ENVIRONMENTAL IMPACT ON THE BUILDING ENVELOPE:

AN ARCHITECTURAL ANALYTICAL STUDY OF HEAT EXCHANGE IN NEW MOSQUE DESIGN IN BAGHDAD

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THESIS SUBMITTED IN FULFILMENT
OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF BUILT ENVIRONMENT

UNIVERSITY OF MALAYA

KUALA LUMPUR

JULY 2004

ACKNOWLEDGMENTS

I wish to thank my supervisors, Assoc. Prof. Dr. Ahmad Ramly, Prof. Dr. Peter Woods and Puan Seri Nila Inangda for their supervision and support. Their guidance and useful suggestions were particularly important in helping me through this project.

Special thanks are also due to Professor Ezrin Arbi, Dean of the Faculty of Built Environment, for his expertise and willingness to help.

I also thank the staff of the Department and other administrators of University Malaya for their assistance and their readiness to help.

Finally, and importantly, I express my special gratitude to my family, who share much of my joy and sorrow. Words cannot express my gratitude for their love, concern, support and patience that have sustained me during my postgraduate studies.

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ABBREVIATIONS

AHU	Air-handling unit
ASHRAE	American Society of Heating, Refrigerating & Air-conditioning Engineers
BRC	Building Research Center-Baghdad
C	Degree Celsius
C.H.	The undesirable internal temperature of a building that is to be cooled or heated By active means
CIBSE	Chartered Institute of Building Services Engineers
cp	Specific heat, cal/(g degree.c)
HBLC	Heat Balance Loads Calculator
Heat 2	Computer program for numerical heat flow calculations
H.S	Horizontal angle between north orientation and the vertical shadow of the object on the ground
HVAC	Heating, Ventilating and Air-conditioning System
IAQ :	Indoor Air Quality
ISO	International Organization for Standardization
OTTV	Overall Thermal Transfer Values
ρ	Density, gram/cubic cm
RH	Relative humidity
RC	Reinforced concrete
SVR	Surface to Volume Ratio
Try	Test Reference Year
TM	Thermal Mass
V.S	Vertical angle of objects' shade

GLOSSARY

Abbasid Style: An Islamic style of Architecture in Baghdad 750-1258AD.

Air vent: A purpose provided air inlet or outlet.

***Asar* or *Asr* Prayer:** Afternoon prayer, which is performed after the middle of the second part of the day when the shade of an object twice its length.

Atabikid Style: An Islamic style of Architecture in Baghdad 1127-1261AD

***Aza'n* or *Adhan* :** Calling for prayer

***Badgir* :** Air shaft (Air Scoop)

Centigrade: Temperature scale proposed by Swedish astronomer Anders Celsius in 1742. A mixture of ice and water is zero on the scale; boiling water is designated as 100 degrees.

Climate: The average weather condition in an area determined over a period of years.

Climatology: Science dealing with *climate* and climatic phenomena.

Environment: The complex of physical, chemical, and biological factors in which a living organism or community exists.

Fahrenheit: Temperature scale designed by the German scientist Gabriel Fahrenheit in 1709, based upon water freezing at 32°F and water boiling at 212°F under standard atmospheric pressure.

***Fajar* Prayer:** Dawn prayer, which is performed one and a half hour before sunrise.

***Fardh* prayer:** An obligatory prayer

***Fershi* or *Matli* :** Local Iraqi traditional square bricks.

Friday *Khutba* : Weekly Friday sermon

***Gharbi* Wind:** Northwesterly wind in Baghdad region

***Hijra* :** The migration of Prophet Mohammad (p.u.h) from Mecca to *Almadina Almunawara.*

Humidity: The "dampness" of the air expressed either as a subjective sensation or as a physical measure of the water vapors in the air.

Ilikhanid Style : An Islamic style of Architecture in Baghdad 1258-1335AD

***Imam*:** A person who leads the praying persons in prayer.

Intermediate Mosque: The early hybrid style mosque after the Second World War.

***Ishak* (or *Isha*) prayer:** Night prayer, which is performed 85 minutes after sunset.

Jalairid Style: An Islamic style of Architecture in Baghdad 1357-1411AD

***Jum'a* prayer:** Friday noon prayer

***Juss*:** Domestic Baghdadi mortar used in traditional buildings.

***Ka'ba*:** It is a building 50 feet high, 30 feet wide and 40 feet long, its door height is 6.5 feet. It is located in the centre of the courtyard of *Almasjid Alharam* in Mecca.

***Madrasa (Kuttab)*:** Islamic traditional school

***Maghrib* Prayer:** Prayer performed at sunset.

Masjid Alharam : The most holy mosque in the holy city of Mecca surrounding the *Ka'ba.*

Masjid Ja'mi : The place where all the five obligatory prayers, Friday prayer and Bariums prayers are regularly performed.

Mecca: The holy city in the *Hijaz* plain (Kingdom of Saudi Arabia) 21 degrees 26.17 latitude, 37 degrees 54.45 longitude.

Meteorology: Study of the atmosphere and its phenomena.

***Mihrab*:** Niche in the wall, which shows the direction of Mecca.

Microclimate: The climate in the immediate vicinity of a building.

***Minbar*:** Small pulpit located to the right of the niche inside the *musalla,* used for delivering Friday Sermon *(Juma' khutba).*

Minaret: Slender or square shaped tower normally found in the mosques with balconies used for delivering *aza'n* (call for prayer).

Mosque: Complex consisting of many community facilities including the *musalla.* It is specifically dedicated as a place for prayer.

Model: A mathematical representation of a process, system, or object developed to understand its behavior or to make predictions.

***Muezzin*:** The person who calls for prayers

***Musalla*:** Prohibited defined enclosed space for prayer within mosque complex, which is oriented towards Mecca.

***Musalla* Envelope:** This is the combination of the floor, walls and roof of the *musalla* building. The external surfaces of a building including the roof, windows, and walls, that encloses the internal space. Generally used in reference to external heating, cooling loads due to climatic effect. Also called building shell or skin.

New mosque: Baghdadi new mosque style refers to the mosques built after the Second World War.

***Nora*:** Domestic Baghdadi mortar used especially in traditional building foundations.

Old (Traditional) Mosque: All Baghdadi mosque styles before the Second World War.

***Qibla*:** Direction of Mecca, where Muslims turn their faces in prayer.

***Qura'n*:** Words of God revealed to Prophet Mohammad (p.u.h).

***Riwaq or Iwan*:** An arcade colonnade semi-covered area, usually attached to the *musalla* building.

***Salat*:** Prayer that usually includes standing, bending, bowing and sitting.

***Shahada*:** There is no God accept Allah, and Mohammad is the prophet of Allah.

***Sherji*:** Southern and southeasterly wind.

Solar Radiation: Energy received from the sun.

Standard Average *musalla* Occupation Capacity: 30 to 45 praying persons per prayer time.

***Sunnah* Prayer:** Optional prayer before and after five obligatory prayers.

***Suq*:** Traditional Muslim market in the traditional Islamic city.

***Tahajud* Prayer:** Optional night prayer usually performed after *Fajar* prayer.

***Tarawih* Prayer:** Optional night prayer (usually performed after *Ishak* prayer) in *Ramadhan* (the holy Muslim month).

Temperature: Measure of the energy in a substance. The more heat energy in the substance, the higher the temperature.

Weather: Atmospheric condition at any given time or place. Compare with climate.

***Wudu'* Area:** Ablution Area.

***Zuhur* Prayer:** Afternoon daily prayer which is performed when the shade of an object equal to its length.

Key to Symbols of Transliteration

Consonants

’	الهمزة	s	ص
a	ا	d	ض
b	ب	t	ط
t	ت	z	ظ
th	ث	‘	ع
j	ج	gh	غ
h	ح	f	ف
kh	خ	q	ق
d	د	k	ك
dh	ذ	l	ل
r	ر	m	م
z	ز	n	ن
s	س	h	هـ
sh	ش	w	و
		y	ي

Long Vowels

ä	ألف المد
ï	ياء المد
ü	واو المد

Short Vowels

a	فتحة
i	كسرة
u	ضمة

ABSTRACT

An efficient building design involves not only functional aspects with respect to structural and space utilization but also environmental aspects and energy considerations.

Architectural design is influenced by the actual thermal behavior of building components, and this depends not only on their steady and periodic thermal characteristics but also on exposure effects, orientation, surface colour and the climate parameters of the location. All these parameters enter into heat transfer computations in a complex manner. The design data and criteria should be produced in a rational way for each location, so that architects and engineers can confidently apply them in their design calculations, and to enable precise evaluation of the influence of various design parameters on the overall thermal performance of buildings.

The present work is carried out with an objective of first, evaluating: the thermal characteristics of opaque and transparent parts of the new mosque "*musalla*" envelope in Baghdad, the impact of sol-air temperatures, heat gain factors and the U-value of envelope section components. Secondly, it aims to assess the architectural criteria for appropriate thermal design of mosques.

The research covers a survey of the design, construction features, and comfort levels in new mosques, and the definition of the "model *musalla*", as well as the identification and thermal assessment of the typical "model *musalla*" taking into consideration, urban planning, available materials, skill and other religious criteria. Computer simulations of thermal conditions; modification for design, building elements and construction are also covered by the research. The findings and conclusion of the impact of simulation changes are stated as well as recommendations given for possible future mosque and design strategy. The findings show that HVAC systems entail capital, functional and maintenance

costs whereas the passive *musalla* building consumes less energy as well as being more likely to be in sympathy with the environment.

Architectural design and construction of the new *musalla* envelope in Baghdad are thermally inefficient in protecting the inner space from climatic fluctuations. Therefore, the existing new *musallas* are not within thermal comfort level. To achieve and maintain that, applying architectural and construction alternatives on the *musalla* envelope contributes to controlling heat exchange through it as well as enhancing its thermal behaviors that contribute to getting internal thermal balance.

ABSTRAK

Sesebuah reka bentuk bangunan yang efisyen bukan sahaja melibatkan aspek fungsi bangunan tetapu juga dari aspek strukturnya, penggunaan ruang, keadaan persekitarannya dan adanya pertimbangan terhadap kegunaan tenaga.

Antara perkaran yang mempengaruhi reka bentuk senibina ialah sifat termal yang terdapat pada komponen bahan binaan yang dibina darinya. Perkara ini yang bukan sahaja tergantung kepada sifat bahan itu yang sering berubah-ubah tetapi juga kesan dari pendedahan cuaca, keadaan orientasi, warna permukaan dan iklim setempat. Kesemua ciri-ciri ini memainkan peranan penting dan menyumbang kepada komputasi peralihan haba yang sumit.

Data dan ciri-ciri reka bentuk haruslah dihasilkan dengan rasional bagi setiap lokasi untuk membolehkan para jurutera and arkitek mengaplikasikan nya dalam kiraan reka bentuk mereka. Faktor ini juga membolehkan penilaian tepat dibuat terhadap kesan berbagai bentuk parameter kepada keseluruhan prestasi termal binaan tersebut.

Objektif utama kajian ini dilakukan adalah untuk menilai sifat-sifat termal bahan lutsinar dan tidak lutsinar pada masjid baru di Baghdad bergelar 'sampul musolla', khasnya terhadap kesan suhu Sol-air, faktor-faktor pertambahan haba dan nilau-U kepada bahan bahagian sampul. Objektif kedua adalah untuk menilai apakah ciri-ciri seni bina yang bersesuaian bagi mencapai keadaan termal yang selesa bagi masjid-masjid.

Kajian ini merangkumi pengajian reka bentuk, sifat binaan, taraf keselesaan dalam masjid-masjid baru, dan definasi 'model musolla'. Kajian ini juga menyentuh pengenalan dan penilaian ciri termal pada model masolla yang tipikal dengan mengambilkira perancangan bandar, bahan-bahan yang senang di perolehi, kemahiran dan lain-lain criteria keagamaan.

Simulasi komputer terhadap keadaan termal, pengubahsuaian bagi reka bentuk, elemen bangunan dan binaan turut dikupas dalam kajian ini.

Hasil dan rumusan kajian terhadap kesan perubahan simulasi telah di nyatakan dengan di sertakan beberapa cadangan untuk masjid yang bakal dibina yang mempunyai strategi reka bentuk . Hasil keajian juga menunjukkan bahawa sistem pengudaraan atau HVAC, perlukan kos permulaan, fungsi dan penyelenggaraan dimana reka bentuk musolla yang pasif menggunakan tenaga yang sedikit serta lebih bersesuaian dengan persekitaran semula jadi.

Reka bentuk seni bina dan binaan sampul musolla yang baru di Baghdad, dari ciri termalnya didapati tidaklah begitu berkesan dalam melindungi ruang dalaman nya dari perubahan cuaca. Oleh yang demikian, musolla yang terdapat pada masakini tidak terangkum dalam musolla yang mempunya taraf selesa termal. Bagi mencapai serta mengekalkan tahap keselesaan ini, perlu digunapakai cara cara alternatif reka bentuk dan binaan pada model sampul musolla agar ia membolehkan perubahan suhu dikawal serta meningkatkan sifat termal yang menyumbang kepada keseimbangan termal dalaman.

CHAPTER ONE

INTRODUCTION

1.1 AN OVERVIEW OF ENVIRONMENTAL IMPACT ON BUILDING ENVELOPE

> *'Architecture is more than just the art of constructing individual buildings. It is also the creation of environment. Buildings do not exist in isolation. They do not only impose their character on their surrounding, but also have an incalculable effect on the lives of the human beings who inhabit them' (Bartuska, 1994:3).*

> *'Architecture may be defined as the art that goes back to the origins-to nature itself. The root meaning of the word is derived from the Greek, archi, meaning "first" or "original"; and tect, meaning the ability to put things together. Thus, architecture implies creation from the origins of nature; putting things together in ways that express an understanding of nature' (Tsui E; 1999:9).*

> *'Components of the built environment are created by human needs, thoughts and actions. Sometimes human actions are shortsighted; a matter that creates uncomfortable situations that are less fit for healthy human activities. Each aspect of the built environment is constructed to fulfill human purpose. Therefore, the built environment strongly influences human life styles and, in their turn, those life styles influence it' (Bartuska, 1994:5).*

There is a dialectic relationship between the human and the built environment that is realized in many examples of traditional mosques in Baghdad.

Since the mosque in Islamic philosophy is God's home; the place where Muslims pray, and prayer is the holy relationship between a person and his God, the building of mosques has the highest value in the hearts of Muslims. In addition, the mosque formed the most important building in the history of our traditional architecture. This is still true nowadays.

The first mosque in Islam, which the prophet Muhammad (peace be upon him) built in *Al-Madina Al-Munawwara*, was simple in the form of composition. Due to the extension in the mosque's functions over a long period, many additional spaces were annexed to it.

Iraq has around 2000 mosques with others are being added yearly. In spite of this, a great deal of research is being done to build one of the biggest mosques in the world in Baghdad, in addition to many other mosque projects, which have been started or are under construction in many states in Iraq.

Although times have changed and populations have grown, the original reasons for creating a built environment and mosque building remain essentially the same. However, the differences normally take place in the form of expression, which we will discover when we compare the proposed new type of mosque with the traditional type in Baghdad.

The impact of Western civilization has been very great and powerful on Iraq. It has influenced all aspects of living, including architecture. Architects in Iraq for example, were so tempted by the minimalist architecture offered by Western civilization that they turned their backs on their traditional architecture. The results are buildings that are totally foreign to the Iraqi environment and our tradition. The main feature of these buildings is the large expanse of glass windows, which suggests a fashionable trend in imitating Western style, but ignores the obvious requirements of a hot-dry climate.

The planning approach of our traditional Islamic environment has lost its character as well as its practical and scientific solutions for the environment, in the face of international style. That character was created over hundreds of years through Islamic philosophy in urban design (Al-Umary, 1988:2-4).

So, modern Iraqi cities have definitely become closely associated with a global trend through the introduction of Western approaches, and through the impact of modern life in general, (Dawud, 1983: 58-60).

> *'Modern building technique systems and new materials contribute to lesser thermal efficiency than was achieved in traditional buildings' (Tappuni;1973).*

Due to the defined daily uses of mosques (as an example), the problem facing architects and engineers is how to achieve thermal comfort during prayer times when the mosque building is occupied. The short time of each of the five daily prayers gives rise to serious problems in terms of providing comfort. It is noticed that it is not enough to reach comfort level even if an HVAC system is used and just operates before each prayer time, and it would be too costly to operate it for a long period before prayer times to provide comfort for very short periods of prayer.

The temperature inside the building is affected by the building design, orientation and envelope, which in turn are affected by the solar radiation, ambient temperature, relative humidity and ventilation (Markus and Morris, 1980).

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; *Musalla* envelope characteristics play an important role in heat-exchange and increasing energy conservation inside the *musalla* building. One of the important characteristics of the *musalla* envelope is the orientation of Mecca (*Qibla* direction), and this design response is constant as the main feature for every mosque.

Conservation of energy is the problem, and improving thermal comfort is the target. Conservation of energy and improved thermal comfort can be achieved through a considered design of the building envelope. The absorptivity of the external surfaces, and the thermal capacity and thermal conductivity of the envelope of the building have a profound effect on the internal environment. This is particularly true in a hot-dry climate characterized by large diurnal air temperature variation and high radiation receipt. (Shaaban and Jawadi, 1973:21, 71).

This research investigates the thermal design of modern mosques in Baghdad. It will be directly related to architectural characteristics and heat exchange, which depends on many variables, such as building shape; orientation, the thermal capacity of the external envelope, and its time lag.

Based on much research in this field (see Appendix B) the orientation of the mosque building, which is fixed to Mecca by 10 degrees southwest (relative to the Baghdad location), has proved to be a good orientation for the mosque zone in general, but needs to be treated with more suitable envelope specifications, particularly in certain directions (West, East and Southwest).

In this research, a survey is conducted covering almost fifty new mosques in Baghdad. The result of this survey indicates that the shape of the major space (*musalla*) should be rectangular, which is regarded as the common shape to be developed in the hot-dry climate of Baghdad (Al-Umary, 1988:4).

Building envelope as an environmental filter represents the exterior skin of a building including all external additions e.g. chimneys, windows. The building envelope is the combination of the foundation, wall, and roof assemblies all working together to provide a comfortable and safe environment in a building. It also preserves the structural integrity of the building. The building envelope also works in conjunction with the heating, cooling, and ventilation systems to perform several major functions; such as controlling the comfort level inside by managing temperature and relative humidity as well reducing heating and air conditioning costs (Bomberg & Brown, 1993).

As a rule, facades are not just simply a structural division between the exterior and interior; they have a wide range of functions, which have to be fulfilled.

–Natural ventilation

–Natural lighting

– Thermally comfortable surface temperatures

– Adjustable coefficients of heat transmission

– Adjustable degrees of total energy transmission

– Creation of visual links between the interior and exterior

Building design takes into consideration the building structure and systems as a whole and examines how these systems work best together to save energy and reduce environmental impact.

Heat, air and moisture transport across a building envelope are inseparable phenomena. Each influences the others and is influenced by all the materials contained within the building envelope. The process of environmental control depends on strong interactions between heat, air and moisture transport. And to ensure that all aspects of the building envelope perform effectively, we must deal with heat, air and moisture transport collectively.

The building envelope provides shelter from the outdoor environment and encloses a comfortable indoor space. In doing so, the envelope must withstand many mechanical and environmental forces and this durability must extend over its service life.

The envelope must also be well insulated to provide the required level of thermal comfort at a reasonable cost (Bomberg & Brown, 1993).

Assessing the thermal performance of the building envelope involves three considerations: the quantity of heat transferred through the walls, windows and other elements of the building envelope -the conductive heat transfer; the quantity of heat needed to bring the temperature of the outdoor air to that of the indoor air-- the air-leakage characteristics or air exchange rate; the differences in temperatures on the inner surface of the building envelope - the mould and mildew control points.

The envelope includes facades, which represent one of the biggest influencing factors on the building's technical systems. In order to act ecologically in the long term, it is necessary to develop facade concepts as an important component in the overall concept for a building. In the medium and long term, this means fulfilling the dream of the polyvalent wall structure, i.e. developing facades which react to seasonal conditions, on the one hand, and also to user requirements, in such a way that they make direct use of natural resources in the operation of a building, on the other.

Accommodating environmental control in building design requires interactive analysis and a willingness to change not only minor details, but to alter the basic concept itself if information indicates that this is desirable. Thus, the design must remain as flexible as possible until all the consequences are fully examined.

The main function of the building envelope in a hot-dry climate is to minimise the heat stress imposed by the external climate. Indoor thermal environmental control through design and planning can only be achieved through a proper understanding of the thermal performance of the building envelope in relation to relevant weather elements. It is being increasingly realised that a lot can be done to mitigate heat stress in unconditioned buildings to reduce cooling and heating loads and the energy consumption of air conditioned buildings, through a proper choice of building components and design.

The envelope's response to climatic conditions is a major determinant of the amount of energy required to maintain the building's thermal environment. The building envelope consists of solid walls, space windows, space doors and other openings; and roof and floor surfaces. It is subjected to the influences of climate by its individual orientation and composition. The building envelope directly influences the cooling peaks and air conditioning system capacity requirements of all the building envelope components. Windows have the greatest effect on energy consumption, since they are major contributors to overall heat loss/heat gain.

The thermal properties of the envelope are determined by the combination of wall mass, thermal resistance; insulation location, external surface colour and texture, and the size and location of glazing. All of those affect energy consumption differently according to weather conditions. The design of the building envelope can also greatly affect infiltration rates.

Heat in all its forms has a profound effect on human comfort. Therefore, control of heat flow through the roofs, domes, walls and windows is of considerable importance. A clear understanding of the modes of heat transfer and the parameters that affect them is a prerequisite for effective control of the thermal environment of buildings. Studies of the Baghdad climate may identify the following as the main factors affecting thermal comfort in the internal environment:

i. Heat gain-due to design and material choice.

ii. Envelope design-opaque transparent ratio.

iii. Orientation.

Therefore, the thermal design strategy is to minimize heat gain through the envelope by enhancing the design of the envelope and choosing appropriate building materials. This can be achieved mainly through;

(1) Redesign of the envelope

(2) Use of alternative material

(3) Use of insulation material

(4) Appropriate ventilation system

(5) Shading and enhancing of surrounding microclimate

(6) Optimum building orientation

(7) Optimum window areas

(8) New dimensions and layout for the inner space; and other architectural structural additions.

1.2 RESEARCH ISSUE

Prayer is the holy relationship between a person and his God, and the building of mosques has the highest value in the hearts of Muslims. In addition, the mosque formed the most important building in the history of Muslim traditional architecture. This is still true nowadays. The relationship between the human and the built environment is realized in many examples of traditional mosques in Baghdad. The creation of a built environment and mosque buildings remains essentially the same. The differences normally take place in the form of expression, which we discover when we compare the proposed new type of mosque with the traditional type in Baghdad.

> *'Modern building technique systems and new materials contribute to lesser thermal efficiency than was achieved in traditional buildings in Baghdad' (Tappuni, 1973).*

That happened under the impact of the industrial revolution and the modern approach to town planning as well as an increase in population and economic progress after World

War II. So, the main issue of this research is "the thermal comfort of the modern mosque in Baghdad".

1.2.1 Statement of Problem

Baghdad's traditional mosques had a clearly defined character during the historical periods when Baghdad was the capital of the Abbasid Empire. Those traditional mosques have been protected from severe environmental swings as an indirect advantage of traditional compact town planning where buildings were attached to each other and surrounded the mosque.

The main factor that has changed in the traditional city of Baghdad under the impact of a modern approach to town planning and architecture is the microclimate of the new physical environment. Modern gridiron town planning has resulted in mosques 'standing alone' in open spaces as monuments in wide plazas and streets. That has had the effect of introducing direct exposure of those envelopes to external environment impact, in addition to other unsuitable modern building treatments.

As a result, mosque buildings have become more exposed to general climatic variations than before.

A new life style and needs have developed in Iraq, necessitating the introduction of new transportation systems that have new requirements such as wide streets, multilevel bridges, and roads. There is also a need for new facilities, buildings, factories, stores, workshops, hospitals, mosques and other buildings.

The impact of international style has influenced all aspects of living in Iraq including architecture. The result is buildings that are totally foreign to our environment and tradition and which ignore the obvious requirements of the hot-dry climate of Baghdad. The mechanical and electrical systems of heating and cooling encourage architects to implement new technical approaches and ideas by creating large openings in buildings' facades as well as employing new constructional materials etc. All this makes people depend on HVAC systems, which consume high amounts of energy annually in an attempt to provide a comfortable inner environment. The mosque buildings are affected by the adoption of new materials and new urban planning as well as new architectural designs, which are not sensitive to the environment, the actual needs of occupants, the building function or comfort criteria. There is little appreciation of the design response (synthesis) as well as the criterion of high thermal conductivity and low heat capacity of newly employed materials.

Modern building systems, like the use of the RC-skeleton structure, which reduces the need for massive roof and massive bearing walls for structural functions in comparison to the traditional approach of construction, reduces envelope heat resistance and thermal capacity. As well as increasing window areas in modern building and ignoring the use of high thermal conductivity materials, all these factors have influenced the comfort level inside the new mosque building.

Previous studies have presented findings, which conclude that the present unconditioned new mosques in Baghdad are not thermally comfortable (Dawud; 1988). The primary factors are high heat gain, and the effect of external temperature fluctuations. This suggests the need for the use of air-conditioning, which would result in high-energy consumption in order to achieve thermal comfort. The findings of the research were based on fieldwork and computer modelling (see Tappuni; 1973). The short daily activity period of each prayer and its repetition five times per day, give rise to many problems if an HVAC system is used to maintain an internal air temperature as well as the need to provide other running costs for system maintenance etc.

It might be proposed to just operate the system before prayer time, but it is noticed that the inner thermal conditions would still not have reached a comfort level when the prayers have finished and people have started leaving the mosque. In addition, this proposal wastes energy without achieving any actual advantage regarding reaching thermal comfort. Since the envelope's response to climatic conditions is a major determinant of the amount of energy required in maintaining the thermal comfort of the inner environment; the problems of the new mosque in Baghdad may be summerised as:

i. The ignoring of the comfort requirements of occupants in the constructional materials, which are used in buildings and the details as well as the architectural treatments of the common new mosques in Baghdad.

ii. Lack of optimum design guidelines of the *musalla's* envelope which achieve the comfort level for the inner environment and which contribute to energy conservation.

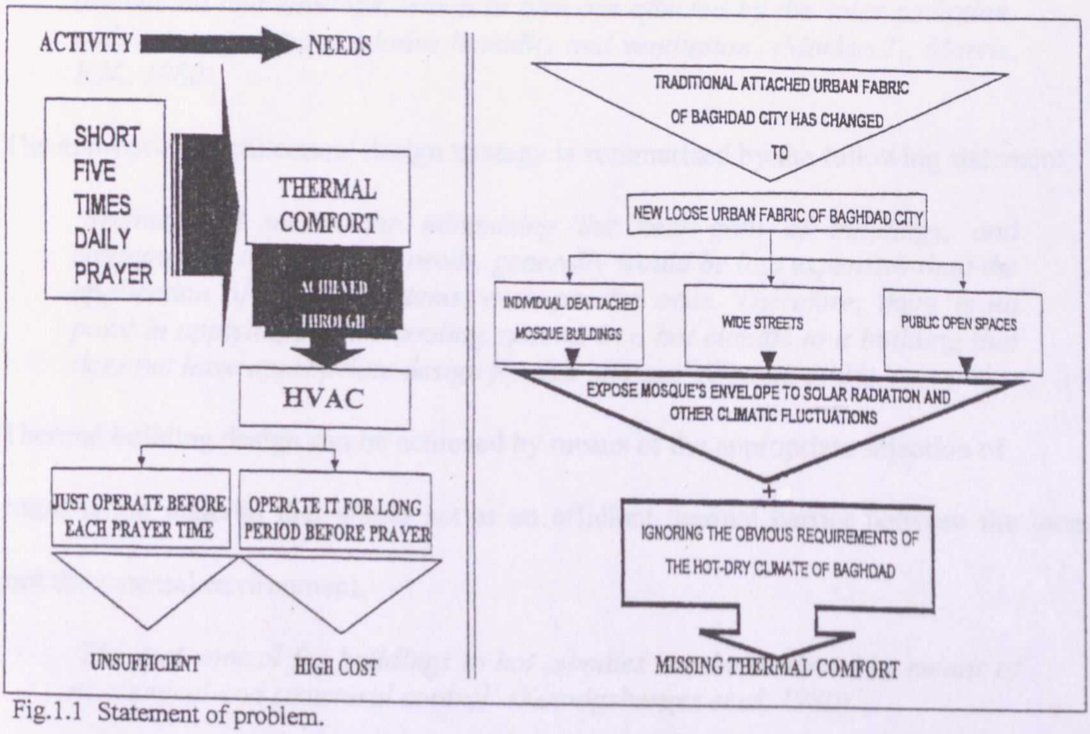


Fig.1.1 Statement of problem.

1.2.2 Literature Review

> *'Many issues and appropriate measures must be considered and adopted at the design stage of new buildings. Among the issues to be looked at is the climatic suitability of the building design and building material. To date there are various published materials regarding the need and the strategies for climatic design of buildings' (Olgyay, 1992).*

> *'The building should be designed to provide desirable indoor climate. Indoor climate is the condition of comfort of a person '(Fanger, 1970).*

> *'There are no obvious cultural symbols of the way people live and move and eat, their habits and life style-culture as a reflection of climate, Udo Kulterman refers to the house-The Roof-Roof house of Ken Yeang –as having demonstrated one possibility of how the traditional climatic and typological requirements could be articulated in the contemporary house, combining lessons from the Malay house as well as solution from colonial English architecture.' (Powell, 1989:24).*

'We can define our design task as the establishment of a "fit" between the pattern of needs and the use: the patterns of built form, servicing systems, technological factors, and environmental factors' (Martin, 1966).

'The design of any built environment is therefore determined by the extent of shelter and comfort required by the people who will use the designed system. The socio-economic-political Structure of that society and its standard of living often influences this. It is these levels of needs and use that initially determine the size and extent of the pattern of built form and servicing systems.'(Yeang , 1995:46).

'The temperature inside a building is affected by the building design, orientation and envelope, which in turn are affected by the solar radiation, ambient temperature, relative humidity and ventilation' (Markus,T., Morris, E.N., 1980).

The appropriate architectural design strategy is summarised by the following statement;

'Architectural means for minimizing the heat gain of buildings, and consequently their cooling needs, generally would be less expensive than the application of cooling systems, even passive ones. Therefore, there is no point in applying passive cooling systems in a hot climate to a building that does not have appropriate design for that climate' (Givoni, 1994).

Thermal building design can be achieved by means of the appropriate selection of construction material that would act as an efficient thermal barrier between the inner and the external environment.

'Thermal control for buildings in hot climates can be achieved by means of mechanical and structural control' (Koenigsberger et al, 1980).

Structural control represents passive cooling via appropriate thermo physical properties of envelope material, orientation, shading devices and fenestration for ventilation. The objectives of the thermal control are to control the heat flow through the envelope and enhance its thermal properties.

'Building material with suitable thermo physical properties could control the process of heat transfer in and out of a building. These properties are:
a) Thermal conductivity, resistance and transmittance
b) Surface characteristics with respect to radiation – absorptivity, reflectivity and emissivity
c) Surface convective coefficient
d) Heat capacity
e) Transparency to radiation of different wave lengths'. (Givoni; 1976).

'A design approach that is based on resource conservation principles such as a design approach based on conservation of resources can be considered in terms of the following alternative design strategies;

> *(1) Measures that reduce the supply to the system*
> *(2) Measures that improve the efficiency and performance of existing systems, and*
> *(3) General measures for the redesign of existing systems or the design of new systems.'(Yeang, 1995:154).*

Energy required for heating and cooling can be greatly reduced through a proper design of the building envelope, in response to the local climatic conditions.

Generally, the climate of Iraq is characterized by a large diurnal air temperature range coupled with a high intensity of incident solar radiation as shown in Chapter Two. On the other hand, in such widely fluctuating climates, building design has great potential in providing thermal comfort and reducing energy consumption. An efficient thermal design of a building envelope should consider three main parameters;

First; the form and orientation of the building.

Second; the fenestration, which includes the size, orientation and exposure of the windows to the sun and the type of glazing.

Third; the thermal properties of the opaque elements. This includes the solar absorptance of the external surfaces and the thermal capacity and conductance of the elements.

> *'Modern building technique systems and new materials contribute to lesser thermal efficiency than was achieved in traditional buildings; and leads to a dependence on mechanical and electrical systems for providing thermal comfort for the internal environment of the new buildings in Baghdad' (Tappuni, 1973).*

The interactive effect of all these parameters presents an extremely complex problem for the designer. The contribution each makes to the heat interchange between the interior environment and the exterior varies with the peculiarities of the design of the *musalla*.

1.3 RESEARCH OBJECTIVES

Conservation of energy and improved thermal comfort can be achieved through a proper design of the building envelope's "passive design". The absorptivity of the external surfaces, the thermal capacity and the thermal conductance of the envelope of the building have a profound effect on the internal thermal environment. This is practically true in Baghdad's hot-dry climate characterised by a large diurnal air temperature variation and high insulation. This study investigates the effect of these building parameters on the inner environmental temperature.

The present research will discuss the thermal design of the new mosque in Baghdad in terms of heat exchange, which is affected by its orientation, the envelope design, its size and constructional components and the material specifications of the envelope. It aims to:

i. Get the thermal efficiency diagnosis of the present new mosque envelope in Baghdad.

ii. Revise the design of the *musalla's* envelope to minimize the environmental impact through it.

iii. Identify the optimum thermal design and construction materials specifications and details for the mosque envelope.

iv. Identify environmental and other suitable treatments, which affect thermal design for the mosque that provides thermal comfort for its occupants and reduces energy consumption.

1.4 SCOPE OF THE RESEARCH

A study of Baghdad's climatic parameters will contribute as the background of the study. Improved thermal comfort can be achieved by means of a suitable passive design of the building envelope, since the envelope of the building has a profound effect on the internal environment. Considerations of all previous criteria contribute to the understanding of the thermal behavior of the new mosque envelope to assess the indoor environment thermally.

The scope of the research also covers an investigation of the thermal design of the typical new mosque that is selected by means of a specific survey of fifty new mosques in Baghdad (as shown in Chapter Five), taking into consideration heat exchange, other constants and variables, like orientation, mosque design, size, as well as climatic fluctuations, construction materials and components of the mosque envelope.

1.5 RESEARCH CONSIDERATIONS

The following categories are considered in the research as explained below:

1. It is considered that the *musalla* envelope is treated thermally as one homogeneous shell including all other parameters with a certain thickness, section and defined opaque and transparent areas.

2. The floor is treated as part of the envelope of the *musalla.*

3. The *musalla* envelope consists of just external walls treated as one homogenous continuous envelope, comprising the walls, roof and floor.

4. Sub-parameters, windows, and doors are represented by the "transparent part". Air vents as uncontrolled openings do not exist in the envelope of the *musalla.*

5. Since the air inside the *musalla* is in a dynamic condition, the air cubage is represented by the human "comfort zone" of space. The volume of the *musalla* represents the combination of the human comfort zone, that is within 6 feet in height and the remaining volume of the internal space of the *musalla.*

6. The new mosque type in Baghdad is representative of the mosques built after World War II. It is noticed from the survey of the new mosques in Baghdad (as shown in Chapter Five) that the new mosque type shares the following characteristics:

i.It is located in the vicinity of Baghdad .

iii. It is used usually on five short occasions daily. It is not in continuous use. There is almost no occupation of the *musalla* space in the intervals between prayers.

iii. Its building is passive designed and constructed. HVAC is not used on account of its high capital and running costs as well as other technical costs and maintenance.

iv. It is noted that the minaret is not part of the *musalla* envelope and has no role in the thermal behavior of the new *musalla* envelope.

7. Any proposed design and construction system for the *musalla* building must take into account the following;

i The thermal comfort requirements of praying persons and the impact of climatic fluctuations over the seasons in the Baghdad region.

ii. The limitations of local construction, available materials and labour skills.

iii. Specific nature of activity *(salat)* inside the *musalla* building and, the short periods of use.

iv. It is not viable to consider heating and cooling functioning costs as well as the capital costs of HVAC systems in the new *musalla* building in Baghdad. The consumption of energy in the new *musalla* in Baghdad is very limited since the cooling in summer depends on simple fans and the heating in winter relies on simple radiant heaters. So there is no use of HVAC systems or other different combinations of components and machinery. It is effectively a passive building. Based on that, there is no consideration of HVAC systems, capital costs and functional costs which affect energy consumption and the total cost of the *musalla* building project.

v. The building fabric should be capable of protecting the inner environment of the *musalla* from the external climatic fluctuations expected in the Baghdad region.

vi. The context of the *musalla* building and the condition of the microclimate as well the pattern of the surrounding urban fabric.

vii. The construction capability (parameters, sub parameters, opaque and transparent parts of the envelope that play a direct role in heat flow).

viii. How all the previous criteria affect economic considerations that represent a major factor in taking design decisions?

1.6 RESEARCH QUESTIONS AND HYPOTHESIS

The research poses the following questions:

i. Is the inner environment of the new mosque in Baghdad within the thermal comfort level?

ii. How is it possible to achieve thermal comfort for the inner environment of the *musalla* and reduce energy consumption?

iii. How is it possible to maintain the thermal comfort of the inner environment?

iv. What are the thermal architectural design parameters for future mosques in the light of the thermal assessment of the typical new mosque in Baghdad?

v. Which envelope materials have suitable thermal specifications for the Baghdad climate that are consistent with available skill and construction technology?

An appropriate thermal design strategy could minimize the thermal impact; this can be achieved by protecting the *musalla* envelope from heat transfer by means of appropriate design and selection of materials. Based on that, desirable internal environmental comfort could be attained with minimum energy consumption.

It can be concluded that for buildings in a hot-dry climate, minimizing the external heat gain through the building envelope would be a good strategy to reduce the dependence on energy in conditions of necessity. That can be achieved by means of appropriate design for the building envelope.

1.7 RESEARCH METHOD

The research has considered the following steps:

i. Conducting survey to a ascertain whether it is true or not that the new mosque in Baghdad is not comfortable thermally for occupants. In order to determine the weaknesses in design and construction components of the mosque, the following investigation steps have been done:

a. Collecting data from 50 new mosques in Baghdad that represent 80% of the new mosques in the Baghdad vicinity in July 1997.

b. Identification of the typical new mosque, "Model Mosque", in Baghdad.

ii. Analysed study and evaluation the architectural and constructional components in relation to heat exchange and heat flow through the envelope of the "model *musalla*" in Baghdad, using heat balance equations as shown in Chapter Five.

Thermal analysis and assessment for the typical mosque, "Model Mosque", is conducted by conventional means to know the actual thermal behaviors of its envelope in terms of protecting the inner environment from the fluctuations of the external environment. The evaluation covers the components of the envelope section specifications and the architectural features. Computing the thermal performance of the building before it is built has several advantages. It becomes possible in the pre-construction stages to refine the thermal properties for each building element.

iii. Assessment for the "model *musalla*" has been conducted, using a computer simulation program after introducing changes to the total transparent area of its envelope, its components and external finish and colour, as well as other architectural and constructional characteristics in order to test the enhancement in the thermal behaviour of the envelope during the hot and cold months. Comparison study with some field test outputs done by the assistance of the building research centre in Baghdad as shown in Appendix B.

The "Model" *musalla* building has been simulated for the four different roof structures and five different wall constructions. To make the simulations comparable, the size of one huge space (*musalla*) and its direction to Mecca at 10 degrees southwest has been treated as a constant.

All that could be achieved through the following detailed strategy:

A. FIRST STAGE;

i. Presentation of Baghdad's climatic parameters, their character and their relationship with the thermal comfort zone to explain the environmental impact on the special case study in Baghdad.

ii. Study of the characteristics of the traditional mosque in Baghdad by examining some historical prototypes by analysing their architectural and constructional features to enable a comparison with the latest new mosque type.

iii. Study of the character of the new mosque types in Baghdad after World War II. This latter type was affected by the modern design approach and employment of new building materials, which indicated the different thermal behaviour of the mosque-building envelope related to the climatic parameters in Baghdad.

iv. Determination of the characteristics of the typical new mosque," model mosque", in Baghdad in light of the author's analyse and the survey conducted in June-July 1997 of fifty new mosques in the Baghdad vicinity (see survey data in Chapter Five).

B. SECOND STAGE;

This includes the following steps:

i. Conducting an analysis study and estimate for the typical new mosque, "model mosque", in Baghdad in order to understand the thermal behaviour of the envelope by means of a thermal assessment of its elements and their role in heat exchange.

ii. Determination of the role of each envelope component (of the section) in providing the required thermal comfort for the inner environment.

iii. Provision of alternatives for envelope elements with new architectural specifications and reassessment of their impact to obtain a comparison between the two outputs of two alternatives with the aim of identifying the thermal behaviour weaknesses of the envelope.

iv. Analysing the base case design using a computer model including the identification of a suitable computer-modelling tool; simulation of the base case design using selected software; simulation tests for the envelope design alternatives; obtaining / drawing conclusions for the simulated proposed design; and comparing the simulated base case and the simulated proposed alternatives.

v. Obtaining research findings and conclusions to determine the optimum constructional elements and architectural specifications for the mosque envelope to enable the making of recommendations for future mosque envelopes with reference to some international, regional and Iraqi experiments and giving appropriate design guidelines.

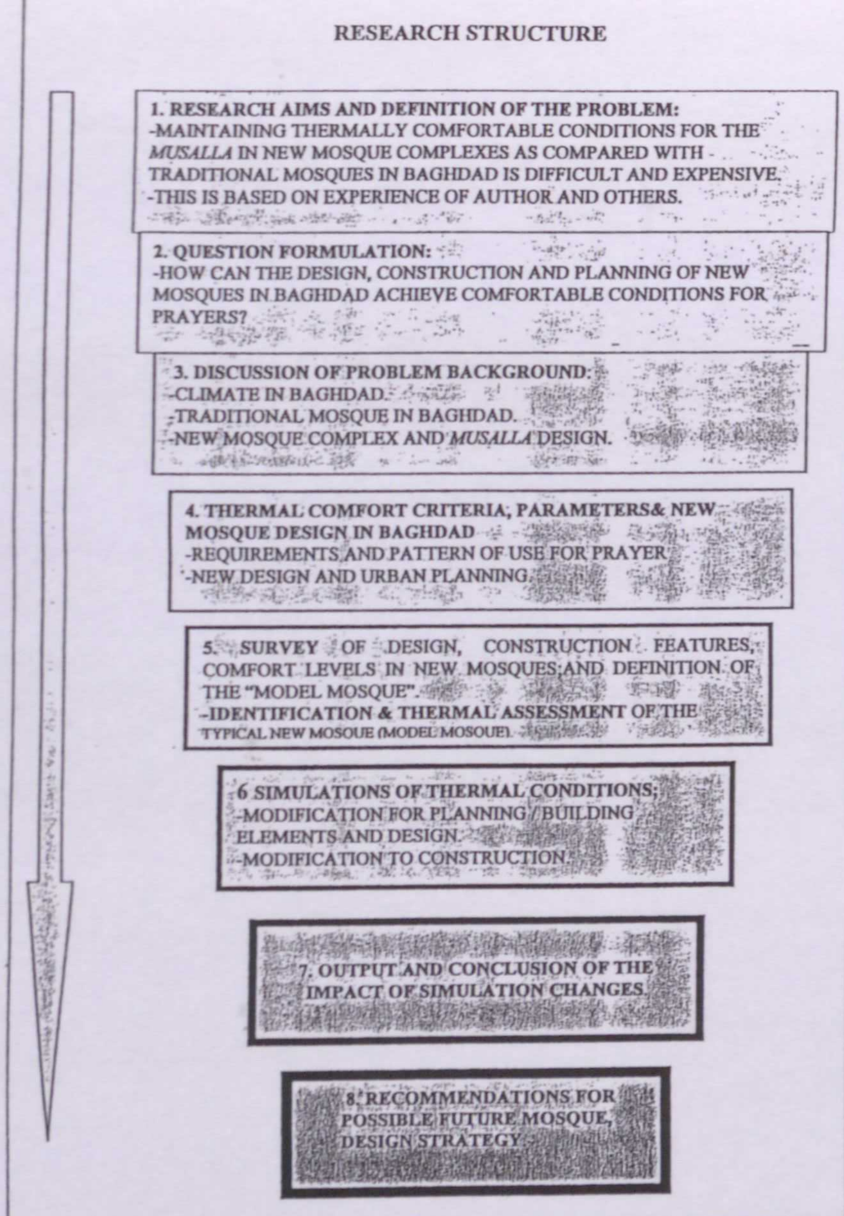


Fig.1.2 Research Structure

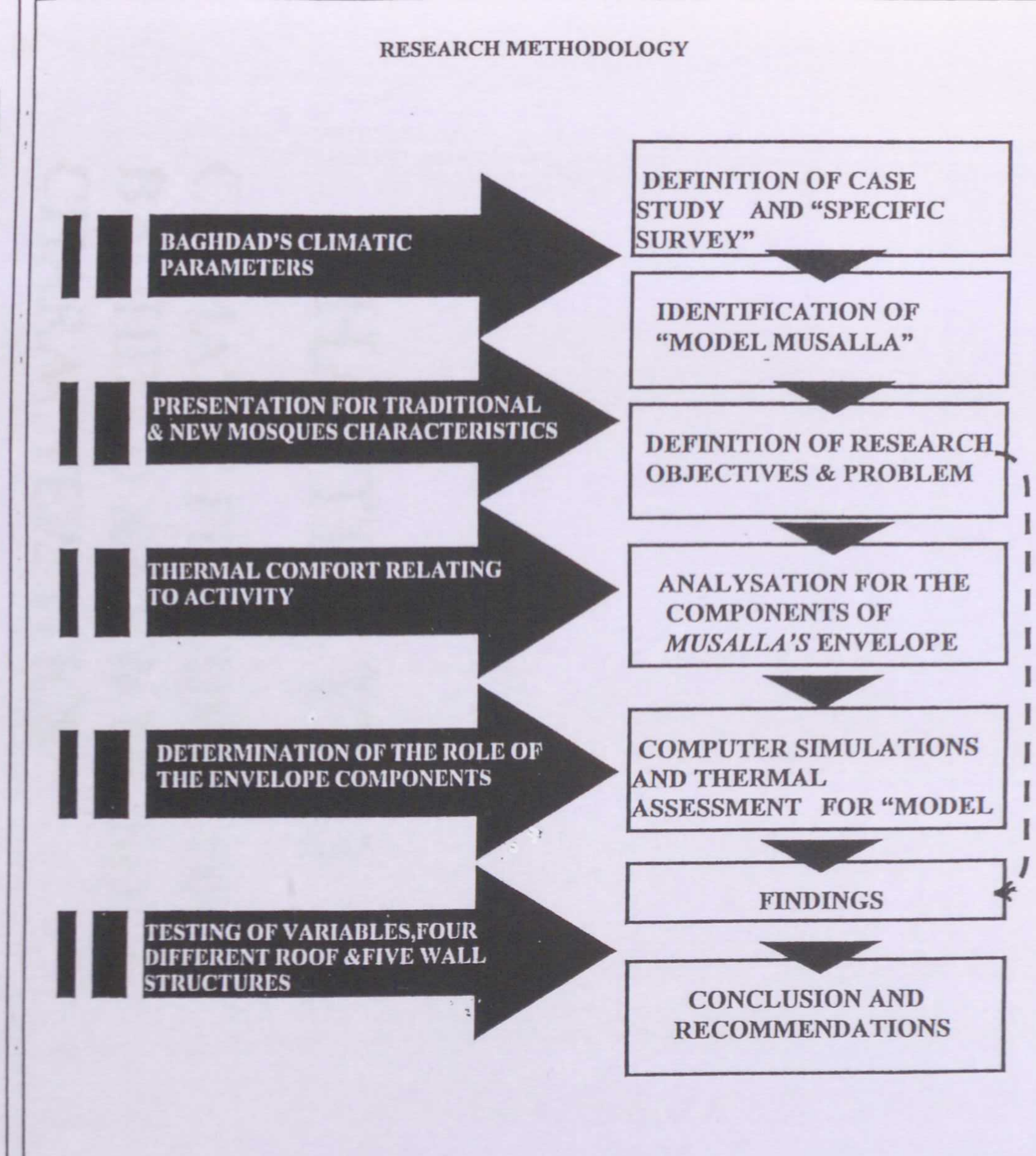


Fig.1.3 Research Methodology

CHAPTER TWO

CLIMATIC FEATURES OF BAGHDAD &NEW MOSQUE CHARACTERISTICS

2.1 INTRODUCTION

The aim of this chapter is to give a general overview of the climate of Iraq, particularly the Baghdad region as far as it concerns the building envelope. It starts by giving basic definitions of the climatic elements. General information is also given about various climate types in order to place the climate of Iraq in the appropriate category of world climates.

The present chapter explains the characteristics of climatic elements and the variations of the climatic stresses throughout the Iraq and in Baghdad in particular. The climate of this country is, then, divided into four zones, according to thermal stress analysis. The impact of climate on regional building character is discussed in general terms (Shaaban & Al-Jawadi, 1973:5).

It paves the way for a study of the thermal behavior of the mosque envelope and the impact of climate on architectural environment. The mosque building has to satisfy two contrasting functions; keeping the heat out in the summer, and keeping the heat inside in winter.

The findings of this chapter are based on the climatic data supplied by the Metrological Department, Ministry of Communication in Baghdad.

