constitute an important and basic element of the mosque as the elements of the mosque were founded in Madinah by the Prophet (pbh) which are architectural elements of design, that is the open courtyard or shaded arcade for prayer.

This model which was built by the Prophet (pbh) later became the basic model based on which most of Muslim mosques in different parts of the world were built, as climatic conditions and exigencies allowed. This constructional system allows Muslims to perform their prayers in a suitable and comfortable internal environment with minimum operation cost of the building of the mosque.

The importance of the natural light generated by the courtyard is not only limited to its being a means of reducing of the electricity consumption in the artificial lighting but it has also a positive role in having an organic and psychological impact on the worshippers.

In study carried out by two researchers on mosques in two cities, Dammam and Al-Eh'sa'a, they came with the conclusion that the existence of dooryard in the building of mosque proved its effectiveness and affirmed that the provision of a courtyard for mosque will reduce the electricity used in air-conditioning mosques in two cities, Dammam and Al-Eh'sa'a, by third [Najim and At-Tafir,1999].

The most important advantages of the use of natural cooling in the courtyard of the Mosque could be summed up as follows:

- Keeping the cool air accumulated in the night for a longer period in the next daytime.
- Provision of the natural lighting for the praying areas around it in lieu of the artificial lighting.
- Provision of natural ventilation for the most parts of the Mosque thus minimizing the need for mechanical means ventilation.

7.2. Wind Catcher

The most effective of the simple wind towers is what is known as wind tower which is a vertical cavity in the building with an upper inlet facing the blowing of the desirable wind for snipping the passing air on the building then pushing it inside the building. During the passage of the air coming from outside to inside the building, it could be wetted if it is hot and dry this is done by the passage of the air through the filter made from cellulose or grass which is continuously wetted with water by a small pump. The surplus water goes down the channel below the window and return to the pump tank again, and then the air inside the tower will become cool and go down, and enter the building instead of the external hot and dry wind. This is how cooler air current is produced.

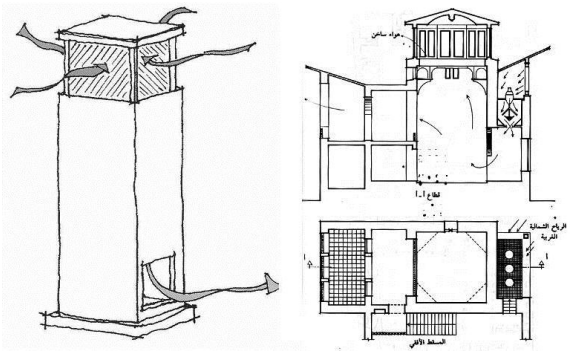

Figure 5: the wind catcher in one of the works of Hassan Fat'hi, [Fat'hi 1998].

The study of the Rahmaniya Mosque in Skaka in the Kingdom of Saudi Arabia (KSA) shows decrease in the consumption rate of electricity compared to similar mosques in Riyadh in similar climatic conditions. The researchers linked this to the existence of wind catcher in the Rahmaniya Mosque and lack of it in mosques in Riyadh [Al-Saoud and Al-Hamdi,1999].

The size of the wind catcher depends on the size of the degree of the temperature of the wind outside. Therefore if the temperature at the entrance of the wind catcher is low the space of the projection should be big, but if the temperature is higher than the maximum degree of thermal comfort then the space of the projection should be small, provided that the wind entering through it is cooled. Also, many wind catchers could be used in the four directions whose opening and closing is controlled to get the wind coming from any direction.

The raising of the entrance of the wind above the surface of the ground generate purer wind than the one close to the surface of the ground, some which enables the wind catcher to collect a pure wind devoid of dust and particles from the upper layers of the outer space, whereas the natural ventilation through the window may let in dust and other sand particles which normally spread near the surface of the ground, particularly in hot regions.

The possibility of getting speedier wind whereby the speed of the wind increases as the raises above the surface of the earth. The wind catcher helps generate natural ventilation by grapping the favorite wind and making it flow through the interior spaces, the general orientation of the building notwithstanding and its relationship with the direction of the wind. The possibility of the ventilating some space without external windows. The wind catcher will help reduce external disturbances and noises which accompany the natural ventilation through the windows.

7.3. Designing of walls and openings

In hot regions the direct sunshine is the most important carrier of hit to which buildings are exposed. There are many means of protecting the external openings of the building from direct sunshine and from the convection resulting from it. These means consist of shading with sunshine breakers or forming a building block whereby they shade one another's parts [Fig. 6].

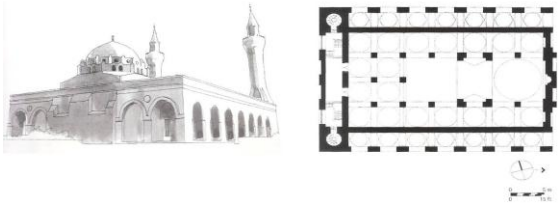

Figure 6: Harazi Mosque Keddah [Holod & Khan, 1997].

