Sustainable design for building envelope in hot climates; a case study for the role of the dome as a component of the roof in heat exchange

Dr. Akeel Noori Almulla Hwaish

Department of Civil & Architectural Engineering, College of Engineering-University of Burimi,Sultanate of Oman

***Abstract*—*Architectural design is influenced by the actual thermal behaviour of building components, and this in turn depends not only on their steady and periodic thermal characteristics, but also on exposure effects, orientation, surface colour, and climatic fluctuations at the given location. Design data and environmental parameters should be produced in an accurate way for specified locations, so that architects and engineers can confidently apply them in their design calculations that enable precise evaluation of the influence of various parameters relating to each component of the envelope, which indicates overall thermal performance of building. The present paper will be carried out with an objective of thermal behaviour assessment and characteristics of the opaque and transparent parts of one of the very unique components used as a symbolic distinguished element of building envelope, its thermal behaviour under the impact of solar temperatures, and its role in heat exchange related to a specific U-value of specified construction materials alternatives. The research method will consider the specified Hot-Dry weather and new mosque in Baghdad, Iraq as a case study. Also, data will be presented in light of the criteria of indoor thermal comfort in terms of design parameters and thermal assessment for a"model dome". Design alternatives and considerations of energy conservation, will be discussed as well using comparative computer simulations.*

Findings will be incorporated to outline the conclusions clarifying the important role of the dome in heat exchange of the whole building envelope for approaching an indoor thermal comfort level and further research in the future.

***Keywords*— building envelope, sustainable design, dome impact, hot-climates, heat exchange.**

I. INTRODUCTION

Conservation of energy is the problem, and improving thermal comfort is the target. Therefore, the state of the building envelope (thermal capacity and thermal conductance of the envelope of the modern mosque in Baghdad) has a profound effect on the internal thermal environment, (Shaaban and Jawadi, 1973:21, 71).

Conservation of energy and improved thermal comfort can be achieved through a considered design of the building envelope. Absorptivity of the external surfaces, and the thermal capacity and thermal conductivity of the building, have direct impact on the thermal comfort of occupants of the internal environment. This is particularly true in a hot-dry climate characterized by large diurnal air temperature variation and a high radiation receipt: "Modern building technique systems and new materials contribute to lesser thermal efficiency that was achieved in traditional buildings" (Tappuni;1973).

Due to the defined daily uses of mosques (as an example), the problem facing architects & engineers is how to achieve thermal comfort during prayer times when the mosque building is occupied. Since the envelope's response to climatic conditions is a major determinant of the amount of energy required to maintain the thermal comfort of the inner environment, the temperature inside the building is affected by the building design, orientation and envelope, which in turn are affected by solar radiation, ambient temperature, relative humidity and ventilation (Markus and Morris, 1980).

In addition to all previous parameters, the form of the building shares the responsibility of the heat exchange percentage and has a role in it. The main two combined forms of the mosque building are the cubic praying hall, and the dome located at the roof.

II. CLIMATIC IMPACT ON THE DOME; A CASE STUDY FOR THE DOME OF NEW MOSQUE BUILDING IN BAGHDAD

All external heat impacts must pass through the building shell before they affect the internal environment. The impact of daily heat variations causes a corresponding oscillation inside the mosque building envelope, which in turn causes variation in the inside temperature.

Two effects do this simultaneously. Firstly, the inside cycle will be dampened by the resistivity of the material. Secondly, the inside cycle will be delayed behind the outside cycle by a period called the "time lag", due to the heat storage value of the material. This gives the opportunity to store peak heat loads and release them at low temperature periods (Dawud; 1983: 14).

A comparison is made between the behavior of heavy and light constructions in a hot-dry climate. For the purpose of comparison, the following general words are used: very hot, hot, warm, cool, cold, and very cold: However, it must be noted that "warm" could mean comfort in winter only, while "cool" could mean comfort in summer only. The extreme effect of heavy construction is evident, for example, in the "crypto-climatic" effect of the pyramid interior tomb space, which is negligible in relation to the immense mass of pyramid material. The interior tomb will constantly be close to yearly average outdoor temperature' (Shaaban; 1973.)

2.1 Heat flow rate through transparent part of the dome

The equations that express the heat flow rate through the transparent part of the mosque envelope are the following:

i. **Heat gain through windows, Qgt.**

Qgt=A.I.S. (CIBSE; 1975)

ii. **The mean heat flow through windows by conduction, Qgc.**

Qgc=A-U. (teo-tei) (CIBSE;1975)

iii. The mean transferred heat through opaque parts of the dome, Qgf

The mean heat flow through walls, the roof and dome; Qgf is obtained from the following equation:

Qgf=A.U. (tao-tei) (CIBSE; 1975)

2.2 The mean of transferred heat by ventilation, Qgv

The value of Qgv is obtained from the following equation:

Qgv=1/3 NV (teo-tei) (ASHRAE;1980)

And the monthly transferred mean heat is calculated as below:

QT=24 x n (Qgt+Qgc+Qgf+Qgv) (Szokolay;1980)

n= number of days in the month
I= the mean of solar radiation on the surfaces (W/sq.m).
S= the mean of heat gain which equals (W/sq.mc).
U= the value of heat conductivity for envelope's elements (W/sq.mc.)
A= the area of element.
tao= the mean external air temperature (C)
teo= the mean sol-air temperature (C)
tei= the mean air temperature of inner environment of the mosque (C)
V= mosque volume (m^3)
N= number of times of air changing per hour for the inner space of the mosque

The monthly positive mean of cooling and the monthly negative mean of heating can be calculated as below:

i. The annual total cooling needs equal the total cooling needs for the hot months in Hot-Dry climate of Baghdad: May, June, July, August, and September.
ii. The annual total heating needs equal the total heating needs for the cold months in Baghdad: December, January, and February.
iii. The optimum temperature of the inner environment is 25C° for the cooling season (Summer) and 18.5C° for the heating season (Winter) (Al-Riahi;1985:2-13). The 18.5C is assumed as a thermal design degree for the inner environment of the mosque in winter; see Table 2 and Table 4.

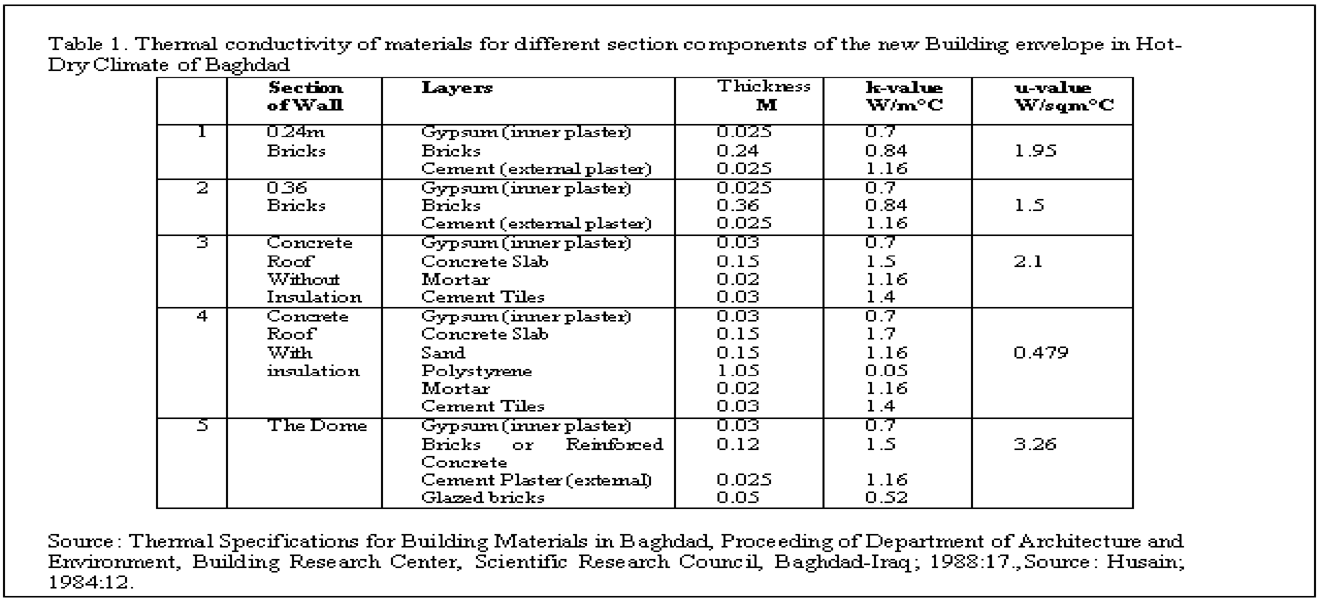

Table 1. Thermal conductivity of materials for different section components of the new Building envelope in Hot-Dry Climate of Baghdad

	Section of Wall	**Layers**	Thickness M	**k-value W/m°C**	**u-value W/sqm°C**
1	0.24m Bricks	Gypsum (inner plaster) Bricks Cement (external plaster)	0.025 0.24 0.025	0.7 0.84 1.16	1.95
2	0.36 Bricks	Gypsum (inner plaster) Bricks Cement (external plaster)	0.025 0.36 0.025	0.7 0.84 1.16	1.5
3	Concrete Roof Without Insulation	Gypsum (inner plaster) Concrete Slab Mortar Cement Tiles	0.03 0.15 0.02 0.03	0.7 1.5 1.16 1.4	2.1
4	Concrete Roof With insulation	Gypsum (inner plaster) Concrete Slab Sand Polystyrene Mortar Cement Tiles	0.03 0.15 0.15 1.05 0.02 0.03	0.7 1.7 1.16 0.05 1.16 1.4	0.479
5	The Dome	Gypsum (inner plaster) Bricks or Reinforced Concrete Cement Plaster (external) Glazed bricks	0.03 0.12 0.025 0.05	0.7 1.5 1.16 0.52	3.26

Source: Thermal Specifications for Building Materials in Baghdad, Proceeding of Department of Architecture and Environment, Building Research Center, Scientific Research Council, Baghdad-Iraq; 1988:17., Source: Husain; 1984:12.