2.2 THE CLIMATIC ELEMENTS

The climate of a particular place depends mainly on the radiation it receives from the sun, which, in turn, affects humidity, rain and wind movements. In the following section, there are general descriptions of each element.

2.2.1 Solar Radiation;

Solar radiation is a prime factor in determining the climatic character of a given location. The rates of solar radiation for the four seasons in the Baghdad region are influenced by the declination angle and seasonal variation as well as cloud coverage and other forecast phenomena. Solar radiation is more intense in summer than in winter, the annual total radiation range in Iraq varying from 15 mega Jule/m.day in the northern zone to 21 mega Jule/m.day in the southern zone (see Fig.2.1a.). The mean is 18 mega Jule/m.day (Central Region) for the country (Shaaban & Al-Jawadi, 1973).

> *'The clarity of the atmosphere also affects the quantity of solar radiation. In the hot-arid regions, for example, the sky is deep blue in color and with low brightness (unless there is dust in the atmosphere), but the ground receives a large amount of radiation. Thus, a strong reflected sunlight emits from it. In the hot-humid climate, on the other hand, scattered clouds reflect bright sunshine and increase the intensity of radiation from the sky. Under overcast conditions, the sky and not the sun is the main source of energy. Solar radiation intensity, on the other hand, increases (its fall on the surface) according to the short distance, which the radiation crosses through the atmosphere' (Olgyay, 1957:56).*

The Meteorological Station makes recordings of global radiation on the horizontal surface in Baghdad (This was measured in cal./m^2/day, and only for the years 1967-1969). The records show that the maximum value of 750 cal./m^2/day occurs in December (Shaaban & Al-Jawadi: 1973).

2.2.2 Air Temperature

Air temperature varies according to the latitude, height above sea level and geographic character of the region. In hot-dry climate areas, where the sky is mostly clear, there is a free path for incoming radiation during the day and outgoing radiation during the night, which causes large diurnal temperature variation. Annual variations are also large. In hot-humid climate areas, where the sky is overcast, the diurnal and annual variations are small.

2.2.3 Humidity

Humidity is an important factor in the assessment of climatic stress. Comfort can be achieved if relative humidity is approximately 30% to 70%(Shaaban & Al-Jawadi; 1973).

ince Iraq's location is adjacent to the Arabian Gulf in the south, and the mountains in the northeast, the relative humidity varies. The annual highest and lowest relative humidity in most regions of Iraq (including Baghdad) is 30-60% while it is lowest during summer (15% during the day and 30%-40% at night).

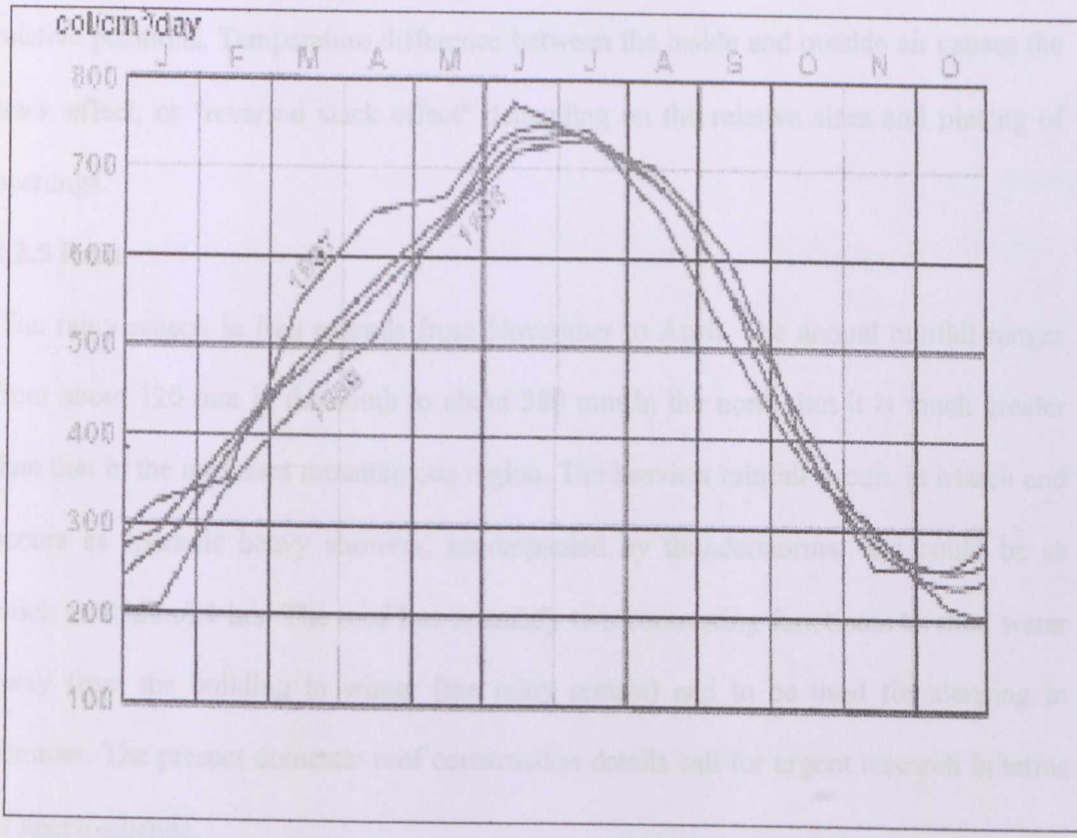


Fig.2.1a. Daily incoming radiation in the Baghdad region
Source: Shaaban; 1973.

Since summer usually extends over more than seven months, the climate is generally considered to be a hot-dry climate, while the range of relative humidity is 50%-60% during wintertime and the highest relative humidity is 90% (Shaaban & Al-Jawadi; 1973).

2.2.4 Wind

Wind speed varies with location, topography and height. It is important to assess the direction and speed of prevailing winds in the cold and hot periods. This will influence the size and positioning of openings and orientations. Wind may be welcomed in the hot-humid zone to enter the building for cooling effect, while it could be a nuisance in the hot-dry climate where it brings heat and dust. In the grouping of buildings and in the assessment of their ventilation, some basic principles must be observed. Wind causes pressure on the windward side and suction on the leeward side of the building. This causes positive and negative zones between the buildings depending on their sizes and relative positions. Temperature difference between the inside and outside air causes the stack effect, or "reversed stack effect" depending on the relative sizes and placing of openings.

2.2.5 Rain

The rainy season in Iraq extends from November to April. The annual rainfall ranges from about 120 mm in the south to about 380 mm in the north, but it is much greater than that in the northeast mountainous region. The heaviest rainfall occurs in March and occurs as sporadic heavy showers, accompanied by thunderstorms, and could be as much as 85mm/24 hrs. The roof has to satisfy two contrasting functions: to shed water away from the building in winter (the rainy season) and to be used for sleeping in summer. The present domestic roof construction details call for urgent research in terms of heat exchange.

2.3 CLASSIFICATION OF HOT CLIMATES

The classification of the climate depends on the amount of solar radiation received, latitude, height above sea level, wind and rainfall, relationship of land and sea and topography. The climate of Iraq lies somewhere between hot dry and hot humid with some upland climate (Dawud, 1983:9).

2.3.1 Hot-Dry Climate

The characteristics of this climate are the longer over-heated period and large diurnal and annual temperature variations. The sky is usually cloudless, deep blue, of low brightness, except when dust laden, where the brightness increases considerably. The light reflected from light colored paved ground is very bright and painful. Rain is scarce, but nights are cool and calm and the roofs are used for sleeping. The layout of traditional buildings in towns and villages emphasizes the concentration of masses; buildings are very close to each other leaving shaded alleyways in between and exposing the minimum area to the sun. The traditional building is usually heavy weight and has high thermal capacity construction to give good time lag. Fig. (3.34).

2.3.2 Hot-Humid Climate

The characteristics of the hot-humid climate are the small diurnal and annual temperature variations. The hot periods are never as hot as those of a hot-dry climate. However, high humidity makes for very uncomfortable conditions. The sky is usually overcast through the year, so diffuse radiation is the main source. The intensity of radiation increases considerably in a partly cloudy sky because of the reflection from clouds. The view of the sky should be cut off and the eye is directed to green and shaded areas.

Rain is heavy and falls almost throughout the year and this affects the building structure and details. Air movement through the building mainly contributes to comfort within the building. The character of the building is dependent on this main objective. The roof becomes the main element of design, while the walls lose their usual function and become a light screen between the inside and outside, and must allow as much breeze through as possible.

2.4 CLIMATIC ZONING OF IRAQ

A systematic approach is adopted to calculate the climatic stress for monthly temperatures and the mean maximums of each month from Table (2.2) are compared with day comfort limits. The same applies to comparing monthly mean minima with night comfort limits. The result of the comparison will be H- (Humid), M-(Moderate), or C-(Cold) as explained in the tables (2.1,2.2,2.3b and 2.5) .

These symbols of comparison are tabulated for each location. These give us the number of over-heated, under-heated and comfortable periods for each location.

Based on this information, together with others, such as geographic information, the climate of Iraq can be divided into the following four climatic zones:

Table 2.1: Humidity, rain, and wind for the Baghdad Region.

RH.(percentage)		J	F	M	A	M	J	J	A	S	O	N	D
Monthly Mean (max.) (daytime)		87.0	74.0	74.0	68.0	45.0	34.0	32.0	32.0	38.0	50.0	67.0	89.0
Monthly Mean (min.) (nighttime)		50.0	41.0	35.0	27.0	21.0	13.0	12.0	13.0	15.0	21.0	39.0	51.0
(Average)		71.0	61.0	53.0	43.0	30.0	21.0	22.0	22.0	26.0	34.0	54.0	71.0
HumidityGroup seetable3A-1		4	3	3	2	2	1	1	1	1	2	3	4
Rain (mm)	**Average of 30 days**	24.5	24.8	28.5	15.5	7.1	0.1	0.0	0.0	0.1	3.0	21.5	25.7
	Max. in 24 hrs	35.3	38.0	55.6	25.0	65.0	2.5	0.0	0.0	0.6	15.8	48.9	40.0
Wind	**Prevailing**	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
	Secondary	SE	SE	SE	N	N	N	N	N	N	N	N	SE

Total Average of Rain for 30 days is 150.8 mm . Source: Shaaban: 1973.

Table 2.2. Monthly air temperature for the Baghdad Region

Temperature	J	F	M	A	M	J	J	A	S	O	N	D
Monthly Mean (max.)	15.9	18.5	22.2	29.0	35.8	40.9	43.4	43.5	39.9	33.9	24.5	177
Monthly Mean (min.)	4.2	5.7	9.2	14.5	19.9	23.3	25.2	24.7	21.0	16.2	10.5	5.2
Monthly Mean Range	11.7	12.6	13.0	14.4	15.9	17.6	18.2	18.8	18.9	17.7	13.9	12.5

Source: Shaaban: 1973.

Highest	Lowest	
43.5C°	23.8C°	AMT
40.2C°	35.3C°	AMR

AMT= Annual Mean Temp

AMR=Annual Mean Range

Average RH%	HG
20-30	1
30-50	2
50-70	3
70-100	4

HG= Humidity Group

Table 2.3a Daily rates of air temperature for annual months in Baghdad.

Months	Temperature °C
Jan.	10.0
Feb.	12.4
Mar.	16.3
Apr.	21.9
May.	28.3
Jun.	33.0
Jul.	34.8
Aug.	34.4
Sep.	30.6
Oct.	24.5
Nov.	17.0
Dec.	11.1

Source: Coordinative test shared with Building Research Center in Baghdad.

S= South Zone N= North Zone

M= Middle Zone D=Desert Zone

Zoning divisions and the chosen Meteorological Stations are shown in Fig.(2.1). Information on the climatic elements and climatic stresses of the stations in these zones can be seen in Table (2.3), (Climatology Atlas No.II for Iraq).

2.4.1 South Zone

The climate here is hot dry, but it is further complicated by the humidity of the sea. The moisture saturated "*Sherji*" winds raise humidity to an unbearable level.

The climate requirements are therefore, contradictory in certain periods of the year. For example on one hand we need heavy walls and small openings for the hot dry climate, while, on the other hand, we need light walls and large openings for the hot-humid climate. The designer must reach a compromise of satisfying different functions of the building at different times of the year by appropriate selection of material and planning for functions, see tables (B.1, B.2 and B.3, APP.B). Soil in this zone is difficult to cultivate due to the high water table, fast evaporation and large areas of marshland (Shaaban & Al-Jawadi: 1973). Rising damp in walls is a serious problem. The overheated discomfort period is rather difficult to overcome because of high humidity. Sleeping at night is disturbed because of high humidity and mosquito attacks. The quality of available building materials is very poor such as bricks and reeds. Concrete is now used only in towns.

2.4.2 Middle Zone

The climate of this zone is hot dry in the summer, but swings sharply into cold dry in some winter months. It is a common mistake to consider this climate as hot dry only and design for that because it has about three winter months. The zone can be divided into two parts: *Ma*, which has some of the characteristics of the Northern zone, and *Mb*, which has some of the characteristics of the Southern Zone and includes the city of Baghdad (see Fig.2.1).

2.4.3 North Zone

Soil in this zone is fertile when irrigated, but naturally dry with a low water table. However, rainfall increases as we approach the extreme northeast and the land becomes green and bushy (Shaaban & Al-Jawadi: 1973). The available building materials are mainly stone and poplar trees. This zone can be divided into two distinct parts:

Sub zone "Na":

This is a rough mountainous region (see fig 2.1). The climate is cold in winter, where the temperature drops far below freezing. In the summer, the day is comfortable, and the temperature does not exceed 30°C; the clear sky allows outgoing radiation, and nights are usually cold. Unfortunately, no climatic records are available on this region yet, but a meteorological station has been established recently in *Sulaimania*, although this will not represent the whole region. Other stations should be installed in *Arbil*, *Rawanduz*, *Quala* and *Zakho* in order to get the true picture of the region. The buildings have to keep out cold winds, snow drifts and rain in winter. At the same time, they have to satisfy completely different requirements in the summer such as keeping heat out, sleeping on the roof, etc.

Sub zone "Nb":

This is a hilly region, which is a transition between the flat Middle Zone and the Mountainous region (see fig.2.1). It actually exhibits the character of both zones. In the summer, it is almost hot-dry, while winter can be severe and the annual rainfall is about 370 mm as compared with 125 mm for the Middle Zone.

2.4.4 The Desert Zone

This is an uninhabited area and no climatic records are available for the zone. The climate is purely hot-dry, with large diurnal and annual ranges. Dust storms make life difficult to support. Buildings should be of heavy construction in this zone.

Table 2.3b Temperature ranges in Baghdad region.

Month	Average high (°F)	Average low (°F)	Warmest ever (°F)	Coldest ever (°F)	Average dew point (°F)	Average Precipitation (°F)
JAN.	58	38	75	25	38	1.1
FEB.	64	43	84	25	40	1.1
MARCH	73	50	88	30	42	1.1
APRIL	84	59	100	43	44	0.7
MAY	96	68	111	50	44	0.3
JUNE	105	74	120	63	43	0
JULY	110	78	122	61	46	0
AUG.	108	75	118	63	48	0
SEPT.	103	70	117	55	46	0
OCT.	91	60	105	39	45	0.1
NOV.	74	47	90	28	41	0.8
DEC.	62	42	76	25	42	1.0

Latitude: 33 degrees Longitude: 44 degrees

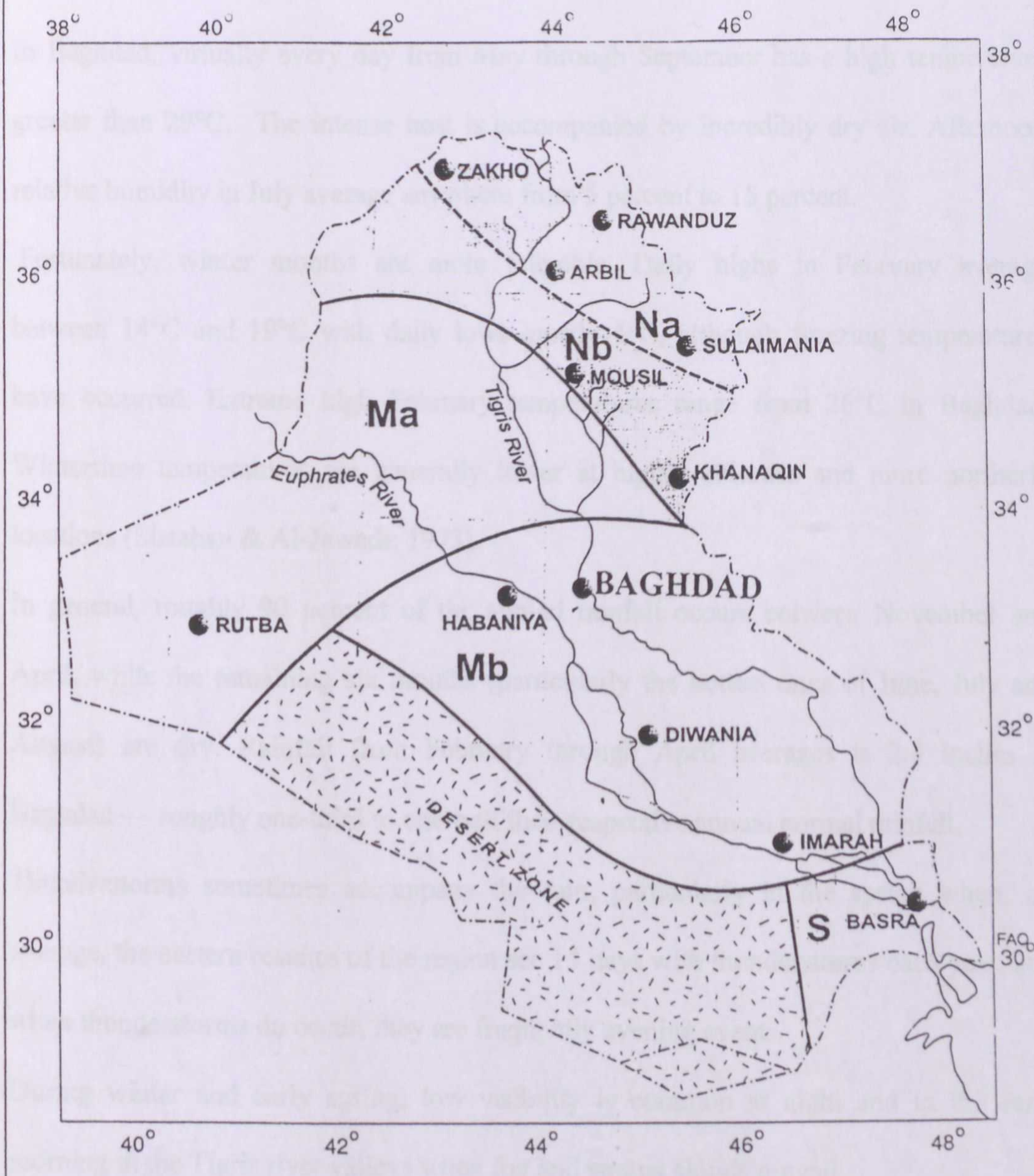
Source: Meteorologists Bruce and Frank, watsonwx@aol.com

2.5 THE CLIMATIC ANALYSIS OF BAGHDAD

Baghdad is the capital of Iraq. Its position forms a big region in the middle of Iraq, so it represents the middle zone (Mb). It is situated at 33° north latitude and 44° east longitude. The annual average daytime air temperature of Baghdad is 23° Celsius and the relative humidity average is 43%.

The summer season starts in April; the high temperature months are June, July, August and September. The average over this period is 43°C, 28°C, high and low temperature respectively, and the usual range is 35°C.

The annual intensity of solar radiation received is about 7350 mega. Jule/m and the average intensity of solar radiation for a July day is 25 mega. Jule/m (see Dawud, 1983:10-14). The rate of sunny hours during each sunny day is about 12.2 hrs/day. The relative humidity during the day is 31% and during the night is 34%.



Ma & **Mb** / Hot Dry Zone

S / Hot Humid Zone

Na / Up Land Zone , **Nb** / North Zone

Fig.2.1. Climatic Zones of Iraq. Source: Shaaban, Dr.AC., Jawadi, Dr. M. 1973.

The weather becomes cold in the period between October and mid-January. The highest and lowest temperatures reached in January are 16°C and 4°C respectively. The coldest months, on the other hand, are December, January and February. Frosty days are documented during January. The intensity of solar radiation during winter is 10.5 mega. Jule/m. The number of sunny hours during daytime is 5.5 hrs/day. The lowest and highest relative humidity is 50% and 84%.

In Baghdad, virtually every day from May through September has a high temperature greater than 29°C. The intense heat is accompanied by incredibly dry air. Afternoon relative humidity in July average anywhere from 5 percent to 15 percent.

Fortunately, winter months are more tolerable. Daily highs in February average between 14°C and 19°C with daily lows mostly 4°C, although freezing temperatures have occurred. Extreme high February temperatures range from 26°C in Baghdad. Wintertime temperatures are generally lower at higher altitudes and more northerly locations (Shaaban & Al-Jawadi: 1973).

In general, roughly 90 percent of the annual rainfall occurs between November and April, while the remaining six months (particularly the hottest ones of June, July and August) are dry. Rainfall from February through April averages is 2.4 inches at Baghdad — roughly one-third to one-half their respective annual normal rainfall.

Thunderstorms sometimes accompany the rain, particularly in the spring when, on average, the eastern reaches of the region see 14 days with thunderstorms each year, and when thunderstorms do occur, they are frequently evening events.

During winter and early spring, low visibility is common at night and in the early morning in the Tigris river valleys when fog and stratus clouds prevail.

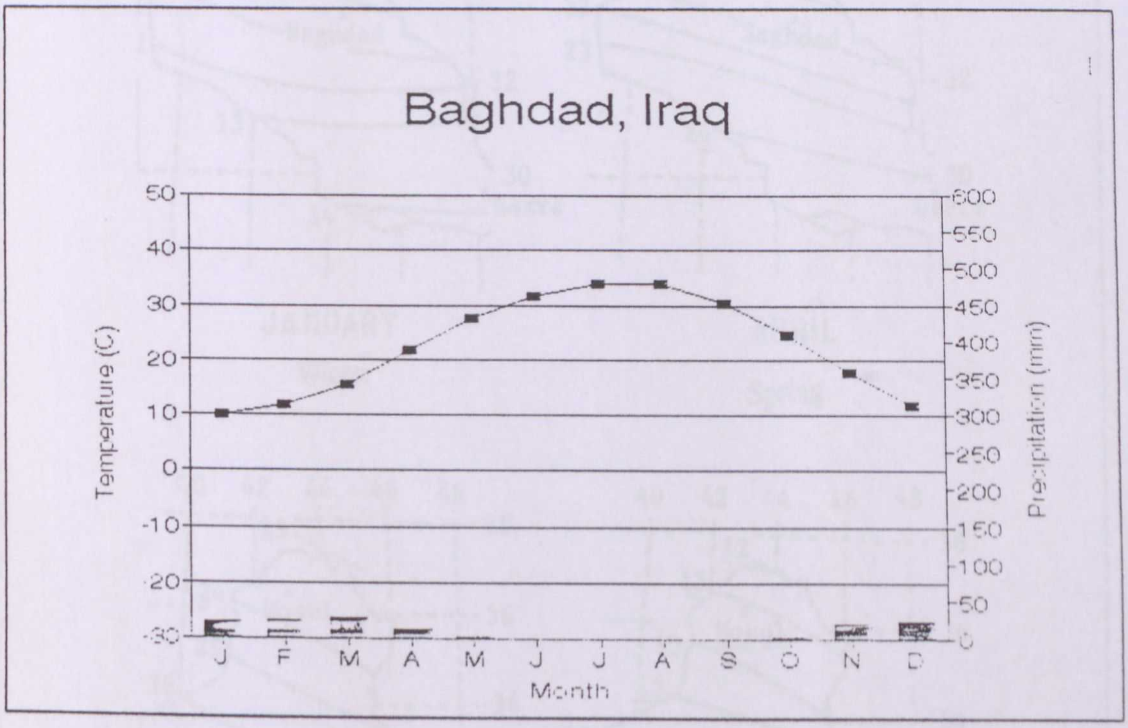
Another unique climatic feature in Iraq are winds. Specifically, the summer months are marked by two kinds of wind phenomena:

Southern and Southeasterly *Sharji*: The southern and southeasterly *sharji*, a dry, dusty wind with occasional gusts of 80 kilometers an hour (50 mph), occurs (from time to time) from April to early June and again from late September through November.

These winds may last for a day at the beginning and end of the season, but for a few days at other times. This wind is often accompanied by violent sand and dust storms.

Northwesterly ***Gherbi*****:** From mid-June to mid-September the prevailing wind, called the *shamal* also, is from the north and northwest. It is a steady wind.

The very dry air brought by this *shamal* permits intensive sun heating of the land surface, but the breeze has some cooling effect (Climatology Atlas No.II for Iraq)



Latitude: 33 degrees, Longitude: 44 degrees. Fig.2. 2a Temperature fluctuations in the Baghdad region.
Source: Meteorologists Bruce and Frank, watsonwx@aol.com

Table 2.3: Climatic Data for Mosul , Baghdad, and Basra.

DATA	Place	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly mean Min (ºC)	MS	2.5	3.5	6.3	10.2	15.0	19.5	22.9	21.8	16.6	11.4	7.0	3.3
	BG	4.3	5.9	9.6	14.6	20.0	23.4	25.3	24.6	21.0	16.2	10.3	5.5
	BS	7.0	8.7	12.6	18.0	23.7	26.9	27.7	26.3	22.6	18.3	13.2	8.0
Monthly mean (ºC)	MS	6.9	8.8	12.4	17.5	24.1	30.4	33.9	32.7	27.2	20.3	13.3	8.2
	BG	10.0	12.1	16.1	22.1	28.4	33.0	34.8	34.4	30.6	24.6	17.1	11.3
	BS	12.2	14.4	18.6	24.0	29.4	32.6	33.9	33.5	31.1	25.9	19.3	13.7
Monthly mean Max. (ºC)	MS	12.8	15.3	19.0	25.4	12.9	39.6	43.4	43.0	38.7	31.2	22.3	15.0
	BG	15.8	18.7	22.7	28.7	15.8	41.0	43.4	43.3	39.8	33.4	24.6	17.7
	BS	18.6	21.0	25.3	30.8	16.1	38.8	40.5	41.3	39.7	35.0	26.7	20.0
Monthly Average Rainfall (mm)	MS	67.2	63.4	69.3	50.8	25.3	0.70	0.1	0	0.7	9.9	36.1	65.3
	BG	24.8	24.0	23.1	21.5	7.3	0.10	0	0	0.3	3.7	17.4	22.7
	BS	24.2	14.3	20.3	20.9	7.8	0	0	0	0	0.8	22.5	29.3
Relative Humidity %													
Monthly Average at 6.00 am	MS	92	90	87	86	74	53	44	46	55	57	81	91
	BG	84	78	73	64	47	34	32	33	38	49	70	84
	BS	89	87	84	74	65	60	58	50	62	67	83	89
Monthly Average at 3.00 pm	MS	64	57	47	41	26	15	15	13	16	28	44	60
	BG	51	42	36	14	19	13	12	13	15	22	39	52
	BS	62	55	49	41	40	41	35	32	12	36	52	62
Daily Solar radiation MW cm	MS	226	298	385	476	597	658	644	580	580	366	261	190
	BG	306	381	485	585	663	747	730	675	675	456	356	273
	BS	305	399	485	551	615	606	609	597	597	434	340	282

Source :(Al-Riyahi:1985). Mosul (MS), Baghdad (BG), and Basra (BS).

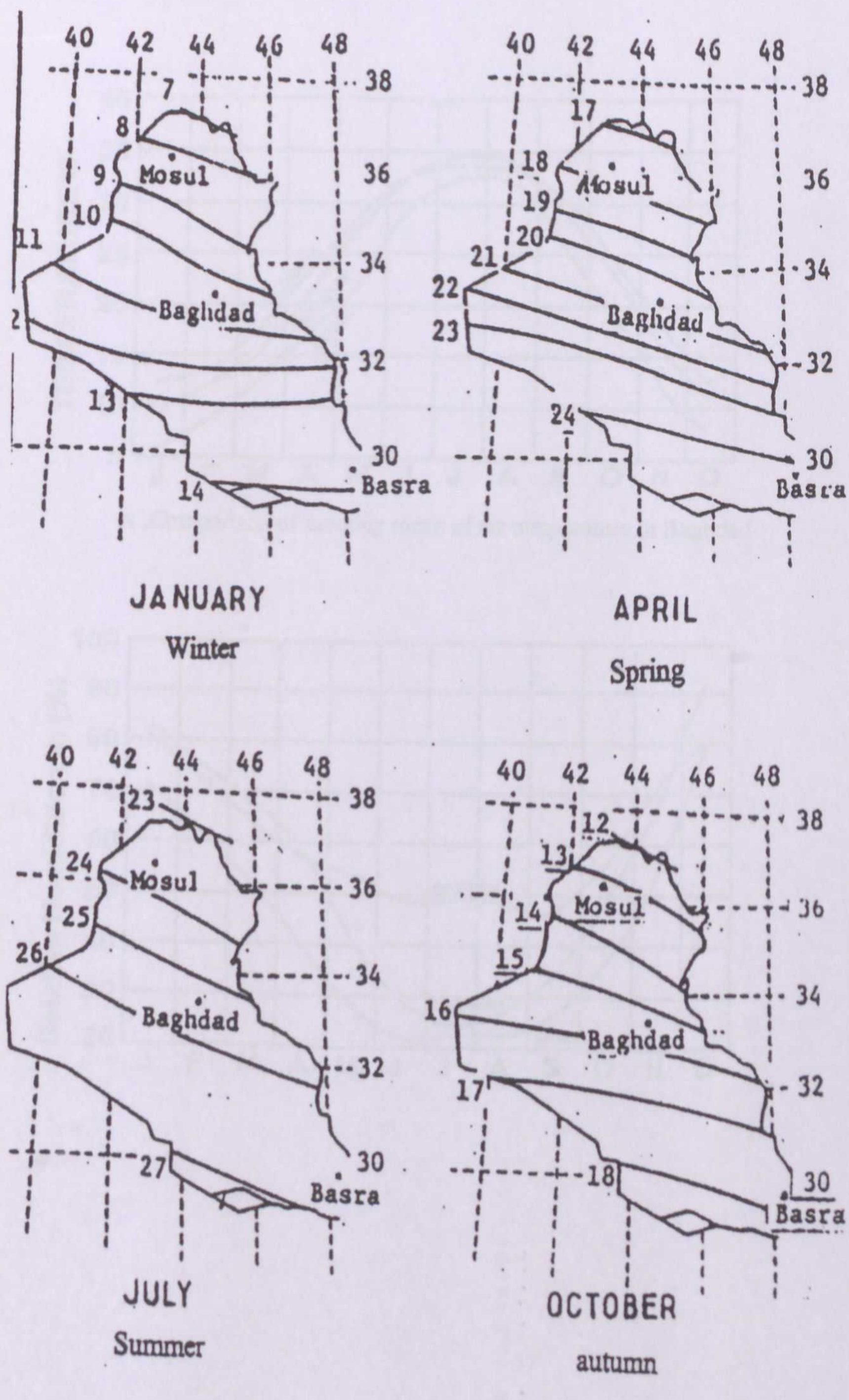
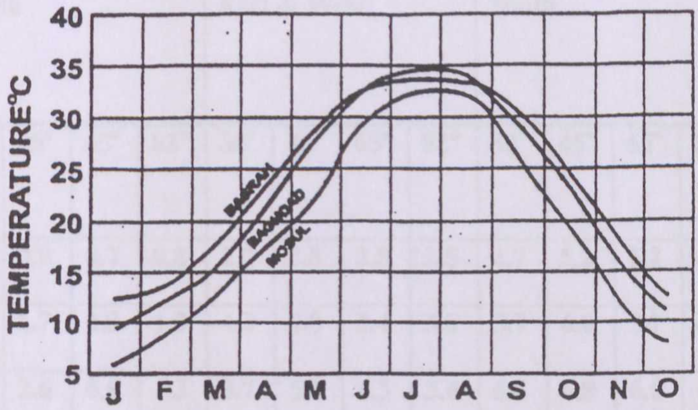


Fig.2.2 Isoradiation Lines for Iraq (MJ/sq. m/day). Source: R.Tappuni ;1981.



A .Comparison of monthly mean of air temperature in Baghdad

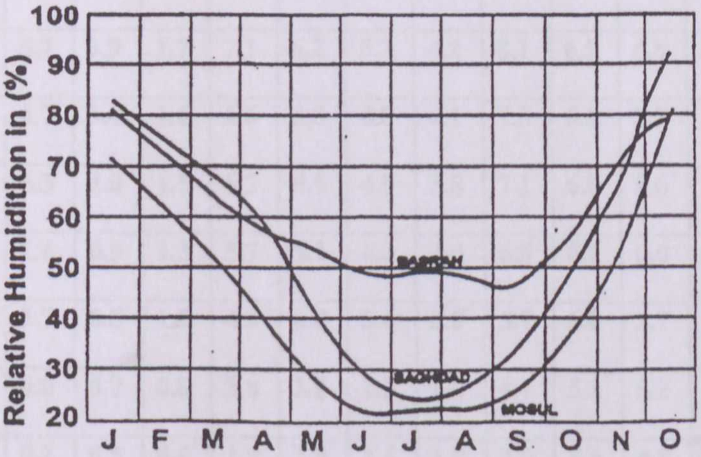


Fig.2.3 Comparison of monthly mean temperature and relative humidity in Baghdad, Source: Shaaban; 1973.

Table 2.4: Daily total rates of solar radiation intensity for inclined surfaces in the Baghdad region kWh/day.

Month	North				East & West				South			
	30°	45°	65°	82°	30°	45°	65°	82°	30°	45°	65°	82 °
Jan.	0.9	0.8	0.7	0.8	2.8	2.8	2.5	2.5	4.7	5.2	5.2	4.9
Feb.	2.4	1.7	0.8	1.0	4.2	4.0	3.4	3.0	5.7	6.0	5.7	4.9
Mar.	3.9	2.6	0.9	1.3	5.7	5.1	4.3	3.6	6.8	6.8	6.0	5.1
Apr.	4.5	3.6	2.0	1.5	6.2	5.5	4.5	3.8	7.1	6.6	5.6	4.4
May.	5.7	4.7	3.0	1.6	6.6	5.8	4.8	4.1	7.5	6.6	5.3	3.6
Jun.	6.8	5.7	3.9	1.7	7.1	6.2	5.2	4.2	8.1	6.5	4.8	3.2
Jul.	5.7	4.7	3.0	1.6	6.6	5.8	4.8	4.1	7.5	6.6	5.3	3.6
Aug.	4.5	6.3	2.0	1.5	6.2	5.5	4.5	3.8	7.1	6.6	5.6	4.4
Sep.	3.9	2.6	0.9	1.3	5.7	5.1	4.3	3.6	6.8	6.8	6.0	5.1
Oct.	2.4	1.7	0.8	1.0	4.2	4.0	3.4	3.0	5.7	6.0	5.7	5.0
Nov.	0.9	0.8	0.7	0.8	2.8	2.8	2.5	2.5	4.7	5.2	5.2	4.9
Dec.	0.4	0.2	0.5	0.6	1.9	1.9	1.6	1.9	3.6	4.6	4.8	4.9

Source:(Al-Riyahi:1985).

Table 2.5 Temperatures and rain fall statistics for Baghdad

Baghdad, Iraq					
January	**February**	**March**	**April**	**May**	**June**
Dry October	Dry May	Dry September	V Dry July	V Hot V dry July	X Hot X dry July
July	**August**	**September**	**October**	**November**	**December**
X hot X dry July	X hot X dry July	X hot dry July	Warm dry July	Dry May	Dry October

X means extreme, V means very

Month	High Tf/Tc	Low Tf/Tc	P in	P m	Month	High Tf/Tc	Low Tf/Tc	P in	P m
Jan	20/-7	2/-17	.87	22	**July**	83/28	58/14	3.42	87
Feb	26/-3.3	9/-13	.83	22	**Aug**	81/27	60/16	3.29	84
March	38/3	21/-6	1.42	36	**Sept**	64/18	50/10	3.06	78
April	56/13	36/2	2.17	55	**Oct**	60/16	39/4	1.9	48
May	69/21	48/9	3.34	85	**Nov**	41/5	25/-4	1.38	35
June	79/26	58/14	4.07	103	**Dec**	27/-3	12/-11	.94	24

Tf - Average Monthly temperature, Degrees Fahrenheit
Tc - Average Monthly temperature, Degrees Celsius
P in - Average Monthly precipitation, inches
P m - Average Monthly precipitation, millimeters

Source: Meteorologists Bruce and Frank, watsonwx@aol.com

2.6 SUMMARY

Studying climatic elements and the variations of the climatic stresses through the country, and particularly in Baghdad pave the way for the research project, which will study the thermal behaviors of the mosque envelope and the impact of climate on it.

It was stated that the climate of Baghdad could be considered generally as of the hot-dry type. Its main features are the long overheated periods and the large diurnal and annual variations in temperature. Daytime high temperatures average above 34°C during the summer and often remain above 24°C at night. Afternoon relative humidity in July average anywhere from 15 percent to 25 percent in Iraq, and 17 percent in Baghdad.

The low rainfall in the Baghdad region qualifies it as a desert climate. Iraq's average rainfall is generally between four and seven inches a year. Another unique climatic feature in Iraq are the winds. Specifically, the summer months are marked by two kinds of wind; Southern and Southeasterly *Sharji* and Northwesterly *Gherbi.*

The sky is mostly cloudless and deep blue with low brightness unless dust-laden. The light reflected from the dry ground is very strong and that leaves high impact on building envelope. Sunlight is then a major problem for the architects and engineers who try to get a thermal balance for the inner environment. They have to decide when and to what extent it should be admitted or rejected.

The diagnosis of natural, geographical and climatic phenomena contribute to the architectural and constructional determinants of the building envelope in such a climate as that of Baghdad, which is a hot-dry climate, to provide the optimum thermal requirements for the human body to perform the duty of prayer under physiological and psychological standards of comfort.

CHAPTER THREE

THE BAGHDADI MOSQUE: ARCHITECTURAL AND CONSTRUCTIONAL CHARACTERISTICS AND ENVIRONMENTAL ASPECTS

3.1 INTRODUCTION

The previous chapter introduced the climatic and geographical features of the Baghdad region, which must be considered in an evaluation of the thermal behavior of the *musalla* building, to identify optimum design parameters.

All great religions establish proper places for their worship. Islam, as a great religion, has developed its own unit, the mosque. The mosque has some additional functions besides praying. Some are religious and others are secular-related-for example, meetings. It is also a religious school, a place for individual meditation and study, and a place for meetings on special occasions. The *Quran* calls it also (*masjid*), i.e. mosque:

> *"Now shall we turn thee to the Qibla that shall please. Turn then thy face in the direction of the Sacred Masjid, wherever you are turn your faces in that direction."* (The Holy *Quran, Al-Baraqa:* 144).[i]

In the era of the Prophet Muhammad, the mosque played a major role inside the Muslim community. Prayer (***Salat***) is the main function, although there is no concrete evidence about praying only in the mosque. However, mosques provide the most convenient place for performing congregational prayers. A mosque did not only function as the place for prayer (*salat*), but also had other major roles such as.

i. A social administrative center

> *'Wherever Muslims exist there are many social obligations which need to be fulfilled. Thus, the mosque function was recognized as a parliamentary body. Therefore, at the time of the Prophet, the mosque functioned as a place of political and governmental body' (Mohd Rasdi, 1998: 103-5).*

ii. An Educational Centre: The mosque taught people about survival and the positive development of the community. It was also the place where children learned about good manners, behavior, and the rituals and values of the Islamic religion.

iii. A centre to provide a foundation for the welfare of the needy people: the mosque all through Islamic history has fulfilled this role. Mosques have provided temporary shelter for poor people, students, and travelers.[2]

Table 3.1. Morphological Stages of Mosque Elements.

MORPHOLOGICAL STAGES OF MOSQUE ELEMENTS		
ORIGINAL FEATURES	**INTERMEDIATE ANNEX FEATURES**	**LATEST MODERN ANNEX FEATURES**
After 600 AD 1. *Musalla* One. Covered Area Two. Open Area 2. *Minbar* in simple form 3. *Mihrab* at rock mosque in Jerusalem) first and at Medina* mosque after that. 4. No inside & outside decoration. 5. No interior and exterior decorative surfaces. 6. Attached type related to the surroundings.	**After 700 AD** 1. Minarets. 2. Domes. 3. *Wudu'** area. 4. Arched spaces. 5. Gardens. 6. Tombs and shrines. 7. Mezzanine inside *musalla* space. 8. Space for women. 9. Staff rooms. 10. *Minbar** & *mihrab** with additional features and decorations. 11. Compact type mosque related to historical and physical forms. 12. Many types of outdoor & indoor decoration. 13. Attached type related to the surrounding's physical environment.	**After 1945 AD*** 1. Occasional hall. 2. Library. 3. Classes for Islamic studies. 4. Women's prayer spaces (separated). 5. Open (mosque in general related to urbanization treatments.) 6. Less indoor & outdoor decoration. 7. Detached type related to the surroundings.
* *Medina*: where the first mosque of Islam has been built.		
* *Wudu'* area: the area where ablution is performed.		
* *Minbar*: the place where the speaker stands while giving his sermon on Fridays and other occasions.		
* *Mihrab*: is the place where the 'Imam (the leader of prayers) stands ahead of everybody, and it indicates the direction of Mecca.		
*Mosque type appeared after Second World War in 1950 AD and became the standard for design.		

Source: Based on the conclusion of author's survey and some historical references.

iv. A centre to perform judicial function: This is the place where the public may witness the law of Islam in action and in this way; they can educate themselves about Islamic law.

v. Occasional facilities: It can, therefore, be seen in addition to being the place for worship, as a fort, and the house of the leader. Thus,

> *'it has a multifunctional facility with the purpose of organizing and developing the Muslim community in most aspects of the Islamic way of life. It is truly the symbol of the Muslim community, much more than being just a place where prayers are performed. It is the House of God, as Muslims believe' (Mohd. Rasdi, 1998: 105-106).*

3.2 MAIN ACTIVITIES OF MUSLIMS IN THE MOSQUE

The activities practiced in the mosque are the following:

i. Daily Prayers

1. *Fajr* (dawn), which is, performed one and a half hour before sunrise.

2. *Zuhr* (noon), which is performed directly after midday .

3. *'Asr* (afternoon) which is performed after the middle of the second part of the day.

4. *Maghrib* (evening), which is performed directly after sunset.

5. *'Isha'* (night) which is performed 85 minutes after sunset.

ii. Weekly and Yearly Prayers

In addition to these functions, Friday prayer is performed once a week in the afternoon instead of the *Zuhr* prayer. There are also additional prayers during *Ramadan* (the holy month in Islam). Moreover, there are the prayers of the two yearly festivals: *Eid Al-Fitr* (lesser Bairam) and *Eid Al-Adha* (greater Bairam).

3.2.1 Definition of *salat* (Prayer)

i.The obligatory *salat* (*fard*): this is performed five times daily.

ii.The optional *salat* (*sunna*): this type was added by the Prophet Muhammad (peace be upon him) and it is usually performed after and/or before the first type.

3.3 ARCHITECTURAL DESIGN GUIDELINES FOR THE MOSQUE

> *'The guidelines of the contemporary mosque design are related to its size, site, types of spaces, relationship between the spaces, and the relevance of mosque features, the design of some common architectural elements of the mosque and its architectural language or expression.*[3] *So the guidelines include both the suggested guidelines for the (musalla) and other annex spaces' (Mohd Rasdi, 1998:103, 105-6).*

3.3.1 Size

> *'There is no specific guideline, but in the architecture, there are two fundamental factors controlling the determination of the size. The first factor is related to occupancy while the second concerns the aesthetic or symbolic aspects of the building'.*
> *'It is related to the aesthetic intention –symbolizing an object – economic constraint and the visual impact of the building in its surroundings context..*
> *'Therefore, the Damascene mosque – the great mosque ('Umawi mosque in Damascus) – is very big in the Spanish city. The mosque built in the grandiose scale is an example' (Mohd Rasdi, 1998:253-5).*

3.3.2 Location

Contemporary mosques are built for symbolic purposes in addition to their original functions. The architects make use of that purpose to create a distinguished urban landmark. So the best choice is a land site, on a hill, distinguished site within the urban fabric and, usually, romantic, e.g., in the middle of a lake. On the other hand, the mosque should also be built at a site where great numbers of people are found.[4]

3.3.3 Activities and Types of Spaces of the Mosque Complex

There are four "main types" of spaces. These are listed below:

i. Prohibited Space (*musalla*): for men and women.

ii. The Specific Spaces: ablution space, teaching rooms, library, etc.

iii. The Outside Spaces: outdoor prayer area, garden, and gathering space.

iv Administrative & Service Spaces: offices, kitchen and stores.

The prohibited space (*musalla*) – the major space – is the area of the building, which has been intended by the builders, architects, and the actual patrons to constitute the mosque. The multifunctional space is important because most of the social and religious activities take place in it. The single function space, on the other hand, is for a specific function. The open spaces – which include open paved spaces, gardens, outdoor prayer area, *musalla*, and so on – are like courtyards and they are the places where many facilities are available, and where certain events can take place. In addition to the above-mentioned spaces, mosques include annexes the size of which depends on the size of the mosque and the program of the project[5](see Fig.3.2.)

3.4 THE RELATIONSHIP BETWEEN THE MAIN SPACES OF THE MOSQUE COMPLEX

For the relationship, the prayer place must be oriented towards the *qibla* (the direction of Mecca), and this space or *block* influences the distribution of all the other blocks in location. An example of this is the construction of toilets, which must face away from the direction of Mecca (*qibla*). In other words, their axis has to be perpendicular to the *qibla*. The ablution place is usually grouped together with the toilet facility and the facility for washing the dead. Other places can be located in any direction, but this usually depends on the cultural context (Mohd. Rasdi, 1998:256-7). The women's space (inside the *musalla*) should be separated from the men's space. It should be higher than that of the men. This is usually practiced in Iraq to emphasize the separation. In addition to being higher, there should be a separate entrance to the women's *musalla* place. Other facilities, such as the Islamic school and the library, need to have clear access in relation to the main entrance of the *musalla*. At the same time, the entrance (s) to the mosque can be on all the sides of the building, with the exception of the *qibla* wall to avoid distracting Muslims during prayers. All these spaces, which are closed, must have a suitable arrangement in relation to the traditional main feature, which is the courtyard, the open space. The courtyard represents the major central element, and it functions as a private space, fortress, or outdoor prayer place during the times when the climate conditions allow people to perform prayers without the need for shelter, or at times when the covered area is not large enough to support the number of people inside it.

The courtyard also includes some vegetation elements, usually small gardens in traditional Iraqi mosques. The courtyard also represents the transition space from outside the semi-closed arcade (*Iwan*) around the outside body of the *Musalla*. Finally, the courtyard represents the direct connection to the sky (Heavens).

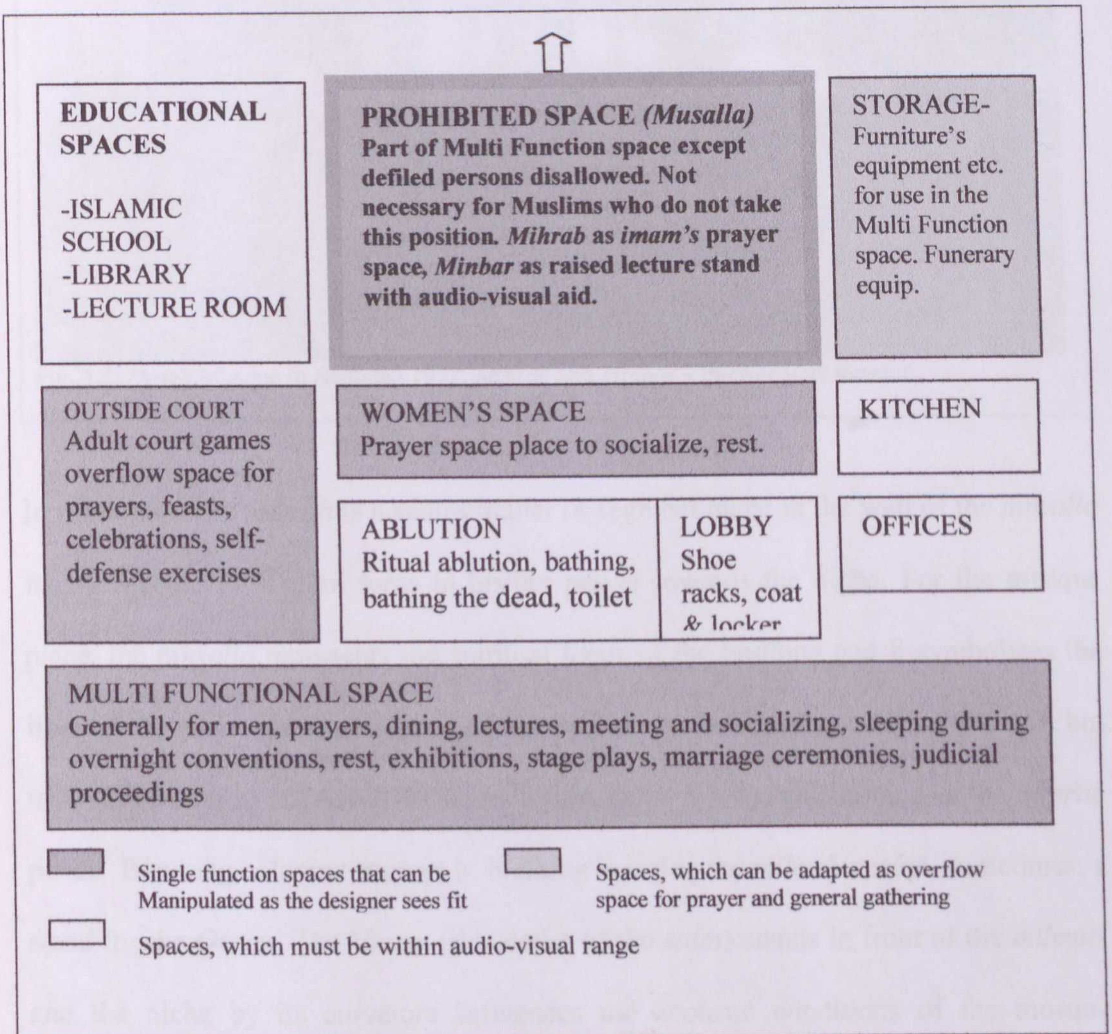


Fig.3.1.Main Spaces in the New Mosque in Baghdad. Source: Authors' survey in July 1997.