The designing of the shading devices either fixed or mobile could be used to control the degree and time of direct exposure to the sunshine, whereby the sunshine is allowed inside the building during the winter while provide protection against the sunshine during autumn.

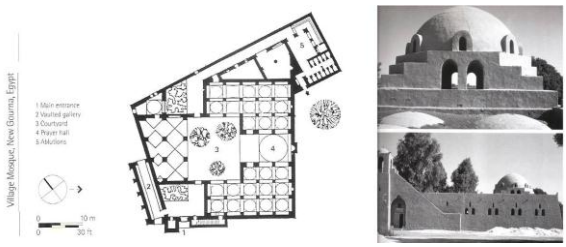

Figure 7: village mosque, Qarna Jadidah, Southern Egypt [Holod & Khan,1979].

7.4. Roof Design

The most obvious traditional architectural elements in the mosque are the domes which help to make the hot air rise to upper zone of the interior, in addition to the function of echoing of the voice of the Imam. Also, the domes reduce the exposure of the roof to sunshine during its movement between rising and setting.

The sunshades made with thick textile materials or grasses which could be used in covering the courtyard of the mosque or spaces surrounding it have the advantage of being light, something which will help reduce its capability to store the temperature due to its thermal capacity. The most important examples of the use of sunshades are those shades which cover the courtyard of the Prophet Mosque in Madinah Al-Munawwarah . They provide sunshades to the worshipers if need be while at the same time they could be folded to allow air movement if there is no need for them (Fig. 8).

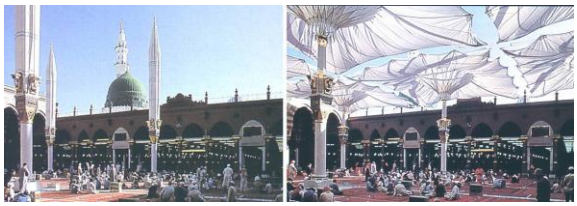

Figure 8: The courtyard of the Noble Prophet Mosque covered with sunshades during the daytime and could be folded in the night.

7.5. Landscaping

The main source of temperature in hot regions is the sun. The direction of a building related the sun movement will affect solar heat gain. Planning and distribution of trees and plants around the building in addition to the direction of the building itself which could control the air movement around and inside the building through external openings, will affect its exposure to the direct sunshine. The building materials used in the area around the building in accordance with the thermal characteristics will affect the decrease and increase of the direct and indirect convection to which the building is exposed. Seasonal trees and plants can provide shade during summer and allow sunshine reach the building through its leafless branches during winter (Fig. 9).

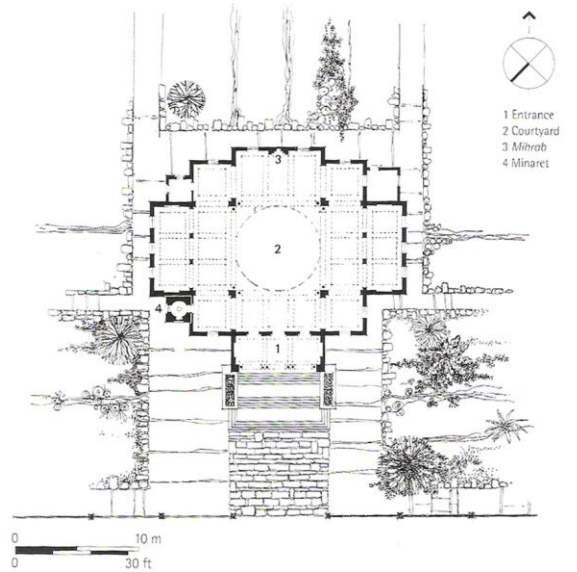

Figure 9: Sayda Safiyya Mosque Cairo[Holod & Khan,1979].

8. CONCLUSION

The design and construction of mosques in Arabian and Muslim societies, in the past, take the needs and thermal comfort of the worshippers into consideration in conformity with reality of the natural environment. Mosques are houses of God on earth; they should serve as examples to be followed in the adoption of principles for conserving the God created environment, balanced and suitable for the life of human being at all times and in all places. It is necessary for architects and designers to consider the traditional construction and the approaches used in building of houses in general and in building mosques in particular, in order to develop what is positive and suitable for modern exigencies without ignoring the socio-cultural aspects before discarding it out rightly and putting it aside.

It is also necessary to consider the modern architectural elements and their styles before adopting any of them and applying them to the construction of mosques. The most important of these approaches are the internal courtyard, the natural cooling towers, besides the designing of the walls, the roofs and the openings in a way that will help reduce the needs for cooling the interior milieu by using automated means that would consume a lot of energy.

9. ACKNOWLEDGMENT

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