Research Paper Engineering

Sustainable "Adaptive Mechanism" for Retaining Thermal Comfort Level of Congregational Majestic Space in Hot Climates;A case Study of New Mosque Building in Baghdad

Dr Akeel Noori Almulla Hwaish

Department of Civil &Architectural Engineering, College of Engineering, University of Buraimi, Sultanate of Oman

ABSTRACT

This research assists in maintaining sustainable thermal comfort standards of a built environment to satisfy users' needs and provides a definition of what, in a sustainable thermal comfort context, could be considered as the main responsibility for architects and engineers.

The "Adaptive Mechanism" is an integrated approach that contributes much for providing sustainable thermal comfort for occupants. It could be attended to through some human behaviors and treatments.

The present work is carried out with the objective of first, evaluating the thermal characteristics of a new mosque building as a case study for congregational space in the hot region of Baghdad, Iraq; and secondly, discussing the architectural criteria of an appropriate thermal design for the new mosque building.

As such, the short periods of each five daily prayers creates serious problems in regards to providing comfort. It is noticed that there is not enough time to reach the desired comfort level if the HVAC system is used just before prayer time, and it is too costly to operate it for long periods before prayer times. The adaptive approach takes into account the actions that we can and do take in order to achieve thermal comfort for the individuals inside an internal environment at a certain temperature when it is hardly utilized under certain critical climate fluctuations.

KEYWORDS Adaptive, Mechanism, Thermal, Comfort, Building, Design

1 Introduction

The short daily activity period of each prayer time (which nearly does not exceed 25 minutes per prayer) and its repetition five times a day, gives rise to many problems when an HVAC system is used at certain periods of the year in Baghdad--situated at 33 Latitude – to reach the thermal comfort level for the inner environment. To maintain an internal air temperature through air-conditioning in the day time requires high energy consumption as well as the need to provide other running cost for system maintenance etc. It may be proposed to operate the system just before prayer time, but since the inner thermal temperature still would not have reached the thermal comfort zone when the prayers finishes and people start leaving the prayer hall (mosque), the second proposal is not sufficient. In addition, this proposal wastes energy without achieving an actual advantage of reaching thermal comfort. The need for a sustainable Adaptive Mechanism is proposed here as an alternative approach for maintaining the thermal comfort level of the occupants inside the mosque: "A person attains thermal comfort when he is no longer aware of ambient temperature. This happens within a temperature interval denoted as the comfort zone, indoor climate should be kept within that zone or else space users will suffer mentally and physically. Both of which decrease the productiveness of people and their quality of life" (Davis: 1999).

Moreover "It is important to note that many factors influence the perception of the thermal comfort (Fanger; 1992)

1. Air Temperature
2. Relative Humidity
3. Air movement
4. Radiant Temperature
5. Activity Level
6. Clothing"

In addition to:

7. Local parameter variations, like asymmetrical surface radiation (e.g. hot ceiling) and;
8. Fluctuation in air movement.

All will also affect thermal comfort. Fanger's work shows that "it is impossible to satisfy everyone at any given temperature" (Fanger; 1992).

"The aim of comfort studies is twofold, viz,

(i) To determine the environmental conditions that would produce thermally pleasant sensations to occupants for different activities in their ordinary daily life and

(ii) To evaluate the degree of discomfort that is likely to be uncounted in buildings due to the prevalence of an oppressive thermal environment."

"The first would provide guidelines to the air conditioning industry on the required precise indoor conditions.

The second would be of relevance to non-air-conditioned buildings redesign (envelope shape, section, other architectural and constructional specifications"(Fanger; 1992).

The thermal balance of the human body and air ventilation are very important because breathing increases (in addition to the essential ventilation) to radiate the heat from the body in order to feel the comfort. As the number of praying persons increases, we must calculate the metabolic rate for their movements. For that to be measured, we need a field survey and a health assessment. The proposal here is to simplify that by considering the praying movements as being equivalent to the movements of labour in a handicraft factory, (Fanger Classification, table.1). It is found also that a person walking at a rate of 2mile/h produces heat from his body more than if he were at home.

Table. 1 Finger's Classification for human activities and metabolic rates.