3.5 OTHER ARCHITECTURAL ELEMENTS

3.5.1 The *Mihrab*

The *mihrab*[6] is the indication of the direction of the *qibla*, and that determines the holy *Ka'ba* in Mecca (Stierlin, 1992).

The first *qibla* was *Al-Quds* (Jerusalem), which was changed, in the second year of *Hijra* (632 AD) – in accordance with the order of Allah Almighty revealed in the *Quran* – to reorient to *Ka'ba* in Mecca.


Fig. 3.2: *Dragh* Mosque in Baghdad 1957, *Mihrab* and *Minbar* – intermediate mosque.

In most cases the *mihrab* is a semi-circular or segment niche in the wall of the *musalla* facing Mecca. A Muslim turns in his/her prayer towards the niche. For the mosque place, the m*usalla* represents the spiritual focus of the building and it symbolizes the links of the *qibla*. The introduction of the *mihrab* can be stated as early as 662 AD, but more frequently in 667AH-704AD. As a rule, there is a special framing of the *mihrab* panel.[7] Blanking columns support it. Nothing is inside the *mihrab* except, sometimes, a stand for the *Quran*. The '*Imam* (the leader of the *salat*) stands in front of the *mihrab*, and the niche by its curvature influences the acoustic conditions of the mosque (Prochazka, 1988).

3.5.2 The *Minbar*

Prophet Muhammad (peace be upon him) used a low stool made of a trunk of a palm tree as a distinguished high place for the '*Imam*. This high place was later developed to be a *minbar*. In Arabic, *minbar* means a high place for the speaker. This practice of the Prophet was followed by the caliphs and later developed to a higher *minbar* with multi steps which were added by '*Amr bin Al-'As*, the governor of Egypt. In the early Islamic

Fig. 3.3 *Noori-Al-Mulla Hwaish* Mosque – Baghdad 1994.

period. Nowadays, the *minbar* is used for the purpose of the Friday sermon (*khutba*) and it is usually placed to the right of the *mihrab*. It is composed of a staircase that leads to a small platform covered by a canopy or a small domed roof.

3.5.3The Minaret

A Minaret[8] is a tower for the *Mueezin* (the man who stands and announces that it is time for a prayer). The announcement of the time for praying7 (*'aza'n*) originated at the time of the Prophet Muhammad (peace be upon him), and at that time *Bilal bin Rabah*, the famous caller for prayers, used to climb over the top of the *Ka'ba* and call for prayers. The minaret is the highest point of the mosque or the highest point of the traditional Islamic city. Nowadays, minarets are equipped with loud speakers. It still provides a traditional symbolic feature and makes a landmark. It is also a primarily decorative, symbolic or ornamental element. In all parts of the Islamic world, there is frequently more than just one minaret in a single mosque, for example, there are seven minarets in the Central Mosque in *Al-Haram* in Mecca, and the Turkish mosque, Sultan Ahmed in Istanbul, is equipped with a pair combination of up to six minarets. The highest minaret is that of *Al-Hasan's* mosque in Rabat, Morocco, which is 96 meters high,

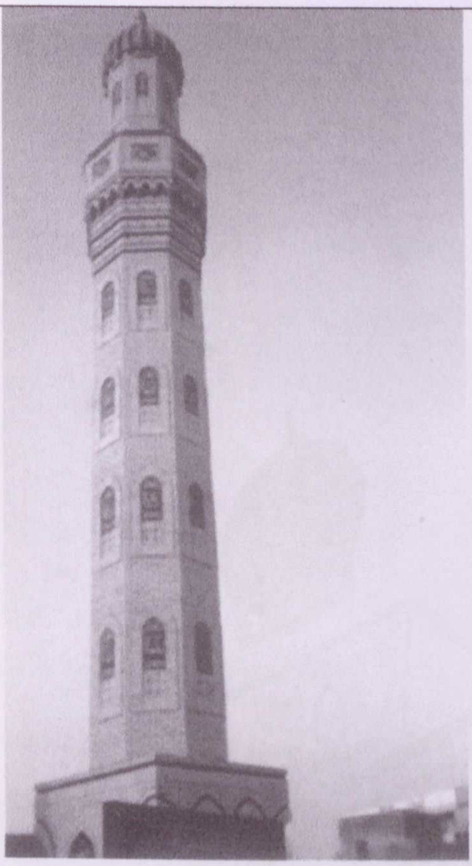


Fig.3.4 Minaret of *Al Adil* Mosque in Baghdad 2000

Fig.3.5Minaret *Rawda Al Muhamadia* Mosque1992.

for the monumental height is a matter of prestige and pride. To recapitulate, **the functions of the minaret** are:

i.As a landmark to indicate the presence of the mosque.

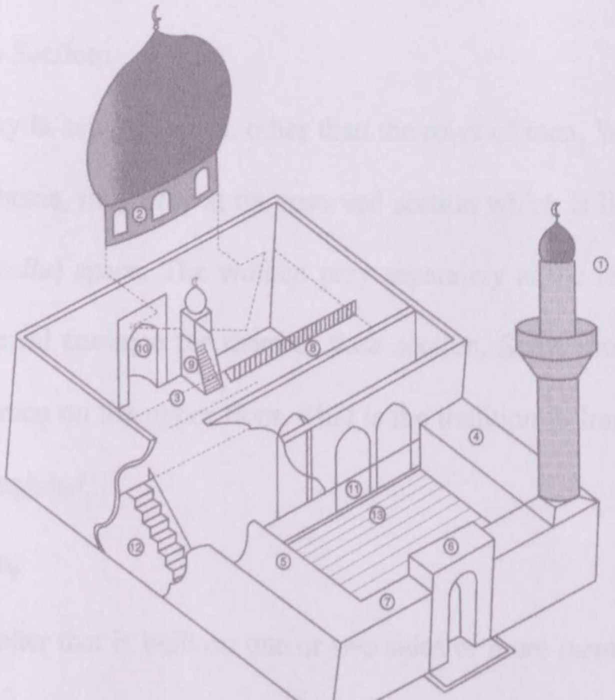
ii.To provide the highest place in the traditional Islamic city and that is to indicate the Islamic urban fabric historically.

iii.To perform the *aza'n* (the call for prayers).

iv.As a monument of Islam in any city in the world.

v.To show the power of the Caliph (historically) – at the big mosque – in the middle of the Islamic city.[9]

vi.To indicate the political symbol of the ruling patron.



1. Typical Baghdad Minaret
2. Typical Style of Baghdad Dome
3. Prohibited Space *(Musalla)*
4. Staff Rooms
5. Ablution Space
6. Entrance
7. Stores
8. Women's *Musalla,* sometimes used for *Quran* Readers at *Jumua* Prayer.
9. *Minber*
10. *Mihrab*
11. *Riwa'q*
12. Staircase Leading To Women' *Musalla*
13. Courtyard

Fig.3.6 Architectural elements of the intermediate mosque in Baghdad from 1940 to 1955AD.

* Attached type with the surroundings

*It represents the intermediate type between the traditional and contemporary type.

3.6 THE MAIN TRADITIONAL SPACES OF A MOSQUE COMPLEX

3.6.1 Prohibited Space (*Musalla*)

This space is prepared for the religious activities, and this is the main function of the mosque or the whole complex. This space is constructed using a rectangular plan or sometimes a square one, or other shapes because when Muslims stand up to perform their prayers they form rows, just like those formed by soldiers, which shows the concept of equality in Islam (Mohd. Rasdi, 1998:257-8).

3.6.2 Women's Section:

The women pray in separate rows, other than the rows of men. When they, the women, do not pray at home, they pray at the reserved section which is like a gallery inside the prohibited (*musalla*) space. The women pray separately at the rear of the mosque and they have a special entrance for them to their section. Some mosques have a separate *musalla* for women on the upper floor. That is the tradition in Iraqi mosques, especially those built in Baghdad.

3.6.3 *Al Riwaq*

The exterior shelter that is built on one or two sides or more (semi-closed space), which served as a praying, place and for Muslim community gathering is known *iwan* or *Riwaq*. It is also used as a *musalla* or, more accurately, *Riwaq al-qibla* (arcade area). It is the main type in historical Islamic mosques that can be seen in the earliest congregational mosques. The courtyard was inside the surroundings walls of the *Riwaq*. The *Riwaq's* arcade rows and aisles are recorded to be erected parallel to the *mihrab* wall, perpendicular to it, or even in some combination. If the arcade row is directed towards the *mihrab* wall, it differs from the other (side and rear) *Riwaqs*. As a result, side *Riwaqs* are omitted in those cases.[10]

Fig. 3.7 *Noori M.Hwaish. Mosque 1994-Mezannine as Women's Musalla.*

Fig. 3.8 *Al Khudairi* M. Entrance Baghdad 1982

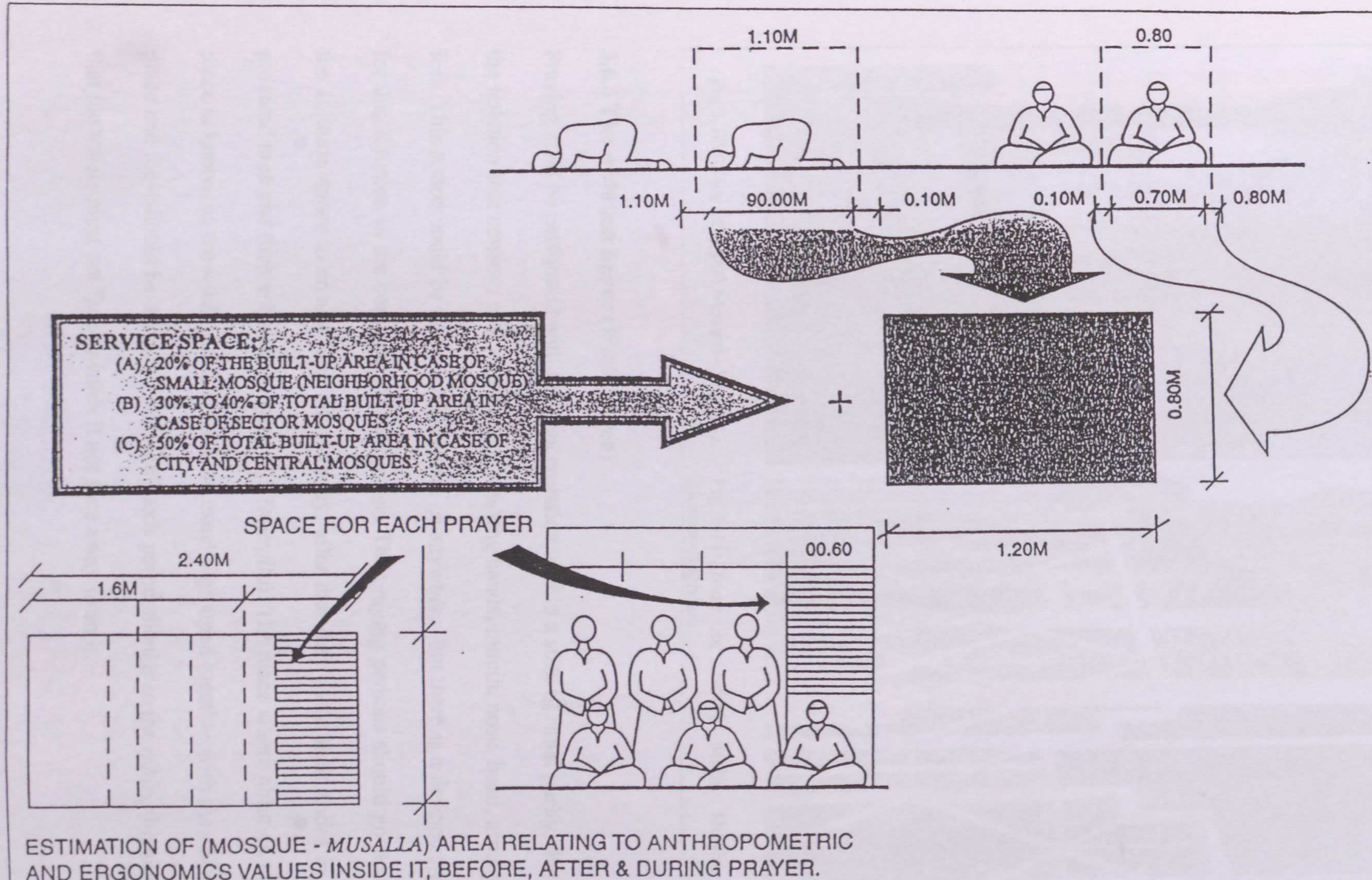


Fig.3.9 The main activities inside the mosque.

Fig.3-10:*Riwaq* of *Draqh* Mosque –Baghdad.

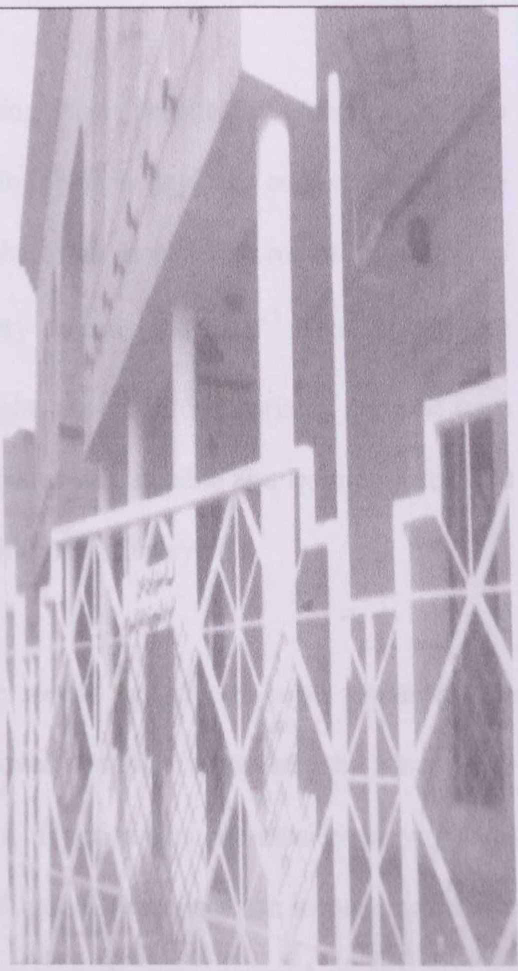


Fig..3-11:*Riwaq* of Noori Mulla Hwaish Mosque-Baghdad.

3.6.4 The Ablution Space (*Wudu'* Area)

Praying must be performed with full concentration, and in a state of ritual purity, that is, the ablution that consists of a sequence of washing hands, mouth, nose, head, arms and feet. This action could be performed at home or anywhere, but there is a defined space for this function in the complex of the mosque. The praying persons should go first to the ablution space to ensure their ritual purity, after that they place their shoes in the provided area and then enter the praying hall (*musalla*). The place where ablution takes place is known as the *wudu'* area. Toilets are usually grouped together with the ablution place and they should be designed with their axis perpendicular to the *qibla*, this means that the toilets must not face towards it nor face away from it.

3.6.5 Islamic Teaching Space (*Madrasa*)

The mosque has kept the function of teaching Islam despite the numerous modern contemporary schools – religious or secular. In the early days, the contact between the *madrasa* and the Muslims was well established, but in separate rooms or a defined space. The mosque also provided the primary school (*kuttab*).[11] This is the place where children from the age of four are taught, especially memorizing *Quranic* texts inside the *musalla*. The environment of the mosque was suitable as a learning place, and it was usually provided with a small or, sometimes, big library.

3.6.6 Other Activities and Spaces

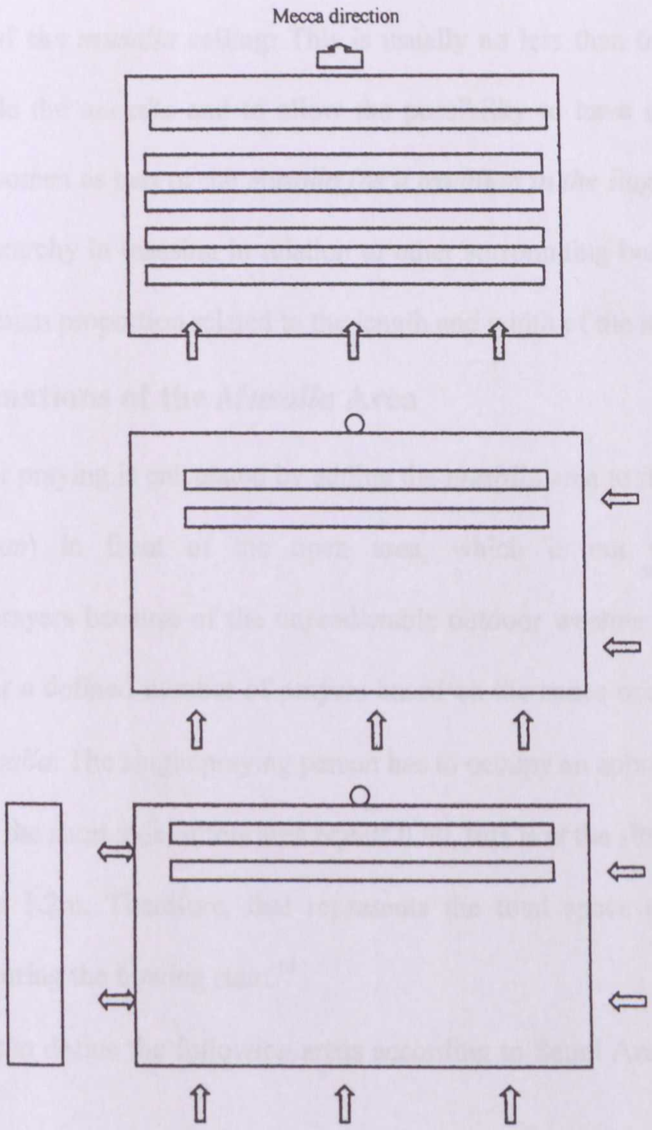
There are other annexed spaces such as the rooms for officers, who administer the facilities inside the mosque. In addition, the paved courtyard surrounded by the arcade – colonnade passage can be structured and it functions as an outside praying area (*musalla*) as well as an outdoor space for celebration. This space can include a garden to encourage Muslims to pass their leisure time at the mosque and to enhance the microclimate inside the complex especially in a hot-dry climate (we can notice this feature especially in the traditional mosques built in Baghdad).'

> *'We can find also a small kitchen, which can be considered, as an important space for food preparation for the many social functions and celebrations in addition to stores for keeping the furniture' (Mohd Rasdi, 1998:225-9).*

3.7 ARCHITECTURAL FUNDAMENTALS OF THE *MUSALLA* BUILDING

i. *Musalla* Orientation: This is the main factor in the architectural design. It is also the main aim to be achieved in the *musalla* and because the entrance to the mosque is accompanied by the feeling of the direction to Mecca where the prayers are oriented. It is the main factor in terms of climatic consideration also.

ii. Entrances: The entrances of the *musalla* are mostly placed on the front wall, which faces the direction to Mecca. Entrances to the mosque can be found on all sides of the building.[12]



1. The Situation of *Musalla* doors-usually-on the walls which are parallel to the *Qibla* wall to let the praying persons rows complete one by one without interference between praying persons activities and the walking persons flow through the doors.
2.At the bigger *Musalla* space, we can add side doors to facilitate flow after finishing prayer during peak time particularly.
3.Sometimes there is a need for attached rooms to the *Musalla*, so we have to use one of the side door corridors between the *Musalla* and the rooms.
Source; Al-Umary, 1988:2,3.

Fig.3.12. Locations of *Musalla* access. Source: Author survey, July 1997.

iii. Windows: These are usually situated above or below eye level to prevent the visual impact on the solemnity of the prayer.

iv. The height of the *musalla* ceiling: This is usually no less than 6m to give a holy atmosphere inside the *musalla* and to allow the possibility to have a mezzanine as a prayer area for women as part of the *musalla* (*as a tradition in the Baghdadi mosque*).[13] Also to get a hierarchy in massing in relation to other surrounding buildings and to get the visually optimum proportion related to the length and width of the *musalla*.

3.7.1 Determinations of the *Musalla* Area

The area used for praying is calculated by adding the *musalla* area to the colonnade area (arcade area-*Iwan*) in front of the open area, which is not always used for congregational prayers because of the unpredictable outdoor weather in general. Thus, the mosque is for a defined number of prayers based on the space occupied by a single prayer in the *musalla*. The single praying person has to occupy an approximate area of 1.00 liner meter; the short side of this area equals 0.80, this is at the sitting state, and the long side equals 1.2m. Therefore, that represents the total space occupied by each praying person during the bowing state.[14]

In addition, we can define the following areas according to Saudi Arabian Standards as follows:

i.Mosque for 200 praying persons = 240 sq.m.[15]

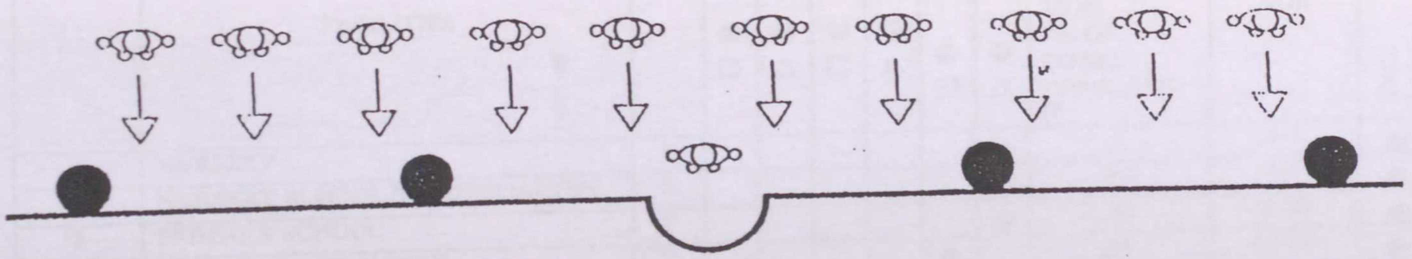
ii. Mosque for 500 praying persons = 650 to 700 sq.m.(see fig 3.9).

iii.In the case of the existence of an open *musalla*-half of its area is added to the original *musalla* building .

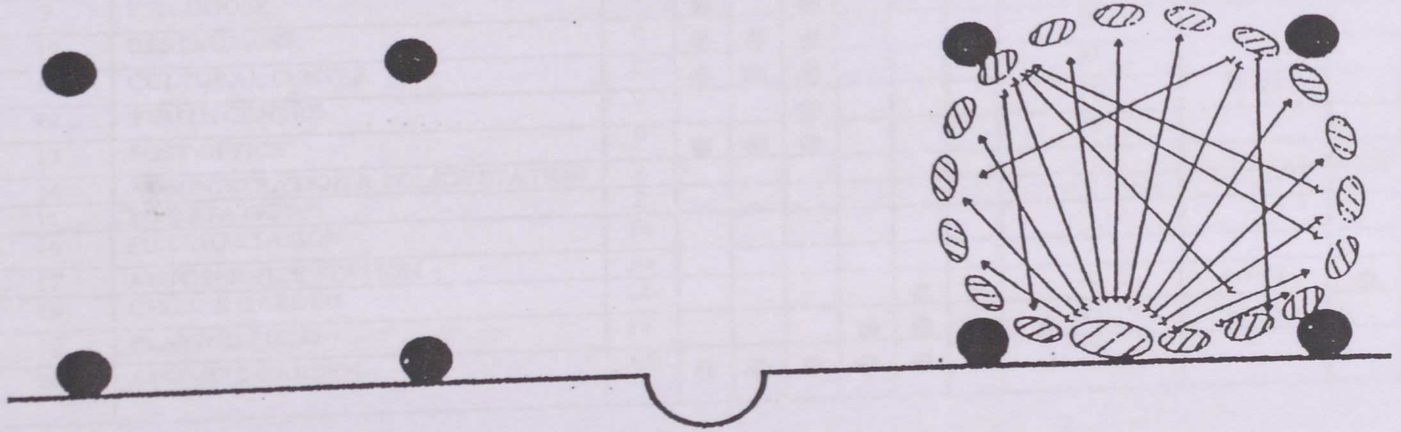
It is assumed that there is parking area of 25 sq.m. for every 15 praying persons.

3.7.2 Other Characteristics of the *Musalla* Building

Architectural space must aid the Muslim to have a sense of solemnity and it should not confuse his thinking or take the praying person's mind away from its main aim.



A-Congregational Prayer Inside the *Musalla*-Rows behind, the guide in the Prayer (*Imam*)



B-Teaching Cluster Before or After Prayer as Tradition, Inside the *Musalla*

Fig.3-13 : The activities inside the *musalla*

No	FACILITIES		USE OF FACILITY BY MEMBERS OF FAMILY: ● □	● △	◒ □	◒ △	◒ □	◒ △	PARTICIPATION / % OF TOTAL POPULATION	AGE	FREQUENCY: ONCE DAILY	3 TIMES A WEEK	ONCE A WEEK	ONCE EVERY
1	NURSERY	N						●	4	0-3	●			
2	NURSERY SCHOOL (KINDERGARTEN)	K						●	2.5	4-6	●			
3	PRIMARY SCHOOL	P						●	20	6-12	●			
4	INTERMEDIATE SCHOOL	I					●		14	12-18	●			
5	SECONDARY SCHOOL	S			●	●			14	12-18	●			
6	HEALTH CENTRE	H	●	●	●	●			100	-				
7	MARKET (SUQ)	S	●	●	●	●	●	●	75	-		●		
8	MOSQUE	M	●	●	●	●	●		33	-	○		●	
9	TEA-HOUSE	T	●		●				33	-		●		
10	RESTAURANT	R	●	●	●				50	-		●		
11	CULTURAL CENTRE	C	●	●	●				33	-			●	
12	YOUTH CENTRE	Y			●				25	12-25		●		
13	POST OFFICE	P	●	●	●				33	-				●
14	ADMINISTRATION & POLICE STATION	A							-	-				
15	FIRE STATION	F							-	-				
16	FILLING STATION	Fs							-	-			●	
17	AUTOSERVICE STATION	As							-	-				
18	CHILD'S GARDEN	CG					●	●	25	1.5-12	●			
19	PLAYING FIELD	PF				●	●		25	12-18		●		
20	AMEMITS GARDEN	AG	●	●	●	●	●	●	75	-			●	

1. ● □ Father 2. ● △ Mother 3. ◒ □ Young son 4. ◒ △ Young daughter 5. ◒ □ Small boy 6. ◒ △ Ssmall girl

Fig.3-14a Community facilities in the new Baghdadi sectors & the need of mosque. This survey was carried out in 1977.It is likely that the population has increased and the need and use frequency changed. Source: General Housing Program for Iraq Report by Polservice Company-Poland and Dar Al-Imarah Consultant-Iraq,1977-4-11.

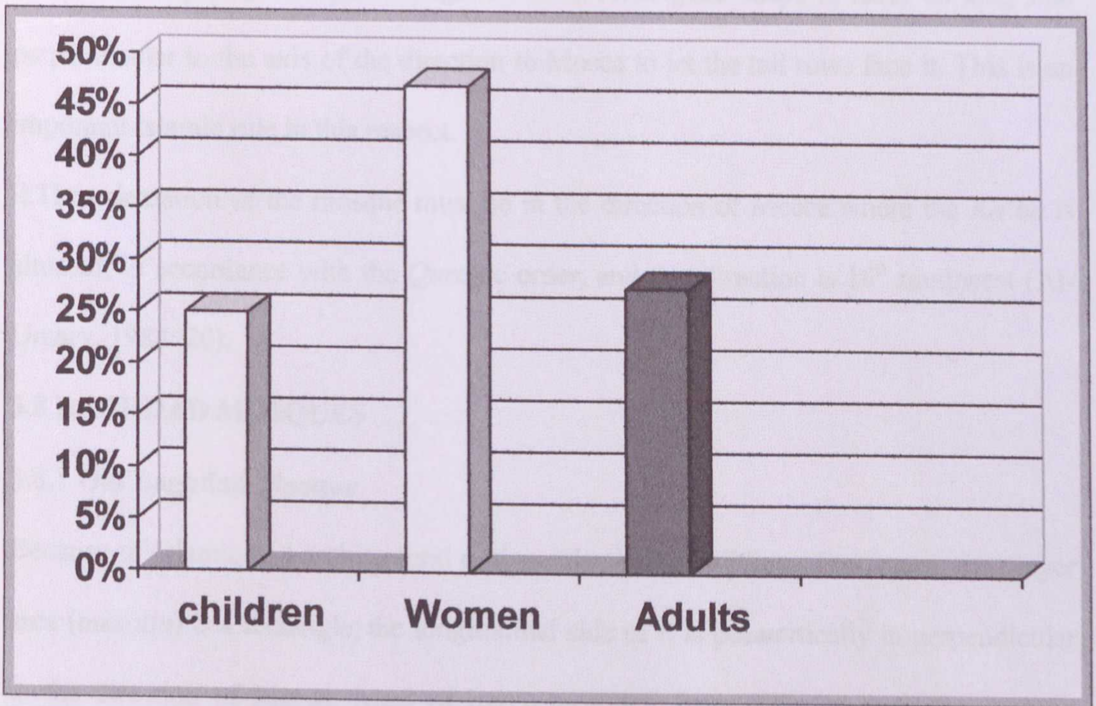


Fig.3-14 Standard classification of population with regards to the prayer duty in Islamic teachings. According to this diagram which reflects the Islamic teachings ,the prayer duty in the mosque is compulsory for 27.5?% of the total Baghdad (Friday prayer-*Jumua* prayer)since the Islamic teachings exempt children of less than eight years and encourage women to pray at home ,so the congregational prayers duty in the mosque just includes adults.,Source:(Al-Umary;1988).

Fig..3-15 *AlKhudairi* Mosque Baghdad 1982.

Fig..3-16a *Bunia* Mosque Baghdad 1971.

i. The contemporary mosque in Baghdad has a rectangular shape to leave its long side perpendicular to the axis of the direction to Mecca to let the tall rows face it. This is an important Islamic rule in this respect.

ii.The orientation of the mosque must be in the direction of Mecca where the *Ka'ba* is situated, in accordance with the *Quranic* order, and this direction is 10° southwest (Al-Umary, 1988: 20).

3.8 BAGHDAD MOSQUES

3.8.1 Old Baghdad Mosque

Because of Islamic and architectural design rules in the building of mosques, the prayer area (*musalla*) is a rectangle; the longitudinal side of it is put vertically in perpendicular to the direction of Mecca. Most of Iraq's mosques, from different periods, are built using traditional constructions: bearing walls are generally 0.80-1.20 m thick (sometimes thicker), using cross vaults and huge arches to support wide roofing spans, and using a domed roof to cover the large spaces. The old mosques are normally attached to the surroundings with small-defined openings to them as in *Al-Muradiyya* Mosque (from the *Saljuq* period) and *Al-Haydarkhana* Mosque (from the *Jalaired* period) in Baghdad.[16] Some of them include outdoor *musalla* for *fajr* (dawn), *maghrib* (evening) and '*isha'* (night) prayers in summer time, which is the hot-dry season in Baghdad.

3.8.2 Modern Baghdad Mosque[17]

As in other cities, Iraqi cities are affected by new planning approaches that have been applied to most of them over the last fifty years. Due to the demands of modern city life, wide streets for vehicles, multi-storey buildings, and other urban facilities have been built. The external surfaces of these large individual buildings are affected by solar radiation. There is little consideration for environmental impact and the use of suitable materials with good thermal specifications, indirect contrast to the thermal isolating considerations of the traditional mosque in Baghdad. Dependence on (HVAC) system has led architects to change from the old approach to the modern one, i.e., wide openings to the surroundings, and unsuitable materials in relation to the special climate of Baghdad.

Some observable features of the new mosques are as follows:

i. 25% of the new mosques do not have outdoor *musalla* (prayer area) and the garden usually takes its place.[18]

ii. Lack of the clear access as an approach found in the traditional mosque's planning and design.

iii. No unified approach to massing on the site resulting in a lack of visual clarity and clear hierarchy.

iv. Lack of self-shading between elements, increasing solar radiation and reducing the efficiency of the envelope is thermal exchange between the outside and inside environment.

v. The appearance of international style affects modern buildings and mosques especially, for example, in the sizes of openings in the new *musalla* building using materials without an understanding of a particular environment.

vi. The use of a thin envelope that has low thermal capacity and high thermal conductivity that causes a reduction in the efficiency of the thermal balance of the modern mosque.

3.8.3 Standard Components of New Mosques in Baghdad[19]

Baghdad has more than 85 mosques, and others are added yearly.[20] In spite of this, research is underway to build one of the biggest mosques in the world in the historical centre of Baghdad, in addition to many other mosque projects, which have been started or are under construction in many states in Iraq. The original purpose of the mosque space, which is directed to Mecca, is to allow worshippers to perform prayers. The first mosque in Islam, which the Prophet Muhammad (peace be upon him) built in *Al-Madina Al-Munawwara*, was simple in its form of composition. Due to an increase in the mosque's functions over a long period, many additional spaces were annexed to it. The latest modern mosques include the following spaces:[21]

i. *Musalla* or Prohibited Space:

The obligation of the adult Muslim is to perform prayers five times daily and, if possible, together with other Muslims in the mosque. This is the area determined for prayers. It is the main space in the mosque's complex. It has a defined voluminous character and other features such as the dome and *mihrab* (to the direction of Mecca). Yet, the main characteristic of this space is its orientation towards the *Ka'ba* in Mecca, 10 degrees southwest.[22]

ii. Occasions Hall: This is the second in importance in the mosque complex. It is used for multipurpose religious occasional facilities.

iii. Classes and Library: These are used for Islamic studies and cultural services for the Muslim community.

iv. Offices / Staff Rooms: the officers use these as well as *Imam* (the prayer leader).

v. Washing Area (Ablution Space): This is the *wudu'* area which is used for washing before prayers.

vi. Minaret (s): This is the symbolic highest landmark of the mosque complex. It was used for calling for prayer in the ancient period.

***vii. Imam's* House.**

viii. Stores with other annexes like the kitchen, pantry and Parking Lot.

Fig.3.17 *Alshahid* Mosque in Baghdad. New Mosque as an isolated building, that exposes it to Environmental impact

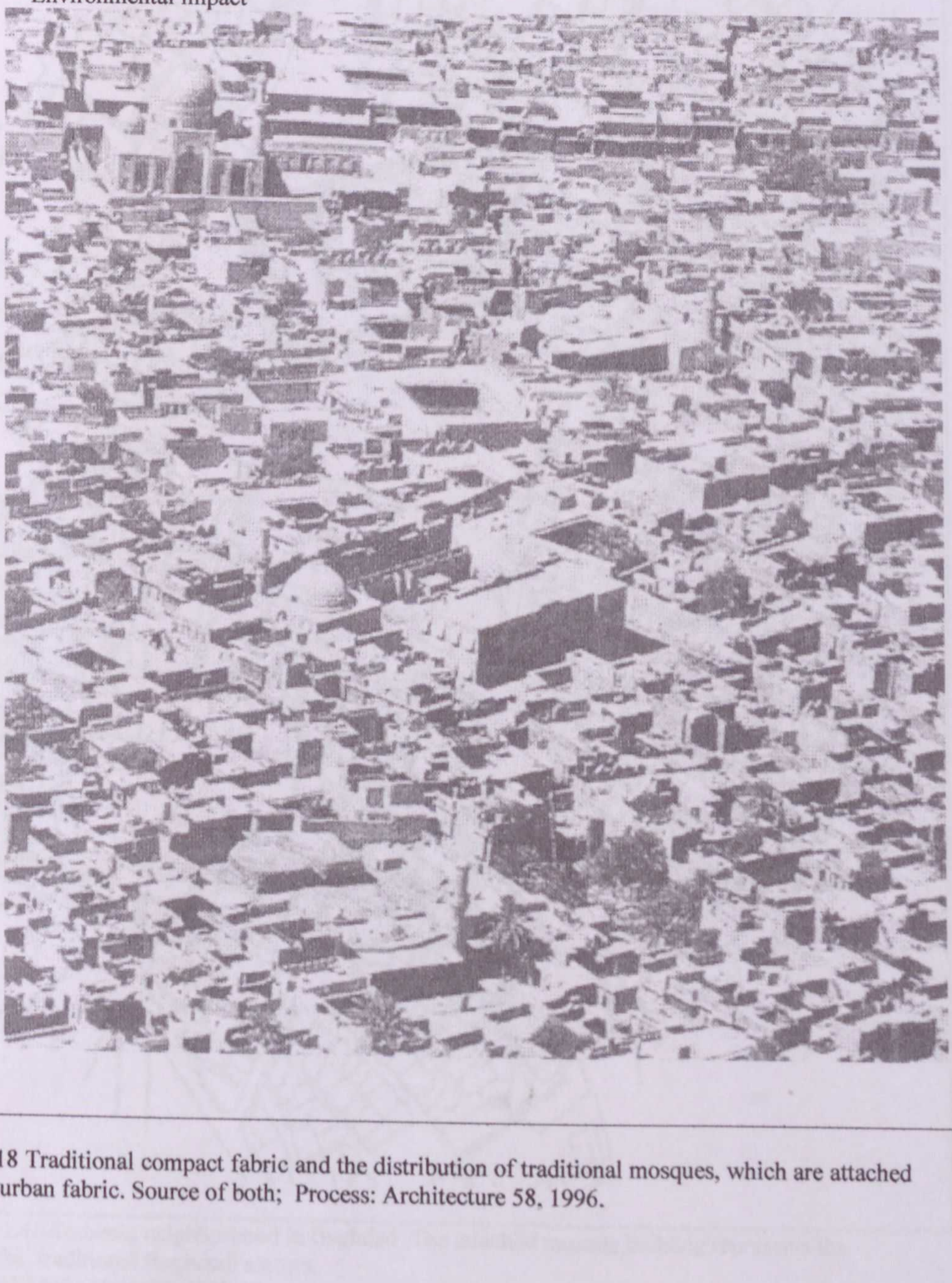


Fig.3-18 Traditional compact fabric and the distribution of traditional mosques, which are attached to the urban fabric. Source of both; Process: Architecture 58, 1996.

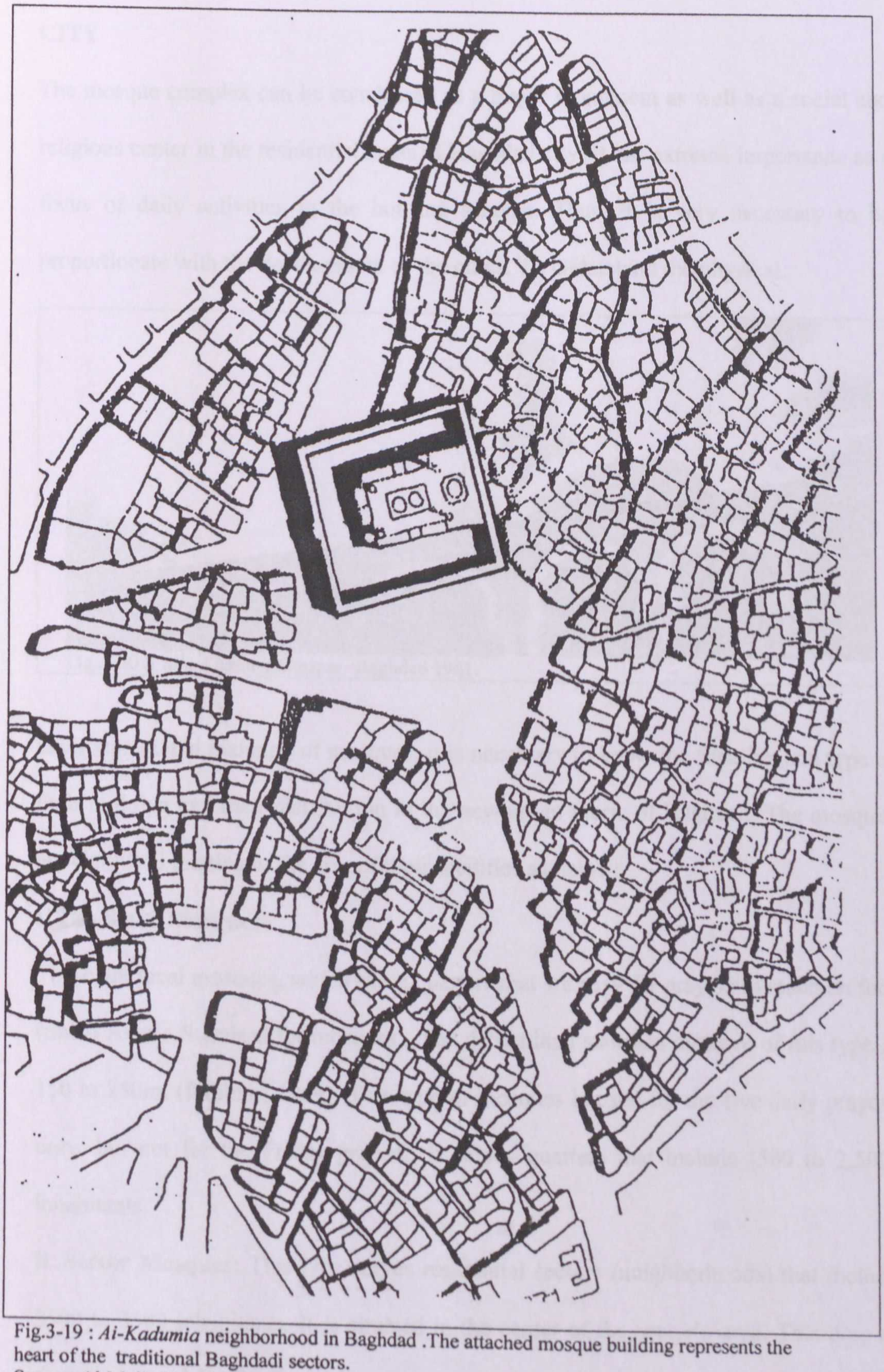


Fig.3-19 : *Ai-Kadumia* neighborhood in Baghdad .The attached mosque building represents the heart of the traditional Baghdadi sectors.
Source: Al-Mulla Huwaish;1989;19.

3.9 PLANNING FOR THE DISTRIBUTION OF MOSQUE BUILDINGS IN THE CITY

The mosque complex can be considered as a major monument as well as a social and religious center in the residential areas of Baghdad city. It has extreme importance as a focus of daily activities in the housing scheme. Thus, it is very necessary to be proportionate with the development of the cities. To understand the physical

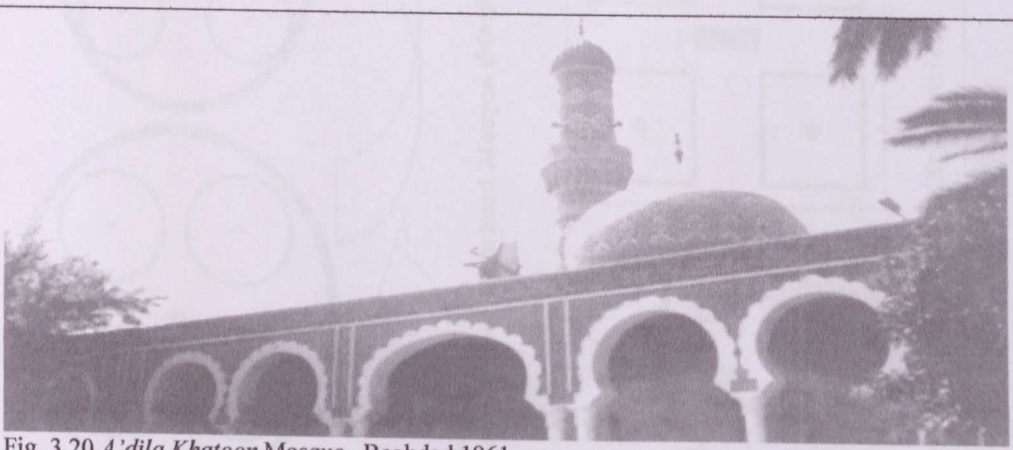


Fig..3.20 *A'dila Khatoon* Mosque –Baghdad 1961.

environment and planning of mosques, it is necessary to know the function and type of their building and their distribution in the new urban fabric of Baghdad. The mosques are classified relating to the size of their facilities as below;

i. The Small Mosques

These are local mosques, which serve quarters that are easy for prayers to reach on foot (Saudi Arabia Standard for mosques). The determined standard distance of this type is 150 to 250m, (Ibrahim, 1969). This type of mosques is used for the five daily prayers only, but not for the Friday prayers. It serves quarters that include (500 to 2,500) inhabitants.

ii. Sector Mosques; This type serves residential sectors (neighborhoods) that include 2500 to 3500 inhabitants. It is situated in the center of the sector's area. This type of mosque is used for the five daily prayers as well as the Friday prayers (Saudi Arabian Standard for mosques). This standard determines that the distance to reach.

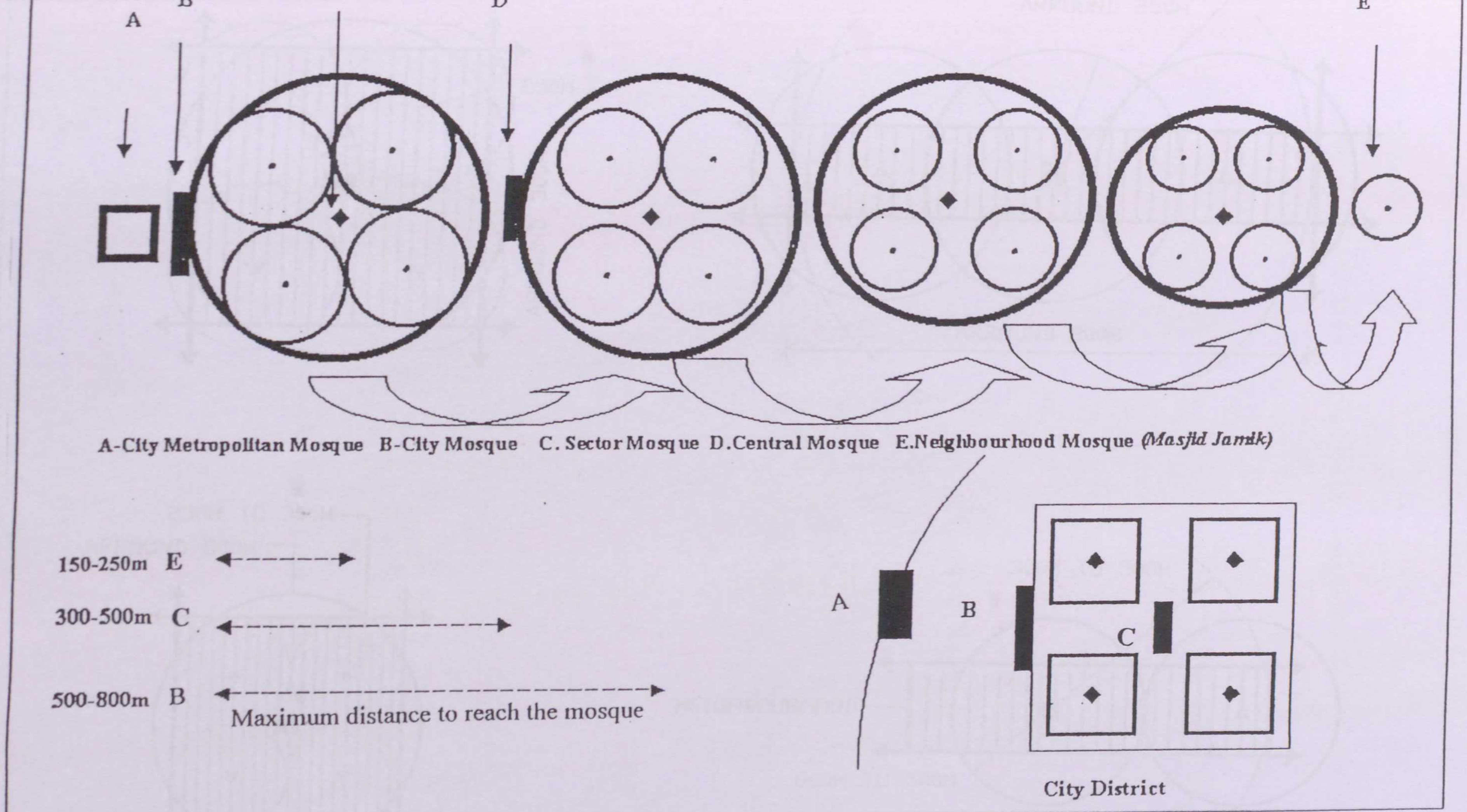


Fig.3.20a Concept of Planning strategy for mosque complex distribution in the urban districts of Baghdad derived from Author's survey.