Table.2: Overheated period in Hot-Dry Climate of Baghdad.

Month	Temp.	R.H	Temp.	R.H.	T.p.	R.H.	T.p.	R.H.	T.p.	R.H.	T.p.	R.H.
April	14.5	68	22.1	48	26.5	33	28.2	27	26.5	32	21.0	47
May	21.1	46	28.5	33	33.4	21	35.2	18	33.4	21	27.5	34
June	24.7	34	32.8	25	32.5	16	40.3	13	39.0	14	32	24
July	26.7	32	34.1	26	40.9	16	42.9	12	41.6	15	33.8	24
Aug.	26.2	32	33.6	27	40.8	17	42.8	13	41.1	16	33.0	26
Sep.	22.4	38	29.8	29	37.5	18	39.3	15	36.4	21	28.8	31
Oct.	17.5	50	24	38	31.3	23	32.7	21	28.6	31	23.3	38

Source: Sun Devices in Buildings, part: 2. The design of shading devices for the Baghdad zone;A.K.Shaaban, M.Al- jawadi and A. Jawad.,R.P. 37/75 Aug. ,Building Research Center (BRC),Baghdad.

3.3 Heat flow rate calculation

i. Heat flow rate through windows

One. The solar heat gain rate through windows Qg (positive gain)

Since the direction of the mosque windows and windows on the drum of the dome, which follow the same directions, have many different orientations, the orientation of the walls are considered to receive different amounts of solar radiation in proportion to the heat gain to the internal environment of the mosque, as explained in detail in the table 3.

Two. The heat flow rate through windows, Qg

And Qg = A.U. (teo-tei)

This concerns the heat flow rate through windows by conduction of one sq. m, and is calculated as kWh/sq.m°C

ii. Heat flow rate through walls, Qg

Qg = A.U. (teo- tei)

iii. Heat flow rate through the roof

Qg =A.U. (teo-tei)

This includes the heat flow rate through the roofs for each sq.m and is calculated as kWh/sq.m.day.

iv. Heat flow rate through the dome

Qgf= A.U.(teo-tei)

This includes the heat flow rate through the dome for each sq.m and is calculated in kWh/sq.m.day (See heat calculation process through all parts of the dome).

v. Heat flow rate by ventilation

Includes the heat flow rate for each m3, which is calculated in kWh/m^3 day.(See Table.4).

Qgr= 1/3 NV (teo-tei)

III. ESTIMATION OF HEAT FLOW IN MODEL MOSQUE

Using standard heat flow estimates (ref.CIBSE); the heat gain/loss flow rate through the building envelope is demonstrated in the tables 4 & 6.

The assumed heat flow through fabric is given in the Table 3, based on calculations by BRC-Baghdad, and the author.

To calculate the total volume of the mosque, the following three types of volumes should be estimated:

1. The volume of the mosque (prohibited main space- prayer area).
2. The women's mosque (the gallery mezzanine inside the main praying zone).
3. The volume of the dome, which includes:
   One, the drum; the lower part of the dome.
   Two, the spherical part; the middle part of the dome.
   Three, the conical part; the upper part of the dome (See figures 1& 2).

The volume of the dome includes the following:

a. The wall area of the drum of the dome; the lower part, (see Fig.1).

The drum is similar and parallel to the walls of the Mosque in terms of window orientation.

Sometimes, instead of having a circular shape it is modified to be a square shape dome drum, with each of the two windows on the drum facing one orientation, parallel to the walls of the mosque. The area of each side of the drum is:

=7.0m x 2.0m (height) = 14m^2

-The area of each window on each side of the drum =2.0m x 0.6m = 1.2m^2

-Thus, the net area of each wall= 14-(2.0 x 0.6) = 12.8m^2

-According to this, the total volume of the drum:

=2 x 7 x 7 = 98m^3

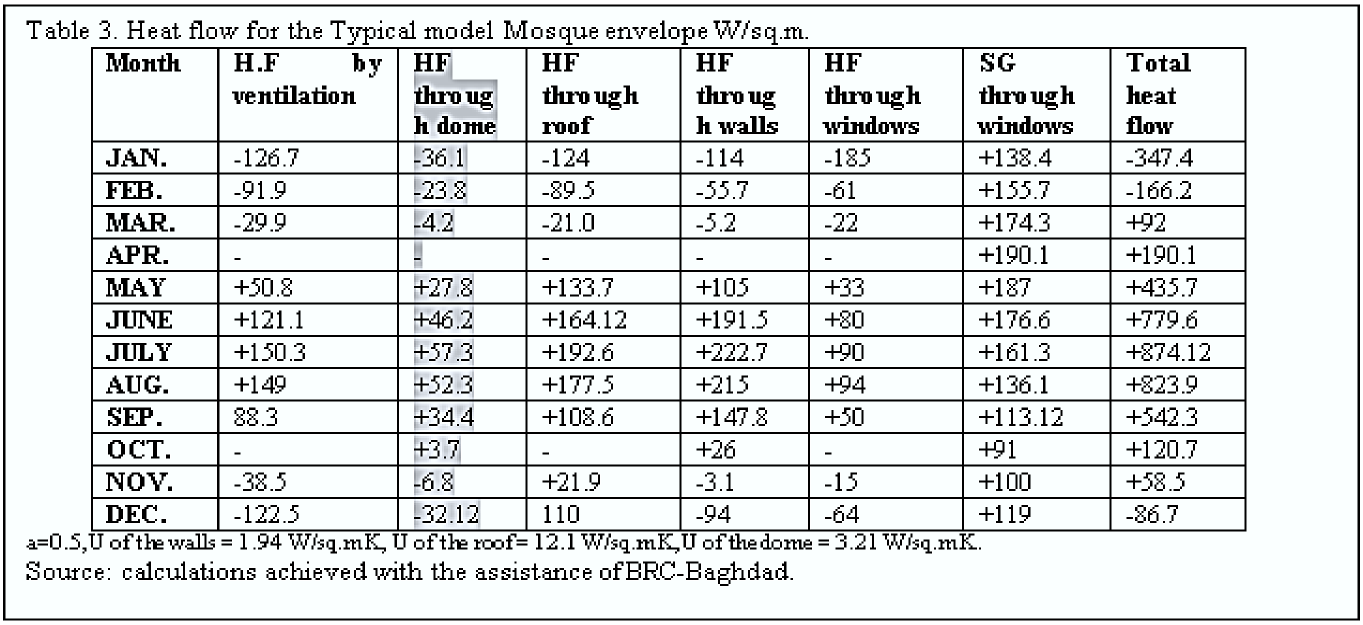

Table 3. Heat flow for the Typical model Mosque envelope W/sq.m.

Month	**H.F by ventilation**	**HF through dome**	**HF through roof**	**HF through walls**	**HF through windows**	**SG through windows**	**Total heat flow**
JAN.	-126.7	-36.1	-124	-114	-185	+138.4	-347.4
FEB.	-91.9	-23.8	-89.5	-55.7	-61	+155.7	-166.2
MAR.	-29.9	-4.2	-21.0	-5.2	-22	+174.3	+92
APR.	-	-	-	-	-	+190.1	+190.1
MAY	+50.8	+27.8	+133.7	+105	+33	+187	+435.7
JUNE	+121.1	+46.2	+164.12	+191.5	+80	+176.6	+779.6
JULY	+150.3	+57.3	+192.6	+222.7	+90	+161.3	+874.12
AUG.	+149	+52.3	+177.5	+215	+94	+136.1	+823.9
SEP.	88.3	+34.4	+108.6	+147.8	+50	+113.12	+542.3
OCT.	-	+3.7	-	+26	-	+91	+120.7
NOV.	-38.5	-6.8	+21.9	-3.1	-15	+100	+58.5
DEC.	-122.5	-32.12	110	-94	-64	+119	-86.7

a=0.5,U of the walls = 1.94 W/sq.mK, U of the roof= 12.1 W/sq.mK,U of the dome = 3.21 W/sq.mK.

Source: calculations achieved with the assistance of BRC-Baghdad.