Activity	MET Units	Energy rate for average size man		
		K Cal. /H	BTU.H	Watts
Sleeping	0.7	67	253	74
Sitting-sedentary	1.0	91	361	106
Drafting	=	=	=	=
Standing, relaxed	1.2	109	433	127
Typing	1.3	118	436	138
Walking, 2mph	2.0	182	722	212
= , 3mph	2.6	237	939	276
= , 4mph	3.8	346	1372	403

Source: Fanger: 1970. One MET unit = 50, k cal/h (m^2) = 18.4, btu h/ft^2 = 58.2 w/m^2

Since the praying person is in continuous movement while performing his prayers inside the prayer space, the calculation of the metabolic energy from the praying person's body to the inner atmosphere is as follows:[1]

Table.2 Metabolic Energy of the Prayer

Number of prayers	Praying period	Number of daily prayers	Metabolic energy kw/hr	Metabolic energy kw/day
1	0.5	5	0.212	6.3

Source:Almulla Hwaish;2004

(Al-mulla Hwaish, Akeel N; 2004 "Environmental impact on the building envelope: an architectural analytical study of heat exchange in new mosque design in Baghdad" (PhD) Thesis – Dept. of Architecture, Faculty of Built Environment, University Malaya, KL, Malaysia

An adaptive principle is the reaction of occupants for discomfort change occurs in a way that contributes to retaining or restoring comfort. The reactions will be varied according to the culture and built environment flexibilities.

The behavioral actions, which should be noted, are:

- Modification of internal body heat generation can be achieved unconsciously through raised muscular tension or, in a more extreme situation, the shivering reflex, or consciously, for instance through practicing obligatory or optional in-advance prayers in cold to increase the metabolic rate of the body, or having a siesta in warmth to reduce it.

- Readjustment of the rate of body heat loss could be changed unconsciously through sweating or consciously by such actions as changing ones clothing, cuddling up or by taking a hot drink before joining the prayer in the mosque.

- Adapting the thermal environment could be achieved through lighting a fire, opening a window or using fans etc.

- Moving to a different environment within the mosque, enclosed or semi open space (arcade) or courtyard space within the mosque complex , these spaces are almost provided as traditional spaces, or moving in the same main space to be closer to the radiant heaters or catching the breeze from a window, Praying the sunset and night prayers "*Maghrib and Ishak"* in the arcade *(Riwaq)* is very normal in the spring and autumn times (Oct.Nov.,Dec., as well as during April and May periods) and in the courtyard also during summer is quite preferable generally as a tradition in the country.

These are only examples of actions which could be considered, and if we are free to take the necessary actions, then thermal discomfort should not be a problem.

2 Study Aim

"There is a wide variation in thermal requirements and sensitivity between individuals in a given group. Probably at best, only 80% of the occupants would be comfortable at any time under the best possible conditions. The individual differences in preferred temperatures arise in part from the differences in clothing, activity and acclimatization to the local time." (Rao; 1991:4).

The Adaptive Mechanism should be considered for attending to the thermal comfort of those who are not feeling comfort because of some other personal acclimatization problem. As such, the aim of the study is to discuss solutions to create conditions for thermal comfort to satisfy the highest possible percentage of the group.

3 Discussion of the Adaptive Comfort

Adaptive comfort models improve thermal comfort for some human behaviors. It is assumed that, if changes occur in the thermal environment to produce discomfort, then those who are praying will generally change their behaviors and act in a way that will retain their comfort level. Actions vary according to the case and the instant activity. In case of prayer activity, this could include taking off part of one's clothing before joining prayer, reducing activity levels like praying just the obligatory prayer and then leaving the mosque to the house to perform the optional prayers, even opening a window to improve the natural ventilation rate, or moving to another area within the mosque complex . The main effect of such models is to increase the range of conditions that designers can consider as comfortable, especially in naturally ventilated buildings where the occupants have a greater opportunity of control over their thermal environment.

As the prayer people depend on human behaviors so much, adaptive models are usually based on extensive surveys of thermal comfort and indoor/outdoor conditions. This research clearly shows that providing praying people with the means to control their local environment greatly increases the percentage of satisfied occupants and makes them more forgiving of congregational prayer periods that expect critical time of crowded spaces and poor activity performance. "According to Humphreys & Nicol (1998) equations" for calculating the indoor comfort temperature from outdoor monthly mean temperature as follows;

Free Running Mosque Building: "Mosque Passive Designed"

(1) $Tc = 11.9 + 0.534\,Tave$

Heated or Cooled Mosque Building:

(2) $Tc = 23.9 + 0.295(Tave-22)\exp([-(Tave-22)/33.941]^2)$

Unknown system (an average of all buildings):

(3) $Tc = 24.2 + 0.43(Tave-22)\exp(-[(Tave-22)/28.284]^2)$

The following graphs show these relationships using a rolling mean monthly average outdoor temperature (from d-15 to d+15). The different formulas can give quite different values so their appropriate application is advised. One should use the "free running" method for any building in which the occupants can directly control their own local environment, with fans, lights and operable windows. The "heated and cooled" formula is more applicable to fully thermostatically controlled air-conditioned buildings.