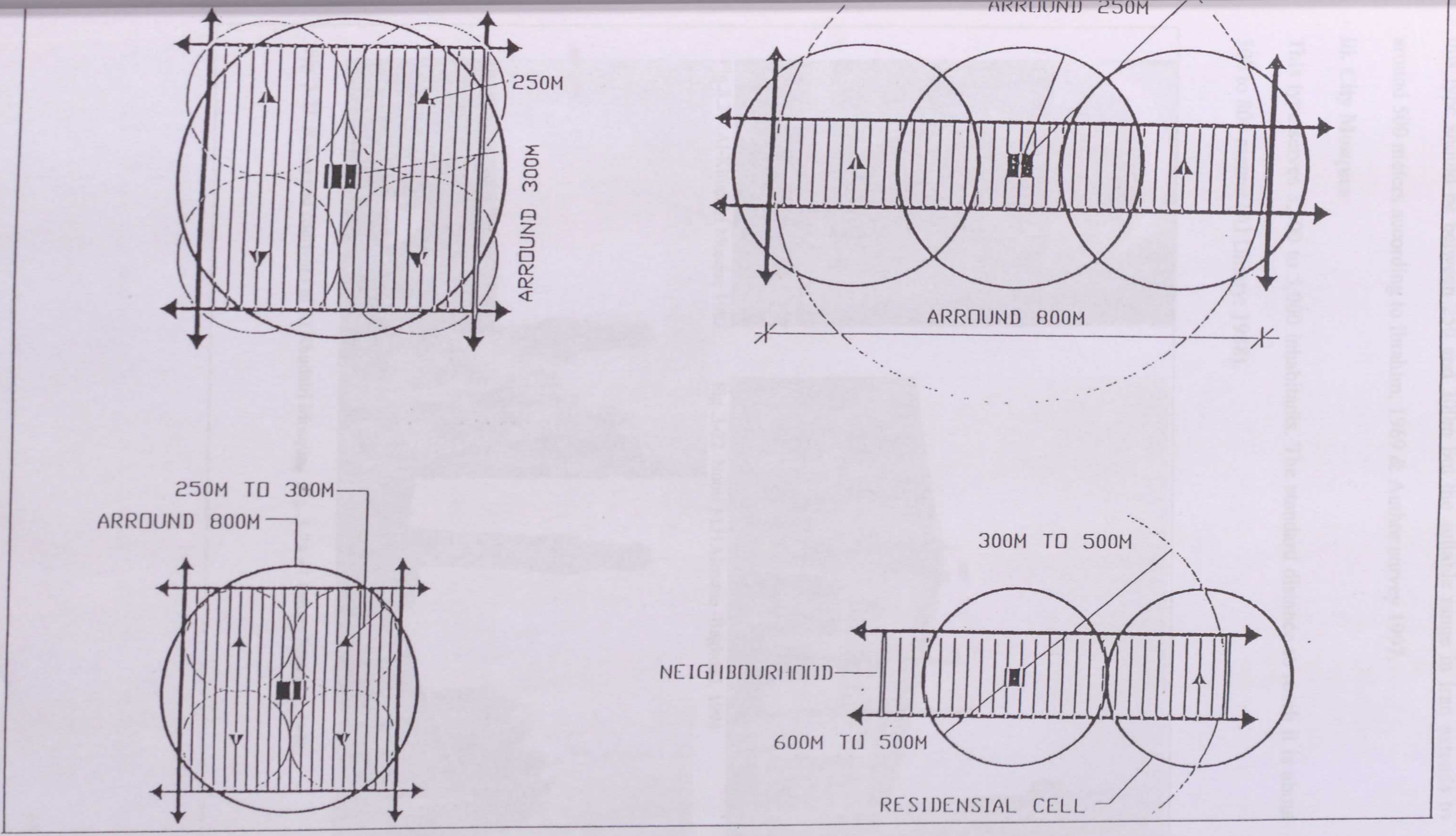


Fig.3.20b Mosque Buildings Distribution in the Residential Sectors obtained from Authors' survey.

this type should be between 250 and 300m but the suitable range in Iraq extends to around 500 meters according to Ibrahim, 1969 & Author survey 1997.

iii. City Mosques

This type serves 3,500 to 5,000 inhabitants. The standard distance to reach it is about 500 to 800 meters (Al Umary: 1988).

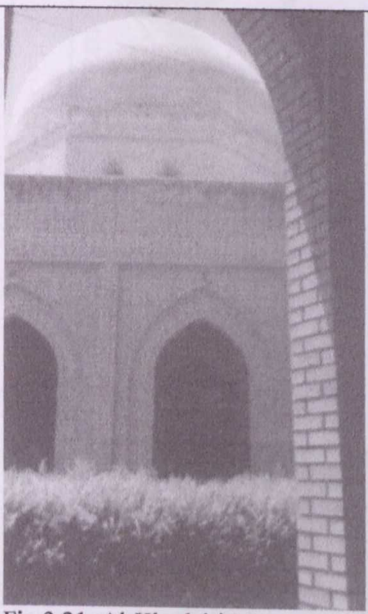


Fig.3.21.:Al-Khudairi Mosque 1982.

Fig..3-22 Noori M.H.Mosque.-Baghdad, 1994

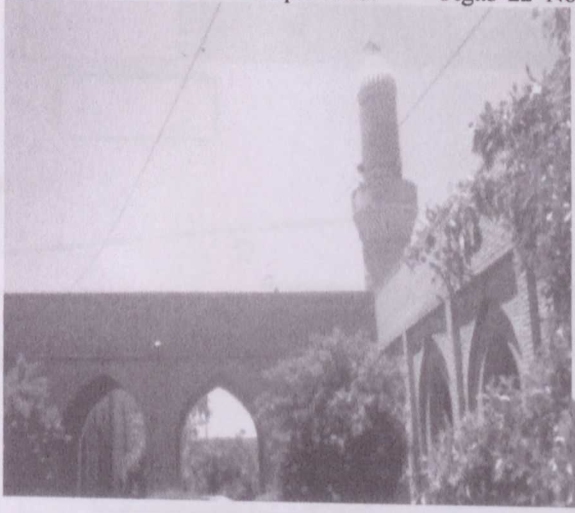
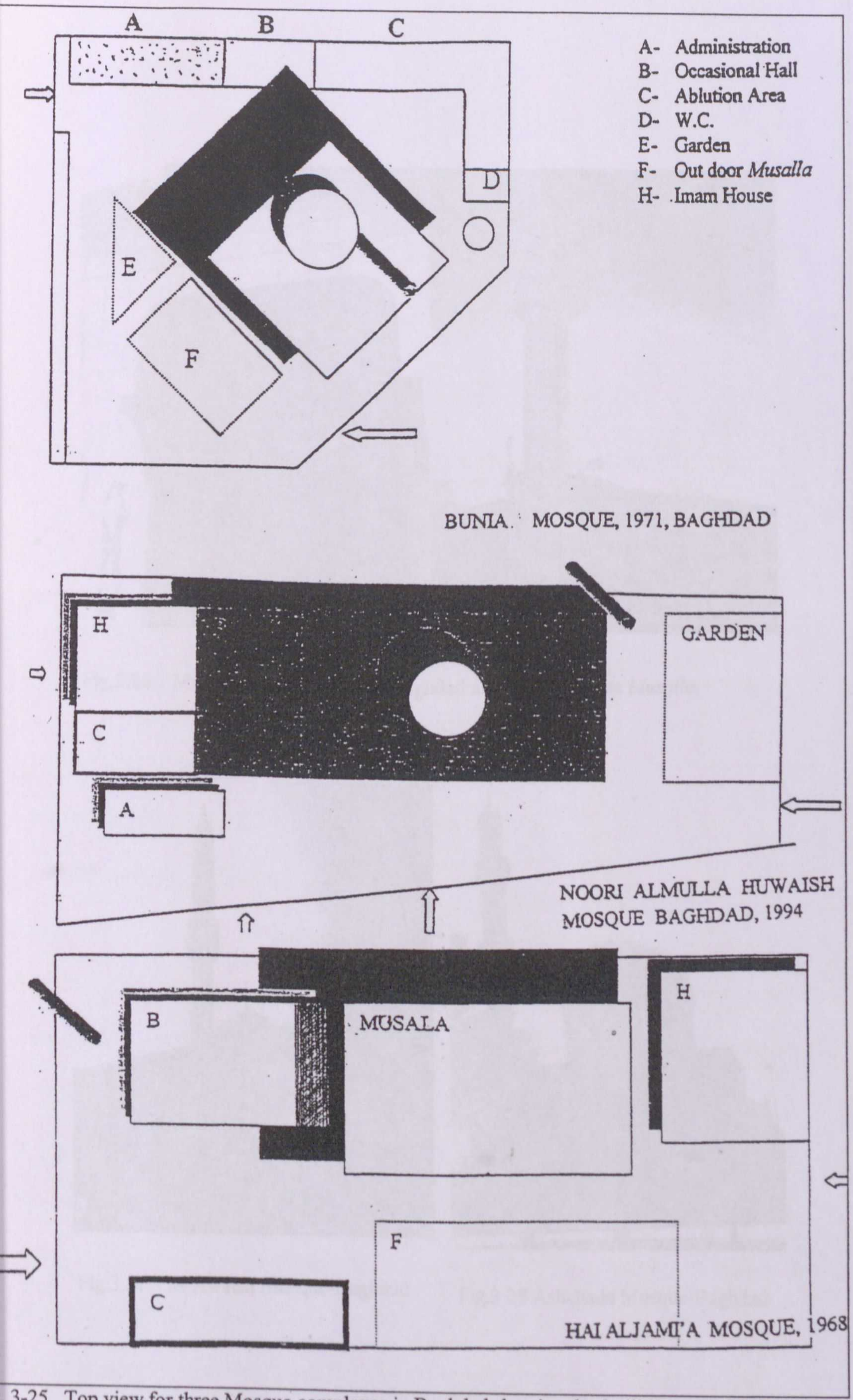


Fig. 3-23 *Riwaq* and courtyard of Al Khudairi Mosque.

Fig..3-24 Al-Umary Mosque , 1977.



. 3-25 . Top view for three Mosque complexes in Baghdad showing the facilities, main blocks and the layout of planning . Source:Author's survey,July 1997.

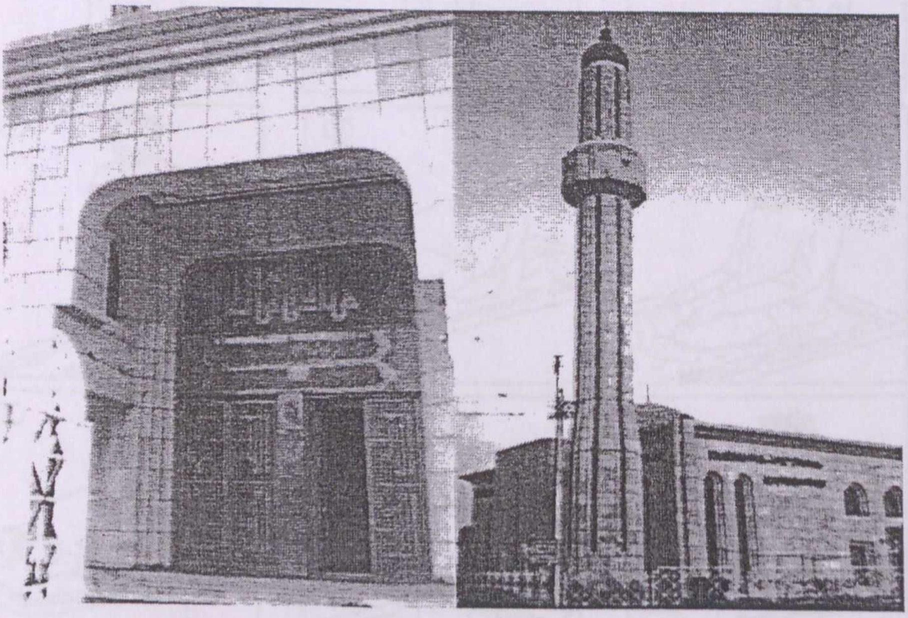


Fig.3.26. Mulla.Hwaish Mosque in Baghdad and the Gate of its *Musalla*.

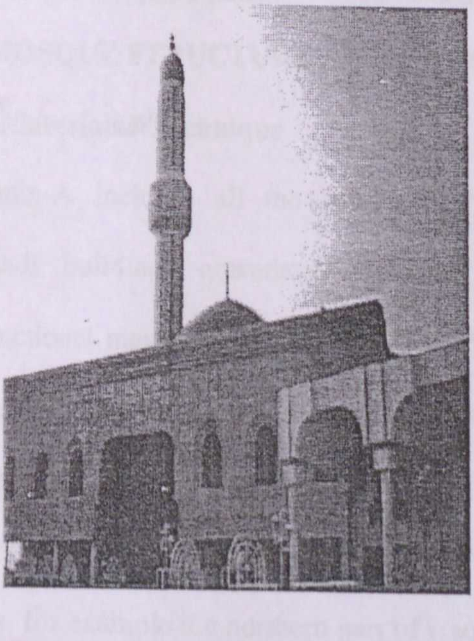


Fig.3.27. M Hwaish Mosque-Baghdad

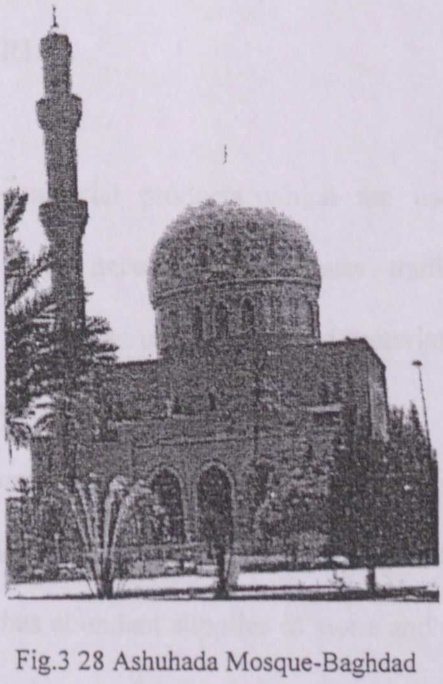


Fig.3 28 Ashuhada Mosque-Baghdad

Fig.3.29 The rites of prayer *(salat)*. Source:Rasdi;1998.

3.10 MOSQUE STRUCTURE AND MATERIAL

3.10.1Materials&Technique

Appendix-A includes all the contemporary material products which are used in Baghdadi buildings nowadays. However, it is necessary to discuss traditional constructional materials, which are still used as well as other developed materials that are reused because of their suitability to the Baghdad environment. 23

In Iraq, both the type of materials and the climate play decisive roles in determining the form of local monuments. Various building materials are to be found in different parts of Iraq, for example the northern part of Iraq has abundant supplies of stone and wood. The type of building materials available in each part of Iraq also decides the type of architecture. In the central (Baghdad region) and southern part of Iraq, the lack of wood and stone makes brick architecture inevitable. But it seems that brick is preferred even in districts where stone is available. This is because it is cheaper than wood and stone and is more flexible than either of them, especially for building vaults and domes. The building of all previous historical periods employs the following building materials.

3.10.2 Bricks

Bricks are widely used in modern and traditional built environment components in Baghdad. The traditional Islamic monuments in Baghdad show that stone was not as popular as bricks. Its use was confined to the northern part of Iraq, and thus one may see stonework in this part (northern) and brickwork in the center (Baghdad region) and southern Iraq where brick is readily available. Brick has also been the principal source of variations in color resulting from different degrees of firing and this is a noticeable feature of the bricks of all periods. Also it is used in many ways to create inside and outside patterned surfaces, (see Fig. 3.31 and Table 3.2).

3.10.3 Other Materials and Building Process

Before the 1950's, the use of timber in roofing is puzzling. It merely begs the question to propose that builders and users were satisfied with the results and so continued to use what was obviously an impermanent material in defiance of good sense. Timber has its advantages in being a swift, inexpensive method of construction. In addition, it has some further advantages, for example in providing warmth especially on the cold winter nights of Baghdad where sunshade is vertical on the roof (high thermal capacity and high time lag). The financially motivated influence of German technology reached out eastwards through the Ottoman Empire, bringing with it a new method of construction called Jack-Arching for constructing a solid roof by using a combination of brick and iron. Paralleled steel joists (often a simple length of rail) pitched at about 90cm filled with low segmental brick vaults and produced a solid platform with longer spans free from the danger of collapse which was inevitable when termites had penetrated a wooden structure. The mortar used was gypsum (*Juss*), which set quickly like plaster of

Paris, so that the mason could hold the brick in position until it set. After the 1950's, reinforced concrete roofing and skeleton structures were introduced which became commonly used in Mosque construction in Baghdad.

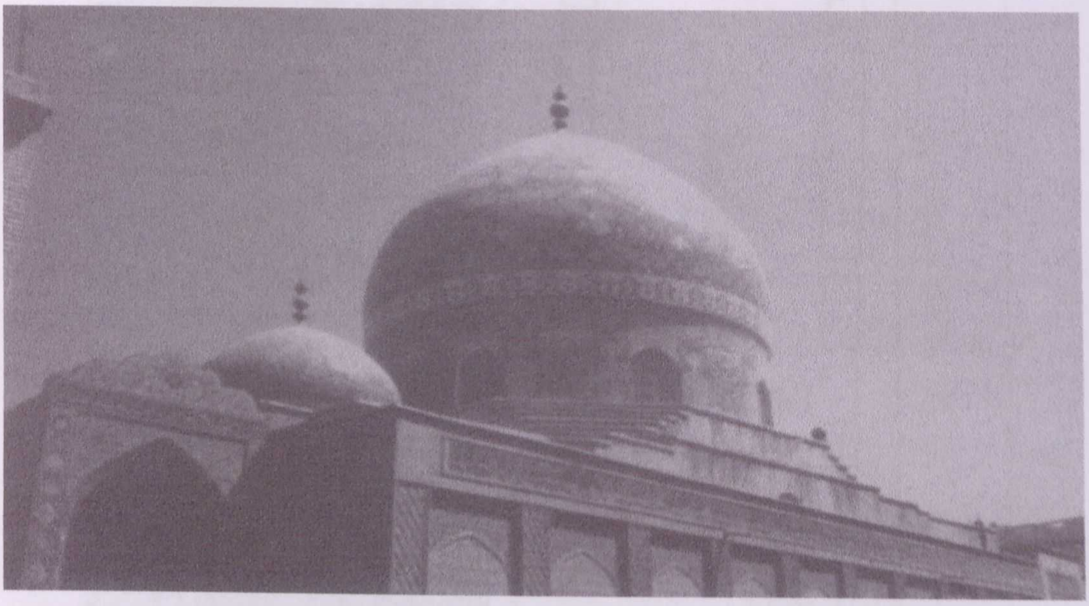


Fig.3.30: *Al-Hydar Khana* Mosque; One of the famous traditional Mosques in Baghdad.

Table (3.2): The main types of materials, which were used in traditional mosques in Baghdad during the mentioned periods.

Name of mosque	Period	Brick specification
Al-Khaffafin (eastern Baghdad)	*Atabikid*	24x24x5cm
Al-Qumriyya (western Baghdad)	Later Abbasid	22x22x5 & 23x23x5cm
Al-Khulafa' (*Suq Al-Ghazl*, eastern Baghdad)	Later Abbasid	20x20x5 & 23x23x5cm
Al-Madrasa Al-Murjaniyya Mosque (eastern Baghdad)	*Illikhanid*	22x22x5cm,26x26x5cm & 22x22x7.7cm
All mosques in this period	*Jalairid*	22x22x7.5cm, 15x15x4cm, 21x21x6cm,25x25x6cm, 27x27x7.5cm, 18.5x18.5x4.5cm,& 19x19x5.5cm

Types of mortar:
Nora: local material used especially in built foundations (lime-cao).
Juss: used in all stages of the building, except the foundations.
Mud: used for building walls, roofs, and external finishing.
Nora + *juss*: used for roof, interior, and exterior finishes.
Timber in Cylindrical section: for columns and roofing system, 0.20 to 0.30 m, diameter normally for each member.
6. Source: Al-Janabi; 1984.

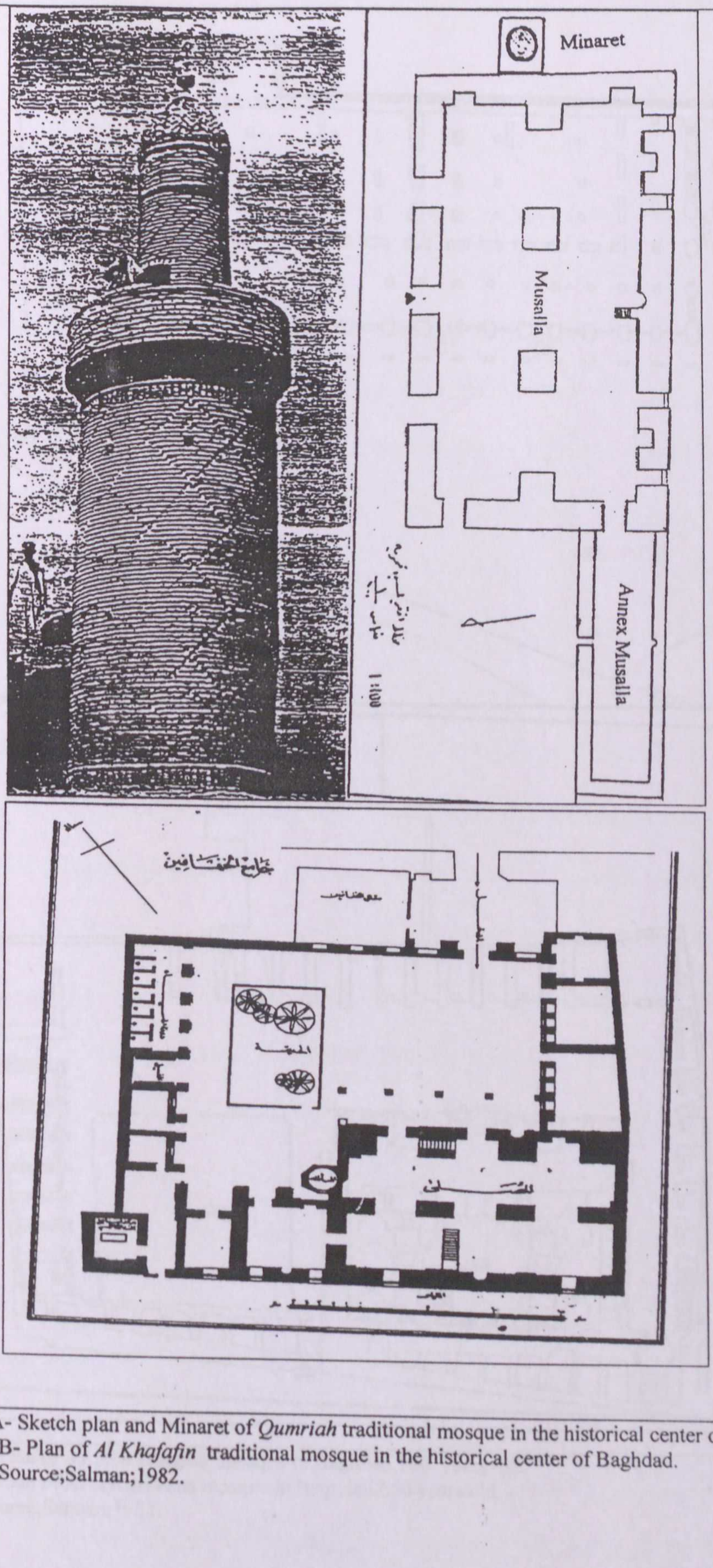


Fig.3.31, A- Sketch plan and Minaret of *Qumriah* traditional mosque in the historical center of Baghdad.
B- Plan of *Al Khafafin* traditional mosque in the historical center of Baghdad.
Source;Salman;1982.

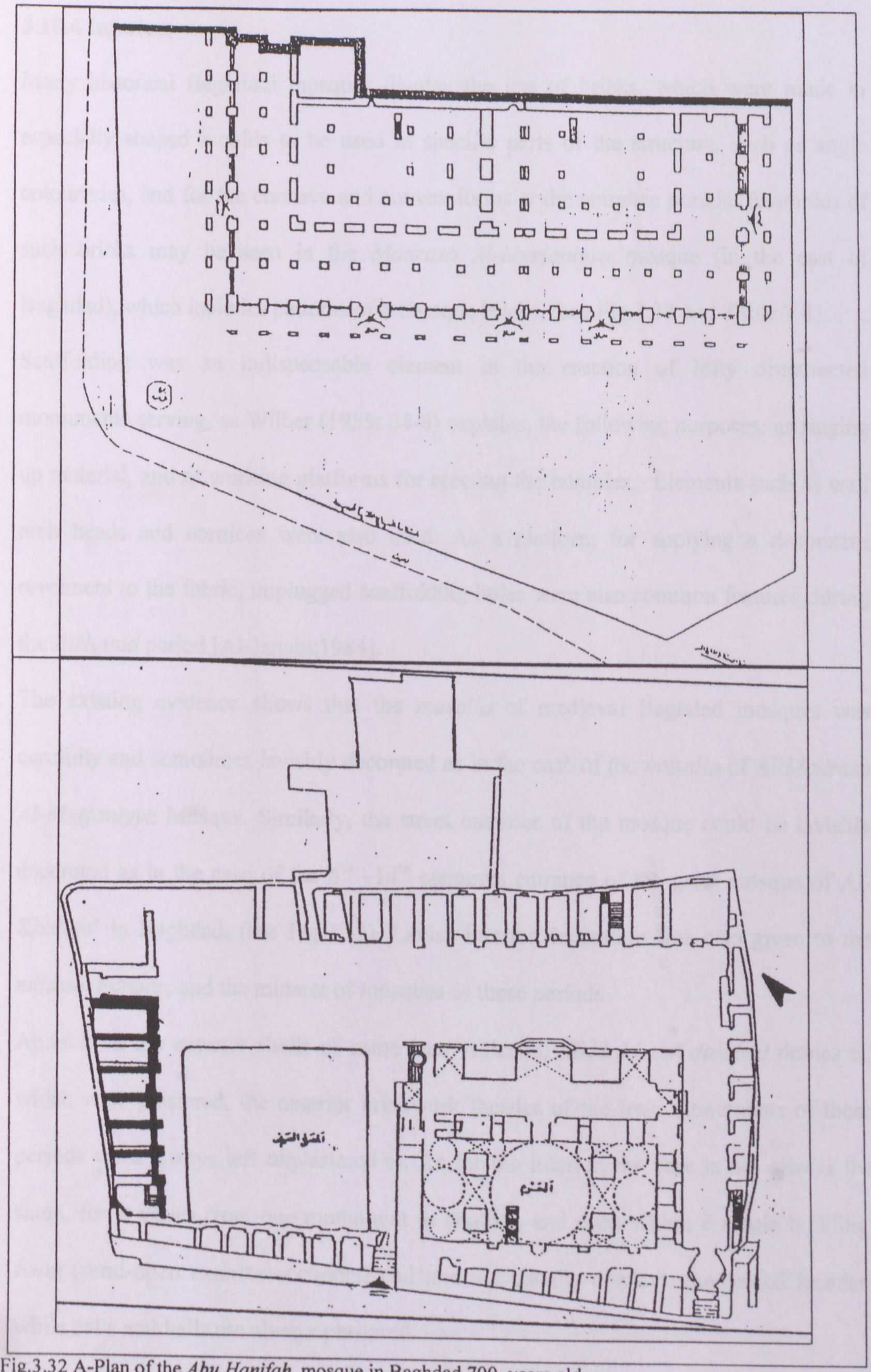


Fig.3.32 A-Plan of the *Abu Hanifah* mosque in Baghdad,700 years old.
B-Plan of Al Hydarkhana mosque in Baghdad,650 years old.
Source;Salman;1982.

3.10.4 Interiors

Many historical Baghdadi mosques display the use of bricks, which were made in especially shaped moulds to be used in specific parts of the structure, such as angle colonnades, and for the concave and convex forms at the entrance portals. Examples of such bricks may be seen in the *Madrasa Al-Murjaniyya* mosque (in the east of Baghdad), which includes patterns of arabesque bricks, (see Fig.3.33 and Table 3-1).

Scaffolding was an indispensable element in the erection of lofty ornamented monuments serving, as Wilber (1955: 54-6) explains, the following purposes: as staging up material, and as working platforms for erecting the complex. Elements such as wall arch heads and cornices were also used. As a platform for applying a decorative revetment to the fabric, unplugged scaffolding holes were also common features during the *Ilikhanid* period [Al-Janabi;1984].

The existing evidence shows that the *musalla* of medieval Baghdad mosques was carefully and sometimes lavishly decorated as in the case of the *musalla* of *Al-Madrasa Al-Murjaniyya* Mosque. Similarly, the street entrance of the mosque could be lavishly decorated as in the case of the 8^{th} –14^{th} centuries entrance of the great mosque of Al-*Khulafa'* in Baghdad, (see Fig.3.33). Lavish interior decoration was also given to the *mihrab*, *minbar*, and the minaret of mosques of these periods.

Apart from the exterior shells of some later Abbasid, *Ilikhlnid* and *Jalairid* domes 24, which were plastered, the exterior brickwork façades of the Iraqi monuments of these periods were always left unplastered 25. As for the interior, the case is not always the same, for it varies from one monument to another, and even within a single building. *Iwan* (semi-open exterior corridors) and *musalla* usually display ornamented façades, while cells and halls are always plastered.

Bricks have been employed in many ways (in traditional Islamic mosques in Baghdad) to create patterned surfaces and decorations, and have thus been made in especially shaped molds. These bricks are also used in specific parts of the interior and exterior surfaces as well as for angle colonnades and for the concave and convex forms at the entrance portals. Examples of such bricks may be seen in *Al-Madrasa Al-Mustansiriyya* Mosque and the *Marjaniyyah* Mosque.

Because of the importance of the *mihrab* as a single architectural element endowed with certain symbolic values, and because of its commanding position in the *musalla*, extreme attention was lavished on it. The examples of *mihrabs* show that their surfaces were adorned with almost every known decorative element .The *Atabikid mihrabs* were characterized by bands of *Kufic* inscriptions of *Qur'anic* texts surrounding the central panel, or a single band containing the *shahada* (that there is no deity except Allah and Muhammad is His Messenger) at the top. A pointed arch carried over a pair of twin columns of the same type, an arabesque depicting a stylized tree of life filling the space within the arch and on its spandrel, and finally an interlaced geometrical pattern which developed a star motif filling the central panel of the *mihrab* gave an idea of the standard flat *Atabikid mihrab* in its early stages and during the *Jalairid* period. Nevertheless, certain developments occurred.

3.10.5 Structures

Other kinds of specially shaped bricks in traditional mosques were made for the construction of arches, which suggests that they were cut before firing. Such bricks are found at the entrance of the great mosque of *Al-Kufa* (south Baghdad, from the Umayyad period). The fact that each of these buildings had particular shapes of moulded bricks suggests that the details of the mosques had been carefully planned before actual construction began. The brick mosques of those periods showed that common horizontal bond and vertical bond were also used, especially in minarets, to divide the ornamented zones as outer frames for historical inscriptions.

That method of construction was first introduced in the Islamic architecture of Iraq in the Great Mosque and *Dar Al-'Imara* in *Kufa* (south Baghdad) in the *Umayyad* period.[9] They demonstrated the following bonding technique; the bricks there were set upright on their edges in rows, one over the other. That technique was also applied on the abstain of the Great Mosque of Samara (100Km north of Baghdad). Here the vertical courses alternated with five horizontal courses creating a simplified geometrical pattern.

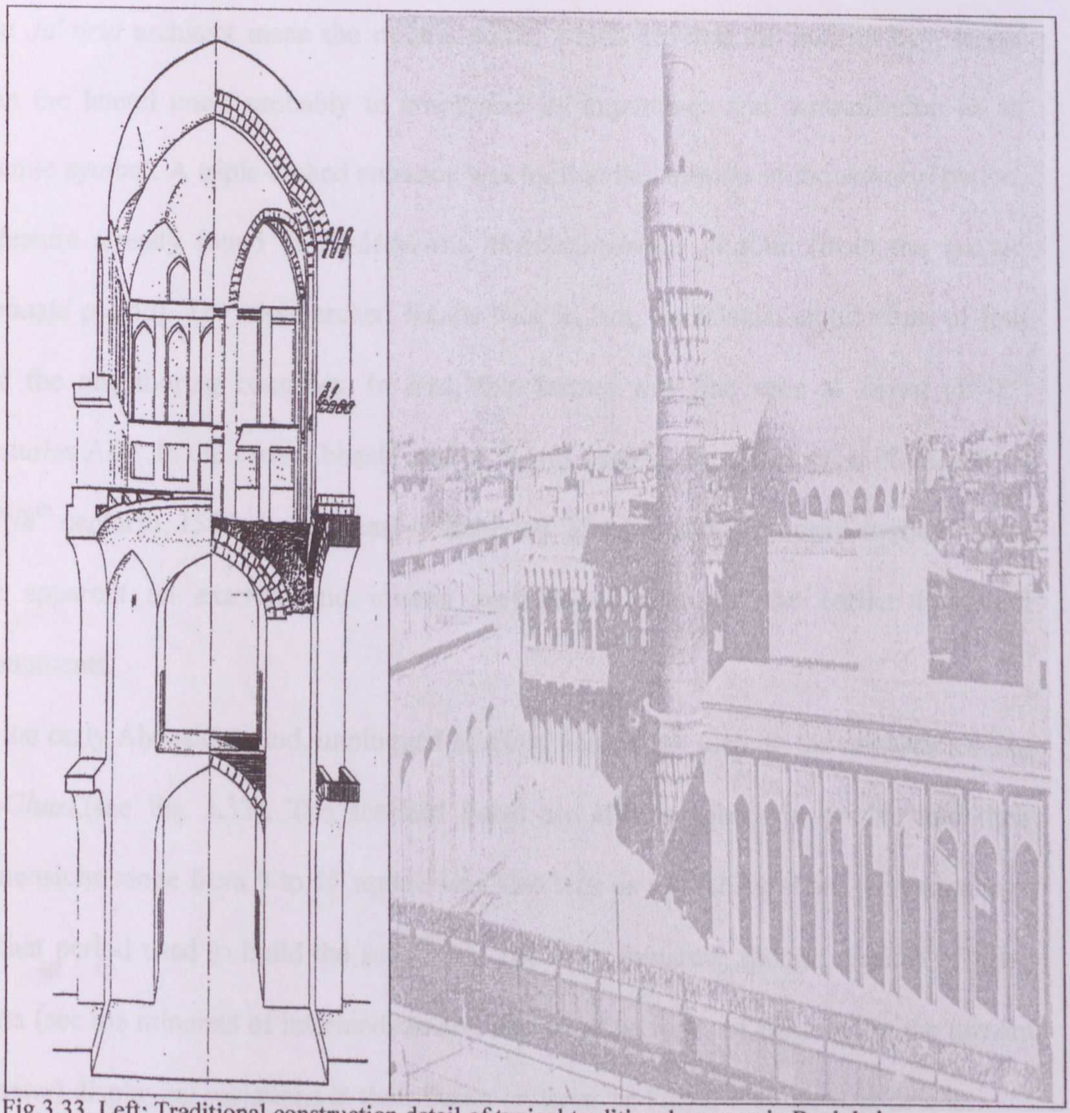


Fig.3.33, Left: Traditional construction detail of typical traditional mosque in Baghdad.
Source: Galdieri E; 1979
Right: Alkhulafa traditional mosque in historical center of Baghdad.
Source: Source:Salman;1982

That method, however, seemed to be a later restoration. The technique of vertical setting combined with horizontal courses reinforced the fabric besides having a decorative effect, (see Table 3.31,and Fig.3.33.)

During the *Ilikhanid* period, the roofing system of the mosque comprised rows of domical vaults resting on substantial piers to cover the *mihrab* bay as well as the lateral bays (see Fig.3.32). The prayer hall (*musalla*) was entered by means of a single arched entrance (Fig.3.34). In the *Jalairid* period, the prayer hall of Al- *Madrasa Al-Murjaniyya* Mosque (in the historical center of Baghdad) showed a single row of three domes carried over wide transverse arches which were used in its roofing.

The *Jalairid* architect made the middle dome, which covered the *mihrab* bay, larger than the lateral ones, probably to emphasize its importance and centralization as an Islamic symbol. A triple-arched entrance was used in the *musalla* of the *Jalairid* period, a feature already found in Al-*Madrasa Al-Mustansiriyya* mosque (from the second A*bbasid* period). The triple arched façade was, in fact, the Islamic architecture of Iraq and the neighboring countries. In Iraq, this feature was first seen at *Hatra* (1^{st}-2^{nd} centuries AD). In the early Abbasid period, it was used in the palace *of Al-'Ukhaydir* 26 (2^{nd}/8^{th} century), 150 km south-east of Baghdad. Plugged and unplugged scaffold holes are apparent on exterior and interior surfaces of many of the earlier Baghdadi monuments.

In the early Abbasid period, unplugged scaffold holes were seen on the minarets of *Suq Al-Ghazl*,(see Fig 3.33). The scaffold holes are always square in profile and their dimensions range from 9 to 15 square cm.(This tells us something about the technology at that period used to build the structure). The main minarets, though, consist of these parts (see the minarets of intermediate and new mosque types of Baghdad in the present chapter) displaying variations in their bases, galleries and other architectural details.

The *Ilikhanid* period in Iraq, for example, *Suq Al-Ghazl(AlKhulafa* mosque),and *Al-'Asafiyya* mosque (in the eastern historical center of Baghdad,(see Fig.3.35).

The minaret of the *Qumriyya* mosque offers further evidence in this respect. This minaret, in fact, followed an earlier native model as far as the ground plan was concerned, (see Fig.3.31). Minarets of completely different shapes were constructed over cubic bases as early as the 3^{rd},and up to the 19^{th} century. Examples include the spiral minarets of the great mosque of *Abu Dulaf* at Samara.27. The plan and style of these minarets were introduced into Egypt by Ahmad bin Toulon. During the *Ililkhanid*

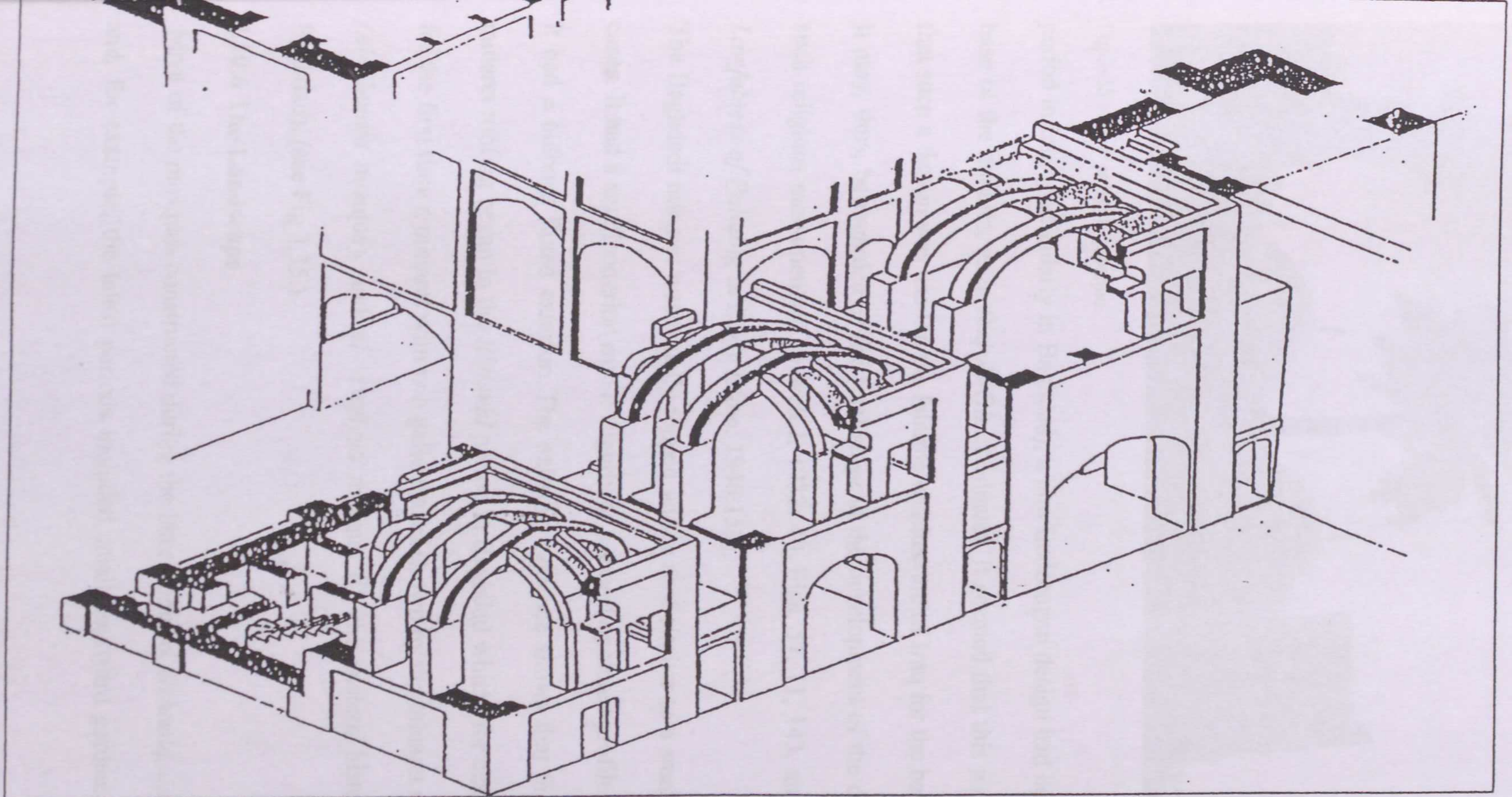


Fig.3.34 Structural system of traditional mosque in Baghdad.
Source: Source: Galdieri E, 1979.

Fig.3-35 : *Al A'* safiyya mosque.

period in Iraq (particularly in Baghdad), a new dodecagon design had been used for the base of the minaret, as in *Suq Al-Ghazl* minaret. It seemed that this was the first time that such a design was used in the Islamic architecture of Iraq for the base of a minaret. It may, thus, be regarded as the final stage in the development of the design bases for such religious monuments (Creswell I, 1932: 40, Figs. 57, 11, 143, and 180; and *The Lawfulness of Painting in Early Islam*, 1946:159).

The Baghdadi minaret was usually topped with a roof similar to a small dome in most cases. It had a small exterior with a slightly or a sharply pointed profile. In other cases, it had a bulbous fluted exterior. The existing evidence shows that the later types of minaret roofing began in the *Ilkhanid* period in Baghdad which, for example, produced for the first time a minaret with two galleries, as shown by the minaret of *Suq Al-Ghazl (Al-Khulafa* mosque), and *Al-'Asafiyya* mosque (in the eastern historical center of Baghdad), (see Fig 3.35.)

3.10.6 The Landscape

Most of the mosques constructed during the later *Abbasid, Ilkhanid, Jalairid, Ottoman* and, for example, the latest periods included small courtyard gardens surrounded by brick paving, which, sometimes, crossed the garden in many directions, and which included many types of trees and shrubs [28], (see Fig.3.31.)

A traditional large brick 30x30x5 cm, which was known locally as *matli or fershi*, was used in the pavement of the courtyards of all the old monuments, such as *Al-Madrasa Al-Murjaniyya* complex (including the mosque), (see Table 3.2). Sometimes, arabesque was used to give a defined pattern to that paving. The use of hard landscape was also noticed in *Al-Murjaniyya* mosque, the courtyard garden and the paving around it, and so on .

The treatment of the landscape inside the courtyards of *Al-Haydarkhana* mosque and *Al-Khaffafin* mosque (on the banks of the eastern Tigris in Baghdad) had the same landscape features and plants, such as date palms, lot- trees, and other shrubs [29].

3.11 SUMMARY

Although time has changed and populations have grown, the original reasons for creating a built environment and the mosque building within it remain essentially the same. However, the differences are normally found in the way of expression, which will be highlighted in the comparison of the new mosque type, with the traditional one in Baghdad, in this chapter.

There is a lot to be learned from traditional architecture in terms of the architectural and constructional approach, use of materials and other architectural details. The urban fabric of the traditional mosque environment in Baghdad is characterized by grouping the buildings close in order to expose an absolute minimum area of those buildings (including the mosque) to the solar radiation, leaving small courtyards and narrow shaded alleyways for pedestrians.

There are many reasons for the changes in the traditional physical environment,

> *'three main factors are believed to have encouraged and helped this process of change. These are: first, the existence of certain implied ideologies; second, changes in the scale of power and technology; and third, problems within the field of architecture and urbanism, and their relationship to the Arab-Muslim context in general' (Al-Hathloul, 1981:258).*

The modern mosque style in Baghdad is affected by the western international style that has influenced all aspects of life including architecture. The designers of this modern style turned their backs on their traditional architecture. The results are buildings, which are foreign to our environment and tradition. The main feature of these buildings is the large expanse of glass windows that is a fashionable trend in imitating international style, but sadly ignores the obvious requirements of a hot climate.

This detached modern mosque, due to its surroundings and the new urban fabric of Baghdad, exposes its envelope to direct high density solar radiation, as well as using the skeleton structure (reinforced concrete columns and beams) that facilitates the use of thin partitions (non-bearing walls) which means low thermal capacity of the envelope and less thermal protection for the inner environment. All these factors lead to a dependence on mechanical and electrical systems to cool and heat the inner space (*musalla)* to the comfort level, taking into consideration the short period of occupation and repetition of that short time –prayer time – five times daily of the occupied *musalla* space, that makes the facilities so costly and difficult to achieve, in addition to disturbing the prayers.

[1] The first *sura* (chapter) of the Holy *Quran*.

[2] See the diagram of the influential factors on the design philosophy of the mosque as a background of research methodology Ch.1.

[3] See the development of the mosque elements via many stages, Fig3.1.

[4] See the competition proposals for the government mosque in Baghdad in 1983, Figs. 7.14 and 7.15,Ch.7.

[5] See the relationship and types of spaces in the mosque center (complex), Fig.3.2.

[6] *Mihrab* is so symbolic that it is not influenced by the envelope design in terms of heat exchange &physical character.

[7] *Mihrab* is originated and developed architecturally via many historical stages; see (Al-Janabi: 1984).

[8] See the special type of new minaret in Baghdad mosques Figs.3.5 and 3.6, It may be modified to serve thermal design for *musalla* as will be seen in Chapter 7.

[9] Source: www.hotmail.com,Islamic architecture.

[10] *Riwaq* normally serves as thermal protector for one, two or three sides of the *musalla* zone by providing shade to them.

[11] See the approach of teaching groups inside the mosque as one of the main facilities inside the *musalla*, Fig.3.13.

[12] See the entrance alternatives, Fig. 3.12.

[13] See this type clearly as mezzanine, women's *musalla,* in intermediate mosque's type in Baghdad, Fig.3.7.

[14] See Fig.3.13.

[15] My estimation & the assistance of the research of Al-Umary,Hafsah. (*New Mosque Building in Iraq*.MSc. Thesis submitted to the Arch. Dep. College of Eng. Baghdad Univ. 1988, pp. 2, 19).

[16] See their plans and elevations in Chapter three.

[17] See the typical new Baghdad mosque, Fig 5.3.

[18] Based on author's survey in June-July, 1997,see APP.B.

[19] See the typical new Baghdad mosque, Figs5.3 and 5.4.

[20] Author's survey in addition to information obtained from the Ministry of *Awqaf* and Religious Affairs, Baghdad, Iraq.

[21] See the axonometric sketch of the intermediate mosque in Baghdad, Fig. 3.7.

[22] Based on researcher's survey in June-July, 1997, see survey data in Ch.5.

23. We can give many examples of that, e.g., the dome of *Al-Madrasa Al-Murjaniyya* Mosque on the east of Baghdad and all the *muqarnas* laquearia domes of the later Abbasid and *Ilkhalid* periods.

24. Second Islamic empire capital, located southeast Baghdad.

25 See Fig. 3.5 and 3.6.

26 The triple-arched scheme, as Herzfeld (Islamic civilization historian) has pointed out, was probably derived from the Roman triple triumphal arch and archway of colonnaded streets,see (*Easter Vorlau Figer Bericht*).

27. See Creswell,Ema II.pp.254-65,Western scholars think that this mosque was built in 232 AH/847 AD.

28 Inner courtyard, it becomes a tradition since it is used as a prayer area in the night during summer time.

29 See the plan in Fig.3.32.

CHAPTER FOUR

THERMAL COMFORT AND DESIGN PARAMETERS OF THE NEW MOSQUE BUILDING

4.1 INTRODUCTION

> *'The study of thermal comfort touches on many discipline including heat and mass transfer, thermal physiology, psychophysics, ergonomics, biometrology, architecture, and textile engineering. The reason for creating thermal comfort is first and foremost to satisfy man's desire to feel thermally comfortable, in line with his desire for comfort in other directions' (Fanger; 1970.)*

Thermal comfort is a complex and subjective problem and is related to a combination of physical, physiological and psychological factors.