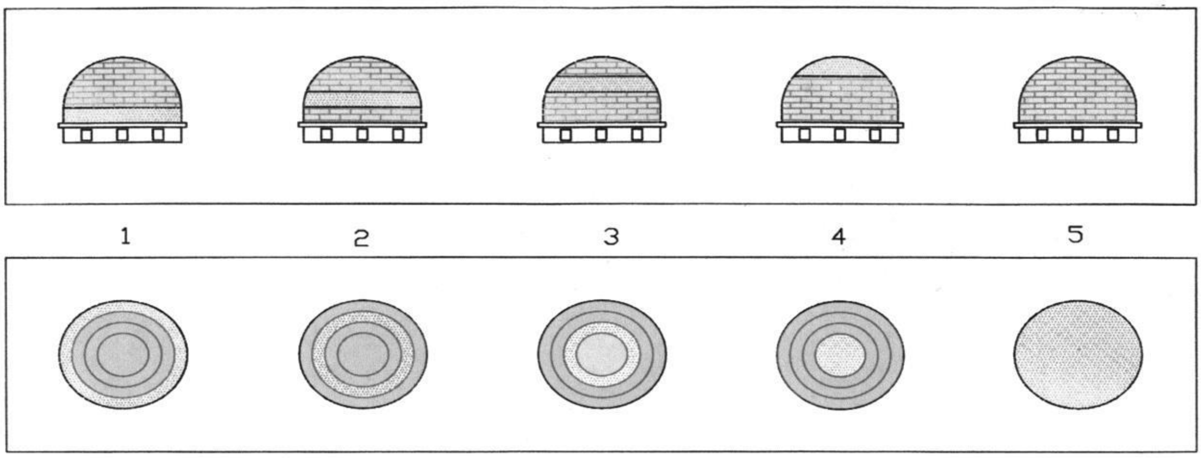

Fig.1: Split the dome in to horizontal layers to estimate thermal gain through each layer that has a different slope relating to the falling solar radiation. Source; Author's Survey 2013

1.The slope of light area is 82 degree

2.The slope of light area is 65 degree

3.The slope of light area is 45 degree

4.The slope of light area is 30 degree

5.Top view of the dome -------------

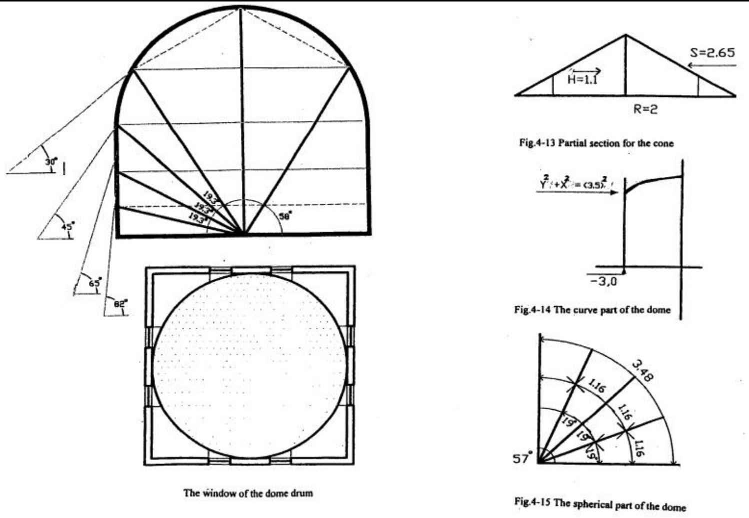

Fig.2: Detailed analysis for the dome parts for thermal estimation purpose,see (estimate of heat flow in "Model Mosque"

b. The cone; represents the upper part of the dome, and is situated above the spherical part (the middle part).The radius of this part is 4m, while its height is 1.10m, and the length of the slope surface is 2.65m, as shown in Fig.1. Thus, the surface area of the cone is:

S = 2πs = 3.14 x 2 x 2.65 = 16.66 sq.m

The surface area of this cone is split into four equal parts (triangles), each of which is oriented to one of the four ordinal points (North, East, South, and West), and is equal to 16.66 /4 = 4.2m2. The volume of the cone, V =1/3 π r = 1/3 x 3.14 x 2.0 = 2.4m^3

c. The spherical part (the middle part of the dome)

This part represents part of the sphere. It is divided into three horizontal parts, each of which has a slope angle that is related to the horizon as follows: 45o, 65o, and 82°. Moreover, each part is, in- turn, divided into four parts; each of which faces one of the four orientations (see Figs.1 & 6). According to this, the surface area of the dome, the spherical part or middle part, equals:

$$S = \int_{a}^{b} 2\pi\, f(X)[1+f^{1}(X)]^2\, dX$$

$$Y = (3.5)^2 - X^2$$

$$Y = \sqrt{(3.5)^2 - X^2}$$

$$Y1 = \frac{X}{\sqrt{(3.5)^2 - X^2}}$$

$$Y2 = (3.5)^2 - X$$

$$S = \int_{-3.0}^{0} 2\pi \sqrt{3.5 - X^2}\, \sqrt{1 + \left(- \frac{X}{(\sqrt{3-5-X^2})}\right)^2}$$

$$= 2\pi\, [3.5X]_{-3.0}^{o}$$

$$= 2\pi\, [3.5(0) - 3.5\,(-(3.0))] = 21x\ 22/7$$

$$= 21\pi = 66m^2$$

$$V = \int_{-3.0}^{0} \pi\, [f(X)]^2\, dX = \pi \int (3.5^2 - X^2)dX$$

$$\pi\left((3.5)^2 X - \frac{X^3}{3}\right)_{3}^{0} = 87.2\ m^3$$ (see Figs.1and 6).

Sphere circumference = C = its diameter X π,

C= d= 3.14x7 = 22m

57x 22/360 = 3.48 m, the height of the curved surface of the spherical part. According to the dividing of the sphere into three horizontal parts, the height of each part will be =3.48/3 = 1.16m, and the height of each part will be (spherical strip), (see Fig.1 and 6).