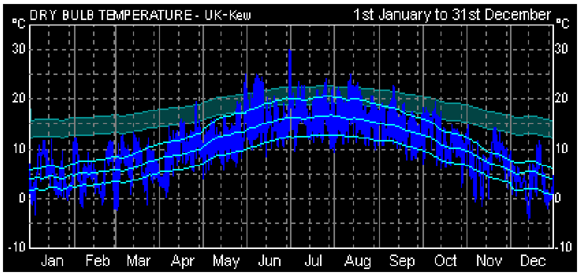

Figure 1 - Comfort zones plotted against outdoor dry bulb temperature (blue).

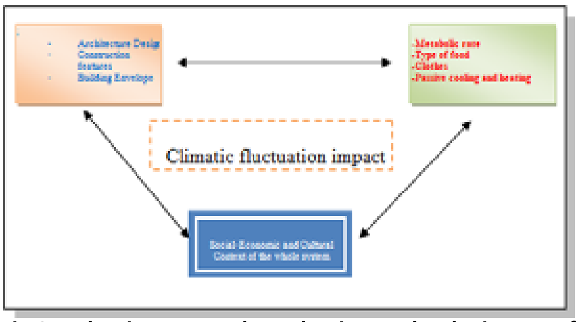

Fig.2 Adaptive approach mechanism under the impact of climatic fluctuations
Source; Author ; Oct.2014

Table 3. The effect of adaptive behaviors on optimum comfort temperatures.

BEHAVIUOR	EFFECT	OFFSET
stress level	Varies met by +0.3	±12.6k
Walking 2mile/h=prayer	Variesmet by+0.4	±3.4k
Vigour of activity	Varies met by +0.1	±0.9k
Consume cold drink	Varies met by –0.12	+0.9k
Consume hot drinks/food	Varies met by +0.12	-0.9k
Operate desk fan	Varies vel by +12.0m/s	+12.8k
Operate ceiling fan	Varies vel by+1.0m/s	+12.2k
Open window	Varies vel by +0.5m/s	+1.1k

Taken from BRE Adaptive Thermal Comfort Models (Oseland, 1998)

The graphs show the equation's relationships using a rolling mean monthly average outdoor temperature (from ***d-15*** to ***d+15***). The different formulas can give quite different values so their appropriate application is advised. However building would be to use the free running method for mosque building in which the occupants can directly control their own local environment, with fans, lights, operable windows and simple radiant heaters in winter which are available easily in Baghdad. The heated and cooled formula is more applicable to fully thermostatically controlled air-conditioned buildings. It might tend to use the average of all buildings formula in some cases that depend on a simple mechanical air cooler which utilizes water with blowing air to help with air movement as well as moisturizing the inner environment of the prayer space. Such a simple low energy consumption "Evaporator System" is traditionally used in Baghdad.

3.1 The Auliciems Model

Auliciems built somewhat on these adaptive models for Australian conditions. However, the adaptive comfort equation he developed is a function of both the mean outdoor dry bulb temperature and the average indoor temperature (T_i). In most design situations, the indoor temperature will not be known. However, this can be useful in the analysis of existing buildings or the determination of comfort from internal hourly temperature predictions. Auliciems equation is given as:

$$T_c = 9.22 + 0.48\,T_i + 0.14\,T_{ave}$$

3.2 Constraints

There are usually constraints which limit our ability to take actions to avoid discomfort. For instance, climate cost and fashion. If we have no direct control over the environment (for instance when the heating engineer sets the temperature for everyone) this can increase the likelihood of discomfort. In addition, many of the actions we could take to improve comfort have a distinct time limitation (Fanger; 1992), building a new *prayer space*, changing clothing, moving to pray in another place within the mosque complex and so on, all need time to compete. Actions are also limited in how successful they can be; removing a garment can only compensate for a limited change in temperature.