It is achieved when there is a balance between the generation of metabolic heat within the body and the loss of heat from the body via the mechanisms of conduction, convection, radiation and evaporation. Where there is this balance, a person will feel neither too hot nor too cold. Individuals are not the same and some people will feel warm when others feel cool. However, generally we are remarkably similar in the way that we react to different temperatures, and as temperatures move away from a neutral balance point, an ever-greater proportion of people will feel increasingly uncomfortable. The heat generated in the body through metabolism will depend primarily upon the activity being undertaken. The greater the exertion, the greater will be the metabolic heat generated within the body.

Buildings must be designed to use less energy. Reducing the energy consumed by mosque buildings may be achieved by exploiting to the full the natural advantages of a site, adopting appropriate building forms and using types of construction that are energy efficient. Buildings that tend to produce comfortable conditions via a naturally passive response are likely to be energy efficient structures. Energy in new mosque buildings for thermal comfort has not been a great concern in the past. The functionalism of the 1920's and 1930's urged that the form of a building, and particularly its plan, should clearly reflect, express or make plain the nature of the activities carried out inside that building.

Passive solar design is the process by which climate oriented buildings are understood. Passive solar mosque buildings will be more energy efficient, more comfortable and easily used.

To provide a comfortable environment in the *musalla* is an intricate problem because the problem itself is not always clearly defined. The climatic environment operates with many variables, which will be discussed in the present chapter relating to all *musalla* design criteria. They act on the human body in an inter-related action. They affect the physiological and psychological well being of the occupants.

This chapter is confined to the effect of air movement, air temperature, radiation and humidity, and on how an improvement of comfort can be achieved in the occupied space of the new *musalla* in Baghdad.

4.2 THERMAL COMFORT FACTORS

> *'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).*

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

1. Air Temperature

2. Relative Humidity

3. Air movement

4. Mean Radiant Temperature

5. Activity Level

6. Clothing

7. Local parameter variations, like asymmetrical surface radiation (e.g. hot ceiling) .

All of the above parameters will affect the thermal comfort. Fanger's work shows that it is impossible to satisfy everyone at any given temperature (Fanger; 1970).

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 encountered in buildings due to the prevalence of an oppressive thermal environment.

This would be of relevance to non-air-conditioned buildings redesign (envelope shape, section, other architectural and constructional specifications). There is a wide variation in thermal requirements and in thermal sensitivity between individuals in a given group. The aim should be to create conditions for thermal comfort to satisfy the highest possible percentage of the 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 the clothing, activity and acclimatization to the local time.' (Rao S. P; 1991:4).*

4.2.1 Air Temperature

The lowest range of air temperature in terms of thermal comfort is 18-20°C, and the highest range is 26-30°C. When the air temperature falls below the lowest range, clothes become necessary to control the heat exchange between the human body and the environment. The clothes increase the isolation and conserve human body temperature by maintaining the temperature of the surrounding air, which is under the clothes and reducing heat gain in a dry environment (Dawud; 1983: 15-16). When air temperature rises above the highest range then sweating begins, with air movement contributing to providing thermal comfort. The annual average air temperature over 24 hours in Iraq is 16-17°C (this rate is represented by the climate characteristics of Baghdad, which is located in the middle zone of Iraq) in the northern zone; the temperature gradually increases to 24 °C in the southern zone. The weather gradually starts to cool in October, and the temperature drops continuously until the end of January. While the highest temperature is not more than 18°C in the southern zone during winter and 8°C in the northern zone, the lowest temperature is 6°C in the southern zone; 4°C in the middle zone (Baghdad region); and 2°C in the northern zone (Shaaban & Al-Jawadi; 1973), (See Appendix A3).

The difference between the highest and lowest daily average temperatures as is 20C° in the Baghdad zone, but increases gradually towards the northern zone of Iraq where it becomes 27C°.

4.2.2 Relative Humidity

The range of relative humidity for the human body comfort zone is 20%-80%. Under the lowest limit, the air becomes dry and that influences human skin. Cracks on lips may appear as a result of dryness. On the other hand, when relative humidity rises above the highest limit, evaporation is reduced and the air saturates with moisture. The human in this case feels uncomfortable. The annual range of highest and lowest relative humidity for most regions in Iraq (including Baghdad) is 30-60%. It is at its lowest during summertime (15% during the day and 40%-30% at night) and the range of relative humidity is 50-60% during wintertime. The highest level of relative humidity can reach 90%.

4.2.3 Air Movement

Air movement influences the thermal balance of the human body according to the phenomena listed below:

i.Heat exchange increases between the human body and the air due to an increase in surrounding air movement.

ii.Body cooling by sweating increases due to an increase in evaporation (body evaporation cooling) and air movement contributes to that.

iii.The human body's ability to cool by sweating and evaporation is important to reduce human body heat, and to feel healthy thermal comfort. (Szokolay;1980).

Therefore, the air speed temperature, and vapor pressure affect the amount of evaporation from the human's skin surface, which increases as air speed increases. For this reason, a human feels cool even though the vapor pressure is still high. Air movement in the Baghdad region usually reaches a peak speed of 14m/sec.

4.2.4 Mean Radiant Temperature and Mean Radiation

This phenomenon has a considerable effect on human thermal comfort. Heat exchange through radiation depends on the mean-radiant temperature; so human beings feel comfort in a conditioned environment when the difference between the human body temperature and surrounding surfaces becomes small, and vice versa. One-degree air temperature difference changes the temperature of a radiant surface (0.5-0.8) (Dawud; 1983). Solar radiation is greater in summer than in winter, the annual average total radiation in Iraq being 15 mega J/sq m.day in the northern zone, and 21 mega J/sq m.day in the southern zone. The mean is 18 mega.J/sq m.day for the country (and for Baghdad).

4.2.5 Activity Level

There is a relationship between thermal comfort and human activity. Different physical and physiological human activities have different effects. These effects are less for women's bodies than for men's bodies and less still for children's bodies.

i. Heat Flow as a Result of the Biological Activity of Praying Bodies

The human body produces metabolic heat (metabolic energy) because of biological activities. Therefore, heat comes through the skin and radiates to the surrounding atmosphere through convection and radiation. Thus, a feeling of comfort depends on the skin temperature, which is normally 31°C to 34°C. It is possible to keep this level constant, if there is a balance between the inner temperature and the out-flow temperature according to the following heat **balance equation**[1]:

$$\text{Met} - \text{Evp} \pm \text{Cnd} \pm \text{Cnv} \pm \text{Rad} = 0$$

(Koenigsberger & Others, 180: 76; and Dawud; 1983: 16)

Positive and negative signs depend on human and environmental phenomena. The **positive signs** are used for the following cases:

Cnd = if the air temperature is higher than the skin temperature (conduction)

Cnv = if the air temperature is higher than the skin temperature (convection)

Rad = from the sun, sky, or hot bodies (radiation)

The **negative signs** are found in the following cases:

Cnd = contact with cold bodies (conduction)

Cnv = if the air temperature is lower than the skin temperature (convection)

Rad = the radiation to cold surfaces (radiation)

Evp = from moisture and sweating (evaporation)

It is evident that the thermal balance does not depend only on physical reactions inside the human body, but also on climatic environmental factors, such as air temperature, relative humidity, air circulation, mean radiation temperature, and other secondary factors like age, sex, and health conditions. Therefore, in hot climates, a building, which is designed according to good thermal and environmental criteria, can provide a thermally comfortable inner environment. Where air temperature keeps on continuously increasing, the building starts to lose its thermal and physical efficiency. Therefore, it needs a mechanical process to restore the optimum thermal comfort, and that depends on the expected difference between the inner thermal environment and the human thermal comfort level (Dawud; 1983: 15-16 and 27-29).

The biological processes that take place inside the human body release energy to the surrounding atmosphere (inside the *musalla*). This fact has a positive effect on the requirements of heat during winter and a negative effect on the cooling requirements during the long summer in Baghdad.

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

The metabolic heat from the praying person's body caused by biological processes is

Table.4.1 Metabolic Energy of the praying person

Number of prayers	Praying period Hour	Number of daily prayers	Metabolic energy kW/hr	Metabolic energy KW/day
1	0.5	5	0.212	0.508

Source: Fanger; 1970.

measured by using the unit of kW/h, since the praying person's activities are equivalent to the activities of a person who is walking at a speed of 2 mph. (For more details, see Fanger's classification, Table 4.2). Thermal comfort is affected by the type and level of human activity. Consumption of energy is measured by met as a unit, which represents the produced thermal mean from the human body at comfort levels; it is equal to 58.02 Watt/sq.m, while the mean value for a human body equals 100 watt.

A human can control the heat exchange between his body surface and the environment by wearing clothes, which can increase the efficiency of thermal isolation by keeping the air temperature around his body constant. Suitable clothes can reduce heat gain in a hot-dry climate; the heat resistance of clothes is represented by (Clo.)

ii. Prayer (*salat*) and thermal comfort

The person doing the prayer movement looks like someone performing a light sports movement. Thus, when we make a comparison between the metabolic rates of the human body during prayer in the standing, sitting and bowing positions, with the metabolic rate of a person walking at medium speed, we will discover that the praying person needs a lower temperature for the surrounding air than a person in a physically inactive condition. The thermal condition 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 comfort. As the number of praying persons increases, we must calculate the metabolic rate of their movements. For that to be measured, we need field survey and health assessment. The proposal here is to simplify this by considering the praying movements as being equivalent to the movements of a laborer in a handicraft factory, (Fanger Classification, Table.4.2), which is similar to a person walking at a rate of 2miles/h who produces more heat from his body than if he were at home.

Table. 4.2 Fanger's Classification for human activities and metabolic rates. Source: Fanger: 1970.

Activity	MET Units	Energy rate for average sized man		
		K Cal. /H	BTU. H	Watts
Sleeping	0.7	67	253	74
Sitting-sedentary	1.0	91	361	106
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
One MET = 50, k Cal/h (m^2) = 18.4, Btu h/ft^2 = 58.2 W/m^2.				

4.2.6 Clothing

The isolation of the clothing is generally expressed in 'clo units'. The clo unit was introduced to facilitate the visualization of clothing level, and is the insulation necessary to keep a person comfortable at 21°C- about that of an office worker's suit. The traditional *muslim* overall wrap (gown) clothing is usually used by persons doing the prayer in the new *musalla* in Baghdad with the following additional specification details;

Table 4.3 Clothing commonly worn by praying people in Baghdad

GARMENT DESCRIPTION	clo.	sq.m k/W
A. Long sleeved wrap (Gown), long	0.53	0.082
B.Lights trousers (in summer)	0.20	0.031
C.Normal trousers (in winter)	0.25	0.039
C&C. Normal long sleeved shirt (in winter use with trousers normally)	0.25	0.039
A&C. Jacket (in winter)	0.35	0.054
B.Underwear shirt, sleeveless (in summer, spring, autumn)	0.06	0.009
A&C. Underwear shirt with long sleeves (in winter)	0.12	0.019
A&C. Underwear short (in summer, spring and autumn)	0.06	0.009
A&C. Underwear pants-long legs (in winter)	0.1	0.016

Source: www.squ 1.com.
A-Traditional clothing used in all seasons,
B-Normal clothing in summer.
C-Normal clothing in winter.
A&C , A&B-Mix between two of them sometimes to get certain uniform and feel comfort.

Normally the prayers inside the *musalla* when performing prayer use three types of clothing as below;

i. Long sleeved wrap (Gown), which is type A, used by 70% of the praying persons in summer.

ii.Light trousers and shirt in summer, used by 30% of the praying persons in summer.

iii.Normal trousers + long sleeved shirt +jacket, used by 30% in winter.

One overall uniform (case A) that is normally worn by 70% of praying persons represented by one loose piece of uniform which lets air be in touch with the body more than in (case C) of wearing trousers and a shirt in addition to a jacket in winter. The people from long of experience know that the loose type of uniform feels more comfortable and continue wearing it generally inside the *musalla* for worship.

In addition to acting as insulation against the transfer of heat, the clothing has an effect on the heat loss by evaporation. Firstly (in summer) the clothing effects evaporative cooling by introducing extra resistance to the diffusion of water vapor away from the skin. The strength of this effect depends on the nature of the clothing and its permeability to moisture that happens in (cases B&C) more than in (case A). The second way clothing effects evaporative cooling is that it absorbs excess moisture next to the skin. The absorbed moisture is then evaporated from the clothing and not from the skin, so that the latent heat is removed from the clothing and is not so effective in cooling the skin in winter when that one piece is thicker and woolen and covers quite thick additional underwear in winter.

The actual way in which clothing works is often far more complex than the classic model outlined above .In Baghdad's hot-dry climate, for instance, the prayers wear loose, multiple layered clothing. The function of the clothing is then to keep the high environmental temperatures away from the skin, whilst allowing heat loss by evaporation when dry air is pumped through the clothing as the body moves as in (case A). Where there is a high rate of sweating the heat loss can actually be increased by the clothing, by providing extra surfaces from which evaporation can take place and cooling the space between the skin and the inner layer of clothing.

Another complication in dealing with clothing is that its function is not purely thermal. The way in which we use clothes is determined by our social as well as our thermal needs as mentioned. Such variations as wearing a jacket open or closed can make a significant difference to its thermal characteristics.

By choosing optimum clothes, a human body can thermally control different conditions of heat exchange between his body surface and the environment.

Clothes increase the efficiency of thermal isolation during prayer activity by keeping the surrounding air of the human body at a constant temperature. On the other hand, clothes reduce heat gain in the hot-dry climate in Baghdad. The thermal resistance of clothes calculated by "Clo." unit, is equal to 6.5 Watt.s.m². on the body surface, and this equals the output for a human wearing a complete suit, which consists of all clothes including under wear, (see Table 4.3). This is exactly the condition of a person praying in wintertime in Baghdad, (see Tables.4.1, 4.2 and 4.3).

> *'In order to combine factors which affect indoor thermal comfort, like air dry bulb temperature, humidity, air movement and radiation, several thermal comfort indices have been proposed...The best-known index of this kind is "Effective Temperature". This was developed in 1923-1925 by Hongton ,Yaglow and Miller. This index included air temperature, humidity and air velocity. Later the "Effective Temperature" was developed where the globe thermometer reading replaced the dry bulb temperature. The CET² for temperature climate is generally recommended to be 21.7°C for summer conditions for normally clothed male subjects at rest.'*
> *(Rao; S.P: 1991:5).*

That is the desired condition in the long summer time when the people praying are usually wearing light clothes.

4.3 THERMAL DESIGN PARAMETERS

Fanger has set the international standard for thermal comfort studies by quantifying all of the previous parameters and putting them into a unified "thermal equation". This equation predicts the mean thermal comfort level for people under any circumstances. The detailed calculation is found in the references (Fanger;1992)

Fanger has proposed the use of complex comfort equations and diagrams which include several variables such as activity level, Clo-values, air velocity, air humidity and ambient temperature.

Envelope climatic design for any building should fulfill human needs; the requirements of users, and the final shape of the building should be the conclusion of many requirements. Thermal design of the building considers variations in climatic elements.

-The determinants of thermal design are:

4.3.1 Orientation: Optimum building orientation should guarantee obtaining the highest amount of solar radiation during the winter season when heating is necessary and the lowest during the summer season when cooling is necessary.

Dawud A J (1983) found that the best orientation in the hot and tropical regions is 20-degrees southwest or southeast (Dawud; 1980), (fortunately the *Qibla* direction in the Baghdad region is within this range of south-west). Since a rectangular shape approach, a square shape (due to that proportion the width should be not so much longer than the length) it represents the best shape for the *musalla* building in terms of both Islamic teachings and environmental assessments. This ratio becomes more acceptable when the long sides of the *musalla* face those optimum orientations.

The direction to Mecca in Baghdad is 10^{o} south-west and this orientation is good in terms of thermal gain generally in a hot-dry climate (since the two longest walls of the rectangular shape of the *musalla* which is common in the new mosque envelope in Baghdad face north and south, and therefore receive approximately the lowest amount of solar radiation in summertime and the highest in wintertime.

4.3.2 Size of the *Musalla* building

The dimensions of any building influence heat gain through its envelope. The dimensions, which are manifested by length, width and height, also define the total

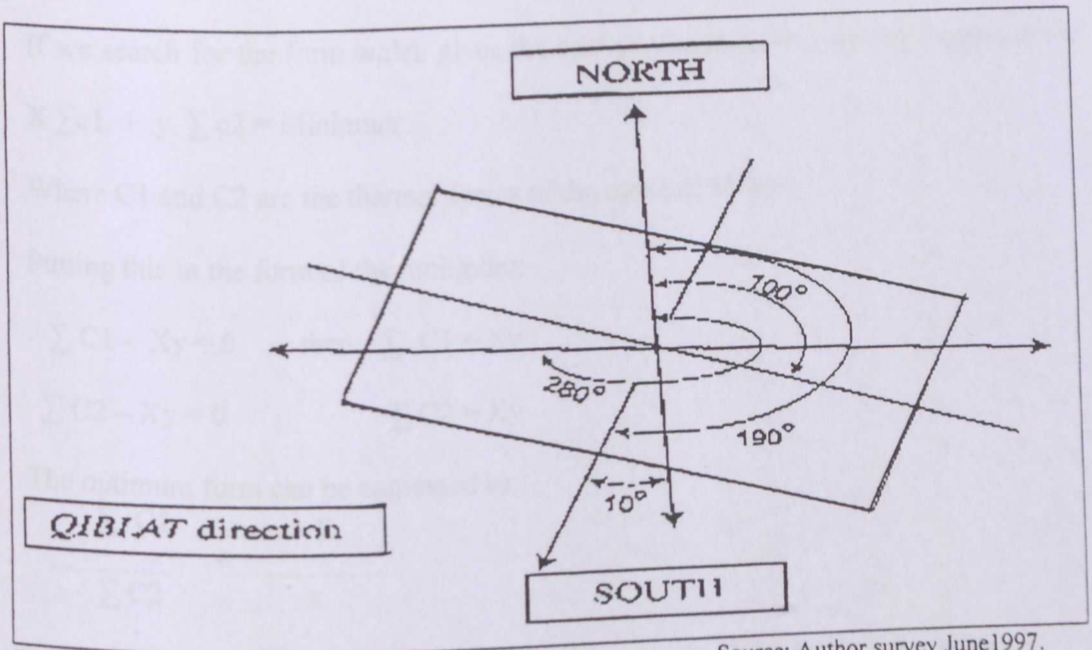


Fig.4. 1 Mecca *(Qibla)* direction . Source; Author survey June1997.

surface area of the building. This area changes according to changes in the dimensions even though the size is still sometimes constant.

The proportion of the total surface area of the building to its total volume represents an important factor in terms of heat exchange.

It can be taken as a rule that the optimum shape is that which loses the minimum amount of outgoing heat in winter, and accepts the least amount of incoming heat in summer.

The "optimum shape" refers to certain proportions of the building, which influence heat gain and loss according to the definition of the surfaces, sizes and orientation. These proportions lead to certain dimensions, which are mean length, width and height. Those give the surface areas of the building and those dimensions are changeable for a fixed size. So the proportions of the surface areas of any building related to its total size represent an important factor in the heat exchange process. It is widely believed that a square-shaped building has the best characteristics for preserving heat in winter and remaining cool in summer.

Let us call the interior heat affects C1 and the sides of the "*Musalla*" "X" and "y"

Then the area of a given plan is: A=Xy

If we search for the form which gives the best performance, this can be expressed as:

$$X \sum c1 + y \sum c2 = \text{Minimum}$$

Where C1 and C2 are the thermal forces of the opposite sides.

Putting this in the form of the multiplier:

$$\sum C1 - Xy = 0 \qquad \text{then} \quad \sum C1 = Xy$$

$$\sum C2 - Xy = 0 \qquad\qquad \sum C2 = Xy$$

The optimum form can be expressed as:

$$\frac{\sum C1}{\sum C2} = \frac{y}{x}$$

> *'When an inverse relationship exists between the thermal impacts and the sizes of the sides of the structure, the optimum form represents the thermal forces in equilibrium' (Randal, 1992:86- 88.)*

This is the conclusion reached from the comparisons done by Markus (1980:392) for many forms when he tried to get many results of the percentage of the total surfaces of each shape regarding the same size for all shapes.

By giving different values to the surfaces for a constant size of the building, we can say that a cubic shape for the *musalla* building is the optimum shape for the Baghdad region in accordance with the solar radiation amounts falling on the surfaces compared with other shapes of the same size. The cubic shape represents the lower percentage of the area of the surface size with regard to other shapes in general. At the same time, this shape also receives the lowest solar radiation (Markus, 1980:390-392).

4.3.3 Ventilation

Ventilation is necessary for thermal comfort in the inner environment for the reasons listed below:

1. It helps increase human body heat loss by removing humidity from the internal environment, which is the output of metabolic and other inner activities.

2. It reduces the air temperature of the inner environment when it is more than external air temperature.

3. It provides the inner environment with fresh air and takes out polluted air and water vapor as well as bad smells. The required amount of air, which fluctuates, depends on usage of space; number of users, kind of activities, and building function.

> *'The natural or mechanical ventilation is necessary, but during winter time the external temperature is lower than the internal environment temperature, so there is no need to use ventilation' (Shaaban A K & Al-Jawadi M; 1973.)*

i. Ventilation and Indoor Thermal Conditions

The influence of the indoor thermal environment on thermal comfort is widely recognized. Thermal comfort has been studied for decades resulting in thermal comfort standards and models for predicting the level of satisfaction with the thermal environment as a function of the occupants' clothing and activity level (ASHRAE; 1997).

Air temperature and humidity also influence perceptions of the quality of indoor air and the level of complaints related health symptoms (often called sick building syndrome symptoms). Higher air temperature has been associated with the prevalence of increased sickness symptoms in several studies (Skov et al. 1989, Wyon, 1992; Menzies et al. 1993). Occupants' perceived acceptability of air quality has been shown to decrease as temperature and humidity increase in the range between 18 °C, 30% RH and 28 °C, 70% RH (Fang et al. 1997, Molhave et al.; 1993).

Moisture is not a pollutant but it has a strong influence on indoor environmental quality particularly inside the *musalla* and the hot-dry climate in Baghdad. Water vapor is generated indoors due to human metabolism and human activities involving water use, as well as due to unvented combustion activities and by humidifiers. Moist soil may be a source of moisture in indoor air and in the flooring materials that contact the soil. The implications of high humidity for human health are complex and still a subject of debate (Arens and Baughman; 1996). The impact of moisture and pollutants still has no clear influence in general in Baghdad's hot-dry climate region particularly on the indoor environment of the new *musalla* where prayers are performed, but humidors are used to cool the inner environment sometimes.

ii. Basic Principles of Natural Ventilation for the *Musalla* Building

-Natural ventilation is defined as ventilation driven by the natural forces of wind and temperature. Natural ventilation is created by pressure differences between inside and outside of the building induced by wind and air temperature differences. These provide the two main mechanisms of wind induced ventilation and stack ventilation or thermal buoyancy ventilation. The existence of a courtyard in the new mosque complex contributes in this phenomenon. Solar assisted ventilation uses the solar thermal energy to increase the thermal buoyancy, either within a building envelope or associated flue, and therefore enhances any stack effect that exists.

-Good design is based on the principle that adequate ventilation is essential for the health, safety and comfort of building occupants, but that excessive ventilation leads to energy waste and sometimes to discomfort. The aim of good *musalla* building design is therefore to 'build tight - ventilate right'. That is, to minimise uncontrolled (and, usually, unwanted) infiltration by making the building envelope airtight while providing the required ventilation with `fresh' air in a controlled manner. We need to remind ourselves that the *musalla* building cannot be too tight-but that can be under-ventilated. For an overall successful natural ventilation strategy, the three issues of: building tightness, good ventilation for praying people, and natural ventilation design have to be considered together in an integrated manner for *musalla* design.

-Ventilation must be providing safe, healthy and comfortable conditions for building occupants. An over-riding principle in "ventilating right" is that ventilation should be for prayers-not for the building. This is important in the *musalla* building, which is voluminous related to the limited number of occupants performing the five daily prayers.

-In naturally ventilating the *musalla*, two distinct strategies have to be developed, one for the winter and other for the summer.

The key issue for winter ventilation is the control of indoor air quality (IAQ). Summer ventilation is usually linked to the control of internal temperature. - Control of the airflow rate is in itself not so important. The issue is that of overheating in the summer and one of the main technical barriers considered.

iii. Flow Caused by Wind

Major factors affecting ventilation wind forces include: average wind speed; prevailing wind direction; seasonal and daily variation in wind speed and direction; local obstructing objects, such as nearby buildings and trees; position and characteristics of openings through which air flows; and distribution of surface pressure coefficients for the wind.

iv. Guidelines for Natural Ventilation for the *Musalla* Building

The following guidelines are important for planning and designing natural ventilation systems in the *musalla* buildings: a natural ventilation system should be effective regardless of wind direction and there must be adequate ventilation even when the wind does not blow from the prevailing direction; inlet and outlet openings should not be obstructed by nearby objects; windows should be located in opposing pressure zones since this will usually increase ventilation rate; a certain vertical distance should be kept between openings for temperature to produce the stack effect; that is, it could be achieved using low level openings as inlets for fresh air to get cross ventilation with the existence of high openings on the drum of the dome. Openings at the same level and near the ceiling should be avoided since much of the air flow may bypass the occupied zone which is situated at a height of eight feet; architectural elements like wing walls, parapets and overhangs may be used to promote air flow into the *musalla* building; landscaping, courtyards which almost always exist in the traditional mosque complex in Baghdad, and the surroundings of the *musalla* buildings should be used to redirect airflow and give maximum exposure to breezes; according to the fixed orientation of the *musalla*, the long façade of the building and the door and window openings generally oriented with respect to the prevailing wind direction (northwest in the Baghdad region); window openings should be accessible to and operable by occupants; vertical shafts and open staircases may be used to increase and generate the stack effect; openings in the vicinity of the neutral pressure level may be reduced since they are less effective for thermally induced ventilation; if inlet and outlet openings are of nearly equal areas, a balanced and greater ventilation can be obtained as well as adding humidors which contribute to enhancing the hot-dry climate in Baghdad(see survey strategy in Chapter five.)

v. Barriers to the Application of Natural Ventilation for the *Musalla* Building

A successful application of natural ventilation strategies is only possible when there are no problems in many areas at various levels from the design stage to actual operating demands placed on the building users (Allard; 1998). **These potential barriers include**:

-Barriers during building operations; are not expected in case of the *musalla* for limited activities and periods of occupation.

-Safety concerns; are not expected in the *musalla.*

-Noise from outdoors; is not expected since the *musalla* is surrounded by other mosque complex facilities which protect it from outside noise.

-Dust and air pollution; that is expected in case of a southeast wind blowing during a few days in summer.

-Solar shading covering the openings; particularly Islamic grilled patterns on the *musalla's* windows that are uses traditionally. It does not represent a major barrier.

-Draught prevention; it could be controlled through the design process of the *musalla* envelope and microclimate.

-Knowledge of the users about how to take the best advantage of natural ventilation; it concerns the design process of the *musalla* also.

-Barriers during building design; it is expected in case of ignoring passive design criteria, which is the target in this research

-Building and fire regulations; it is not expected to form any barrier in Baghdad.

-Need for acoustic protection; it should be considered in the design process to prevent any barrier.

-Devices for shading, privacy & day lighting may hamper the free flow of air; they could be treated to prevent any barrier through the design process.

-Problems with automatic controls in openings; it is not expected to be a barrier in the case of the *musalla* building.

-Lack of suitable, reliable design tools; it might be expected in case of ignoring the passive design criteria, which are discussed in the present chapter.

-Other barriers;

-Impact on architectural & envelope design; which has priority and is considered as a major factor. This research concerns the prevention of such barriers.

-Fluctuation of the indoor conditions; it is expected to some extent at the beginning and end of summer season in the Baghdad region.

-Design of a naturally ventilated building requires more work but could reduce the need for mechanical systems; it is possible through suitable envelope design and *musalla* microclimate to remove any expected barrier.

-Lack of suitable standards; it could be a barrier because the passive design in Iraq is still relatively new.

-Indoor Air Quality; that is influenced by the number of praying people their activities and time of occupancy. This represents a minor factor because of all that factors and limited activities and praying persons relating to the *musalla* volumetric space.

vi. Chimneys; Natural Ventilation Alternatives

Chimneys (or vertical air tunnels) can often be utilized in the *musalla* to conveniently Provide effective ventilation.

The chimney can be designed for remodeling purposes in the *musalla* building or modified environment building. When the inside air temperature is higher than the outside air temperature, a pressure difference is created that causes the warmer, less dense air to rise. The natural process behind this air movement is commonly referred to as thermal buoyancy or the stack effect.

Natural ventilation by thermal buoyancy is affected by inlet and outlet area, height difference between the inlet and outlet (we can benefit from this phenomenon for such typical high spaces of the new *musalla* in Baghdad generally), and the difference between inside and outside temperatures that occurs normally with the existence of a courtyard. Utilization of the stack effect for ventilation can provide the primary air exchange needed during summer periods particularly in congregational prayers, and supplemental ventilation for the *musalla* in other defined conditions during other seasons.

Air moves through the lower openings of the *musalla* to the upper openings, and out of the *musalla* under the impact of the stack phenomenon. The chimney concept can contribute more in this case to get highest ventilation efficiency. Inlet openings must exist around the perimeter of the *musalla* envelope to allow cooler outside air, which move from the traditional courtyard in the new mosque complex under the impact of the buoyancy phenomenon, to enter the *musalla*. This fresh air replaces air that is exhausted from the upper openings of the *musalla* envelope.

vii. Mixed Mode

From CIBSE AM13: 2000 'Mixed mode' is a term used to describe servicing strategies, which combine natural ventilation with mechanical ventilation and/or cooling in the most effective manner. The mixed mode approach to achieve indoor environmental conditions involves maximising the use of the building fabric and envelope, and then supplementing this with degrees of mechanical systems, in all or parts of the building. The greatest saving can be made if the improvements to the fabric allow a building services system to be completely eliminated from part if not all of the building. For example:

-Reducing fabric and internal heat gains may allow mechanical cooling to be avoided.

-A highly insulated and airtight fabric with low-powered mechanical ventilation and heat recovery may allow both mechanical refrigeration and perimeter heating to be avoided.

-The effective use of external night-time temperature differentials in summer can permit any excess heat built-up during the day to be removed at night, using natural ventilation, thereby reducing, and possibly eliminating, the need for simple mechanical cooling during the daytime.

4.3.4 Thermal Properties of the *Musalla* Building

The building envelope is the division between the external and internal environment, so its thermal specifications determine the impact of climatic variations on the thermal environment of the building.

The envelope parameters, which include walls, windows, doors, roofs, and domes, have different effects on heat exchange, whereby heat gain through unshaded windows and roofs represents the largest proportion of the total amount of heat gain of the building, (see Fig.4.2).

Radiation is absorbed, reflected or passed through the building envelope and heat is radiated to the sky through it. This process depends on the physical and thermal specifications of the envelope.

The absorption of the external surfaces depends on exposure time which determines the heat gain of the section, so low absorption means low heat gain. It also depends on the color, texture and the material of the surface because light colors with smooth textures reflect the radiation more, and vice versa, (see Fig.4.2.)

The U-value of the building is one of the envelope characteristics. It is an indicator of heat gain through the section. When the thermal conductivity is high (that means low resistance of the section) the heat gain and heat loss become high, and thus the insulation materials have low conductivity with high resistance to the heat transmission through it. Its efficiency depends on its quality and location, but it has a negative impact on the transmission from the internal space to the outside through the section, particularly in summertime (see Fig.4.2.)

Research performed by Givoni (1970) and Van Straateen (1967) shows that insulation layers in the section "on the external surfaces" are better for envelope efficiency than "the internal surfaces."

However, there are different elements of the envelope such as the windows, doors, walls, domes, flat and pitched roofs. Each of these elements and parameters has a different impact in terms of heat exchange, while the heat gain through unshaded windows and roofs represents the most effective part regarding heat gain, in comparison with other parts of the building envelope (Shaaban & Al-Jawadi; 1975), (see Fig.4.6.)

Some of the radiation falling on the envelope is reflected; some is either transmitted or absorbed depending on the thermal and physical specifications of the building envelope materials, common local materials used in the new *musalla* in Baghdad.

The solar absorptivity of the external surfaces of the building defines the heat gain by certain section specifications; this also depends on surface color and texture. Light and smooth surfaces reflect more, this means the low absorptivity factor of the wall or roof and vice versa.

Other envelope characteristics, like conductivity (U-value), represent one of the heat flow indicators through the envelope section. When the conductance is high because section components have low resistance, the heat gain and loss become high.

> *'There is much energy and much money to be saved by employing climatic design principles, i.e. adjusting the building to the climate. The potential energy savings can be determined'....'A prerequisite for understanding*

energy saving in building is through an understanding of the mechanisms, which influence the energy balance' (Reimann; 2000).

Displaying the various heat flows for buildings as Koenigsberger & Others (1973) explain for energy balance for building in formula is described in detail below:

$Q1+Qs+Qc+Qv+Qm-Qe = 0$

Q1 = Internal heat gain (human bodies, lamps, appliances etc.).

Qs = Solar heat gain through windows.

Qc = Conductance of heat through walls, roofs and foundation.

Qv = Heat exchange by ventilation.

Qm = Heat removal/ supply/ by mechanical controls (eg. air-conditioner and heater).

Qe = Evaporative cooling from building surface (eg. a roof pool).

All the respective heat fluxes in the equation must add up to zero to maintain the desired indoor temperature. If the heat fluxes add up to a positive number the temperature of the *musalla* (building) will increase and vice versa. This equation applies to all climates as heat transfer by conductance (Qc), ventilation (Qv) and mechanical control (Qm) can be both positive and negative. The outdoor climate and usage of the building are constantly changing, and the indoor temperature will therefore vary accordingly. The air flow-energy of the building is to keep temperature variations within the comfort zone of the occupants at minimal (energy) cost-i.e. Minimizing Qm (Reimann; 2000).

Storage of heat (which indicates the time lag factor or thermal mass of the envelope) transfers from the envelope to the lower heat medium (external environment).

In this manner, the heat flow to the inner environment is reduced, so heat time lag delays heat flow to the inner environment when the external environment heat becomes high and heat flow to the external environment also delays as a result of that. Low external air temperature takes away the stored heat of the envelope when the external air temperature becomes lower during the night. The opposite heat flow during night-time may happen depending on the external environment air temperature; the internal air temperature; and the envelope thermal specifications. Envelope heat capacity delays cooling and heating periods at daily heat flow circulate.

i. Components of the *Musalla* Building Envelope and Thermal Comfort

> *'Integrated resource planning shows that it is five times cheaper to save energy in buildings (US$ 400/kW) than to increase the power production capacity (US$ 2000/kW)...it is economically feasible to save an estimated 40-50% of the energy in new buildings (new envelope) and 15-25% in existing buildings.' (Kannan; 1999).*

> *'Denmark has been very successful in attaining energy savings in buildings. The energy consumption for space heating per.sq m floor area has been reduced by 50% over the last 20 years. During this period, the building codes have gradually become more stringent.' (Longhi; 1999).*

Envelope characteristics play an important role in increasing energy conservation inside the building, (see Fig.4.2). One of the important characteristics of the *musalla* envelope is the orientation towards Mecca, which is constant as a main feature for every mosque. Therefore, the envelope design represents the third and last variable after the thermal specification of envelope materials and orientation, which plays a major role in protecting the inner environment. The building envelope consists of both the opaque and transparent parts of the walls and roof, which are in contact with the external environment. These may be single or multi layer, and represent the partition between the external environment (microclimate around the *musalla*) and the internal environment (Al-Umary;988).

The functions of the envelope perform structural, aesthetical, environmental and other tasks. The environmental function represents the main function that protects the inner environment of the building from the impact of external variations of climatic phenomena (see Fig.4.4, 4.5.) It may depend on mechanical and electrical systems –as additional elements to the thermal efficiency of the building–to reach the comfort zone when the envelope is unable to maintain the internal environment, and to achieve a thermal balance inside the *musalla*(Al-Rawi; 1988).

Since Iraq does not have any energy regulations for buildings yet, there is not much to say about energy regulations for buildings in Iraq, and it needs to establish more up-to-date regulations and progressive systems concerning energy standards.

> *'A design criterion –the OTTV (Overall Thermal Transfer Values) is applied to the building envelope. The idea is to set a maximum level for the heat gain through the building envelope (walls, roof and windows) in order to reduce the cooling load' (Reimann; 2000).*

Since the envelope consists of two kinds of elements; the opaque part, which includes constructed walls and roofs; and the transparent part represented by windows or openings, it is necessary to know the specifications of each as detailed below.

1. Opaque Part

As a result of the difference between the inner and outer environmental temperatures, as well as the effect of falling solar radiation on the external surfaces of the envelope, heat is transferred to the inner environment by conduction. In addition, solar radiation is absorbed by external surfaces and transferred across the envelope section, and heat is transferred by convention from the inner surface of the envelope through the air to the inner environment. The heat transmission continues to reach the inner wall surface by conduction, and later to the inner environment by conventions, which convert it to the inner surfaces by radiation.

2. Transparent Part

Some solar radiation falling on transparent surfaces such as window glass is reflected, but other amounts are absorbed by the glass and transferred through it to the inner environment.

So, this radiation adds to the amount of heat, which is transferred in other ways, and increases the amount of heat in the inner environment through the additional amount of solar radiation transmission. This is what is called 'solar heat gain'. In addition, the conduction method through transparent parts is due to the difference between the external and internal air temperatures, (see Fig.4.6)

ii. Building Envelope Treatments Under Different Environmental Conditions

An isolated envelope during the cold season represents a barrier to prevent heat from escaping from the inner environment, so an insulation layer should be used to enhance the ability of the envelope and should be attached to the external surface of the envelope.

An additional smooth thin layer must be attached too to the inner surface of the envelope section to prevent vapor condensation and its appearance on the inner surface of envelope.

The thermal capacity of the envelope in a hot-dry climate helps reduce the thermal temperature instability of the inner environment and delays the heat from reaching peak levels.

In addition, since the external thermal temperature during night-time drops, it is necessary to protect the inner environment from external variations of temperature, (see Fig.4.3.4.4 and 4.5.)

The transparent part of the envelope plays an additional role in heat exchange: It permits solar radiation wave transmission, and prevents its reflection out of the inner environment when the short wave becomes long wave.

The transmitted solar radiation across window glass is able to increase the air temperature of the inner environment to a level higher than the external air temperature, through what is called the 'Green House' Effect, while the normal transmission range through glass is 70% of solar radiation falling on it (Al-Rawi, 1988;47).

Thus, it is necessary to limit solar heat gain by the inner environment through the following listed recommendations:

1. Use heat filter glass for windows. (See Appendix A1) P.286.

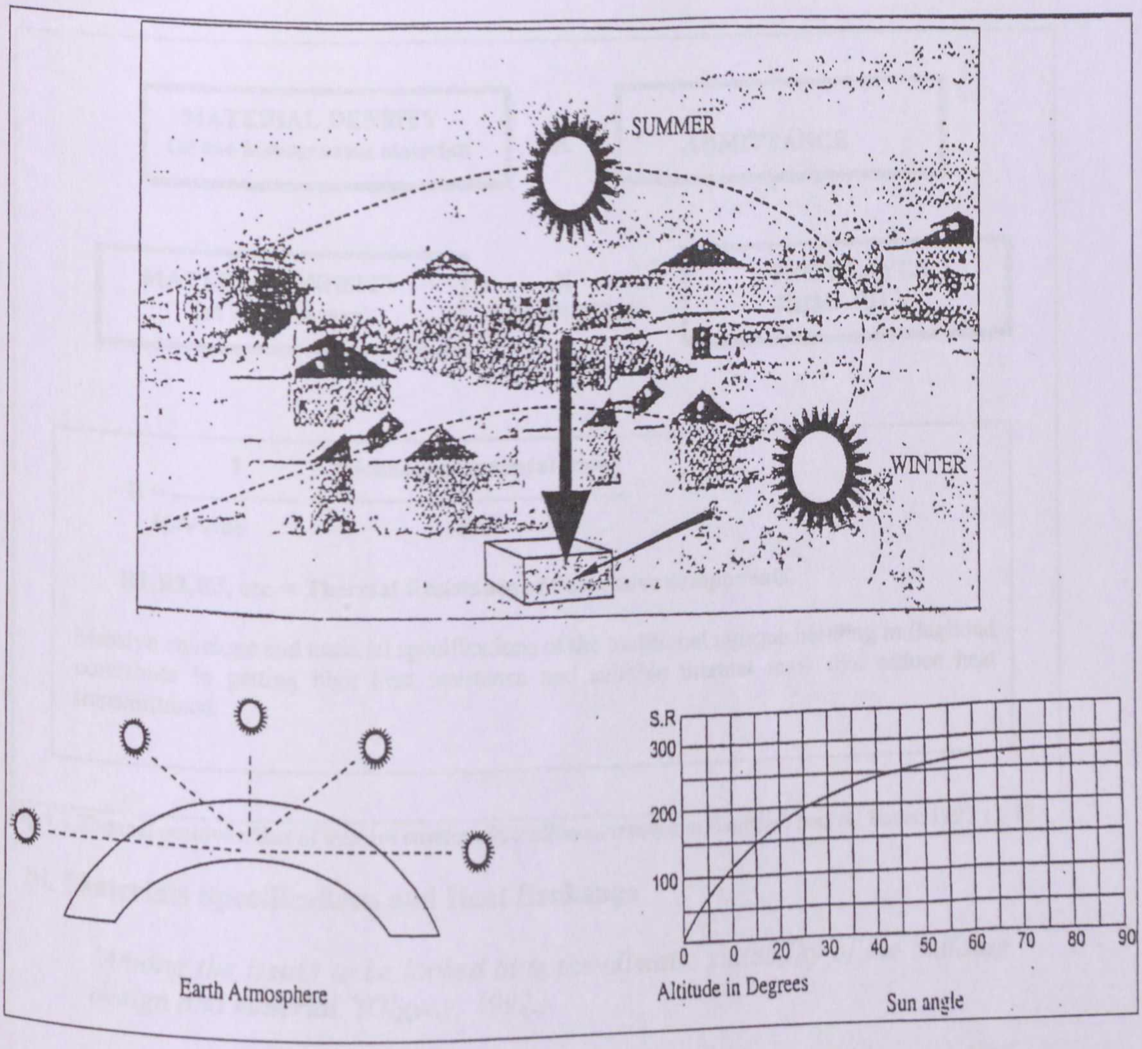
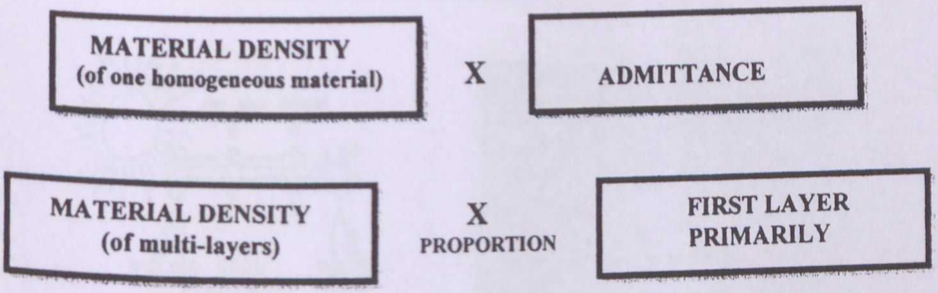


Fig.4.2 Solar radiation impact on building envelope. Source; Al-azawip;1984.

2. In other building typology, optimizing building orientation contributes to getting the lowest window exposure to solar radiation, but it is impossible in case of the *musalla* building since the orientation is a constant factor. Enhancing the *musalla* building microclimate affects the comfort level inside the *musalla*.
3. Use shading devices (louvers), vertical, horizontal and compound types according to the need for each orientation, particularly the southwest, west north and north east sides of the *musalla* building.
4. Reduce the percentage of glazing area on the southeast, west north and northeast sides of *musalla* envelope.



$$R = \frac{1}{\text{K-Value}} \times \frac{\text{thickness of material (mm)}}{1000}$$

R1,R2,R3, etc. = Thermal Resistance of Successive components.

Massive envelope and material specifications of the traditional mosque building in Baghdad contribute in getting high heat resistance and suitable thermal mass that reduce heat transmittance.

Fig.4.3 Thermal positive effect of massive envelope in traditional mosque in Baghdad. Source: Baden 1997;12-13.

iii. Materials Specifications and Heat Exchange

'Among the issues to be looked at is the climatic suitability of the building design and material.'(Olgyay; 1992.)

'Thermal control for building in hot climates can be achieved by means of mechanical and structural control' (Koenigsberger et al.; 1980.)

It means that mechanical control involves the use of mechanical or active systems for cooling or heating needs. Structural controls are passive cooling via appropriate use of thermo physical properties of materials and other parameters.

Thermal design of buildings is design with appropriate construction materials that act as an efficient thermal barrier between the inner and outer environments.

'Building materials with suitable thermo-physical properties could control the process of heat transfer in and out of a building.
These properties are:
a) Thermal conductivity, resistance and transmittance.
b) Surface characteristics with respect to radiation-absorptivity, reflectivity and emissivity.
c) Surface convective coefficient.
d) Heat capacity.
e) Transparency to radiation of different wavelengths.'(Givoni; 1976).

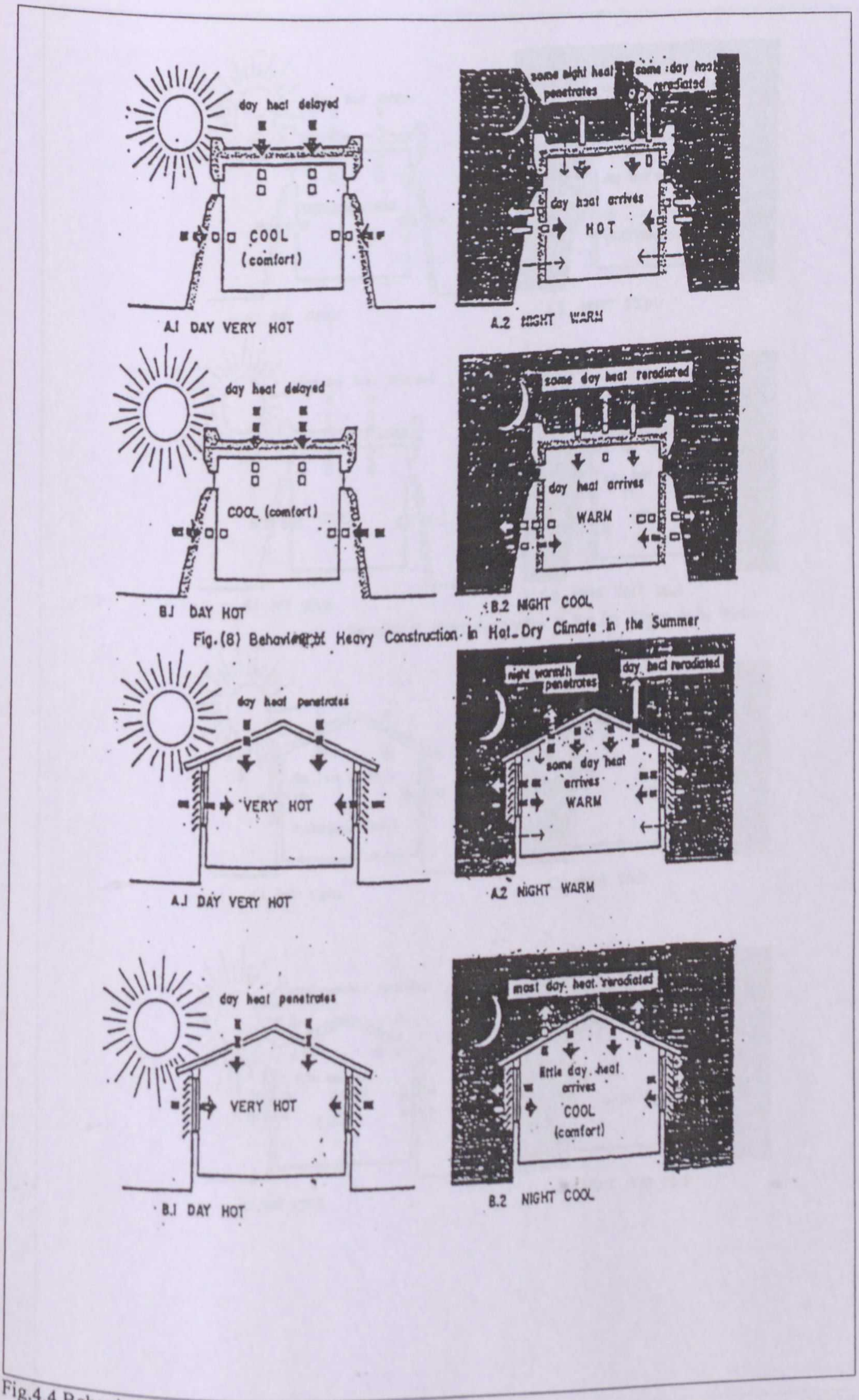


Fig.4.4 Behavior of envelope in a hot-dry climate.

Source: Shaaban. A K.;210;1973.