The area of the lower, spherical strip, (see Fig.1) equals:

1. 1.16x 3.14 (3.5/2 + 3.35) x2= 24.97m^2 (see Fig.1, case 1).
2. So, the area of each piece from the lower part is: 24.97/4 = 6.24m^2
3. The area of the middle part, spherical strip, (see Fig.1) equals: 1.16 x 3.14 (2.9/2 + 2.9) x 2 = 28.79m^2 (see Fig.1, case 2). So, the area of each piece from the middle part is: 22.79/4 = 5.7m^2
4. The area of the upper, spherical strip, (see Fig.1) equals:

1.16 x 3.14(2.9/2 + 2.0) x 2 = 17.87m^2 (see Fig.1, case 3). So, the area of each piece from the upper part is: 17.87/4 = 4.5m^2 Therefore, the volume of the dome will be: 87.21 + 2.4 = 89m^3

Previous calculations for the surface areas of the three parts of the dome, the drum, where all windows of the dome are located (the transparent part of the dome skin),the spherical part and the conical part, show less heat transmission compared with a flat roof as stated in the Tables 5&6and figures 3,4 and 5.Inclined surfaces of the spherical and conical part, the vertical surface of the drum, and the concentration of transmitted radiation at the central point in the internal circular base of the dome, which all relate to the form of the dome , play the major role in giving such distinguished features of heat exchange for the dome. The total volume of the Mosque will be equal to:

= The volume of the Mosque+ the volume of the women's Mosque + the volume of the drum (the base of the dome) + the volume of the dome (which consist of 2 parts, spherical and conical part)

= 89.61 + 151.2 + 230.77 + 1483.2 =954.78=1955m^3

Table.4: Daily rate of heat flow through the dome (Kwh/day)

Orient. of wall		Area	Heat loss						Heat gain					
			N	D	J	F	M	A	M	J	J	A	S	O
North	30	4.16	0.5	2.4	2.8	1.9	0.7	0.0	1.6	3.6	3.7	3.6	3.6	0.0
	45	6.24	0.7	3.6	2.8	1.9	0.7	0.0	2.2	4.9	5.3	4.3	2.7	.0
	65	5.78	0.7	3.3	3.9	2.7	1.0	0.0	1.6	4.2	4.6	4.2	2.5	0.0
	82	4.46	0.6	2.5	3.0	2.1	0.7	0.0	1.2	2.8	3.4	3.3	1.9	0.0
			2.5	11.8	12.5	8.6	3.1	0.0	6.6	15.5	17.0	15.4	10.7	0.0

Orient. of wall		Area	Heat loss						Heat gain					
			N	D	J	F	M	A	M	J	J	A	S	O
West & east	30	4.16	8.5	2.4	2.8	1.9	0.15	0.0	1.9	3.6	4.3	3.9	2.4	0.0
	45	6.26	8.7	2.4	4.2	3.1	0.5	0.0	2.7	5.2	5.9	5.6	3.6	0.1
	65	5.78	8.7	3.3	3.4	2.1	0.3	0.0	2.5	4.7	5.3	5.8	3.6	0.1
	82	4.46	2.2	2.5	2.8	1.8	0.15	0.0	3.6	4.2	4.8	2.5	8.15	0.3
			4.1	10.6	13.2	8.9	1.1	0.0	10.6	17.7	20.3	17.8	9.7	0.5
South	30	4.16	0.2	2.4	2.5	1.5	0.0	0.0	2.22	3.9	4.9	4.2	2.8	3.4
	45	6.24	0.0	3.1	3.3	1.8	0.0	0.0	2.9	5.3	6.1	6.3	4.3	3.9
	65	5.78	0.0	2.7	2.7	1.8	0.0	0.0	3.4	4.5	5.5	5.4	4.0	1.0
	82	4.46	0.0	1.6	1.9	1.2	0.0	0.0	2.1	3.3	4.3	3.9	2.8	0.9
			0.2	9.8	10.4	6.3	0.0	0.0	10.6	17.3	20.8	19.8	13.7	8.2
Total		69.82							81.12					

Source: Achieved with assistance of Building Research Center-Baghdad and (Al-Riahi;1985)approach.

Table.5: The lost thermal energy through the elements of the envelope in winter time.

Elements of envelope	The gained energy during heating season kwh	
	Quantity	Percentage (%)
The walls	8322	19.9
Glass of windows	7472	17.7
The roof	11121	26.4
Through the dome	3119	7.4
The ventilation	12085	28.7

Table.6: The heat gain energy of the envelope elements in summer time(cooling time).

Elements of envelope	The gained energy during cooling season kwh	
	Quantity	Percentage (%)
The walls	27467	23.0
Glass of windows	42420	36.0
The roof	23492.2	20.0
The dome	6706	5.6
The ventilation	16925	14.4

Source : Documented with the assistance of "BRC-Baghdad" July 2013.