In the dynamic relationship with the environment, constraints are the key to deciding whether a particular temperature is comfortable, and whether comfort can be achieved:

"The implication of the adaptive principle is that given sufficient time, people will find ways in which to adapt to any temperature so long as it does not pose a threat of heat stroke or hypothermia. Discomfort will arise where temperatures:

* Change too fast for adaptation to take place
* are outside normally accepted limits
* are unexpected
* are outside individual control"(Humphreys, M., Nicol, J.,1998)

Changes which take place too fast will not allow for preventative action to be taken. Within a single day the change may be too much to be compensated for by changing clothing. The variation in the environment is the cause of discomfort, which happens in Baghdad in the spring because of the large temperatures variations between day and night. It is important to make the distinction between imposed variations which can cause discomfort and chosen variation which can reduce it. Chosen variations may be the way in which the person keeps comfortable, such as opening the windows towards the side garden or courtyard to get moisturized breeze inside the prayer space**.**

The range of temperatures which any society normally encounters is limited. Outdoor temperature experience may be comfortable for praying people because they have the experience to deal with such conditions for certain night prayers during certain season, like praying ***Fajar*** in the ***riwaq*** and ***Ishak*** and ***Maghrib*** prayers in the courtyard during (April,-May,June),and(October , November) which are the times of spring and autumn seasons . To define the comfort limits these normal limits need to be known in detail relating to the specified climate, region, activities and time.

In any particular situation, praying people have expectations about the thermal conditions they will meet in that specified space for a certain specified prayer. These are usually based on experience. The success of the thermal permanent or adaptive strategy they take will depend on the accuracy of this prediction. Arriving at a praying hall (***mussalla***) for instance, one might find the hall hotter or colder than expected and may be unable to get comfortable. Discomfort would then be unavoidable – but still such critical conditions are very limited but expectable in few days in summer and winter in the Baghdad region, or even dusty or polluted environments, particularly in the case of wind moving from the south west direction, which brings dust, or the peak hot days in mid-August usually which requires air filtration treatment for buildings.

In any situation an individual will have a desired ***musalla*** temperature, if he cannot control the temperature (in case one can't move to a better location also) then discomfort can occur. One of the problems for environmental engineers is to deal with a multi-occupied space such as the indoor ***musalla, Riwaq*** or courtyard, where there are variations in the needs of different occupants. The heat-balance model of thermal comfort answers this by providing the temperature with the lowest PPD for the assumed clothing and activity. The adaptive model favors some measure of control being at the disposal of each individual. Praying persons in Baghdad deal with this condition over long periods of time; they use different types of clothes to suit the climate in different seasons, so they change them from time to time trying while trying to get comfortable.

The impact of adaptation on the comfort temperature is influenced by the given time and opportunity for people who will try to suit themselves to the average temperature they experience (some of the adaptation processes are expressed in the temperature itself, some in the person's adaptation to it). As such, we would expect the comfort temperature to be close to the average temperature they experience.

3.3 Impact of Adaptive Measures on IAQ
Indoor temperatures, which the users of the space will experience, should be accurately controlled during the process of any adaptation. Outdoor conditions are more easily obtained from meteorological data. In a development of Humphreys's work correlating comfort temperature with indoor temperature, (Humphreys (1978) , correlated comfort temperature with outdoor temperature and indoor temperature with outdoor temperature for surveys conducted in free-running buildings. The results are shown in figure 2. The relationship between the mean indoor (T_m) and outdoor (T_o) temperatures are particularly interesting as evidence of adaptive action taken by building occupants. The equation for the line of best fit is:

$T_m = 0.55T_o + 14.1$ (4.1)

The indoor temperature is changing at only half the rate of the outdoor temperature. At temperatures in excess of about 31°C (at which point $T_m = T_o$) the indoor temperature is below outdoor temperature, at temperatures below this figure indoor temperature exceeds outdoor temperature by an increasing amount. This fact clarifies that the internal adaptive temperature of the ***mussalla*** could be easily approached during winter season of the months; December ,January, February and March by little heating with thick garments to be worn by occupants since temperatures in winter are nearly lower than 31C,while it is almost above this during summer months; May,June,July,August, and October adaptive means should work with the cooling system and proper passive building design that protects internal space from harsh high external temperatures.