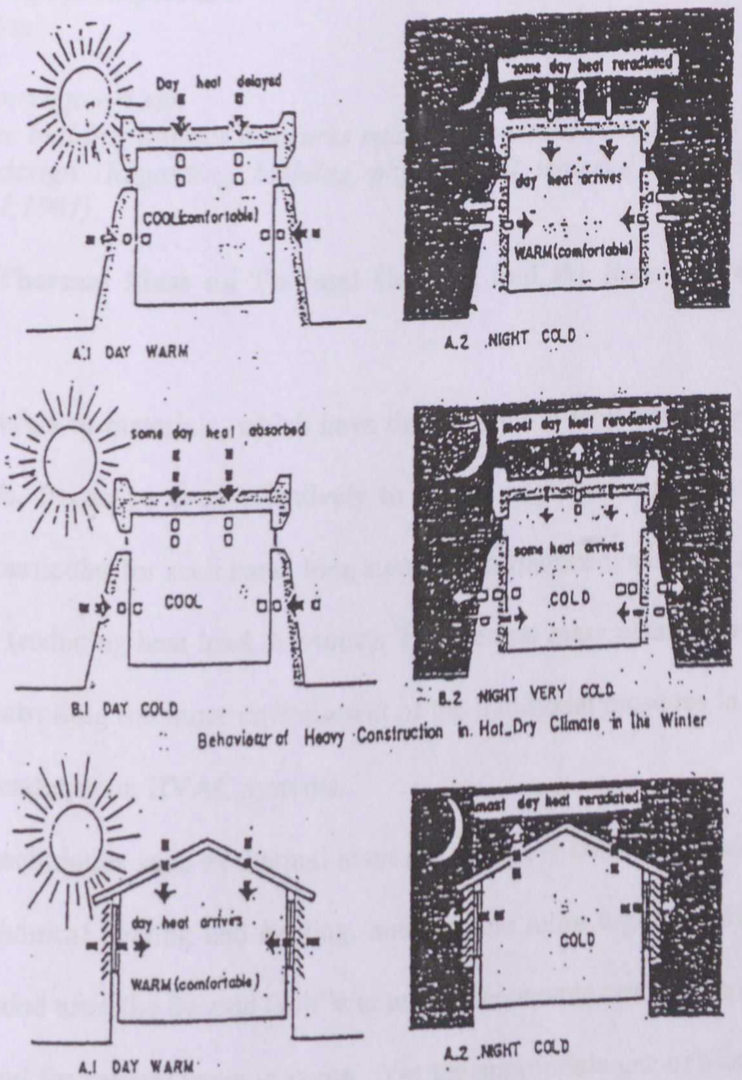


Fig.4.5 Behavior of light & heavy envelope in a hot-dry climate in winter. Source:Shaaban.cit.:211;1973.

'For these climatic conditions (hot dry-climate), the following building physics design principles are:
a) insulation
b) storage
c) protection against sun
These three building physics measures must be translated consequently into building design. Regarding building physics and material technology' (Gertis A.J;1981).

iv. Impact of Thermal Mass on Thermal Comfort and the Role of the *Musalla* Envelope

Thermal mass refers to materials, which have the capacity to store thermal energy for extended periods. It can be used effectively to absorb daytime heat gains (reducing cooling load in particular for such harsh long summers in Baghdad) and release the heat during the night (reducing heat load in winter). The thermal mass phenomenon is used effectively in controlling the inner environment of the traditional mosques in Baghdad, and reduces dependence on HVAC systems.

Today, passive techniques such as thermal mass are ironically considered "alternative" methods to mechanical heating and cooling, and become more urgent in the *musalla* building in Baghdad after the Second Gulf War and the economic crisis in Iraq which is expected to extend for several years to come. Yet the appropriate use of thermal mass offers an efficient integration of structure and thermal services.

The thermal properties of the main common materials used in the construction of the new mosque building in Baghdad are:

Table 4. 3a Density of common construction materials used in mosque buildings in Baghdad.

Material	Density (kg/m3)
Concrete	600-2200
Stone	1900-2500
Bricks	1500-1900
Earth	1000-1500 (uncompressed)
Earth	1700-2200 (compressed)

See more explanation in Tables 5.9 and 5.10, Chapter five. Source: www.squ 1.com.

The basic properties that indicate the thermal behavior of materials are: density (p), specific heat (cp), and conductivity (k). The specific heat for most masonry materials, which represent more than 60% of the structure of the new mosque building in

Baghdad, is similar (about 0.12-0.25 Wh/kgC°),see more details in p.120. Thus the total heat storage capacity is a function of the total mass of masonry materials, regardless of its type (concrete, brick, and earth). Due to the high thermal ranges and external climatic fluctuations during day and night in Baghdad which have a major impact on the inner thermal comfort of the *musalla*, the high thermal mass of the *musalla* envelope can protect the inner space from thermal unsuitability through the previously mentioned traditional treatments. Based on the research of Evans (1980), the desired time lag of the envelope walls in a hot-dry climate should be within 8 to 14 hours. A greater time lag than this range will not enhance the inner environment thermally to reach comfort level because of overlapping occurrence with the heat gain of the roof by ventilation. The desired time lag for the roof is normally in the range of 20-30 hours.

Considering an external wall exposed to a high outside air temperature and a lower inside air temperature, the rate of heat flow transmitted through the wall from the outside air to the inside air is proportional to the air temperature difference, area of the wall, and rate of global heat transmittance that can be determined from an analysis of the components of the total resistance to heat flow. The total resistance is composed of the resistance to heat flow through the material, the interfacial resistance at the external surface, and the interfacial resistance at the internal surface. Since the interfacial resistances are determined primarily by temperature conditions over which the builder has little control, his principal effect on the heat transmittance is in changing the resistance to heat flow through the wall material. To reduce the heat transmission from one side of a wall to the other, the thermal transmittance must be reduced as much as possible by either increasing the thickness of the wall or using materials of lower thermal conductivity and, therefore, of higher resistance. Often walls composed of several materials, are used to provide the desired thermal and aesthetic wall characteristics. In hot-dry climates, the coefficient of thermal transmittance should be about 1.1 kcal/hm²°C (0.225 Btu/hft²F°) for an outer wall to have an appropriate thermal resistance to heat flow through the wall material.

Light-colored materials reflect sunlight; dark materials absorb the radiation. A *musalla* building with dark walls and roof is less expensive to heat in winter, but more costly to cool in summer. Light-colored walls and roofs lower cooling costs but increase the need for winter heating. The use of light-colored materials is more cost effective and energy efficient, since the cooling season is longer than the heating season.

V. Insulation Materials

The most available and economical thermal insulation material used for external brick wall and RC roof for the *musalla* in Baghdad is polystyrene. This is widely used in Baghdad buildings generally. The most important properties in the selection of the insulation materials are (1) low thermal conductivity, (2) low density, (3) low initial and labor costs, and (4) long thermal life. (See Table.4.6).

> *'The location of insulation material should be near the external layer of the wall, and there should be a gap for ventilation between it and the layer which is beyond it to prevent water vapor condensation' (Husain, 1984:4).*

VI. Shading devices and Thermal Comfort for the *Musalla* Building

Because of the necessary sun shading measures, small windows and relatively compact external facades are correct for the *musalla* building in the climate of Baghdad. The *musalla* building should open onto (shaded) inner courts. If this design is not followed, then highly efficient sun shading devices must be attached to the windows (external roller blinds or awnings).

The decision for selecting the proper shading device presents many difficulties. One of the main difficulties is that it should exclude the sun in the overheated period, yet it should allow sun penetration in the cold period. It is noticed from Fig.4.6 that in the graph of the apparent seasonal movement of the sun changes in declination are symmetrical about the solstices (zero declination). It can also be seen in the graph of (v.s (vertical angle of objects' shade) for south elevation at noon) that the v.s. is

Table. 4.4. Heat capacity for local building materials in Baghdad.

Specific Heat Material	Capacity J/kg.K	Specific Heat Material	Capacity J/kg.K
Ordinary bricks	800	Plastic tiles for flooring	968
Lime bricks	985	White marble	720
Concrete	1180	Black marble	500
Asbestos sheets	1220	Squared-bricks-*Fershi* 0.30x0.30x0.05m	480
Hillan stone-local stone	906	Cement bricks	815
Seino stone-local stone	925	*Marblex* finish for walls	750
Cement mortar	950	Natural Stone	613
Ordinary tiles for flooring	960	Artificial marble	835
Mosaic tiles	956	Concrete bricks	1280
Small size aggregate	700	Ordinary soil	1115
Sand	760	Tar	1568
Mud bricks	1150	Waterproof layers	1580
Juss (local mortar)	1025	Thermo stone bricks	1280
River sand	817	Big size aggregate	843
Ceramic tiles	550		

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

Table 4.5 Thermal conductivity of materials for different section components of new *musalla* envelope.

Material	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 Cement Glazed bricks	0.03 0.12 0.025	0.7 1.5 1.16 0.52	3.26

Source: Husain; 1984;12.

Table 4.6.Ranges of (polystyrene) Most common and Economical Thermal Insulation Materials in Baghdad.

ORIENTATION	MOST ECONOMICAL INSULATION MATERIAL THICKNESS (cm)	ECONOMICALLY ACCEPTED THICKNESS RANGE (cm)
HORIZONTAL (FLAT ROOF)	11	9-13
NORTHERN	10	8-13
NORTH-EAST	10	8-13
EASTERN	10	8-12
SOUTH-EAST	9	8-11
SOUTHERN	7	7-10
SOUTH-WEST	10	8-13
WESTERN	10	8-13
NORTH-WEST	10	8-13

Source: Husain ; 1984;12.

symmetrical. So, the seasonal variation in air temperature has a time lag behind the seasonal variation of the declination of the sun. This presents a problem, for example, if we want to give complete shading for October, it means we also give complete shading for February. On the other hand, February is the cold period, and it does not require any shading. Obviously we cannot have a perfect solution. We must reach a compromise at the expense of part of the overheated period and part of the cold period. Three suggestions are given in Fig.4.6. In the case of the new *musalla* building, the first suggestion might be applicable, because the sun is needed in winter, and some sun heat during the short prayer time which is tolerated at the end of the hot period in Baghdad in such a unique space is not acceptable since the praying people have no choice to shift their prayer place to another shaded area. The final decision will have to be made by the architect. It obviously depends on the circumstances and the type of building (Shaaban A K,Aljawadi M,Jawad A;1975.)

By looking at the overheated period chart in Baghdad Table 4.7, it is noticed that the type of shading devices used for southeast orientation is not the same as those used for southwest for example, even though the values of H.S. and V.S. are similar. Even south windows require different values of protections to their sides, (see Fig.4.6.)

4.4 ESTIMATION MODEL OF HEAT FLOW RATE THROUGH THE *MUSALLA* ENVELOPE

Heat flow happens where there is thermal difference between the inner environment of the *musalla* building and the external environment.

There are many methods used to estimate the heat flow rate through the *musalla* building envelope. Therefore, the estimation of the heat mean method has been chosen to calculate the heat transmittance and the average energy needed to attain inner thermal comfort, which is influenced by environmental impact as well heat exchange as a phenomenon of it.

-The heat flow transfers through the following structural components:

i. Roof	-Reinforced concrete.
ii. Walls	-Bricks.
iii. Windows	-Glass.
iv. Doors	-Normally timber.
v. Flooring	-Normally cement tiles.

vi. As well as heat transfer by ventilation.

vii. The heat transfers through air infiltration.

The estimation of the amount of air getting through cracks is given by:

Q = KL(AP)n

L = Length of crack or opening (m)

AP = Applied Pressure difference (pa)

n = Flow exponent taken as 0.67 (see Baden; 1997)

Typical values of K in liters per second per meter of crack length for an applied pressure difference of 1pa are 0.80 for sliding windows and 0.21 for pivoted windows. (This equation may be used as an additional effective factor in cold countries, which have long harsh cold winters unlike the Baghdad region).

Where Q = flow rate (m^3/s)

K = window leakage factor

For each item and material there is a defined equation to calculate the heat flow through it. The equations to be mentioned below express the heat flow methods through the envelope according to the CIBSE.

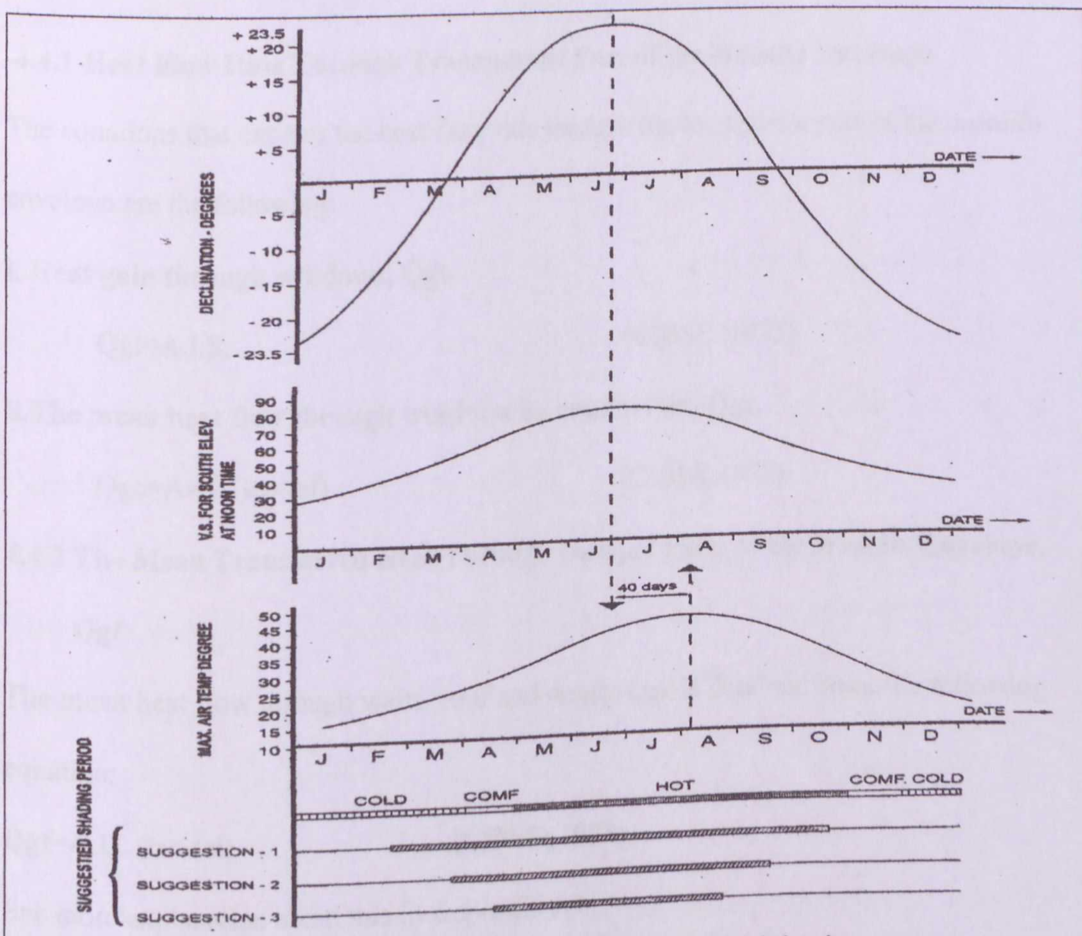


Fig.4.6 Comparison of sun position and overheated period in the Baghdad region.

Table 4.7 Over heated period in Baghdad.

Time / Month	6.00		9.00		12.00		15.00		18.00		21.00	
	Temp.	R.H.	Temp.	R.H.	Temp.	R.H.	Temp.	R.H.	Temp.	R.H.	Temp.	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. ,BRC-Baghdad.

4.4.1 Heat Flow Rate Through Transparent Part of the *Musalla* Envelope

The equations that express the heat flow rate through the transparent part of the *musalla* 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)

4.4.2 The Mean Transferred Heat Through Opaque Parts of the *Musalla* Envelope, Qgf

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

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

See more explanation about this in Appendix A1.

4.4.3 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:

Q_T=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 = 5.6 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 *musalla* (C)

V= *musalla* volume (m^3)

N= number of times of air changing per hour for the inner space of *musalla.*

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 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 18.5°C is assumed as a thermal design degree for the inner environment of the *musalla* in winter in spite of its being lower than the comfort zone. This is because the produced heat from the continuous movements of the praying person, viz., the bowing, standing, sitting, etc., increases the feeling of warmth. This happens as a result of the impact of the metabolic rate temperature. Meanwhile the temperature in summer is assumed to be 25°C.

4.4.4 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 *musalla* windows and windows on the drum of the dome, which follow the same directions, have many different orientations, the orientation of the walls and angles as in Tables A3.A7 and A3.A8, APP.A3 are considered to receive different amounts of solar radiation in proportion to the heat gain to internal environment of the *musalla* as explained in detail in the mentioned tables.

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., (See Tables.A3.A8 and A3.A9,APP. A3.)

ii. Heat Flow Rate Through Walls, Qg

Qg = A.U. (teo- tei)

The section of the typical walls of the *musalla* envelope consists of 0.24m thicknesses of bricks and 0.025m finishing (using local gypsum) for the internal surfaces and 0.025m finishing (using cement mortar) for the external surface. Thus, the u- value (heat conductivity) will be 1.94 W/sq.mc. (See Table. A3.A1,A3.A2,A3.A3 APP. A3).

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. (See Table. A3.8b, APP. A3).

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 Table A3.7, APP.A3 and all the details of heat calculation process through all parts of the dome in Chapter five).

v. Heat Flow Rate by Ventilation includes the heat flow rate for each m3, which is calculated in kWh/m^3 day. (See Table. A3.8, APP.A3).

Qgr= 1/3 NV (teo-tei)

vi. Heat Flow Rate in Conditions of Increasing Humidity

The use of fountains, water sprinklers and water surfaces, in general is suitable to alleviate the hot-dry summer climate of Baghdad. This method will be useful to enhance the *musalla* microclimate then reduce the environmental impact on the inner environment of it to reach thermal comfort. However most researchers are unable to include this in the calculations because of the difficulties of estimating heat flow using this method.

4.5 IMPACT OF THE CLIMATE ON THE NEW *MUSALLA* BUILDING

4.5.1 General

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 *musalla* building envelope, which in turn causes variation in the inside temperature. Two effects do this simultaneously. Firstly, the inside cycle will be damped 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 in Figs.4.4 and 4.5 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.)*

An example of the extreme effect of light construction is that of a small shed with a corrugated metal roof. The internal environment is at the mercy of the external climate.

4.5.2 Microclimate and Site Design

Site layout followed by landscaping can improve the microclimate around the *musalla* building, taking advantage of existing topographical features, adjacent buildings and vegetation for solar protection. Good site layout can also take greater advantage of local breezes by the formation of air tunnels and also aid natural ventilation by staggering the building layout or optimum location within the mosque complex. The presence of water and vegetation on the site can also be used for natural cooling. Good site layout can reduce cooling loads appreciably by optimising natural solar protection and local breezes. Staggered layouts can enhance natural ventilation. Proper siting of the building can provide good comfort conditions within the building as well as reducing energy costs to a large extent. Elements of site design that can be used for efficient natural cooling include landscaping, orientation to sun and wind, building shape and planning, and natural ventilation.

i- Landscaping

Landscaping can improve the microclimate in both summer and winter, providing shading, evaporative cooling and wind channeling in summer by the appropriate location of the *musalla* building among the other buildings within the mosque complex, or shelter in winter. Vegetation absorbs large amounts of solar radiation in summer helping to keep the air and ground beneath (which is used in old traditional mosques, and even other traditional buildings in Baghdad) cool while evapotranspiration can further reduce temperatures.

Use of shade trees, shrubs and vines can provide protection from solar radiation in summer. Careful planting of trees for wind channeling can provide efficient ventilation and circulation of summer breezes in addition to creating attractive spaces for outdoor *musalla*.

Grass and other ground cover planting can also influence the microclimate, keeping the ground temperature lower than most hard surfaces as a result of evapotranspiration and their ability to reduce the effect of solar radiation. This happens due to the shading provided by the grass which prevents radiation from reaching the ground, resulting in a difference between asphalt and lawn being as much as 25 degrees F (figures taken from Climatic Design, Energy efficient building Principles & Practices/ Donald Watson and Kenneth Labs, http://21st –century-home.com).

Windbreaks can enhance air pressure differences around buildings in the mosque complex and improve cross ventilation. Hedging, for example, can allow a gentle breeze to filter through the foliage, while masonry windbreaks can create a calm, sheltered zone behind them. Gaps in windbreaks, openings between buildings or openings between the ground and canopy of trees can create wind channels, increasing wind speeds by about 20%. So, *Riwaq* and other arcade corridors within the mosque complex and around the *musalla* building in particular should be oriented to the prevailing wind direction (which is northwest in the Baghdad region). Thus contributes to getting air tunnels, which then enhance ventilation for the inner *musalla* environment, (Parker; J.H. 1981).

Water can also be used effectively for cooling the internal as well as the surrounding environment. Ponds, streams, fountains, sprays and cascades can be used where water is available in summer. These are particularly effective in the dry conditions of summer days in the Baghdad region where relative humidity levels are low. They should be located near the north and north east side of the *musalla* building.

ii. Cooling Effect of Transpiration

Plants release water through pores in their leaves. The evaporative loss of this water is called transpiration. As hot air passes over the surface of the leaves, the moisture absorbs some of the heat and evaporates. The process thus cools the air surrounding the leaf surface. This interaction is called evaporative cooling, which can lower air temperatures surrounding vegetation by as much as 9°F (5°C) (Climatic Design, Energy efficient building Principles & Practices/ Donald Watson and Kenneth Labs, http://21st –century-home.com).

The greater the leaf area in the landscape, the greater the cooling effects of transpiration. The use of plants for shade and wind control instead of structural features, such as fences and arbors, thus provides an additional benefit toward maintaining thermal comfort during Baghdad's long summer. Air temperatures near shade trees and foundation shrubs are considerably lower than in open areas, resulting in lower heat gains through nearby walls or windows of the *musalla* building. If summer breezes are channeled through and across vegetation, their cooling capacity in non-humid weather is increased. To maximize the effects of evaporative cooling, increase the amount of plant cover around the *musalla* building. Use turf grasses and ground covers to their fulle potential in the landscape as alternatives to paved surfaces such as asphalt or concrete.

iii. Impact of Orientation to Sun and Wind on the Mosque in the Urban Area

The orientation of the building on site is very important to achieve reduced heat gain and improved wind circulation and ventilation. The major openings in the *musalla* building envelope should be placed on the north while the south and south-east faces should be adequately protected from heat gain by using shading devices or vegetation as well as extension of *Riwaq* to embrace the *musalla* building from several sides. As far as possible all windows of the *musalla* envelope should benefit from shading to reduce heat gain. The prevailing wind direction should be taken into consideration while deciding the position and size of the openings to ensure proper cross ventilation. This can go a long way in improving comfort conditions within the building.

iv. Building Shape, Site Planning and the *Musalla* Microclimate

The configuration of the *musalla* building and the arrangement of internal activities can help to influence the exposure to incident solar radiation, the availability of natural daylight and airflow in and around the building.

In general, a compact building will have a relatively small exposed surface as mentioned in the discussion of the optimization of the size of the *musalla* zone, or in other words a low surface to volume ratio (SVR). This can offer advantages for the control of heat gains through the building skin without conflict between the design priorities for winter and summer months. There are ranges of other options to improve thermal performance including courtyards (which represent the main element in the site design of the mosque complex in Baghdad), massive construction, use of wing walls, etc. However, the relationship between form and thermal transmission are not very critical as a number of strategies are available to counteract its negative effects. More important are the effect of the majestic size of the *musalla* building that helps wind channeling and airflow patterns and the opportunities for enhancing the use of daylight.

v. Role of Natural Ventilation in Enhancing the *Musalla* Building Microclimate

Ventilation provides cooling by using air to carry heat away from the building and from the human body. Air movement may be induced either by natural forces (wind and stack effect) or simple mechanical fans. Airflow patterns are a result of differences in pressure patterns around and within the *musalla* building. Openings should be oriented to catch the prevailing summer breeze from the northwest as far as possible.

Air moves from high-pressure regions to low pressure ones. When the outside air temperature is lower than the inside air temperature, building ventilation can exhaust internal heat gain or solar heat gain during the day and cool air during the night, if required. Indoor air movement enhances the convective exchange at the skin surface and increases the rate of evaporation of moisture from the skin. Evaporation is a very powerful mechanism for cooling which may bring a feeling of comfort to the occupants under hot conditions. However, to be effective the surrounding air should not be too humid (relative humidity less than 85%). Turbulent air movement will hinder both of these mechanisms of heat removal.

Both the design of the *musalla* building itself as well its surrounding spaces can have a major impact on the effectiveness of natural cooling through ventilation. The rate of air flow through the building will be affected by location, sizing and air flow characteristics of the openings (wing walls, louvers, overhangs can be used to direct summer wind flow into the interior), the effect of indoor obstacles to air movement (open plan spaces of the *musalla* building promote air flow), the effects of the external shape of the building in relation to wind direction, etc. The total airflow normally depends on a combination of buoyancy and wind pressure differences, and is affected by the size and location of openings and the courtyard treatment in terms of vegetation, corridors around it as well water elements (Wolman, Abel,; 1965). Proper placement of openings along with the use of wing walls can greatly enhance the effect of ventilation by increasing wind pressure differences and consequently air velocity within the space. Other strategies for improving ventilation are wing walls, wind towers and solar chimneys.

vi. Architectural Design for a Comfortable Microclimate and Building Materials

Before the advent of modern mechanical means for obtaining thermal comfort, people in the hot-dry zones were forced to devise ways to cool their buildings with only natural sources of energy and physical phenomena. Generally, these solutions have been found to be much more in harmony with the human physiological functions than such modern means as electrically powered desert coolers and air-conditioners, and for other important reasons particularly in Iraq after the Second Gulf War.

This situation is unchanged for the majority of people in the industrially developing countries, where the conventional energy sources of the industrialized world are not readily available at affordable prices. There is a clear need to further develop the traditional systems of mosque building in Baghdad based on natural resources. Before inventing or proposing any mechanical solutions, rich traditional solutions in vernacular architecture in Baghdad should be evaluated, and then adopted or modified and developed to make them compatible with modern requirements. This process should be based on modern developments in the physical and human sciences, including the fields of materials technology, physics, aerodynamics, thermodynamics, meteorology, and physiology, (see Fig.4.7.)

vii. Architectural Design for a Comfortable *Musalla* Building Microclimate

In designing and planning for the hot-dry zone, two of the main problems confronting the architect are to ensure protection against heat and provide adequate cooling. The Earth's major source of heat, the sun, also creates the secondary climatic elements of wind and humidity that affect physiological comfort. These are caused by the configuration and nature of the local surface, such as the mountains, plains, oceans, deserts, and forests. The interplay between this astronomical source of energy with the effects it causes and the landscape creates the microclimate, which is the concern of the science of meteorology.

However, the built environment for the defined site of the mosque complex in Baghdad produces changes in the microclimate. The configuration of buildings, their orientations, and their arrangement in space create a specific microclimate. To this must be added the building materials, surface textures and colors of exposed surfaces of the buildings, and the design of open spaces, such as pavement, arcade routes, courtyards, and gardens. These man-made elements interact with the natural microclimate to determine the factors affecting comfort in the built environment: light, heat, wind, and humidity.

There is no doubt that certain configurations create better microclimates than others. For each site, but in such for such building typology of *musalla* and such hot-dry climate of Baghdad, there is an optimum arrangement in space that the designer should seek and use as a standard of reference in the process of deciding upon a certain design. Where it can be avoided, it is inappropriate and irresponsible to implement a design that adds even one degree of temperature or reduces air movement by one centimeter per second, if this would negatively affect thermal comfort for such a particular free running *musalla* building.

viii.Other Structural Features

In summer, large roof overhangs can help shade windows and walls, as well as walkways adjacent to the *musalla*. Arbors or trellises over outdoor living areas increase comfort and shade nearby walls. If possible, driveways and *Riwaq* should be located on the south, southwest and northeast sides of the *musalla* building, east or north side of it, to reduce heat buildup during warm afternoons.

Solid surfaces such as concrete and asphalt, which reflect a great deal of heat, should be kept to a minimum around the *musalla* building. Brick driveways build up less heat than either asphalt or concrete and produce less glare than concrete; in this case local traditional squared fired bricks *Fershi* (0.30x0.30x0.05m) might be used. Ground cover plants and organic mulches are the best option for covering large areas. Ground covers offer a cooling effect and are not energy intensive.

Organic mulches reduce runoff, are inexpensive and an attractive alternative to pavements.

ix. Creation of Micro-climate

In the hot-dry climate of Baghdad, the design of buildings for comfort must address:

-resisting summer heat inflow from outside

- ejecting the heat build up emanating from occupants and appliances inside the building

This approach is appropriate for comfort design for the *musalla* building in Baghdad.

Variations in weather occur every day.

Even though it varies in detail from day to day, it is nevertheless uniformly composed of three contributing influences:-

- sun heating
- wind
- moisture mixed to varying degrees

These forces are the component pieces of micro-climate.

By erecting a building on a piece of land, the climate changes on the land. This occurs with every building constructed on every site.

Now there is shade cast by the building onto the ground to the south of that building, and the portion of the site north of the building receives additional reflected heat load from the building's walls. By constructing a building on the land, the site is segmented into a sunny side hot zone and a shaded side cool zone. This occurs as part of locating the building on the land.

x. Using Microclimate Forces for Comfort

Warm external afternoon spaces are pleasant places to live in winter, cool outside spaces are comfortable in summer. But these changes to the *musalla* building site's microclimate also affect the interior comfort of the *musalla* building. By creating variations in heat load, wind pressure and moisture on different faces of the *musalla*, the interior can be kept comfortably warm in winter and ventilated and cool in summer. This is described in detail in other areas below. Microclimate occurs on every *musalla* site within the mosque complex, with the combination of the land's existing features, and by placing the building appropriately on the site.

The first considerations in planning the new *musalla* are:-

- which existing features of the land affect the microclimate, and determine where the building is to be situated on the land for comfort.
- which way the walls face and openings are to be oriented to maximise comfort,
- and the heat, cooling and air flows which are created by the above for comfort in other areas on this site.

4.6 CLIMATIC DATA TEST

The climatic data that are needed are the means of air temperature and solar radiation for Baghdad. Therefore, the definition of the two temperatures (25 and 18.5°C for cooling and heating) means that when the air temperature of the inner environment drops off to 18.5°C there will be a need to increase it or a need to heat, taking into maximum comfort temperatures for the human body (Dawud; 1983: Appendix A, Table A2). This is due to the reasons stated below:

-People praying are continuously moving; therefore they produce energy of more than 1.0 met (metabolic process), (see Fangers' classification, Table4.2).

-People praying wear all their clothes during the prayer time (see more details about common clothes used by praying people inside the new *musalla* building in Baghdad under the topic of clothing in the present chapter, (Table no.4.3).

4.6.1 Calculations of Heat Transmittance (U-value)

The u-value calculation for the structural components of the *musalla* envelope depends on the section area and heat transmission factor of materials, and also the inner and

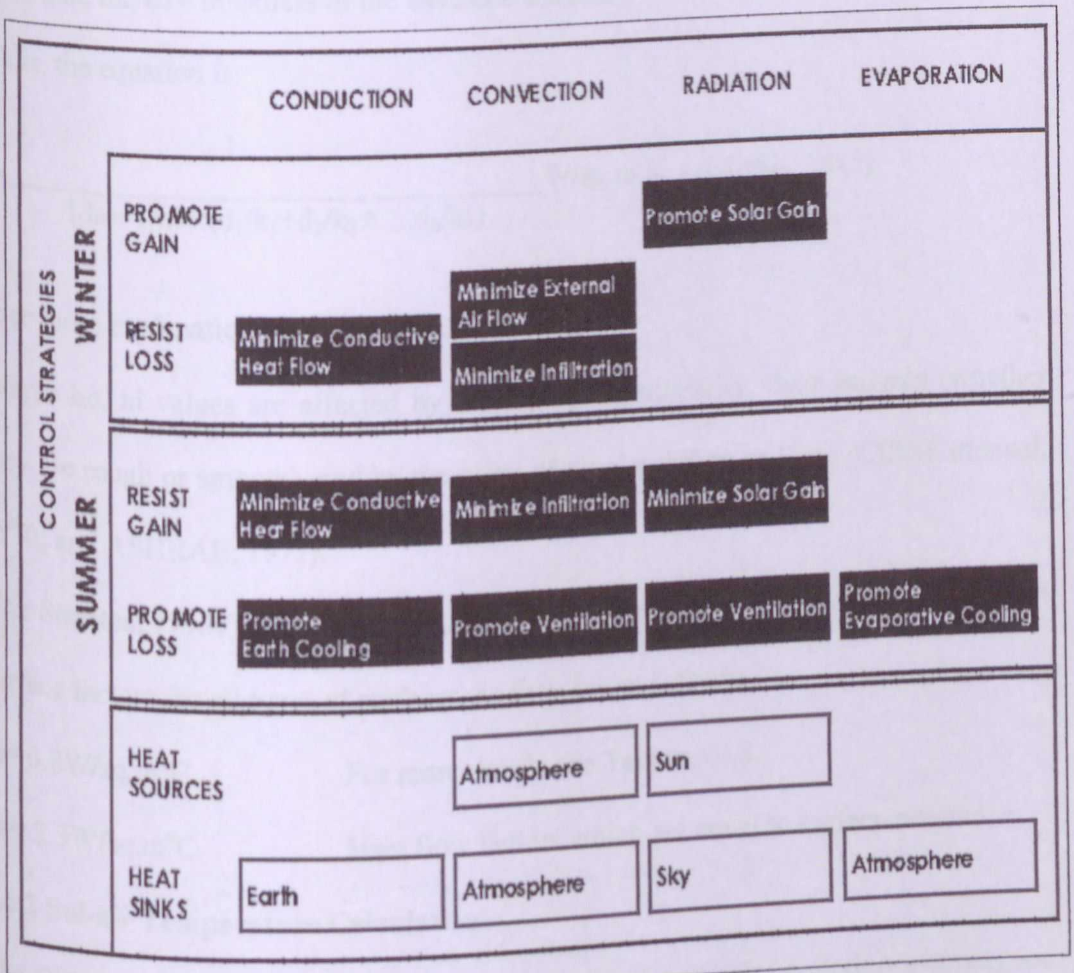


Fig.4. 7. Climatic control criteria. Source; Watsonwx@aol.com.

consideration that those thermal degree limits are lower than the minimum and outer surfaces' resistance. That represents a primitive thermal efficiency calculation for the construction elements of the envelope, but it is not enough because it neglects the actual temperature of the external surfaces of the envelope by just assuming the temperatures for the inner and outer surfaces. It will be completed after using it in the heat flow equations by using the difference in the sol-air temperature and designing temperature.

All the following values, which are used in the equations, should be provided to calculate thermal transmittance (U-value):

U= heat transmittance value of section.

hi= heat flow factor of the inner surface.

ho= heat flow factor of the outer surface.

Kn…K3, K2, K1= external heat conductivity for constructed section's layers.

dn,….d3, d2, d1= thickness of the envelope section.

Thus, the equation is:

$$U = \frac{1}{1/ho + 1/hi + (d_1/k_1 + d_2/k_2 + \ldots d_n/k_n)} \text{ W/sq.m.K} \quad \text{(CIBSE, 1975)}$$

(See more explanation in Appendix A2).

Where ho, hi values are affected by the surface emmissivity, their textures (whether they are rough or smooth), and by the mean of air circulation on them (CIBSE manual, 1970; and ASHRAE; 1977).

Van Straaten; (1969), and the ASHRAE manual documented the internal and external surface factors for all types of surfaces, so they are as follows:

hi= 0.8W/sq.m°C For more details see Table no.4.5.

ho= 2.3W/sq.m°C Heat flow factors which are equal to surface resistance.

4.6.2 Sol-air Temperature Calculation

The CIBSE manual (1975) states that air temperature and solar radiation intensity are important factors, which affect the solar air temperature value. Thus, the solar air temperature value can be calculated by using the following relationship (Dawud;1983: Appendix A, Table A2).

$$teo = tao = Rso\,(aIt - EI_L) \qquad \text{where:}$$

teo= sol-air temperature

tao= outdoor air temperature

a= absorption of the outer surface of the wall or roof

It= intensity of solar radiation

E= emissivity of the outer surface to long-wave radiation.

I_L= long-wave radiation temperature from black surface

Rso =external surface resistance. According to the ASHRAE manual (1977), for horizontal surfaces that receive long-wave solar radiation only from the upper side, the optimum value, which is taken into consideration, is:

E= 0.9 and R= 0.045m-2 c/W, and for I_L= 113.5 W/sq.m

In the case of vertical surfaces, it is supposed that the heat gain by long-wave radiation from the earth equals the long-wave heat radiation loss to the sky.

Therefore, I_L=0 x I_L= 0. Moreover, the daily mean of sol-air temperature (c) for all directions is calculated using the equation above, and the results are fixed in the tables. This equation is based on the daily mean of solar radiation of the months of the year and the absorbability of the walls and roof, and the considered values of dark and light surfaces, which are 0.5 and 0.8 respectively. (See Table. A3.8b) APP.A3.

4.7 TREATMENTS OF "OUT OF COMFORT ZONE" CONDITIONS OF THE INNER ENVIRONMENT OF THE *MUSALLA* BUILDING

4.7.1 General

According to Givoni (1961)&Watson;(1979), there are defined conditions of discomfort which have to be deal with by defined treatments as in the following sections.

4.7.2 High Mass Zone

Where the air temperature becomes higher than the thermal comfort level inside the *musalla* building, it is possible to reach the thermal comfort level by providing a good thermal design for the *musalla* building envelope, taking into consideration time lag (thermal mass of envelope), because good thermal behavior and suitable time lag of passive envelope design reduce the external impact. This method is applicable in some regions, which have large variations between day and night temperatures, such as in the Baghdad region, (see Fig.4.8.).

4.7.3 Natural Ventilation

When daily temperatures are between 20°C and 32°C, and the daily relative humidity is between 20% and 90% or more, it is possible to conserve the comfort level by introducing natural air into the inner environment through openings facing the prevailing wind direction. The negative and positive pressure zone phenomenon contributes in terms of air circulation (see Fig.4.9.)

4.7.4 High Thermal Mass with Night-time Ventilation

When the temperatures fall to the comfort zone at night, it is possible to provide thermal comfort during the daytime by cooling the inner environment by using the night ventilation, and preventing the hot air from entering the space during daytime. Buildings with thick walls; surface reflectivity can increase their capability in maintaining inner thermal comfort by having shaded openings. The comfort zone is influenced by the day and night air temperature rate. It is usually between 16°C and 22 °C at night in a hot-dry climate of Baghdad. (Dawud; 1981:28), (see Fig.4.9.)

4.7.5 Evaporative Cooling

When the relative humidity of the air is low and the high mass zone and natural ventilation treatments are not enough to reach the comfort level, it is better to use the *Evaporative Cooling Method.* This depends on the phenomenon of the "*Evaporative Equal to Cooling*". Losing energy, through changing the liquid water to vapor, cools the air, and we can thereby reduce the environmental temperature, (see Fig.4.9.)

4.7.6 Air Conditioning

When the aforementioned treatments are not sufficient to achieve thermal comfort for the praying people inside the *musalla* , then using a mixed mode or even an HVAC system to obtain the conditioned air for the space is the last alternative for getting thermal comfort.

Air conditioning systems require investment (additional cost to the capital for the *musalla* building costs) and operating costs. It will become difficult to get the high summer heat load in the Baghdad climate, for the next years with the big economic crisis, which started after the war, in that case where the inner environment requirements for the thermal *musalla* are rather high. If air-conditioning systems are provided, the above-mentioned building physics measures must be planned with special care and limitations. An air-conditioning system can only work economically and be energy saving if all structural possibilities of protection against the sun are exhausted. This fact has not been considered enough in the past. It would be wrong to economize on construction because the mechanical air-conditioning system will repair the sins against building physics (Gertis;1981). Climate-compatible construction and passive design must be given priority more than before in Iraq, and energy saving solutions should be obtained from those criteria.

4.8 ENVIRONMENTS, ENERGY AND WELL-BEING

The largest impact of buildings on the outdoor environment during the whole life cycle is due to the energy used to ensure a comfortable and healthy indoor climate.

According to Orme (1998) ventilation accounts for between 25-30% of the total building energy use. There are large disparities in the energy consumption of similar new buildings in similar locations and this is due to various levels of thermal insulation, services system efficiencies, differences in building construction, more or less effective use of passive design techniques, occupancy behaviors and building management. This is what is expected for the new *musalla* building in Baghdad according to the building typology classification that has been obtained from the field survey. Behaviors of occupants reflect their expectancies and life style that are demonstrated in their workplace as well as their homes and *musallas*. Facilities management is now recognised as an art, which not only looks after systems that make the building operate but also the people. [Roulet; 1995] shows the total energy index (annual energy use divided by the gross heated floor area) for 56 European office buildings. In this sample the largest energy consumption was more than six times the smallest. This variation can be reduced in the case of highly insulated and passive buildings design, but overall it is occupancy behaviors, which contribute the largest effect in this variation, but it has lowest effect in the case of the *musalla* because of the limited number of occupants for each of the five daily prayers as well as the limited period of occupancy for such a volumetric size of *musalla* building. The variation in energy consumption of buildings arises at the design, construction, commissioning and facilities management stages. Many new *musalla* buildings in Baghdad give the occupant very poor control of their environment and this is not only inconvenient but is psychologically necessary. The basic intention of the *musallas* is that they should be planned, designed, built and managed to offer an environment in which occupants can carry out their prayers and feel well and, to some extent, be refreshed by the environment.

4.9 THE ADAPTIVE APPROACH AND MECHANISM

The adaptive approach to thermal comfort starts, not from a consideration of the heat exchange between man and the environment, but from the observation that there are a range of actions that we can and do take in order to achieve thermal comfort. An adaptive principle is at work stating that:

If a change occurs which produces discomfort, praying people react in ways that tend to restore comfort.

The types of action, which can be taken, are:

Modification of the internal heat generation can be achieved unconsciously with raised muscular tension or, in a more extreme situation, the shivering reflex, or consciously, for instance by starting to pray optional prayers instead of sitting in the *musalla* waiting for the obligatory prayer in the cold to increase the metabolic heat or having a siesta in the warm to reduce it. Modification of the rate of body heat loss can be changed unconsciously through vasoregulation or sweating or consciously by such actions as changing ones clothing, cuddling up or by taking a cooling drink before going to pray.

Modifying the thermal environment can be achieved through lighting a fire or radiant heaters, opening window controls or using fans etc.

Selecting a different environment can be achieved within a *musalla* space by moving closer to the radiant heaters or catching the breeze from a window, or moving to pray in the *Riwaq* or outdoor *musalla* (the courtyard) within the mosque complex. Praying *Maghrib* and *Ishak* in the *Riwaq* in spring and autumn (Nov.,Dec., as well April and May) and in the courtyard during summer is quite acceptable generally as an alternative. These are only examples of the action, which can be taken, and if we are always free to take the necessary action then thermal discomfort should not be a problem.

4.9.1 Adaptive Comfort

Adaptive comfort models add a little more human behavior to the mix. They assume that, if changes occur in the thermal environment to produce discomfort, then praying people will generally change their behavior and act in a way that will restore their comfort. Such actions (in case of praying person) could include taking off clothing, reducing activity levels (like praying just the obligatory prayer then leaving the *musalla* after that to perform the rest of the optional prayer at home) or even opening a window to get breeze. The main effect of such models is to increase the range of conditions that designers can consider as comfortable, especially in naturally ventilated *musalla* buildings where the occupants have a greater degree of control over their thermal environment.

As they 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 occasional prayer periods, which are happened by uncomfortable conditions. Humphreys & Nicol (1998) give equations for calculating the indoor comfort temperature from the outdoor monthly mean temperature as follows.

Free Running *Musalla* Building:

$T_c = 11.9 + 0.534\ T_{ave}$

Heated or Cooled *Musalla* Building:

$T_c = 23.9 + 0.295(T_{ave}-22)\ \exp([-(T_{ave}-22)/33.941]^2)$

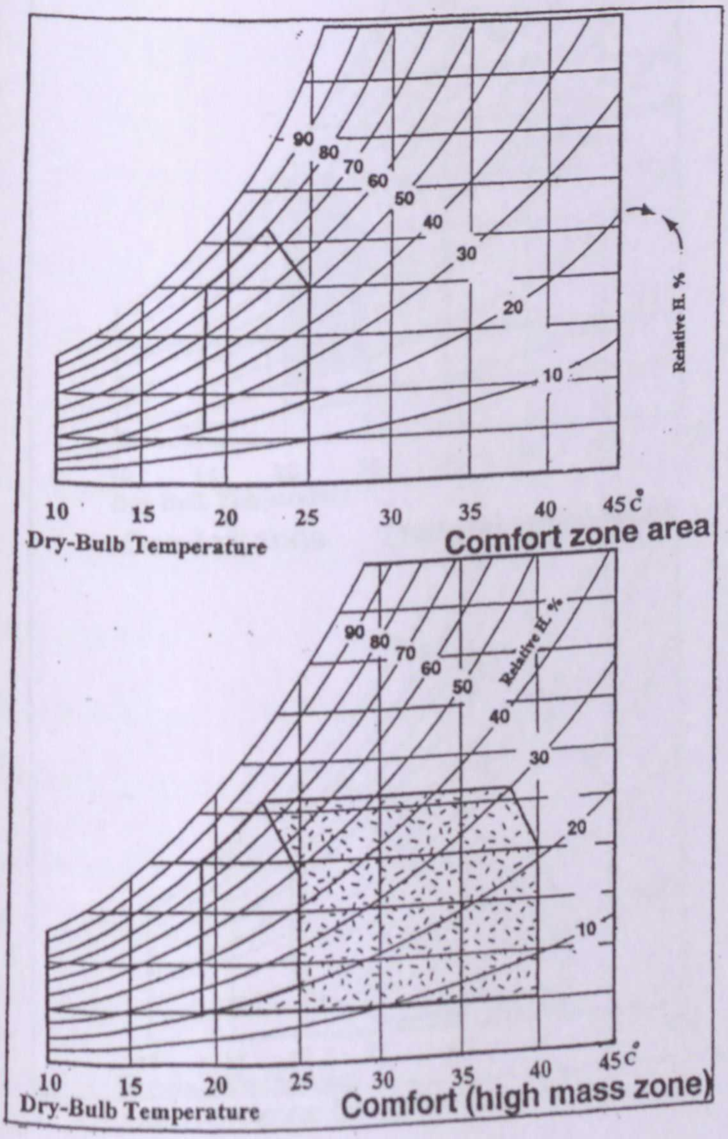


Fig.4.8 Comfort zone area and comfort (High Mass) zone. Source:Shaaban;1973.

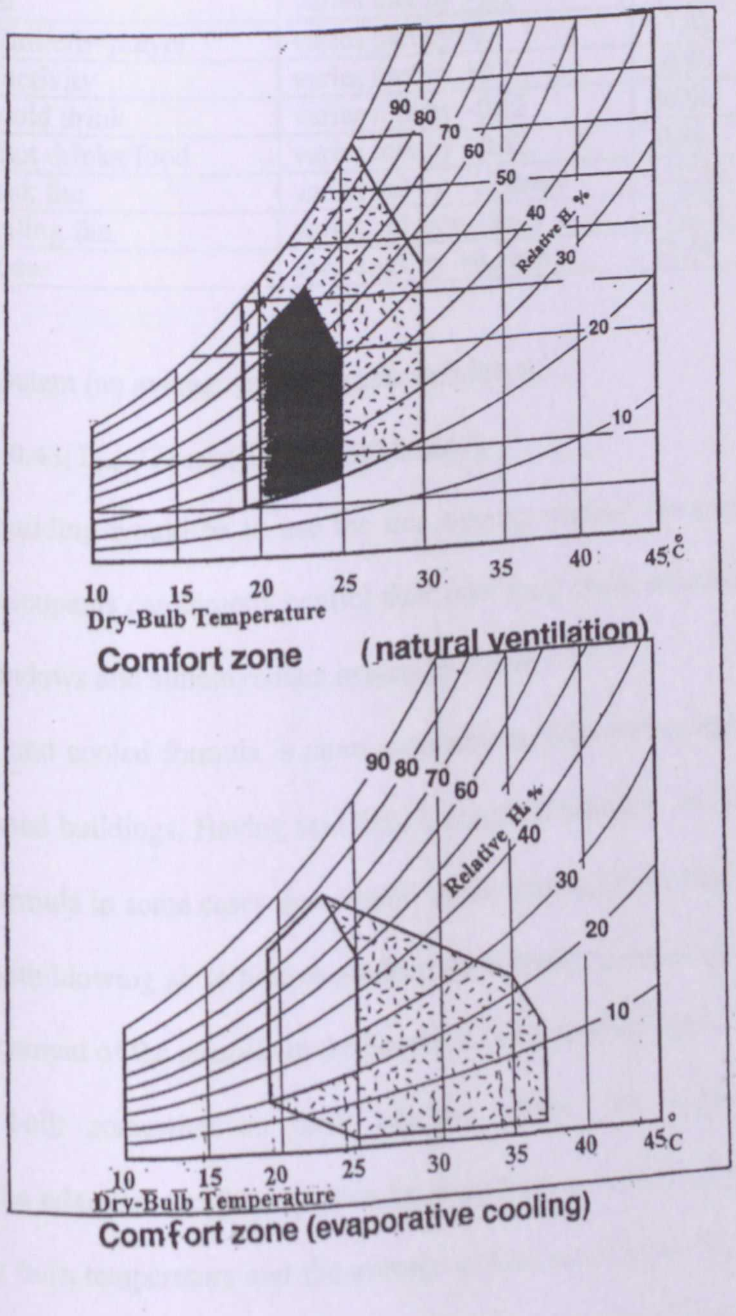


Fig.4-9 Comfort zone in case of natural ventilation and evaporative cooling. Source:Shaaban;1973.