IV. DISCUSSION

This architectural element represents well the main symbolic element in the whole mosque composition and plays a sustainable environmental role . Therefore, it is very important to analyze its thermal impact. Thus, when we look at tables (3,5&6) we find that the dome is responsible for 1/3 of the heat loss through the roof of the mosque. The heat flow rate through the dome from the outside to the inside space during summer is 1/7 of the heat flow rate of the horizontal roof. Consequently, the positive impact of the dome on the inner environment in summer is much more than its impact during winter, so high quantities of heat are expected to cross the envelope of the dome during summer due to the high solar radiation in Baghdad during the summer.

The transmitted solar radiation concentrates in the inner center of the dome, thus the focal point of the solar radiation heat will be in the center of the space of the dome, and exactly in the center of its circular base. This focal point results from crossing all the heat radiation, which emits from the shell or envelope of the dome. The heat is not transferred directly to the inside of the mosque, but it raises the temperature of the attached air to the inner surface of the dome first, and then continues to complete the heating of the inner atmosphere by convection . Thereupon, the heated air flow to the outside happens through the small windows which are situated on the drum (base of the dome, or its lower part) and the high small windows on the walls of the mosque.

Therefore, the dome is very useful in summer time, particularly the Iraqi type of dome, in enhancing the inner environment of the praying area "*musalla*" thermally . This is one of the important reasons, which encouraged the previous architects in Baghdad in many historical periods to increase the number of domes on the roofs, not only of mosques, but also in most of the historical buildings in Baghdad. Therefore, it is easy to see so many types of domes as a construction style of roofing in many historical periods in Baghdad.

V. CONCLUSION

This study concerns optimum architectural envelope treatments and constructional features under the environmental impact for providing thermal comfort for the inner environment of the mosque in the Baghdad region, taking in to consideration the shape of the building, available materials, skill and other constructional and functional criteria. This study has found that raising the roof enables cooling by ventilation; that is also to assure the positive role of the dome in reducing the impact of gained heat, as an additional role of its shape in heat exchange and providing ventilation, as shown in the previous presentation supported by surveys, diagrams and statistics demonstrated in tables and figures. The best result of the U-value for the whole roof and ceiling construction including the dome should be 0.8 w/sq.mc. Climatic information, including air temperature and solar intensity in the Baghdad region, as well as thermal air rates, humidity and other parameters, were obtained from the Iraq Forecast Directory-Baghdad. It was arranged with the Building Research Center in Baghdad to acquire the outputs of some tests carried out by the center's instruments. The heat exchange estimate by heat flow mean per sq.m through walls, windows and the roof has been followed as well as heat flow mean by ventilation per sq.m, owing to the successful results and approach considered.

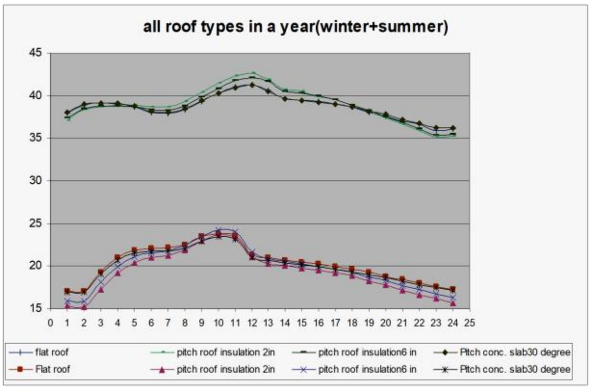

Fig.3: Building envelope behavior using different types of roof.Sourse;Author2013