Even in Passive Designed buildings with no HVAC system, the occupants' efforts to achieve a comfortable environment reduce changes in indoor temperatures below those in outdoor temperature. They achieve cooling in hot conditions and warming in cool conditions.

Comfort level reflects provided air temperature by HVAC system

Humphreys (1978) found that comfort temperatures in heated and air-conditioned buildings were about 2K higher than the world average in American studies and 2K lower than average in the Soviet Union. UK studies showed comfort temperatures 1K lower than average. This might seem to be a confirmation of the correctness of design temperatures since it reflected a difference in standards. However, there is no real reason why these differences between one population and another should occur except that they are differences in expectations, which are also related to the culture of each community & individuals activities. Further studies should take place to obtain specified comfort temperatures for the Baghdad region while relating it at the same time to specified activity. If American workers go to the office expecting 23°C and European workers expect 19°C then each will dress to suit this expectation. There is a cultural element to the difference (American workers expect to work in short sleeves, European workers in a suit, or a pullover), but the standards drive the comfort temperature rather than the other way around. In other words, static comfort standards work and continue to be used because

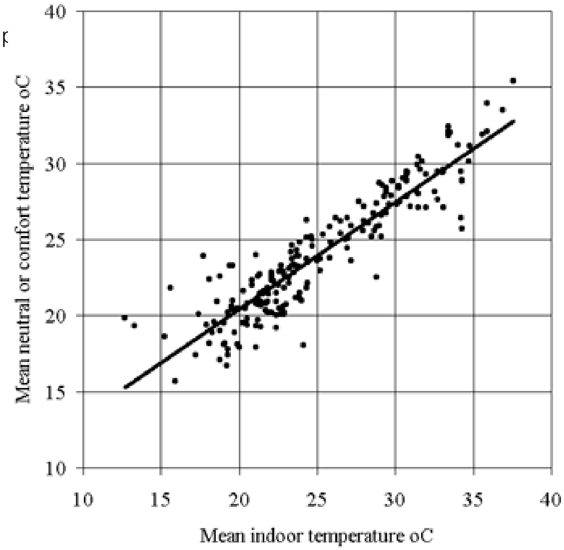

Figure.2 shows the impact of outdoor temperature on indoor neutral (comfort) temperature.

1 The indoor comfort temperature also changes with outdoor temperature, especially in
2 Buildings which are free-running (neither being (neither being heated nor cooled) in-Filled
3 circles and Line A. Sourse;www.new-learn.info/packages/.../comfort

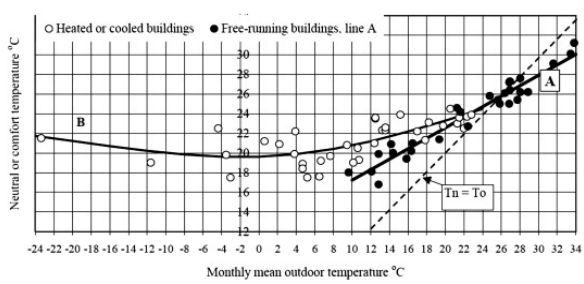

Fig.3 Mean comfort temperature varies with the mean indoor

temperature as shown in the graph. Points represent the mean values.

Source; Humphreys; 1978

3.4 "Adaptive Model" for comfort standards
The Adaptive approach for comfort level simply will be more easily practical for occupants that need to reflect on the interactions between comfort and environment in its formulation. Such a predictable adaptive concept and control will need to be incorporated into the standard formula. We start with the `HYPERLINK "http://www.unl.ac.uk/LEARN/port/1998/mulcom/web/gloss.html" \l "c" \t "gloss" comfort temperature', which we define as the temperature at which there is the probability edge of discomfort, or at which satisfaction with the environment is most likely. The value of the comfort temperature will vary, at the very least, with climate and season. The value of the comfort temperature in free-running buildings can

be deduced from a graph such as that shown in figure 3. Humphreys (1978) found that the best outdoor temperature predictor for the comfort temperature was the mean of the monthly minimum and the monthly maximum temperatures. The prediction was improved significantly by the inclusion of a term for the annual maximum temperature.