Table 4.8. The effect of adaptive behaviors on optimum comfort temperatures. Taken from BRE Adaptive Thermal Comfort Models (Oseland;1998)

BEHAVIUOR	EFFECT	OFFSET
Stress level	varies met by ± 0.3	$\pm$12.6k
Walking 2mile/h=prayer	varies met by+0.4	$\pm$3.4k
Vigour of activity	varies met by +0.1	$\pm$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

Unknown system (an average of all *musalla* buildings):

$T_c = 24.2 + 0.43(T_{ave}-22) \exp(-[(T_{ave}-22)/28.284]^2)$

However, building would be to use the free running method for *musalla* building in which the occupants can directly control their own local environment with fans, lights, operable windows and simple radiant heaters in winter.

The heated and cooled formula is more applicable to fully thermostatically controlled air-conditioned buildings. Having said that, it might be useful to use the average of all buildings formula in some cases that depend on the simple mechanical air cooler which use water with blowing air to help to produce air movement as well as moisturizing the inner environment of the *musalla* in the hot-dry climate in Baghdad.

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. The Auliciems equation is given as:

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

4.9.2 Constraints

There are usually constraints which limit our ability to take action 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 - building a new *musalla*, changing clothing, moving to pray in another place within the mosque complex and so on all need time to complete. 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 principal 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 beyond individual control

Changes, which take place too fast, will not allow preventative action to be taken. Within a single day the change may be too much to be compensated for by clothing changes. The variation in the environment is the cause of discomfort that happens in Baghdad in spring because of the big temperature variations between day and night. It is important to make the distinction between imposed variations that can cause discomfort and chosen variations, 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 a moisturized breeze to the inside of the *musalla.*

The range of temperatures, which any society normally encounters, is limited. A temperature outside normal experience may mean that people become comfortable because they have the experience to deal with such conditions, like praying *fajar* in the

Riwaq and *Ishak* and *Maghrib* prayers in the courtyard during April,May,June,October. To define the comfort limits these normal limits need to be known.

In any particular situation people have expectations about the thermal conditions they will meet. These are usually based on experience. The success of the thermal strategy they take will depend on the accuracy of this prediction. Arriving for a concert, for instance, one might find the hall colder than expected and be unable to get comfortable. Discomfort would then be unavoidable – but still such critical conditions are very limited but foreseeable during a few days in summer and winter in the Baghdad region particularly in the case of the wind moving from the south west direction which brings dust as well the peak hot days in mid August which usually need air filtration treatment for the *musalla* building.

In any situation an individual will have a desired *musalla* temperature. If the individual cannot control the temperature (and if they cannot move to a better location) then discomfort can occur. One of the problems for the environmental engineer 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 adaptive model favors some measure of control being at the disposal of each individual. Praying persons in Baghdad deal with this condition over a long time, and they have varieties of clothes to suit the climate in all seasons, so they change from time to time with the aim of achieving comfort.

4.9.3 Comfort Temperatures Reflect Average Temperatures

First consider the effect of adaptation on the comfort temperature. Given the time and opportunity people will try to suit themselves to the average temperature they experience (note that some of the adaptation is expressed in the temperature itself, some in the person's adaptation to it). So we would expect the comfort temperature to be close to the average temperature they experience.

4.9.4 Indoor Temperatures are Affected by Adaptive Measures.

The designer rarely has accurate knowledge of the indoor temperatures, which a population will experience. Outdoor conditions are more easily obtained from meteorological data. In a development of his 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 4.10. The relationship between 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 the outdoor temperature, at temperatures below this figure the indoor temperature exceeds the outdoor temperature by an increasing amount.

Even in buildings with no heating or cooling plant, the occupants' efforts to achieve a comfortable environment reduce changes in indoor temperatures below those of the outdoor temperature. They achieve cooling in hot conditions and warming in cool conditions.

4.9.5 Setting Comfort Standards Using the Adaptive Model.

Comfort standards based on adaptive assumptions will be more than simply a temperature to aim at. The standard will need to reflect the interactions between comfort and environment in its formulation. Such concepts as predictability, constraints, variety, adaptive opportunity and control will need to be incorporated into the standard.

To start with, the `comfort temperature' may be defined as the temperature at which there is the least probability of discomfort, or at which satisfaction with the environment is most likely. The value of the comfort temperature will vary at the very least according to the 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 4.11. Humphreys (1978) found that the best outdoor temperature predictor for the comfort temperature was the mean of the monthly mean minimum and the monthly mean maximum temperatures. The prediction was improved significantly by the inclusion of a term for the annual maximum temperature, and although we do not know why this should be, it suggests that a climatic effect is involved.

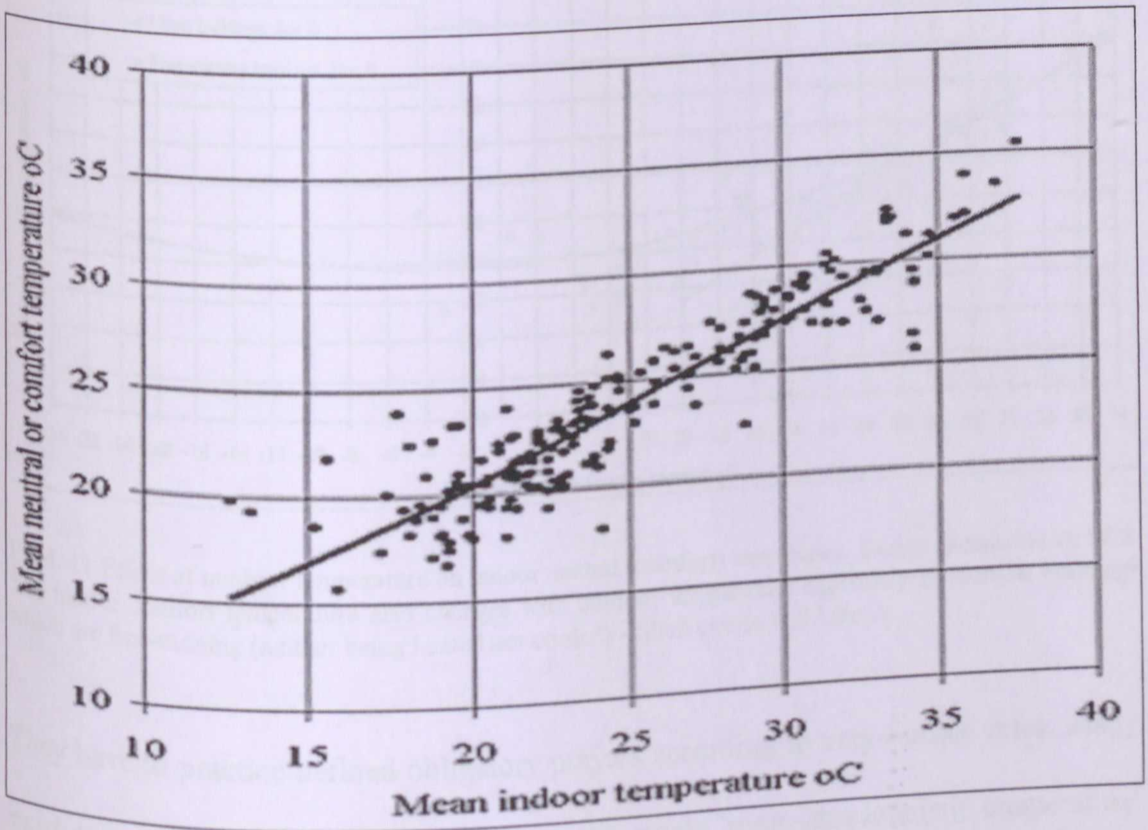


Fig.4.10 This graph shows how the mean comfort temperature varies with the mean indoor temperature. Each point in the graph is the mean value for a whole survey. Source: Humphreys, M 1978.

The comfort temperature is not the only temperature which praying people can find comfortable. Clearly there are allowable variations around it, which will not cause discomfort. The amount of variation allowable will be time-dependent. This is because the longer people have to adapt, the more they can change without significantly increasing discomfort. Thus, we might find that ±2C°was the maximum allowable within-day variation with a maximum within-week variation of, say, ± 5C°. Dynamic temperature standards would change the way in which the designer investigates a building. The dynamic thermal characteristics of free-running buildings as well as the steady-state characteristics would be incorporated in the 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 into 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.

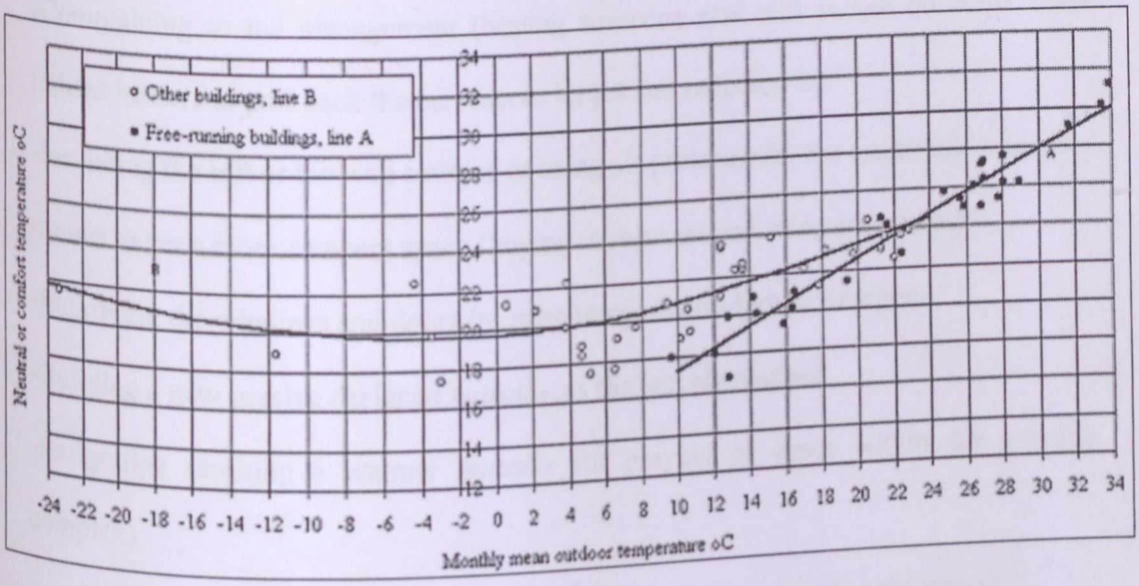


Fig.4. 11 Effect of outdoor temperature on indoor neutral (comfort) temperature. Source; Humphreys M; 1978
The indoor comfort temperature also changes with outdoor temperature especially in *musalla* buildings which are free-running (neither being heated nor cooled) - filled circles and Line A

They have to practice defined obligatory prayers according to 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, and that is still limited in terms of moving from indoor to outdoor spaces since there is normally one indoor *musalla* but on other hand, the prayer persons have the opportunity to move from the enclosed *musalla* to the semi-enclosed *(Riwaq)* or to the open (outdoor) *musalla* which is the courtyard within limited periods of each season.

-Adaptive Action

Some actions in response to cold:

-Increasing the level of activity (generates body heat)

-Adding clothing (reduces the rate of heat loss per unit area), practicing optional prayers (*sunnah, tahajud* or *trawih* ..etc.)

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

-Finding a warmer spot in the *musalla* (maybe fireplace) or leave after the short obligatory prayer, for example *(Fardh)* to (select a warmer environment)

-Complaining to the management (hoping someone else will switch on some other radiant heaters or pull back the curtains to let get sun radiation in)

-Insulating the loft or the wall cavities or using air protector for the cracks and windows frames to get a more compact space (hoping to raise the indoor temperatures)

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

-Building a new passive designed *musalla* .as the last alternative!

-Emigrating (seeking a warmer *musalla* for praying or space within the mosque complex)

-Acclimatizing (letting the body and mind become more resistant to cold stress)

Some conceivable actions in response to heat:

-Taking off some clothing (increases heat loss)

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

-Drinking a cup of tea before coming to pray. That 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 (reduces body heat production), eat breakfast after *Fajar* prayer, lunch after *Zuhur* prayer, and dinner after *Ishak* prayer.

-Switching on a fan (increases air movement, increasing heat loss)

-Opening a window in the direction of prevailing wind to get cross ventilation (increases ventilation and enhances the comfort level inside the *musalla*)

-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 renovating the envelope design as far as possible (long-term way of finding a cooler spot)

-Acclimatizing (letting the body and mind adjust to concentrate on strengthen relationship with the God when practicing prayer, so that heat is less stressful psychologically)

4.10 SUMMARY

> *'Thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment' (ISO 7730;1984 - ASHRAE; 55, 1992).*

> *'The condition necessary for human thermal comfort is the heat balance, i.e. the heat produced by the body's metabolism should be equal to the amount of heat loss from the body' (Fanger; 1970).*

The air temperature affects this, mean radiant temperature, air velocity, humidity, activity level that influences the metabolic rate and thermal resistance of the clothing. Thus, the indoor temperature is one of the direct factors that indicates the thermal comfort level of the occupants. The temperature inside a building is affected by the building design, orientation and envelope, which in turn are affected by the solar radiation, ambient temperature, relative humidity and ventilation (Markus and Morris; 1980; Santamouris and Asimakopolous; 1996).

The climatic stress on human inhabitants has been studied in accordance with comfort limits. The climate of the Baghdad region is severe; it has large daily and annual cycles. It has about two or three comfortable months, three cold months; and seven hot months. The building has to satisfy two contrasting functions: keeping the heat out in summer, and keeping the heat inside in winter. This is even further complicated in the maritime desert in the south and middle region where breeze is required during certain periods of the year.

So, how can the climatic impact on the inner environment of the new *musalla* building which is situated in Baghdad at 33 Latitude, be reduced, taking into consideration the previous mentioned facts and phenomena? And what are the optimum specifications in terms of architectural features and constructional components of the envelope needed to attain inner thermal comfort by economical energy consumption?

In free-running (unheated or cooled) *musalla* buildings the indoor temperature 'tracks' the outdoor temperature. This means comfort temperatures track outdoor temperatures.

Using meteorological records the linear relationship between comfort temperature and outdoor temperature can be used to predict the likely comfort temperature in a free-running *musalla* building.

Prayer people are not simply acted upon by the environment but play a part in deciding it - becoming both the subject and the object. Architects and engineers must deal with the prayers as inter-active beings who can make their own decisions. The behaviors of occupants can be of two basic types, they can adjust their own characteristics so that they are comfortable in the existing environment or adjust the environment to suit their needs.

The traditional approach of mosque design suits the same criteria as the empirical approach that is based on the results of field surveys, known as the 'adaptive' approach The indoor climate in the *musalla* building influences the behaviors of the occupant(s) according to the adaptive principle: If a change occurs which produces discomfort, people react in ways, which tend to restore their comfort.

Naturally ventilated (= low energy) *musalla* buildings are more likely to be acceptable in terms of energy consumption and *musalla* building employment, particularly in Baghdad, with the expected economic crisis after the war.

Control over air movement is related to the availability of fans, openable windows etc, which are usually available and easy to manage in the new *musalla* building in Baghdad.

There are often constraints on the use of clothing, but those constraints do not have a major influence on the acceptability of certain levels of comfort in the inner environment. For example, skin moisture is also cultural, and people in hot-humid climates often take it as natural, and may dislike dry skin, but the opposite is true of people who are familiar with the hot-dry climate in Baghdad.

[1] Prayer facilities inside the mosque, anthropometrics and ergonomic analysis, See the activities inside *musalla* in CH.3 for more details.

2 "Corrected Effective Temperature" represents the combine effect of two or more variables into a single variable on humans, the indices of that have developed in 1923-1925 by Hongton, Yaglaw & Miller, That combine effect included air temperature, Humidity &air velocity. The CET for temperature climate is generally recommended to be 21.7 C for summer conditions for normally clothed male subjects at rest.(Rao S.P;1991).

CHAPTER FIVE

SURVEY DATA AND THERMAL ESTIMATE FOR "MODEL MOSQUE"

5.1 INTRODUCTION

The present chapter includes the collected physical data and occupants' surveys strategy for the fifty selected new mosques in the Baghdad vicinity, as well as a thermal evaluation for the "model mosque" envelope in order to know the actual thermal behavior of the mosque envelope in terms of protecting the inner environment from the fluctuations of the external environment.

The evaluation considers the components of the envelope section, the thickness and area of each regarding thermal performance and their behaviors under climatic impact.

The chapter will give illustration of heat flow through the opaque parts (including walls, roof and dome) from the external to the inner environment of the *Musalla* building and vice versa, as well as for the transparent part (windows and doors) .

The quantitative thermal assessment depends on many equations of heat exchange in order to calculate the Mean Heat Flow through the *Musalla* envelope.

All numerical values and calculations that will be used in the present chapter consider all the data of the previous chapters, which depended on the mentioned references as well as the field survey, and the output of other research in the same field.

5.2 SURVEY STRATEGY

The survey strategy was to scan a large number of new mosques in Baghdad. The strategy depended on the following two stages to perform that scan;

i. First Stage:

This stage required a definition of the following:

1. What is a "mosque" or *"musalla"*?

2. What does the term "new mosque" mean in general?

3. What is the definition of "new mosque" in Baghdad?

ii. Second Stage:

This stage starts after the definitions of the above terminology. Questions, which should be answered in this stage, are:

1. How many mosques in the Baghdad vicinity yield to the definition of "new mosques" in light of previous answers?

2. Which, and how many new mosques in Baghdad need to be surveyed?

3. And, why are those mosques selected to be surveyed?

Visual analysis, some other available research, as well as information that has been obtained from the "Ministry of *Awqaf* and Religious Affairs in Iraq" are the references that help to answer stage two questions as follows:

5.2.1 Definition of Mosque, *Musalla*, its Function and Features

Mosque or *masjid*. A place of worship for Muslims. A place where the obligatory five daily prayers are regularly done, except for the *Jum'a* prayers (the Friday noon prayer and Friday *Khutba*). The *Masjid Jame'* is the place where all the five compulsory *Salat* (Prayers) and the *Jum'a* prayers are regularly done. The *Masjid Jame'* is usually larger than a *Masjid*. Plural: *Masajid*.

The most holy mosque on Earth is the *Masjid al-haraam* (The sacred mosque), in the holy city of Mecca, surrounding the *Kaaba*.

Muslims all around the world are required to face the *Ka'ba* in Mecca when performing their five daily prayers. Mecca is a place on the *Hijaz* plain, 21 degrees 26, 17 latitude 37 degrees 54,45 longitude. The *Kaaba* is a building 50 feet high 30 feet wide, and 40 feet long. Its door height is 6½ feet.

The English term for mosque is derived from the Spanish word for *mosquito* that came into use during the Christian invasion of Muslim Spain in the fifteenth century. Mosques play a vital role in the lives of Muslims. The primary function of the mosque is to provide a place where Muslims may perform their obligatory five daily prayers as a congregation. One can do it alone, but there is a greater blessing if it is done with others. The Prophet once said that it is an extra good deed to pray in a mosque, the reward for doing so is 27 times more than if done anywhere else. Mosques are known for their fabulous architecture, some of which date back to the 7th century. A large dome is a common design, though not in all of them. Many mosques, especially larger or older ones, have a minaret, or a tower from where the call to prayer is delivered. This is done 5 times a day. Nowadays, most have installed loudspeakers, and the *muezzin* does it from a microphone.

The mosque is different than a Christian Church or Jewish Temple. A mosque has no altar or pews. It is a place that is specifically dedicated as a place of prayer.

Mosques can vary in size from small chapels to large Islamic centers that hold thousands of worshippers.

The prayer hall within the mosque complex is called a *musalla*, which is oriented facing the Holy city of Mecca.

The *Musalla* is open and uncluttered to accommodate lines of worshippers who stand and bow in unison. There are no pews or chairs, since prayer consists of bowing and prostrating oneself. Members of the congregation sit on the floor, which is commonly covered with large rugs or carpets. Muslims all stand in this hall facing the same direction, forming rows side-by-side, shoulder-to-shoulder. Muslim men and women form separate rows when praying. Mosques offer a balcony for women. If there is one room, a curtain is placed as a partition from front to back, or the women stand in a row behind the men. Almost all mosques have some sort of *mihrab*, or niche in the wall, that shows which wall faces Mecca. It is often decorated with Arabic calligraphy, and may have a curved shape. In addition, there is also a small pulpit to the right of the niche, known as a *minbar*. During the Friday prayer service, the *imam* (prayer leader) delivers a sermon from the steps of the *minbar*.

A person chosen as the *imam* leads the group in prayer. He stands in front, with all the rows behind him, facing the *mihrab*. which helps reflect his voice toward the congregation. Everyone prays together, and all drop to their knees, then pray prostrate (face to the ground). Prayer is usually short, and the prayer is repeated at different times throughout the day. A person has to be in a state of Ablution (purity) before praying, so there is usually a washroom inside. Aside from prayer, mosques serve a variety of functions. They are often places for meetings and social gatherings, where one can reach out and connect with the local community. They have day care, Arabic classes, youth activities, marriages, funerals, and potluck dinners. Many mosques serve as recreational centers, and can have libraries, classrooms, and offices.

It is assumed that the new mosque is the mosque which is built using new construction materials, technology (comparison to the old type, see Fig. 5.1) under the supervision of engineers and an architect who prepared the design in advance to construct it in new planned districts of the city.

To be more accurate, additional determinants are applied to define the new mosque characteristics in Baghdad, that consider the time period of construction, geographical area and the architectural style. So, the "new mosque" in Baghdad is that mosque which is constructed post Second World War in the Baghdad vicinity. The previously mentioned references have enabled us to answer the questions of stage two also as it is shown in the following:

1.The number of new mosques in the Baghdad area at the time of the survey (July 1997) was 85 mosques, used for five times prayers, *Jumuah* "Friday" prayer as well as two *Eids* "Bariums" prayers. Those mosques are located within the area of Baghdad. There are some other small mosques for just five times prayers here and there, which were not taken into consideration in the survey because they are too small and did not have an acceptable capacity (lower than average capacity) as well as not possessing the architectural identity of the mosque.

2. Fifty of the 85 new mosques in Baghdad were selected for the survey for the following reasons;

i. It is found that those fifty mosques are similar in their architectural characteristics and constructional materials used as well as planning, facilities, annexes, and their locations in new districts of the city (see attached sample of the survey form.)

ii. All those fifty selected mosques have complied in their design and construction details to the special architectural and Islamic instructions of the "Ministry of *Awqaf* and Religious Affairs" in Iraq.

iii. Those 50 selected new mosques have been designed by architects and constructed under the supervision of consultant engineers.

3. The remaining new mosques in Baghdad were not selected for the survey because they were recently completed and not in full use. So the respondents did not give a clear impression and in some cases did not even reply or send back the survey forms.

4. It is found that the 50 surveyed mosques represent an adequate sample of the total number of new mosques in Baghdad to give complete data that serve the research objectives (see attached sample of survey form.)

5.2.2 Survey Form

The research concerns two major points:

1. The architectural characteristics of *musalla* design and the constructional details of the envelope section relating to heat exchange and environmental impact.

2. Thermal design criteria, which concern the impact of climatic fluctuations in Baghdad's hot-dry region that influence the thermal comfort of the inner environment of the new *musalla*. With the aim of collecting enough specific field data that is needed to cover the previous categories, the survey form was prepared to obtain the following:

i.1. Location of the Baghdad region in the map of Iraq.

2. Map of the Baghdad vicinity to show the locations of the surveyed mosques.

3. Location of each mosque related to that district in Baghdad and distinguishing landmark in it.

ii. Complete information about each respondent in each survey form including:

1. The name. 2. Age. 3. Gender. 4. Career and education level

iii. The survey includes the responses of many *Mullas* (Islamic scholars) to be more detailed for all other activities.

iiii. Further information concerned the following:

1.Date of survey. 2. Time of survey 3.Specific time of survey relating to prayer times.

In addition to all the previous categories, the survey form included a further two parts:

i. Part One: Concerns analytical details and the survey for the building envelope, opaque and transparent parts, as well as the following;

1. Mosque specific data, that includes:

   i. Mosque's name and location.

   ii. Mosque building typology.

   iii. Date of construction.

   iv. *Musalla* dimensions.

2. Description of the specifications of the *musalla's* walls section.

3. Description of the specifications of the *musalla's* roof section, dome and minaret.

4. Description of the specifications of the *musalla's* floor section.

ii. Part two: includes documentation of the impressions of occupants of the *musallas* in summer and winter. The impressions of those occupants are obtained from an analysis of their answers to eight questions concerning:

1. Feeling of comfort during prayer times.

2. The impact of natural and simple mechanical ventilation and how that influences their feeling of comfort.

3. Using available traditional mechanical equipment such as, fans, water air-coolers and how that influences comfort levels inside the *musallas.*

4. Natural light relating to the opening areas of the *musalla's* envelope and impact of this factor on thermal comfort.

5. Mosque design and its relationship with the thermal comfort.

Respondents can contribute more by adding further notes in the form.

5.2.3 Sampling Method for Determining of the Typical new Mosque" Model Mosque"

The new mosque in Baghdad has inherited the main characteristics of the traditional Islamic mosque Those characteristics concern Islamic and architectural criteria in mosque building, such as orientation to the *qibla,* other definitions of main spaces and elements like the *musalla* area, ablution area, *minbar, mihrab* and other specific symbolic features like the dome, minaret, *Riwaq*. All those elements are considered as criteria for the classification method that is used in the survey of new mosques to define the mosques, which share common features. Fifty new mosques in the Baghdad vicinity have been chosen including those of the nine districts that compose Baghdad metropolitan area on the two banks of the Tigris River (western bank *(Alkarkh*) and eastern bank (*Arrusafa*) Those fifty mosques represent 59% of Baghdad's total number of new mosques, which have been built from after the Second World War until the time of the survey in July 1997.

It is noticed that the fifty surveyed mosques include some differences that need to be classified into distinct groups to be more accurate in the sampling of the actual typical new mosque. So, they have been classified into four building types A, B, C and D, based on distinguishing architectural and constructional features that are documented in the survey as listed and explained in part one of the attached sample of the survey form.

5.2.4 Mosque Building Typology Definitions

Mosque building typology definitions are as follows:

Type A; represents the new mosque that is more common in the Baghdad vicinity among other surveyed types of new mosques generally.

It includes all the main and common architectural characteristics that are found in traditional Islamic mosques, which are, the dome, the minaret, the courtyard, the *Riwaq* (arcade area, the *minbar*, the *mihrab* (Alumary; 1988).

Survey Form No.	1
Mosque's Name	Dragh
Location	Maruf st., Karkh
Urban Contiguity	Semi attached
Year of Construction	1959 AD
Name of Respondent	Jasim Sedun
Gender	Male
Age	27 year old
Education Level	Secondary School
Date of Survey	12.6.1997
Time of Survey	5.15 PM
Other Information	After *Asar* Prayer

PART ONE	
1.Mosque Building Type.	**B**
2.*MUSALLA* CONTENTS:	
A. Dimensions of *Musalla*	22mx10mx7m
B. Shape of the *Riwaq* (Arcade area)	One Front Side only
3.Total Area of Transparent Part of the Envelope.	52 m.sq.
4.Number of Minarets	1
5.ENVELOPE SECTION AND MATERIALS:	
A-The Walls;	
1.Structural System of the Walls.	Bearing walls (partitions)
2.Section Constructional Details.	Bricks and *Juss* mortar (local gypsum)
3.External Finishing Material; Color, Texture.	Cement plaster (quite rough), Grey color
4.Internal Finishing Material.	Gypsum plaster
5.Transparent Area at S-W & N-E Orientations.	0.0 sq.m. &42 m.sq respectively
B-The Roof;	
1.Type of Roofing System.	RC slab
2.Constructional Details of Roof Layers.	(From down to up) gypsum plaster +RC+Tar (water proofing)+river sand+ local *juss* mortar +cement tiles0.20mx0.20mx0.02m.
3.Internal Finishing of the Roof.	Gypsum plaster
4.External Finishing of the Roof.	Cement tiles 0.20mx0.20mx0.02m
C. The Dome;	
1.Number of the Domes.	None
2.The Location of the Dome on the Roof.	--
3.The Height of the Dome.	--
4.The Diameter of the Dome.	--
D. The Floor;	
1.Constructional Layers of the Floor.	From Down to up; bricks+ mortar+ mosaic tiles.
2.Constructional Material for Finishing.	Mosaic tiles0.30x0.30x0.025 m
3.Other Finishing Material.	Common carpet
6.Other Specific Details or Notes:	
*The mosque represents early new mosque style after Second World War.	

Fig.5.1 Sample of survey form.

PART TWO: SURVEY QUESTIONS:	Note: Please define the number in the appropriate box.						
Use this scale to answer the Following questions	1 Strongly disagree	2 Disagree For certain prayers	3 Disagree	4 Neutral	5 Agree	6 Strongly agree	7 Agree for certain prayers
1. I feel comfort during the prayers in summer (July). 1.اشعر بالراحة أثناء الصلاة في الصيف.	1	2	3	4	5	6	(7) Z&A
2. I feel comfort during the prayers in Winter (February). 2.اشعر بالراحة اثناء الصلاة فى الشتاء.	1	2	3	4	5	6	(7) Z
3. I feel comfort with the natural ventilation in Summer. 3.اشعر بالراحة مع التهوية الطبيعية بالصيف.	1	2	3	4	5	6	(7) F
4.I feel comfort with the natural ventilation in Winter. 4.اشعر بالراحة مع التهوية الطبيعية بالشتاء.	1	2	3	4	5	6	(7) Z
5. Natural lighting and openings sizes of the *musalla* are appropriate. 5.الإضاءة وحجم الفتحات للمسجد مقبولتان.	1	2	3	(4)	5	6	7
6. Fans are efficient to get comfort in Summer. 6.المراوح كافية للشعور بالراحة.	1	2	(3)	4	5	6	7
7. Air-Cooler is enough to get comfort in Summer. 7.مبردة الهواء كافية للشعور بالراحة بالصيف.	1	2	3	(4)	5	6	7
8. The design of the *musalla* is appropriate for the prayers activities. 8.تصميم المسجد مناسب لفعاليات الصلاة.	1	2	3	(4)	5	6	7

Other Specific Details or Notes:
***The Respondent has practiced prayer 7 years in the mosque.**
***The mosque includes an open courtyard with a small garden.**
***It doesn't have an outdoor *musalla*.**

NOTES:

1. {A and B} Share the same characteristics and features except for the dome that exists only in (A) type.2. {C} is Bigger , square shapes or similar , includes additional features, other differences in terms of transparent and opaque total areas.3. {D} more differences, hybrid style, irregular form, different architectural features. 4. All new *Musallas* share the same constructional details of the walls (D) and the same details of the roof (C), see Figs. B.2, B.3 Appendix B.5. The external finishes for 77% of the *musalla's* walls are cement plaster (light color), and glassed fair face bricks (Arabesque-blue color) for the domes.

6. F: *Fajar* prayer, **Z:** *Zuhur* prayer, **A:** *Asar* prayer, **M:** *Maghrib* prayer, **I:***Ishak* prayer.

Fig.5.1 Sample of survey form, continued.

On the other hand, they share certain features that give a very clear architectural identity for all *musallas* of this type, such as similar proportion and ratio of width to length as well as similar height, typical envelope constructional section. They have the same location of domes related to the roof plan of their *musallas* , and all of them have a rectangular plan.

Type B mosques have the same features as type A in general, except for the dome. This reason was enough to segregate those few mosques because of missing that important architectural, constructional, symbolic element which represents the Islamic architecture and gives clear identity to the mosque buildings.

Type C mosques are considerably bigger than type A and type B. The *musalla* plan of this type is square or similar, as well as differing from A and B types in terms of the total opaque and transparent areas of the envelope.

Type D *musalla* include many other differences related to A, B, and C. Those differences concern architectural design and architectural language in general. It has a hybrid design, very big and massive construction, majestic *musalla* spaces, an irregular *musalla* plan as well as other architectural details. This building type of mosques is represented by very few new mosques in Baghdad (see Table 5.1.)

All new mosque buildings have approximately similar constructional materials and details for the roof, walls and floor sections. It is noticed that they have typical constructional details of (C) and (D) in appendices B-1 and B-2 as shown in Fig.5.5a also.

More than 87% of the external finishes of the *musalla* walls of the surveyed new mosques have been done using cement plaster painted with light color and have a rough texture. The roofs were tiled using dark gray cement tiles.

Two hundred survey forms were delivered to the respondents in the fifty new mosques as shown in the attached survey forms and vicinity plan of Baghdad. Just one hundred and fifty-two of them were received from the majority of the respondents i.e. just 75% of them responded.

The completed survey, and previous classification and detailed data in the attached forms lead to the following conclusion:

i. The survey covered fifty new mosques in Baghdad. Since three of them are from C type, and three others from D type, as shown in (Table 5.1), they do not share the majority distinguishing features, so, they have been taken away from the selection of the typical new mosque.

ii. The remaining 44 new mosques include A type and B type. Eleven of them are from B type which is slightly different to A type that represents the majority as shown in (Table 5.1) and a greater part or portion according to the final conclusion of the survey. The main difference between A type and B type is the dome that is missing in the B type. Based on that, the B type has been taken away from of the typical new mosque too.

iii. Based on the previous items (1) and (2), 33 mosques of A type which represent 66% of the 50 surveyed new mosques in Baghdad share the main characteristics of the new mosque style in the Baghdad vicinity. Those mosques of A type share 95% of the major architectural and constructional characteristics of the *musallas* particularly, as shown in (Table 5.1.).

5.2.5 Output of the Survey

Part One:

The previous analyzed presentation of the survey of the new mosques in Baghdad concludes in the following listed categories:

1. The fifty new mosques surveyed were almost all constructed using the same constructional materials, structural system, envelope section details, in terms of thickness and internal and external surface materials, texture and color.

2.Mosques of group A differ from the other groups B, C, D in terms of the existence of a dome, area of transparent and opaque areas of envelope, area and height of the *musalla*, and other dimensions of the *mussalla.*

3. Since 33 new mosques of the group A type share almost all the main characteristics, they are dominant among the 50 new mosques in Baghdad and represent the actual new mosque type in Baghdad. They share the following important features that concern the present research aims as below:

i. Existing dome with almost typical details for all, in terms of diameter, height and its location on the *musalla* roof and constructional layers as explained below:

-Internal surface finishing is treated with 0.025m thickness gypsum plastering.

- Then, concrete slab 0.15m thickness

- And the external surface is treated with arabesque.

ii. Similar dimensions of the *musalla.*

iii. Similar areas of opaque and transparent parts of *musalla's* envelope.

iv. Typical detail of the section of the *musalla* envelope in terms of materials used, layers and thickness of materials used in the section as well as the components and specifications.

v. Layout of architectural design of the envelope, rectangular plan of *musalla* of ½ widths to length ratio as well as the same height and almost all other secondary details.

5.2.6 Definition of the New "Model Mosque"

From the previous stages of the survey, it is found that the new "Model Mosque" in Baghdad has the following characteristics:

i. Rectangular plan with ½ width to length ratio.

ii. Its dimensions are 22mx11mx6m (see Table 5.1)

iii. Has one minaret and one dome located on the middle of the roof.

iv. The dimensions of the dome are 7.0m diameter and 6.5 m height.

v. The transparent area of the envelope is equal to 66.0 m^2 (see Table 5.1)

vi. It has one side *Riwaq* located at the wall that runs parallel to the *qibla* wall; the dimensions of *Riwaq* are 22mx4mx3m.

Although there are very slight differences among a few of the group A mosques (like for example, less than one meter difference in height or transparent areas etc, which are not considered as affecting differences). Mosque no. 28 is selected as the ideal among them even though there are almost no differences among them. Nevertheless one of them should be chosen as the model for testing and that is what happened based on the following criteria:

1. Choosing that mosque which is neither in Baghdad city center nor on the edge of the Baghdad vicinity nor it is one of the famous mosques.
2. Date of construction and design style that reflects the likely design of future mosques.

New Baghdad mosques that were built too early relating to the defined period of new mosques, may be influenced slightly by previous traditional mosques features.

Mosque no.18 was selected as the “Model Mosque” among those three mosques to be tested based on previous criteria as well as visual analysis and final impression of the survivor.

vii. The color of the external surface of the *musalla's* walls was almost light color and rough texture.

viii. Construction details of the *musalla's* walls consist of the following layers:

-Internal finishing is treated in gypsum plastering 0.025m.

-Bricks bounded using cement mortar 0.24m thickness.

-External finishing is treated using cement plastering in 0.030m.

ix. Construction details of roof section of the *musalla:*

-Cement tiles 0.80mx0.80mx0.03m.

-Natural sand 0.15m thickness.

-0.07m thickness tar layer.

-0.15m thickness RC.

-0.025m thickness gypsum plastering (internal finishing)

x. Construction details of floor section of the *musalla:*

-0.01 m woolen carpet.

-0.025m mosaic tiles.

-0.05m cement mortar.

-0.15m Bricks.

Part Two:

This part shows the following conclusions :

i.17% of respondents feel comfortable in summer just at *Zuhur* (afternoon prayer-when the shade of any object in the sun becomes equal to its actual height) & *Asar* prayers (when the shade of the object becomes double its actual height).

ii.17% of respondents feel comfortable in winter just at *(Z)* prayer.

iii.16% of respondents feel comfortable with the natural ventilation in summer just at *Fajar* prayer (one hour before sunrise).

iv.16% of respondents feel comfortable with natural ventilation in winter just at *(Z)* prayer.

v.9% of respondents feel that the size of windows are acceptable.

vi.7% of respondents agree that fans are not efficient to feel comfort.

vii.9% of respondents agree that the water air cooler is enough to feel comfortable in summer just in *(Z)* and *(A)* prayers.

viii.9% of respondents agree that the *musalla* design is appropriate for prayer activities.

It is found from the previous eight items that the inner environment of the new *musalla* in Baghdad fails to meet comfort level under the influence of uncontrolled heat exchange and external environmental impact as well as the optimum protection that should be provided by appropriate envelope design.

5.2.7 SUMMARY OF SURVEY

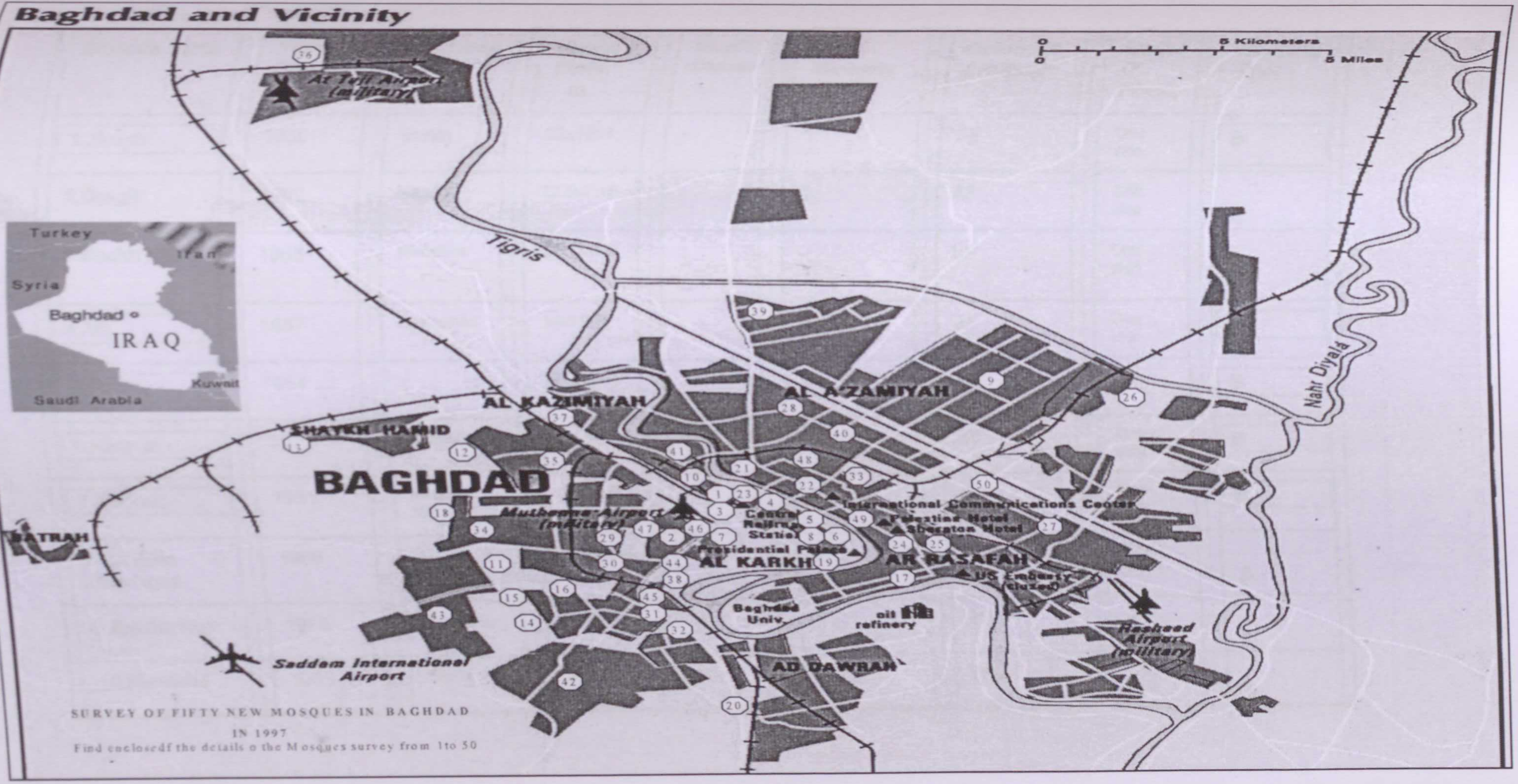


Fig.5.2 Location of fifty surveyed new mosques in Baghdad.

Table 5.1 Summary of data of the fifty new surveyed mosques in Baghdad vicinity.

Mosque Name	Year of Const.	Location	IlaMusa Dims. m	No.of Domes	No.of Minarets	Openings Area/sq.m	Shape Of Riwaq	Building Type
1..Dragh	1959	karkh	22x10x7	-	1	52	One side	B
2.Dragh	1962	Mansur	22.5x11x6	-	1	67	One side	A
3.Shekh Musa	1965	Mishahda	22x11x6.5	1	-	66	One side	A
4.Ata	1967	Suqhamad	18x11x6	-	-	51	One side	B
5.Sandal	1954	=	22x11x7	-	1	64	L	B
6.Hannan	1950	Shuhada	22x13x7	-	1	65	One side	B
7.Haddad	1961	Shekh Maroof	17x8x6.5	-	1	47	One side	B
8.Sa'dBin Abiwaqas	1966	Alawi Alhilla	22x10.5x6	1	1	64	One side	A
9.Ibadurrah man	1973	Wazyria	21x11x6	1	1	63.7	One side	A
10.Almdalal	1965	Utaifia	22x11x6.5	1	1	66.5	One side	A

11.Aljamia	1970	alkhadra	22x11x6.5	-	1	66	One side	B
12.Aladil	1982	Aladil	22x11x6	1	1	65.3	One side	Δ
13.Alfaruoq	1980	Kafa't	21.5x11x6	1	1	64	One side	Δ
14.Dakhiliah	1967	Hai Aldakhilia	22x10.5x6	1	1	62.8	One side	A
15.Alrawda Almuhamadi	1976	Alyermuk	20x10.5x6	1	1	61	One side	A
16.Alshawaf	1981	Alyermook	22x11.5x6	1	1	65.7	One side	Δ
17.Alkhudhairi	1983	Karrada	27.4x15x7	1	1	62	L	C
18.Mulla hwaish	1994	Alkhadra	22x11x6	1	1	66	One side	Δ
19.Al-Bunnia	1971	Alwai	20x20x8	1	1	87.2	L	D
20.Alkubasi	1991	Asshurta-5	22.5x11x6	1	1	66	One side	Δ
21.Addahan	1962	A'damia	22.7x11x7	1	1	66.2	one side	Δ
22.A'dila khatoon	1960	Sarafia	22x11.5x6	1	1	66.8	One side	Δ
23.Ashaikh Taha	1975	Haifa st.	16x8x6	-	-	45.6	One side	B
24.Alurfali	1958	Assadun st.	22x11x6	1	1	53	One side	Δ
25.Ashahid	1963	Assadun st.	30x15x8	1	1	78.7	3 sides	D

26.AlSamarai	1962	Baghdad. Aljadida	22.5x11.5 X6	1	1	68	One side	A
27.Alqazzaz	1965	Zaluna	22x11x6	1	1	66.2	One side	A
28.Assidiq	1978	Raghiba Khatoon	22x11x6	1	1	58.8	One side	A
29.Najat	1984	Mansur	20x10x6	1	-	56	One side	B
30.Alumari	1977	14 Ramadan	22x11x6	1	1	66.6	L	A
31.Almamun	1992	Hai-Almamun	22x10.7 x6	1	1	65.2	One side	A
32.Bilal	1989	Hal-Alqadisla	22.6x11x6	1	1	66.3	L	A
33.Yosuf Ala'ni	1981	Hai-Alsha'b	22x11.5x 6.5	1	1	67.2	One side	A
34.Arrahman	1982	Alkhadra	22x11x6	1	1	65	One side	A
35.Alhuriyya	1966	Hai=Alhuriy	22x11x6	-	1	65.7	One side	A
36.Attarmia	1964	Aldhulula	22.5x11x6	1	1	66.5	One side	A
37.Fattah Basha	1953	Al-kadumia	20x10x7	1	1	56	One side	C
38.Alqubanchi	1988	Al-Harthia	21x12x6	1	1	67.5	L	A
39.Alsha'b	1991	Hai-Alsha'b	22x10.5x6	1	1	65.7	One side	A
40.Ala'ssaf	1961	Aldhubat st.	22.7x11x6	1	1	65.9	One side	A

41.Attikarta	1967	Mahalah Attikarta	18x9.5x6	-	1	49.4	One side	B
42.Umuttubul	1965	Alyarmuk	32x20x10	3	2	118.7	One side	D
43.Alkubaisi	1987	Ala'miria	22x11x6	1	1	64.8.	One side	A
44.Alharthia	1964	Hai-Alharthia	22.5x11x6	1	1	67.3	One side	A
45.Tahir Alani	1981	Alzaitun st	23x10.5x6	1	1	66.2	One side	A
46.Muhawish	1963	Hai-Alandalus	22x11x6	1	1	65.6	One side	A
47.Assa'di	1967	Hai-Alandalus	18x9x6	-	1	63.8	One side	B
48.Huwaidi	1962	Alwaziria	20x10x6	-	1	62.6	One side	B
49.Ashawi	1956	Assalihia	15x10x8	1	1	47.7	One side	C
50.Azzehawi	1981	Azzwia	20x10.5x6	1	1	44.3	One side	A

Notes:

1. {A and B} Share the same characteristics and features except for the dome that exists only in (A) type.
2. {C} more differences, hybrid style, irregular form, different architectural features.
3. {D} is Bigger, square shaped or similar, includes additional features, other differences in terms of transparent and opaque total areas.
4. All new *musallas* share the same constructional details of the walls and the same detail of the roof, see Figs. 5.1,5.5a,and B.2, B.3 Appendix B.
5. The external finishes for 80% of the *musalla's* walls are cement plaster (light color), and glassed fair face bricks (Arabesque-blue color) for the dome.

5.2.8 Summary of Data of the Mosque Survey

-A total of 50 mosques built over the last 50 years were surveyed.

-The mosques are typified as with dome (A), without dome (B), large (C) and of irregular or unusual design (D)

Table5.2 Mosques classification

Type	A	B	C	D
Number (%)	33 (66%)	11 (22%)	3 (6%)	3 (6%)

-The average and standard deviation of the main physical parameters and the survey questions are shown in the following table, for type A & B and all mosques.

Table5.3 Average dimensions for mosques

	Type	Length	Width	Height	Glazed Area	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
	A												
Av		22.0	11.0	6.0	66.0	2.2	3.2	2.7	2.2	3.0	2.9	3.3	3.1
StD		0.58	0.34	0.12	0.76	1.19	1.68	1.22	1.00	0.64	1.37	0.89	0.59
	B												
Av		19.73	10.05	6.36	56.58	2.73	3.58	2.42	2.55	2.70	3.15	3.67	3.06
StD		2.45	1.41	0.44	7.62	1.44	1.71	1.00	1.58	0.64	1.54	1.02	0.56
	All												
Av		21.75	11.27	6.34	65.02	2.37	3.19	2.59	2.22	2.94	2.95	3.41	3.16
StD		2.76	2.14	0.75	10.43	1.29	1.69	1.17	1.15	0.67	1.41	0.95	0.59

- On the basis of the survey data the dimensions of the model mosque used in the computer simulation were chosen as follows, Type A (with dome), **22m x11mx 6m, and the glazed area equal to 66.0 sq.m**

Questionnaire Responses 150 cases

-At each mosque 3 subjects were given the questionnaire, making a total sample of 150. The following table gives the average Likert scale score for each question across all mosques.

Table5.4 Answers of respondents

	Q1	Q2	Q#	Q4	Q5	Q6	Q7	Q8
Av	2.4	3.2	2.6	2.2	2.9	3.0	3.4	3.2
StD	1.29	1.69	1.17	1.15	0.67	1.41	0.95	0.59

-The following table gives the intercorrelation matrix for all question scales for all subjects.