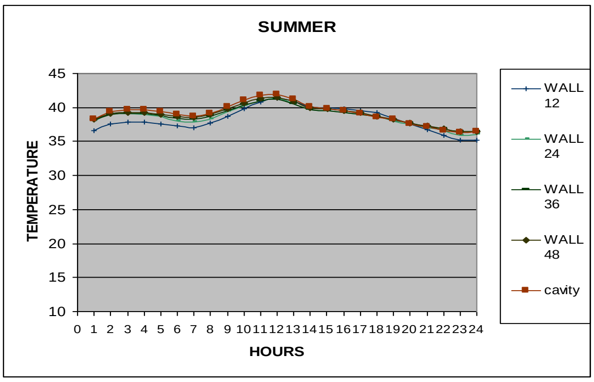

Fig.4: Building envelope behavior before applying simulation. Sourse;Author2013

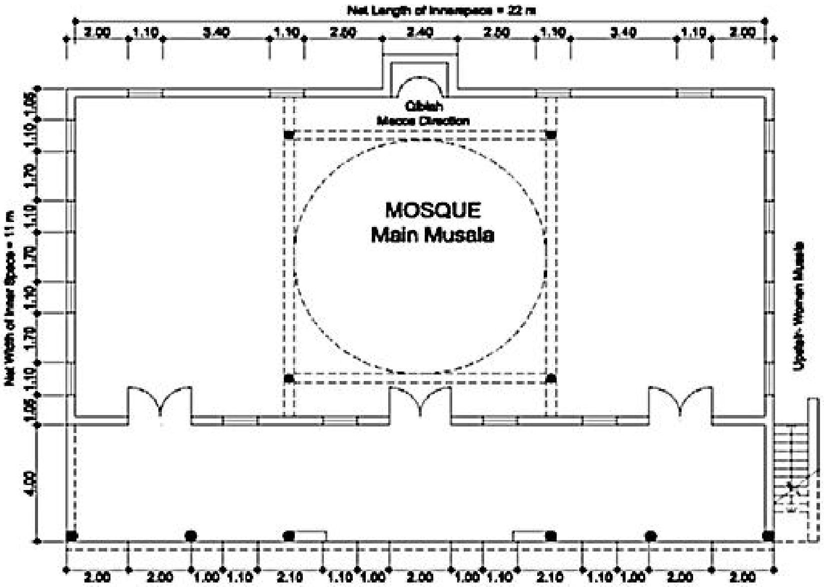

Fig. 6: Plan for the "Model Mosque". Source: Author's survey, June 2013.

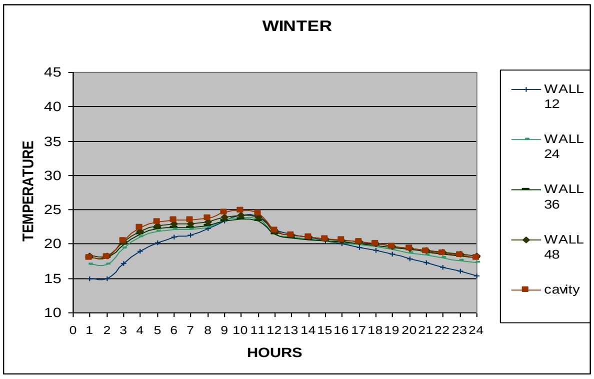

Fig.5: Building envelope behavior before applying, Source;Author's Computer Simulation using BLAST Software, June 2013.

REFERENCES

[1] Al-Riyahi, Mehdi and Akrawi, A*"Evaluation of Direct and Total Solar Radiation on Titled Surface with Different Orientation in Baghdad during Cloudless Days."* Journal of Solar Energy Research. Vol.3, No.1, Baghdad, Building Research Center 1985.

[2] Al-Umary, Hafsah Ramzy " *Modern Architecture of Mosques in Iraq: Analytic Field Study for Baghdad Mosques since Second World War",* Unpublished M. Sc. Thesis (in Arabic) submitted to the University of Baghdad1988 .

[3] Al-Azawi, Muhyi *"The Passive Internal Temperature Of Buildings For Different Design Conditions In Iraq".* (Proceeding of Scientific Research Council-Baghdad Research Center, Building Materials Department-Baghdad-Iraq, Vol.2. Symposium Thermal Insulation in Hot-Dry Climate 26-28 Nov. 1984) Baghdad 1984.

[4] ASHRAE 55-1992, ASHRAE *"Standard-Thermal Environmental Conditions for Human Occupancy"*, Atlanta: American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.1992.

[5] Bomberg, M. & W.C. BROWN *"Building Envelope and Environmental Control"* Part I & II, published in "Construction Canada"35 (1),P.15-18,1993.

[6] Survey done on June & July by Author with the assistance of BRC, Baghdad, for 50 new mosques 2008.

[7] "*Climatology Atlas No.II for Iraq*", Baghdad, Metrological Department, Ministry of Communications 2009.

[8] Dawud, Azhar J" *Passive Approaches to Solar Architectural Design for Iraq"* Unpublished M.A. thesis submitted to the University of Sheffield 1983.

[9] Fanger, P.O*"Thermal Comfort: Analysis and Applications in Environmental Engineering "*,McGraw-Hill Book Company 1970.

[10] Shaaban, Dr. A.C. and Jawadi, Dr. M., *"Analysis of the Climate of Iraq: Its Impact on the Building Character." R.p. 21/73.Baghdad,*Building Research Center 1973.

[11] Tappuni, R. A." *Generative Approach to the Thermal Design of Buildings in Hot Dry Climate",* Unpublished Ph.D. thesis submitted to the University of Edinburgh 1973.

[12] Wasim Y, Saman & Khamis S. Gasim, 1984,*"Thermal Performance of Iraqi Building Construction",* Proceeding of scientific Research Council- Baghdad, Research Center, Building Materials Department, Vol 2. Symposium Thermal Insulation of Hot-Dry Climate 26-28 Nov. 1984.

[13] CIBSE AM13 "Chartered Institute of Building Services Engineers", UK 2000.