The general standard comfort temperature is not the only temperature which people can find comfortable. Clearly there is a range of variations around it which will not cause discomfort. The allowable variations will be time-dependent. This is because of the expected variations of the occupant's age, habits, sex or culture in general. Thus we might find that ±2K was the maximum allowable within-day variations with a maximum within-week variation of, say, ±5K. Consideration of other factors ensures such comfort range as the type of clothes, metabolic rate for prayer persons, in addition to other personal specified criteria. Dynamic temperature standards change the way in which the designer investigates a building. The dynamic thermal characteristics of free-running buildings, as well as steady-state characteristics, would be incorporated in design.

Another factor, which needs clarification, is the variability of temperature (and other factors) within the inner space of the ***musalla*** building. A model, which seeks to explain thermal comfort, needs to take in to account the variations in conditions within a space, and the constraints on the ability of the occupants to make use of this variability, which is very limited in terms of praying people's activities. Since they need to practice two types of prayer, obligatory and optional, they have to practice obligatory prayers within very limited rules. Many existing models of room temperature assume a single `room characteristic temperature' without defining how it might vary from place to place within the room. In conditions where people are able to move around, variability may be a key factor in user satisfaction, since there is normally one indoor ***musalla,*** but on other hand, the praying persons have the opportunity to move from an enclosed *musalla* to a semi enclosed Arcaded Corridor (*Riwaq)* or to the open (outdoor) *,* which is the courtyard.

3.5 Adaptation Process
I. Actions in response to cold:

-Increasing the level of activity (generates body heat through practicing optional prayer; *sunnah, tahajud* or *terawih* ..ect.)

-Adding clothing (reduces the rate of heat loss per unit area)

-Switch on radiant heaters or lighting (usually raises the *musalla* temperature)

-Finding a warmer spot inside the *musalla* or leave it after the short obligatory prayer *(Fardh)* to (select a warmer environment)

-Complaining to the management (hoping someone else will switch on some other radiant heaters or remove the curtains to let some sun radiation in during winter or open windows for natural ventilation during mild days in summer)

-Insulating the loft or the wall cavities or using an air protector for the cracks and windows frames to get more compact space for controlling infiltration through getting a tight building envelope (hoping to raise the indoor temperatures in winter & drop it in summer during HVAC operation)

-Improving the windows and doors (to raise temperatures/reduce draughts)

-Building a new passive designed *musalla* .

-Emigrating (seeking a warmer *musalla* for praying or space within the mosque complex) or getting a multi-level *musalla* with different types of spaces for more adaptation flexibility (enclosed, semi open & open spaces)

-Acclimatizing (letting body and mind become more resistant to cold stress) through creating specified mode for the space using different internal visual effects (colors, textures, dimensions, windows types, decoration)

II. Actions for maintaining the comfort level in summer time:

-Taking off some clothing (increases heat loss)

-Reducing the level of activity by practicing just the obligatory prayers in the *musalla* (reduces bodily heat production)

-Drinking a cup of tea before coming to pray, which is widely available in the cafes near by the center of the neighborhoods where the mosque is normally allocated (induces sweating, more than compensating for its heat)

-Eating less calories food (reduces body heat production), get breakfast after *Fajar prayer (early Morning Prayer),* lunch after *Zuhur* prayer (afternoon prayer), and dinner after *Ishak* prayer (night prayer).

-Accelerating air circulation by switching on a fan (increases air movement, increasing heat loss)

-Providing natural ventilation by opening windows towards the direction of prevailing wind to get cross ventilation (reduces indoor temperature and increases breeze)

-Finding a cool spot or using alternatives to enhance inner temperature (hoping for a cooler temperature)

-Using water sprinkler fans particularly for the *Riwaq* and outdoor *musalla* (selects a cooler environment)

-Building a better passive designed *musalla* or renovate the envelope design as far as possible (long term way of finding a cooler spot)

-Emigrating (long-term way of finding a cooler place for prayer or another *(musalla)*

-Tranquility mode in the prayer will contribute towards acclimatizing (letting the body and mind adjust to concentrate on strengthening one's relationship with God when practicing prayer, so that heat is less stressful psychologically)

4 Conclusion
Since a person praying is normally in continuous movement, a temperature of 25C° is suggested as the design thermal temperature for the inner environment of the *musalla.*

The 25oC as a thermal design degree inside the *musalla* was chosen, in spite of its being lower than the comfort degree during winter inside ordinary buildings in the middle sector of Iraq (Baghdad region). This is because the produced heat from the continuous movements of the person praying, viz., the bowing, standing, sitting, etc., increases the feeling of heat. While the temperature during summer is 18.5oC (which could be made less for the same reason), the aim of this research is to allow users to feel cool inside the building during the long summer in Baghdad. This is the important thing since this temperature leads to raising the building envelope thermal capacity and in-turn the time lag of heat transfer to get an advantage in summer, as well as considering the need for heating during winter. The time lag is mainly caused by the thermal capacity of the opaque external elements, but the heat transfer through ventilation and windows, on the other hand, tends to shorten the lag. The actual time of occurrence of the maximum, therefore, depends on the relative dominance of one over the other.

Further research is needed on the optimal mix of natural ventilation and simple mechanical fans. In theory, it is possible to incorporate heat recovery in these systems because of the additional driving force provided by the fan, but in practice, it may be more difficult to get the optimum level of good cooled ventilation during summer without additional treatments to increase the moisture percentage inside the building (particularly during day-time). As such, using convective and evaporative cooling techniques can obtain the best results. The important passive cooling system, which is a vertical air shaft sandwiched in the mass of the external wall (or minaret,) connects a breeze catcher at roof level or higher, oriented towards the prevailing pleasant wind of northwest to an opening of the *musalla* minaret. A water jug or small pool is usually placed at the inlet to provide evaporative cooling. Development of this system by the provision of movable air scoop and outlet and more elaborate evaporative techniques could be proposed.

Another method, "Vertical air-shafts might be used to promote air-flow into the inner interior parts of the buildings. The transitional spaces for circulation and services, such as stair shafts, mechanical duct shafts, corridors and passageways could also be used as wind conduits to bring ventilation in to the inner parts of the buildings to increase natural cross-ventilation" (Powell;1989;104)

All previous ideas could be applicable steps whenever needed for **Sustainable "Adaptive Mechanism" for Retaining Thermal Comfort Level of Congregational Majestic Space in Hot Climates**

REFERENCES

1.Bartuska,Tom J&Gerald L.young,Editors (1994) "The Built Environment Creative Inquiry In to Design & Planning- A collaborative Work", Bade Printing Company. | 2.Davis, M.P.2001, An interview with the Author in the thermal Experimental House in University Putra Malaysia in 17.04.2001.Fanger P O(1970) Thermal comfort Analysis and Applications in environmental engineering McGrawHall.New York | 3.Fanger, P.O. (1992) "Indoor climate". In: Varme-og Klimateknik. Grundbog, 1. Udgare.2 (H.E. Hansen). Danvak Aps, pp. 17-40. | 4.Fanger, p.o. (1998)"Discomfort Caused by Odorants and irritants in the Air Indoor Air, Suppl.4,81-86. | 5.Fanger P O(1970) Thermal comfort Analysis and Applications in environmental engineering McGrawHall.New York | 6.Humphreys, M., Nicol, J.1998 ,"Understanding the Adaptive Approach to Thermal Comfort", ASHRAE Trans., 1998 | 7.M A Humphreys & J F Nicol, 1998 Understanding the adaptive approach to thermal comfort. ASHRAE Transactions, Vol 104(1), pp991-1004. | 8.M A Humphreys 1978 Outdoor temperatures and comfort indoors Building Research and Practice (J. CIB) 6(2), pp 92-105 | 9.M A Humphreys 1978 Outdoor temperatures and comfort indoors Building Research and Practice (J. CIB) 6(2), pp 92-105 | 10. Powell, Landmark Books PTE Ltd,slowell, Robert With forward by Kisho Kurokawa. 1989, " Ken Yeang Rethinking the Environmental Filter" | 11.Rao, s.p.,1991, " Thermal Comfort And the Design of Personal Environment" Articles Published in "proceeding of the conference on "Indoor Environment" ,An inter faculty seminar, school of Building, National university of Singapore, Singapore, September 1991,ED. Lee , S E and foo,S C.,PPI-15. | 12. www.new-learn.info/packages/.../comfort/ | 13. INNOVA Thermal Comfort booklet; http://www.innova.dk/books/thermal/thermal.htmWeb-Based | Comfort Calculator http://atmos.es.mq.edu.au/~rdedear/pmv/ | 14. www. CLEAR Comfortable Low Energy Architecture | 15. www.new-learn.info › ... › People › Adaptive comfort | 16.The Low Energy Architecture Research Unit (LEARN) of London metropolitan University | 17. (http://www.unl.ac.UK/LEARN/port/1998/mu |