Question								
1	x							
2	0.19	X						
3	-0.01	0.02	X					
4	0.27	0.16	0.37	X				
5	-0.08	0.11	0.05	0.23	x			
6	0.09	-0.22	0.12	-0.11	0.31	X		
7	0.23	-0.07	-0.20	-0.11	-0.12	0.08	x	
8	0.00	0.04	0.15	0.09	0.31	-0.12	0.00	X
Question	1	2	3	4	5	6	7	8

-There is little intercorrelation between the question responses.

-A further study was made of the relationship between the physical dimensions of the mosques and the scale scores averaged for each mosque. The following tables show the summary for all cases and for Types A & B mosques.

Table5.6 Summary of mosque survey

		Summary of Mosque Survey Data Questionnaire responses averaged for each mosque											
		Dimensions				Averaged Questionnaire Responses (Likert scale 1-5)							
Mosque	Type	Length m	Width m	Height m	Glazing sq.m	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1	B	22	10	7	52	2.67	5.00	3.00	2.67	3.00	2.00	4.33	3.00
2	A	22.5	11	6	67	3.00	4.00	2.00	3.00	2.67	2.00	4.33	3.00
3	A	22	11	6	66	2.67	3.00	2.67	3.67	3.33	3.00	2.67	2.67
4	B	18	11	6	51	5.00	5.00	2.00	5.00	2.00	5.00	5.00	3.00
5	B	22	11	7	64	4.00	5.00	5.00	5.00	2.00	5.00	3.00	4.00
6	B	22	13	7	65	5.00	5.00	2.00	2.00	3.00	2.00	3.00	3.00
7	B	17	8	6.5	47	2.00	4.00	2.00	4.00	2.67	2.00	2.67	3.00
8	A	22	10.5	6	65.6	2.67	4.00	2.00	1.67	3.00	2.33	3.00	3.00
9	A	21	11	6	65.3	2.33	3.00	2.67	2.33	3.33	2.00	3.00	3.67
10	A	22	11	6.5	66.5	3.67	3.00	2.00	2.00	3.00	4.00	3.00	2.67
11	B	24	11	6.5	66	2.00	2.33	2.33	1.67	3.67	1.67	4.33	3.67
12	A	22	11	6	65.3	3.00	4.00	3.33	3.00	3.33	3.00	3.33	3.00
13	A	21.5	11	6	65.4	3.00	4.00	2.00	2.00	2.67	3.00	4.33	2.67
14	A	22	10.5	6	65.7	3.00	2.67	2.00	1.67	2.67	1.67	4.33	3.67
15	A	21	10.5	6	65.4	2.00	2.67	2.33	1.67	3.33	1.67	4.33	3.33
16	A	22	11.5	6	65.7	3.00	2.67	4.00	3.00	3.67	3.00	3.33	3.33
17	D	27.4	15	7	62	3.00	4.00	2.00	2.00	2.67	3.00	4.33	3.67

18	A	22	11	6	66	2.00	4.00	2.00	2.00	3.33	3.00	4.33	3.67
19	C	20	20	8	87.12	3.00	2.67	4.00	3.00	3.67	3.00	3.33	4.00
20	A	22.5	11	6	66	2.00	4.00	2.00	2.00	3.00	3.00	4.33	3.33
21	A	22.5	11	6	66.12	3.00	2.67	4.00	2.67	3.00	3.00	4.33	2.33
22	A	22	12	6	66.8	3.00	2.67	3.00	3.00	3.67	4.00	3.67	3.00
23	B	16	8	6	45.6	2.00	2.67	2.33	1.67	3.33	2.67	4.33	3.33
24	A	22	11	6	65.12	2.00	3.67	3.00	3.00	3.00	3.00	3.33	2.67
25	C	30	15	8	78.7	2.00	2.00	2.00	2.00	3.33	3.00	4.33	3.67
26	A	22.5	11.5	6	68	2.00	4.00	2.00	2.00	3.33	2.00	2.67	3.33
27	A	22	11.4	6	66.12	1.67	4.00	2.00	1.67	3.00	2.00	2.67	3.33
28	A	22	11	6	65.5	1.33	2.00	2.33	2.00	2.67	2.00	3.33	3.67
29	B	20	10	6	56	1.67	4.00	2.00	2.00	2.33	2.33	3.00	2.67
30	A	22	11	6	66.6	1.67	4.00	3.00	2.00	2.67	2.00	2.67	3.33
31	A	22	10.7	6	65.12	1.33	4.00	3.00	2.00	2.00	2.00	3.00	2.00
32	A	22.6	11	6	66.3	2.00	3.00	2.00	2.00	2.67	2.00	3.00	3.33
33	A	22	11.5	6.5	67.12	2.00	3.00	3.00	2.00	3.00	2.00	3.00	4.00
34	A	22	11	6	65	2.00	3.00	4.00	3.00	3.00	2.00	2.33	3.33
35	A	22	11	6	65.7	3.00	3.00	4.00	3.00	3.33	3.00	3.00	3.33
36	A	22.5	11	6	66.5	2.00	4.00	3.00	2.33	3.00	2.67	3.00	3.33
37	D	20	10	7	56	4.00	1.33	2.00	1.33	2.00	4.00	3.00	3.00
38	A	21	11	6	67.5	2.00	3.00	3.00	2.00	3.67	4.00	3.00	3.33
39	A	22	10.5	6	65.7	1.33	4.00	4.00	1.33	2.33	3.00	3.00	3.00
40	A	22.7	11	6	65.9	1.67	4.00	2.00	2.00	3.00	4.33	3.67	3.33
41	B	18	9.5	6	49.4	2.00	1.33	2.00	1.33	2.33	4.00	4.33	3.00
42	C	32	20	10	118.7	1.00	1.33	3.00	1.00	4.00	2.00	2.33	4.00
43	A	22	11	6	64.8	3.00	5.00	2.00	2.00	3.67	4.00	3.00	3.00
44	A	22.7	11.5	6	67.3	1.33	2.33	3.00	2.00	3.00	4.00	3.33	3.00
45	A	23	10.5	6	66.12	2.00	2.33	2.33	1.33	2.33	4.00	3.33	3.00
46	A	22	11	6	65.6	1.00	1.33	2.00	1.33	3.00	4.00	3.00	3.00
47	B	18	9	6	63.8	1.67	3.00	2.00	1.33	3.00	4.00	3.00	2.67
48	B	20	10	6	62.6	2.00	2.00	2.00	1.33	2.33	4.00	3.33	2.33
49	D	15	10	8	47.7	2.00	1.67	2.00	2.00	2.67	3.33	3.00	3.00
50	A	20	10.5	6	65.4	2.00	1.00	2.00	1.00	2.33	4.00	3.00	2.33
Averange		21.75	11.27	6.34	65.02	2.37	3.19	2.59	2.22	2.94	2.95	3.41	3.16
StD		2.78	2.15	0.76	10.50	0.89	1.08	0.77	0.87	0.50	0.93	0.67	0.46

Table5.7 Summary of mosque data

Summary of Mosque Survey Data	Questionnaire responses averaged for Type A mosque													
		Dimensions				Averaged Questionnaire Responses (Likert scale 1-5)								
Mosque	Type	Length m	Width m	Height m	Glazing sq.m	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
2	A	22.5	11	6	67	3.00	4.00	2.00	3.00	2.67	2.00	4.33	3.00
3	A	22	11	6	66	2.67	3.00	2.67	3.67	3.33	3.00	2.67	2.67
8	A	22	10.5	6	65.6	2.67	4.00	2.00	1.67	3.00	2.33	3.00	3.00
9	A	21	11	6	65.3	2.33	3.00	2.67	2.33	3.33	2.00	3.00	3.67
10	A	22	11	6.5	66.5	3.67	3.00	2.00	2.00	3.00	4.00	3.00	2.67
12	A	22	11	6	65.3	3.00	4.00	3.33	3.00	3.33	3.00	3.33	3.00
13	A	21.5	11	6	65.4	3.00	4.00	2.00	2.00	2.67	3.00	4.33	2.67
14	A	22	10.5	6	65.7	3.00	2.67	2.00	1.67	2.67	1.67	4.33	3.67
15	A	21	10.5	6	65.4	2.00	2.67	2.33	1.67	3.33	1.67	4.33	3.33
16	A	22	11.5	6	65.7	3.00	2.67	4.00	3.00	3.67	3.00	3.33	3.33
18	A	22	11	6	66	2.00	4.00	2.00	2.00	3.33	3.00	4.33	3.67
20	A	22.5	11	6	66	2.00	4.00	2.00	2.00	3.00	3.00	4.33	3.33
21	A	22.5	11	6	66.12	3.00	2.67	4.00	2.67	3.00	3.00	4.33	2.33
22	A	22	12	6	66.8	3.00	2.67	3.00	3.00	3.67	4.00	3.67	3.00
24	A	22	11	6	65.12	2.00	3.67	3.00	3.00	3.00	3.00	3.33	2.67
26	A	22.5	11.5	6	68	2.00	4.00	2.00	2.00	3.33	2.00	2.67	3.33
27	A	22	11.4	6	66.12	1.67	4.00	2.00	1.67	3.00	2.00	2.67	3.33
28	A	22	11	6	65.5	1.33	2.00	2.33	2.00	2.67	2.00	3.33	3.67
30	A	22	11	6	66.6	1.67	4.00	3.00	2.00	2.67	2.00	2.67	3.33
31	A	22	10.7	6	65.12	1.33	4.00	3.00	2.00	2.00	2.00	3.00	2.00
32	A	22.6	11	6	66.3	2.00	3.00	2.00	2.00	2.67	2.00	3.00	3.33
33	A	22	11.5	6.5	67.12	2.00	3.00	3.00	2.00	3.00	2.00	3.00	4.00
34	A	22	11	6	65	2.00	3.00	4.00	3.00	3.00	2.00	2.33	3.33
35	A	22	11	6	65.7	3.00	3.00	4.00	3.00	3.33	3.00	3.00	3.33
36	A	22.5	11	6	66.5	2.00	4.00	3.00	2.33	3.00	2.67	3.00	3.33
38	A	21	11	6	67.5	2.00	3.00	3.00	2.00	3.67	4.00	3.00	3.33
39	A	22	10.5	6	65.7	1.33	4.00	4.00	1.33	2.33	3.00	3.00	3.00
40	A	22.7	11	6	65.9	1.67	4.00	2.00	2.00	3.00	4.33	3.67	3.33
43	A	22	11	6	64.8	3.00	5.00	2.00	2.00	3.67	4.00	3.00	3.00
44	A	22.7	11.5	6	67.3	1.33	2.33	3.00	2.00	3.00	4.00	3.33	3.00

45	*A*	*23*	*10.5*	*6*	*66.12*	*2.00*	*2.33*	*2.33*	*1.33*	*2.33*	*4.00*	*3.33*	*3.00*
46	*A*	*22*	*11*	*6*	*65.6*	*1.00*	*1.33*	*2.00*	*1.33*	*3.00*	*4.00*	*3.00*	*3.00*
50	*A*	*20*	*10.5*	*6*	*65.4*	2.00	1.00	2.00	1.00	2.33	4.00	3.00	2.33
Average		*22.00*	*11.00*	6.03	*66.01*	2.23	3.24	2.66	2.17	3.00	2.87	3.32	3.12
StD		*0.58*	*0.34*	0.12	0.77	0.66	0.88	0.72	0.62	0.42	0.85	0.60	0.43

Table5.8 Summary of Mosque Survey Data. ***Questionnaire responses averaged for Type B mosque***

		Dimensions				Averaged Questionnaire Responses (Likert scale 1-5)							
Mosque	Type	Length m	Width m	Height m	Glazing sq.m	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1	B	22	10	7	52	2.67	5.00	3.00	2.67	3.00	2.00	4.33	3.00
4	B	18	11	6	51	5.00	5.00	2.00	5.00	2.00	5.00	5.00	3.00
5	B	22	11	7	64	4.00	5.00	5.00	5.00	2.00	5.00	3.00	4.00
6	B	22	13	7	65	5.00	5.00	2.00	2.00	3.00	2.00	3.00	3.00
7	B	17	8	6.5	47	2.00	4.00	2.00	4.00	2.67	2.00	2.67	3.00
11	B	24	11	6.5	66	2.00	2.33	2.33	1.67	3.67	1.67	4.33	3.67
23	B	16	8	6	45.6	2.00	2.67	2.33	1.67	3.33	2.67	4.33	3.33
29	B	20	10	6	56	1.67	4.00	2.00	2.00	2.33	2.33	3.00	2.67
41	B	18	9.5	6	49.4	2.00	1.33	2.00	1.33	2.33	4.00	4.33	3.00
47	B	18	9	6	63.8	1.67	3.00	2.00	1.33	3.00	4.00	3.00	2.67
48	B	20	10	6	62.6	2.00	2.00	2.00	1.33	2.33	4.00	3.33	2.33
Average		19.73	10.05	6.36	56.58	2.73	3.58	2.42	2.55	2.70	3.15	3.67	3.06
StD		2.53	1.46	0.45	7.87	1.30	1.37	0.91	1.44	0.55	1.27	0.80	0.47

-The average data for dimensions and glazed area of the selected *musalla* confirm that the "model mosque" which is exactly the average of the type A sample 33 mosques is representative of the survey sample.-- On the basis of the survey data the dimensions of the model mosque used in the computer simulation were chosen as follows, Type A (with dome), 22m x11mx 6m, and the glazed area equal to 66.0 sq m.

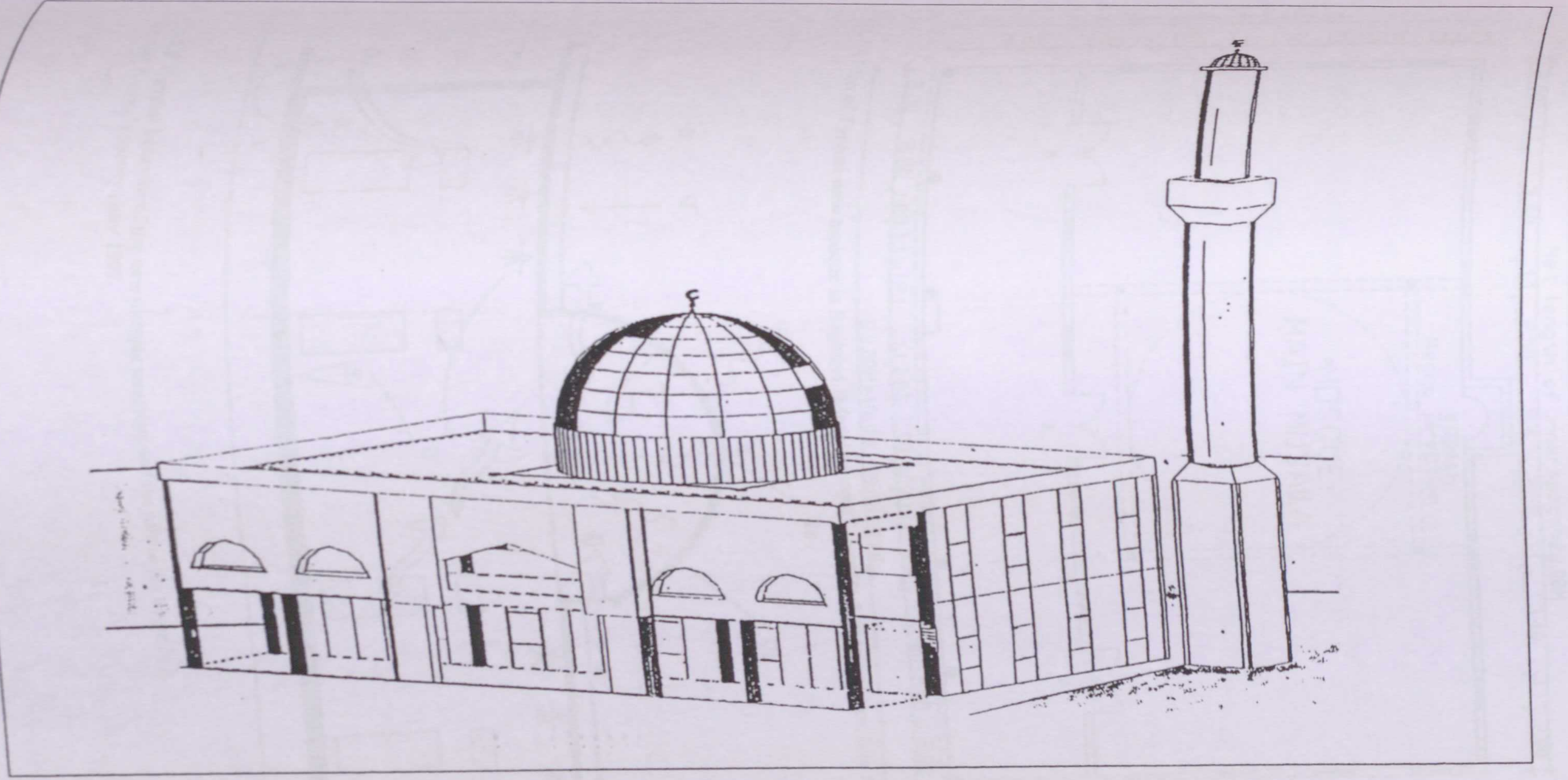


Fig.5.3 Standard components of the typical new mosque "model mosque" in Baghdad.
Source: Author's survey, July ,1997.

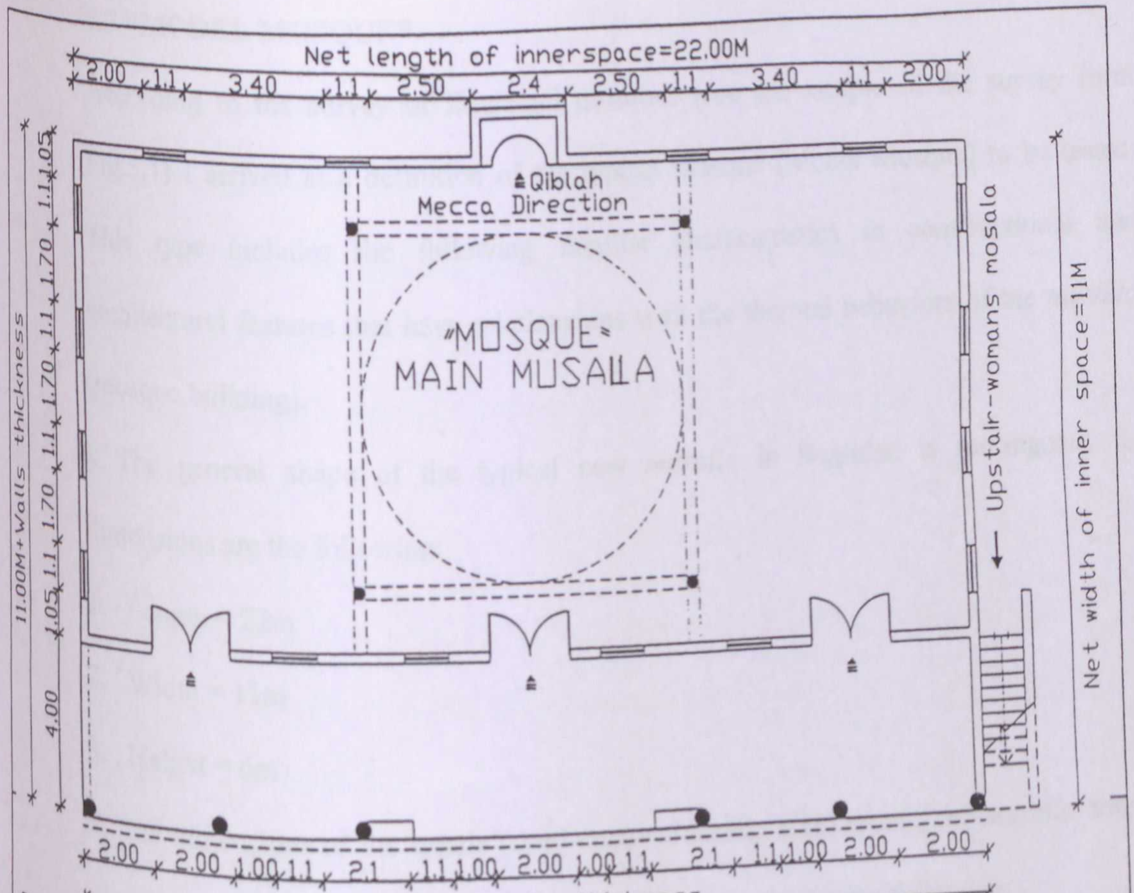


Fig.5.4 Plan of Typical new mosque in Baghdad "Model Mosque". Source: Author's survey. July 1997.

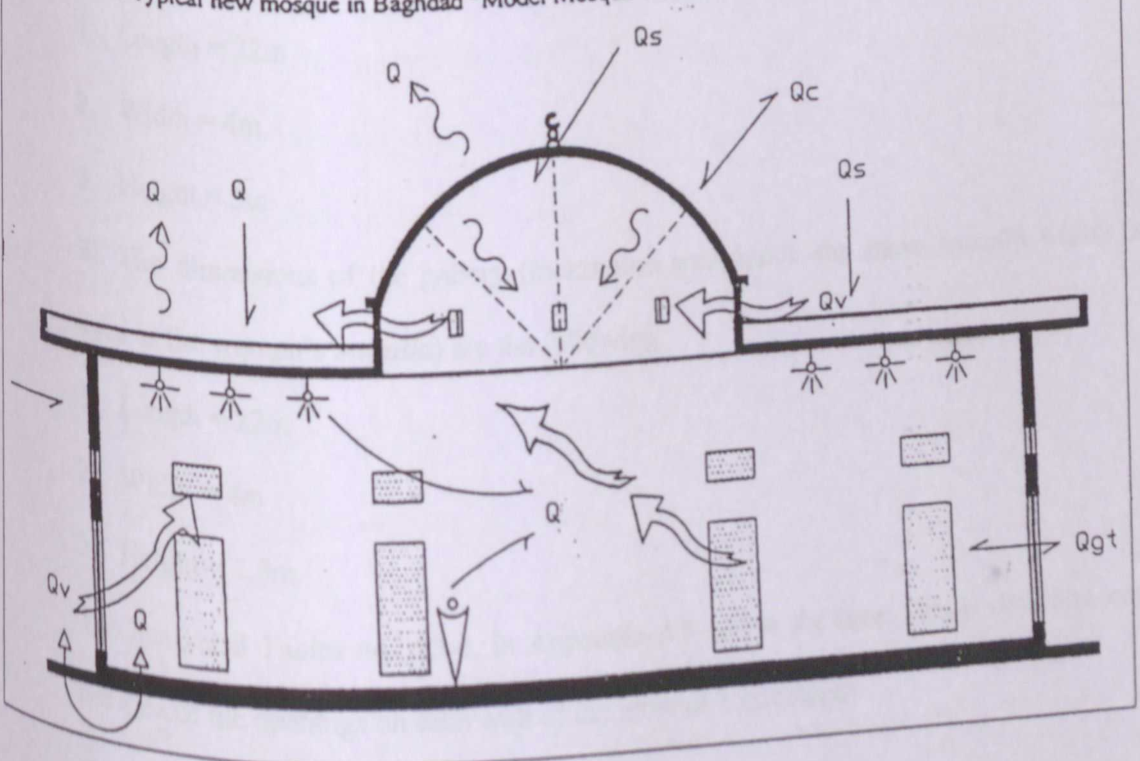


Fig.5.5 Thermal behavior of the new mosque envelope and the role of the dome in it.
Source: Author's survey ,July 1997.

5.3 "MODEL MOSQUE"

According to the survey of Baghdadi mosques (see the sample of the survey form Fig.5.1) I arrived at a definition of the typical mosque (Model Mosque) to be tested. This type includes the following familiar characteristics in constructional and architectural features that have relationships with the thermal behaviors of the *musalla* (mosque building).

i. The general shape of the typical new *musalla* in Baghdad is rectangular. Its dimensions are the following:

1. Length = 22m
2. Width = 11m
3. Height = 6m

ii. The dimensions of the arcade (semi-open-colonnade area) around the *musalla* zone, or just along the wall that faces the entrance of the mosque are the following:

1. Length = 22m
2. Width = 4m
3. Height = 3m

iii. The dimensions of the gallery (mezzanine area inside the main *musalla* which is used as the women's *musalla*) are the following:

1. Length = 22m
2. Width = 4m
3. Height = 2.8m

The analytical Tables no. A3-4, in Appendix-A3- show the areas, angle direction and net area of the openings on each wall of the mosque's envelope.

5.3.1 The General Form of the Mosque (*musalla*)

The freestanding *musalla* zone is one of the important features that distinguish it from other buildings in the mosque complex site. It has a rectangular shape with a length no more than twice the width, and the average height of the ceiling is no more than 6.0m with an approximate area of 200-250 sq.m.

5.3.2 *Musalla* Orientation to Mecca (*Qibla*)

The definition of the direction to Mecca depends on the situation of the mosque. This direction should be shifted approximately (3°) southwest of the magnetic direction (the south-west magnetic direction is shifted at an angle of 7° from the south geographical direction). Therefore, the direction of Mecca is (10°) from the geographical southern direction to the western direction.[1]

The orientation of the *musalla* in the Baghdad region to Mecca is 10° southwest. Thus, its building (*musalla*) is shifted alone (among all the blocks in the site of the mosque complex) in this direction, where the regulation planning of the other blocks of the mosque complex are not influenced by this factor. Therefore, the (*Riwaq*) or the arcade area, if it exists, is parallel to the wall which is in the direction of the *qibla* or Mecca (perpendicular to the direction of Mecca), or, sometimes, continues to make an 'L' or 'U' shape around the *musalla* building (in 30% of the surveyed mosques in Baghdad.).

5.3.3 Wall Directions of the *Musalla*

According to the direction of Mecca in Baghdad, the orientation of the walls of the *musalla* is as follows:

i. The wall which faces Mecca (*qibla*) is 10° from the northern to the eastern direction (clockwise movement in this direction).
ii. The eastern wall = 100° from the northern to the eastern direction (clockwise direction).
iii. The southern *qibla* wall is 190° from the northern to the eastern direction.[2] The western wall is 280° from the northern to the eastern direction (see fig.4.1, P.99).[3] Normally, in Baghdad, the roof is a horizontal surface that does not have a direction.

However, if there are other walls, they will follow the same directions, and bases, but the dome splits or divides into four parts according to the same directions.

5.3.4 The Mosque Construction

The typical *musalla* is normally constructed according to the following specifications:

1. Concrete skeleton structure, in general, for columns, beams and reinforced concrete slab roofing of 0.15m thickness as well as other layers of roofing which are added over it (tar 0.07m + sand 0.19m + cement tiles 0.80x0.80m of 0.025m thickness) In addition, there is finishing material (Gypsum plastering) = 0.03m.
2. Brick walls 0.24m thick, usually finished with gypsum plastering treatments of 0.025m thickness + painting. The external finishing consists of 0.025m thick cement treatment plus suitable painting or texture of gray to white or, sometimes, with the use of local bricks or stone. This applies especially to modern mosques, which have been built in the past ten years.
3. The flooring is constructed in four layers. The first layer consists of brick; the second consists of a 0.10m concrete layer; the third, cement mortar; while the fourth layer is mosaic tile 0.30x 0.30 x 0.03m. The floor is usually covered with carpets.

5.3.5 The Dome

This is the unique or distinguishing feature of the modern mosque. It is usually constructed with average reinforced concrete shell thickness of 0.15m (in 65% of the new mosques) but in 35% of the new mosques bricks are used (Jack arching system of-just bricks and mortar) .It has a spherical or semi-spherical shape and is finished at the top in a cone (see Figs. 5.6 and 5.7). Its external appearance is treated with arabesque (cerulean blue color ceramics, in general, and includes some local Islamic patterns) and its internal finishing is treated with *Juss* (local Gypsum), in more than 65% of the modern mosques that have domes.

Table. 5.9 Heat capacity for local building materials in Baghdad.

Specific Heat Material	Capacity J/kg.K	Specific Heat Material	Capacity J/kg.K
Ordinary bricks	800	Plastic tiles for flooring	968
Lime bricks	985	White marble	720
Concrete	1180	Black marble	500
Asbestos sheets	1220	Squared bricks-*Fershi* 0.30x0.30x0.05m	480
Hillan stone-local stone	906	Cement bricks	815
Seino stone-local stone	925	*Marblex* finish for walls	750
Cement mortar	950	Natural Stone	613
Ordinary tiles for flooring	960	Artificial marble	835
Mosaic tiles	956	Concrete bricks	1280
Small size aggregate	700	Ordinary soil	1115
Sand	760	Tar	1568
Mud bricks	1150	Waterproof layers	1580
Juss (local mortar)	1025	Thermo stone bricks	1280
River sand	817	Big aggregate	843
Ceramic tiles	550		

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

Table 5.10 Thermal conductivity of materials for different section components of new *musalla* envelope.

	Section of Wall	Layers	Thickness m	k-value W/mK	u-value W/sq.mK
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 Cement Glazed bricks	0.03 0.12 0.025	0.7 1.5 1.16 0.52	3.26

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

5.4 THERMAL ASSESSMENT OF THE TYPICAL NEW MOSQUE "MODEL *MUSALLA*"

The typical mosque has the same specifications as all the modern types in Baghdad. It was found that these specifications are the following:

i. The *musalla* has a detached rectangular form with inside net-dimensions in general 22mx11mx6m in height. It includes a central dome, the diameter of which is 7.0m and the height of which from the base to the top of the cone is 4.5m. This rectangular shape has one attached arcade laid at the same longitude wall, which is parallel to that which faces the *qibla* or Mecca.4

ii. The main feature of the *musalla* mass is the dome which lies in the center of the roof. The dome has three levels from bottom to top, (see Figs 5.4,5.5 and 5.6). The first part is the drum (dome base). Its height is 2.00m. Above it there is a spherical part and the upper part is the cone. All these components are usually found in the typical Baghdadi dome. Four columns support the dome; the average thickness of its concrete slab is 0.1.5 m and includes eight small arcade windows normally situated on the drum part of the dome, (see Fig.5.6).

iv. The *musalla* is usually constructed from a reinforced concrete skeleton structure with brick wall partitions. The roofing slab thickness is 0.15m, and the brick wall is 0.24m thick. Above the concrete slab of the roof there are many layers which consist of the waterproof layer (0.07m), natural clean sand (0.15m) and rough sand (0.05m) and cement tiles (0.03m). The dimensions of each cement tile are 0.80mx0.80m. The interior finishing of the dome and the walls is fine gypsum, and its thickness is 0.025m, (see Tables 5.9 and 5.10).

5.4.1 Thermal Impact of the Dome

This architectural element represents well the main symbolic element in the whole mosque composition just like the minaret. It is noticed that the dome may have a role in the thermal behavior of the envelope; therefore, it is very important to analyze its thermal impact. Thus when we look at Tables (A3.A1 and A3.A2) in Appendix A3, 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. The transmitted solar radiation through the dome shell concentrates in the inner center of the base of the dome (as shown in Fig.5.5), thus the focal point of the solar radiation heat will be concentrated in the center of the space of the dome, and exactly in the center of its circular base. This focal point results from crossing the heat radiation, which emits from the shell or envelope of the dome.

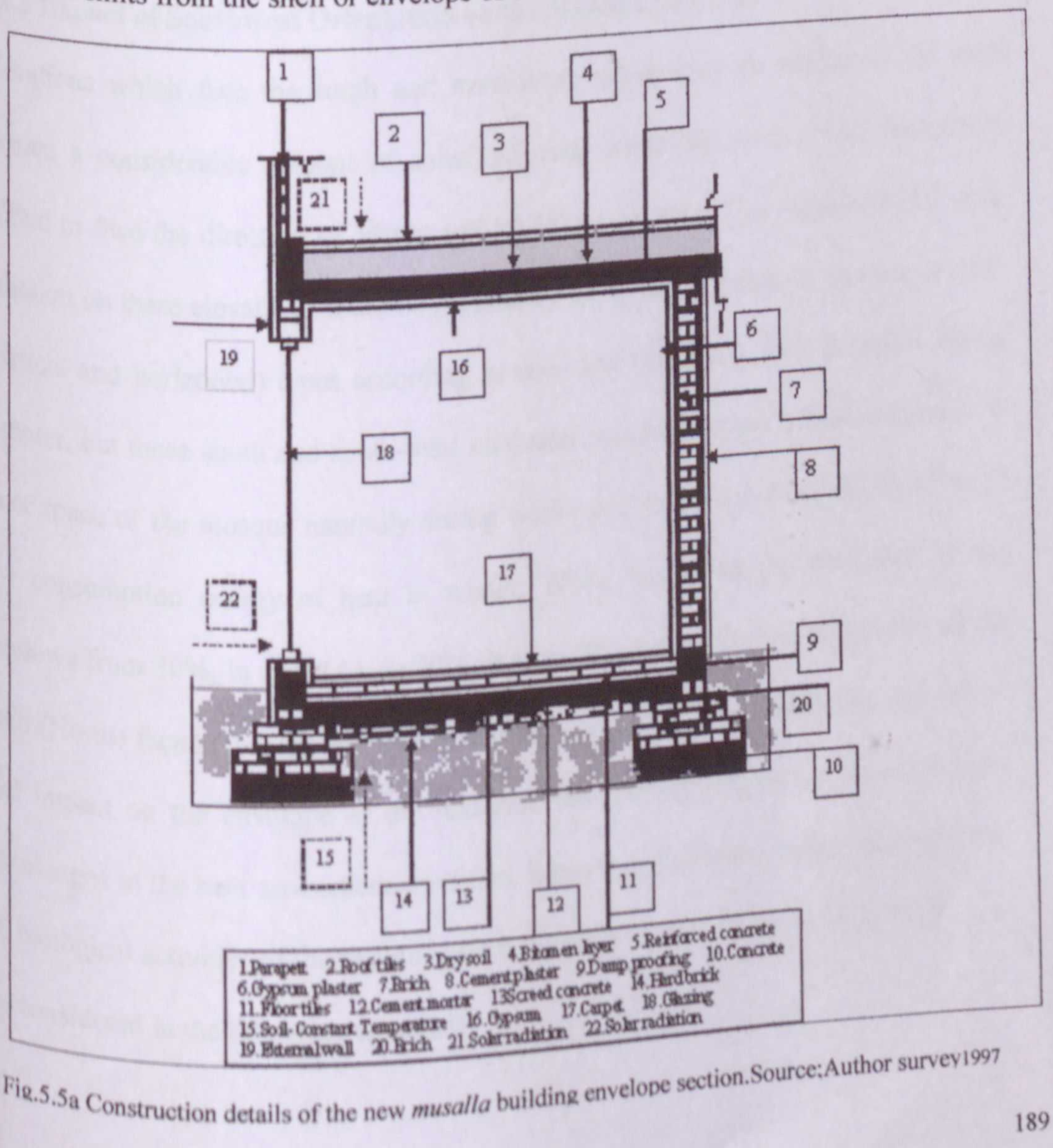


Fig.5.5a Construction details of the new *musalla* building envelope section.Source:Author survey1997

The heat is not transferred directly to the inside of the *musalla,* 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 *musalla*. Therefore, the dome is very useful in summer time, in enhancing the inner environment of the *musalla* thermally. This is one of the important reasons, which encouraged architects in Baghdad in many historical periods to increase the number of domes on the roofs not only of mosque buildings, but also in most of the other the historical buildings in Baghdad.

5.4.2 Impact of Southwest Orientation on the *Musalla* Envelope

Elevations which face the south and even those which may be shifted to the west receive a considerable amount of solar radiation, while the zone of the *musalla* is shifted to face the direction of Mecca (*qibla*) 10° south-west. The impact of this solar radiation on these elevations could be reduced by using shading devices and sun louvers (vertical and horizontal) types according to need and direction. This is useful during summer, but these south and south-west elevations receive enough radiation to heat the inner space of the mosque naturally during winter and that is an advantage in terms of low consumption energy of heat in winter. When decreasing the total area of the windows from 30%, in case (A), to 20%, in case (B), and putting the wider area on the main (North) façade, we get the lowest heat flow rates to inner environment and lowest heat impact on the envelope of the *musalla*. The following equation determines the percentages in the heat assessment condition. Since the additional energy obtained from the biological activities of the human body is constant in the two cases (A) and (B), it is not considered in the following equation:

$$\text{Heat assessment} = \frac{\textbf{Total percentage of window area at each wall}}{\textbf{Total area of inner space of mosque } (\textit{musalla})}$$

The heat flow through the flooring is neglected because of a number of important factors, for example, the floor of the mosque consists of many layers of semi- insulation as listed below.

i. Compacted fine mixed aggregate layer attaché to the ground.

ii. Compacted earth layer upon the first layer at (1).

iii. Compacted layer of rubble fired bricks, which has high thermal insulation.

iv. Cement mortar and mosaic cement tiles as the latter have a higher finish.

v. Carpet, which is normally put on the floor throughout the year.

For all these reasons, and in order to facilitate the calculations, the other unaffected factors in my estimations are neglected.

Table 5.11 Heat flow for the *musalla* envelope of typical new mosque 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
MARCH	-29.9	-4.2	-21.0	-5.2	-22	+174.3	+92
APRIL	-	-	-	-	-	+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.m K, U of the roof = 12.1 W/sq.m K,U of the dome = 3.21 W/sq.m K.
Source: calculations achieved with the assistance of BRC-Baghdad.

5.4.3 Impact of the Type of Color of the External Surface of the *Musalla* Envelope

Based on achieved field experiments by Dr. Awni K. Shaaban at Texas University for the double building envelope for natural cooling of buildings in hot-dry and hot-humid climates (Shaaban; 1981), a light color external building surface contributes to cooling the inner environment. In addition, the performed field test by Mr.Mohd.Peter Davis (Thermal House-Environmental Studies Department-University Putra Malaysia) on 22 Feb. 2001, using eight different colored metal sheets exposed directly to the sun showed that the sun's impact is 13-15 °C more on a dark surface than a white surface.

5.5 ESTIMATATION OF HEAT FLOW IN THE "MODEL" MOSQUE

Using standard heat flow estimates (ref.CIBSE, see Appendix A3 and Chapter four item 4.4.4); the heat gain/loss flow rate through the *musalla* building envelope is demonstrated in Fig.5.5. Assumed heat flow through fabric is given in the Table 5.11 based on calculations by BRC-Baghdad and the author.

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

1. The volume of the *musalla* (prohibited main space- prayer area).
2. Women's *musalla* (the gallery mezzanine inside the main *musalla*).
3. The volume of the dome which includes:

a. The drum – the lower part of the dome.

b. The spherical part – the middle part of the dome.

c. The conical part – the upper part of the dome.

1. <u>**The area of the *musalla* (main space)**</u>

   22m (length) x 11m (width) =242m^2

   a. The total areas of all the walls of the mosque in all directions are:

1. The area of the wall at 10° orientation:

   $22 \times 3 + 22 \times 2.6 = 123m^2$

2. The area of the wall at 100° orientation:

$11 \times 6 + 2.8 \times 4.0 = 77.0m^2$

3. The area of the wall at 190° orientation:

$6 \times 22 = 132m^2$

4. The area of the wall at 280° orientation:

$11 \times 6 + 4x\ (2.6) = 77.0m^2$

b. Window and door area:

i. The area of the windows at 10° orientation:

$= (1.10 \times 1.75) \times 4 = 7.7m^2 = 8m^2$

ii. The area of the doors at 10° orientation:

$= (2.0 \times 2) \times 3 = 12.0m^2$ (Normally two or three doors)

Thus, the net wall area at 10° orientation is:

$123 - (12+8) = 103m^2$

2. i. Area of the windows at 100° orientation:

$= (1.10 \times 4.0) \times 4 + (1.10 \times 0.55) \times 4 = 20m^2$

ii. The net wall area at 100° orientation is:

$11 \times 6 + 3.75 \times 2.80 = 77.0m^2$

77.0 - 20.0 = 57.0 sq.m

3. i. The area of the windows at 190° orientation:

$= (1.75 \times 0.55) \times 4 + (1.00 \times 0.55) \times 4 = 6.00m^2$

ii. Thus, the net area of the walls at 190° orientation is:

$132 - 6 = 126m^2$

4. i. The area of the windows at 280° orientation is equal to the area of the windows at 100° orientation = $20m^2$.

ii. Thus, the net area of the wall at 280° orientation is equal to the same area at 100° orientation = $57.00m^2$.

5. The total volume of the typical mosque is:

22m (length) x 11m (width) x 6m (height) = $1452m^3$

6. The total area of the women's *musalla* (upstairs as a gallery or mezzanine) is:

22 x 3.75 = $82.5m^2$ – (The wall of the women's *musalla* is calculated already with the main *musalla* walls estimate).

2. <u>**The volume of the women's *musalla***</u>:

= 22 x 3.75 x 2.80 = $231m^3$

3. <u>**The volume of the dome includes the following:**</u>

a. **The wall area of the drum of the dome, the lower part,** (see Fig.5.7)

The drum is similar and parallel to the walls of the *musalla* in terms of window orientation. Sometimes, instead of being a circular shaped it is modified to be a square shape dome drum, with each of the two windows on the drum supposed to face one orientation, parallel to the walls of the *musalla*. 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 = $98m^3$

b. **The cone:**

This 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.5.7.

Thus, the surface area of the cone is:

$S = 2\pi s$ = 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 $16.66 / 4 = 4.2m^2$.

The volume of the cone, $V = 1/3\ \pi\ r = 1/3 \times 3.14 \times 2.0 = 2.4m^3$

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: 45°, 65°, and 82°. Moreover, each part is, in turn, divided into four parts (Qadir; 1990), each of which faces one of the four orientations (see Figs.5.6 & 5.7). According to this, the surface area of the dome, the spherical part or middle part, equals:

$$S = \int_a^b 2\pi\, f(X)[1+f^1(X)]^2\, dX$$

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

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

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

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

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

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

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

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

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

$$\pi\, (3.5)^2 X - \frac{X^3}{3})_3^0 = 87.2\ m^3$$

(See Figs. 5.6 and 5.7).

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.5.6 and 5.7).

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

   24.97/4 = 6.24m^2
4. The area of the middle part, spherical strip, (see Fig.5.7) equals:

   1.16 x 3.14 (2.9/2 + 2.9) x 2 = 28.79m^2 (See Fig.5.7, case 2).

   So, the area of each piece from the middle part is:

   22.79/4 = 5.7m^2
5. The area of the upper, spherical strip, (see Fig.5.7) equals:

   1.16 x 3.14(2.9/2 + 2.0) x 2 = 17.87m^2 (See Fig.5.7, 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:

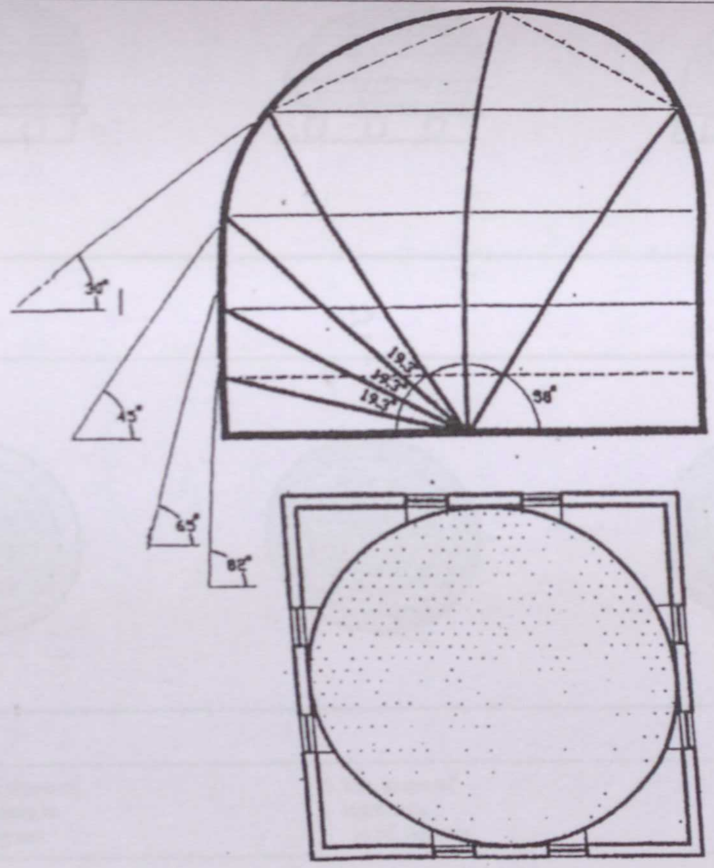
   87.21 + 2.4 = 89m^3

The total volume of the *musalla* will be equal to:

= the volume of the *musalla* + the volume of the women's *musalla* + the volume of the drum (the base of the dome) + the volume of the dome (which consist of 2 parts, the spherical and conical part),(see (Qadir;1990)

= 89.61 + 151.2 + 230.77 + 1483.2

=954.78=1955



The window of the dome drum

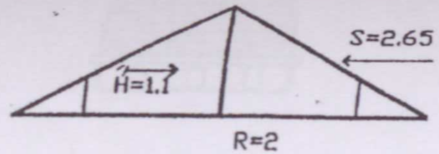


Fig.4-13 Partial section for the cone

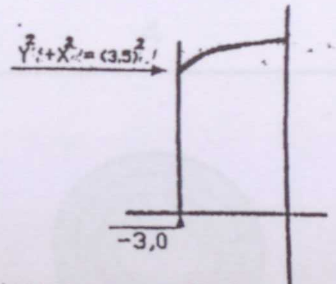


Fig.4-14 The curve part of the dome

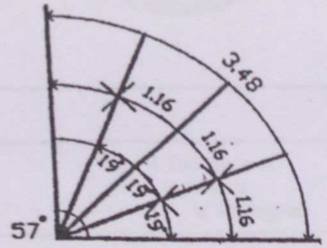


Fig.4-15 The spherical part of the dome

Fig.5.6 Detailed analysis for the dome parts for thermal estimation purpose, see (estimate of heat flow in "Model *Musalla*" in Chapter 4.
Source:Qadir;1990.

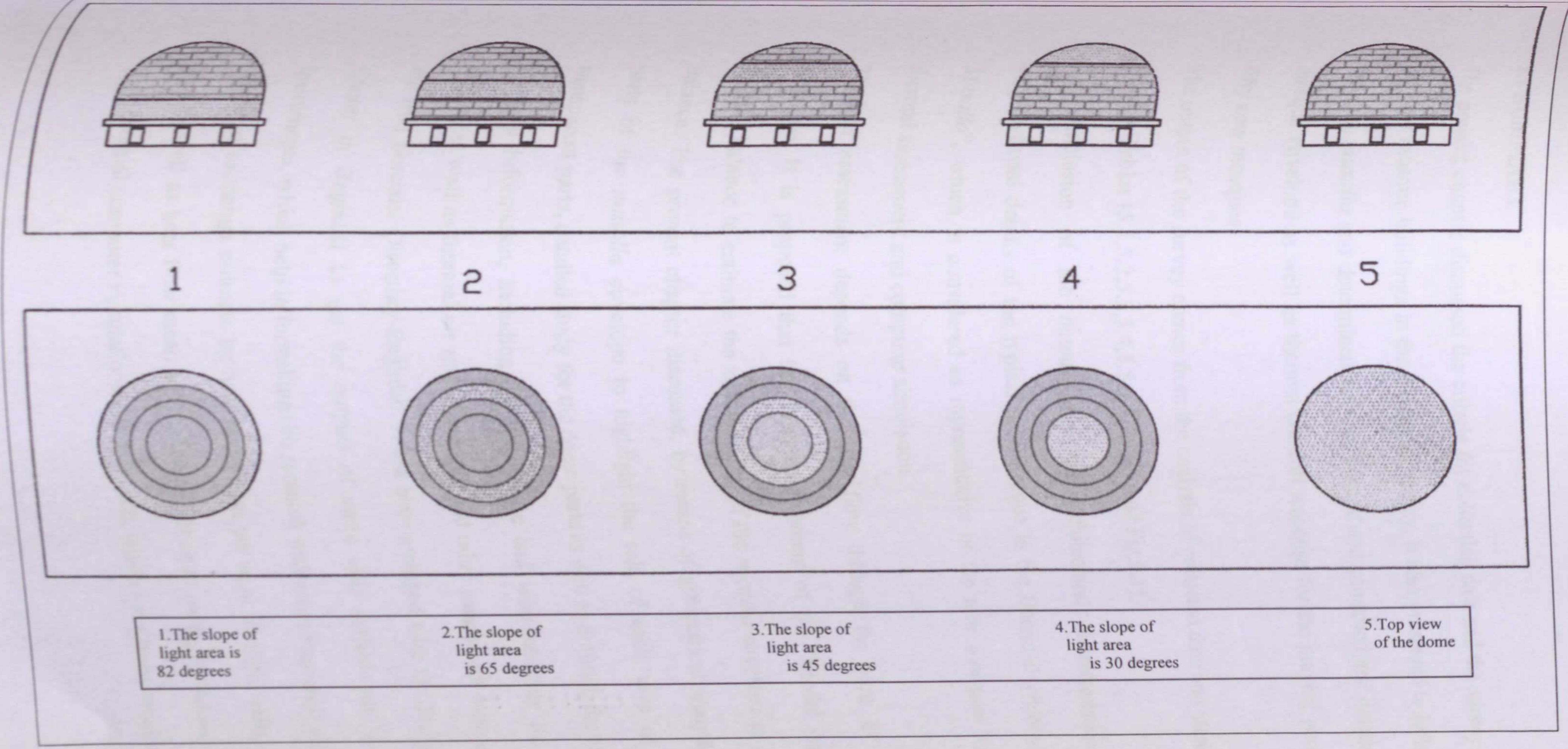


Fig.5.7 Split the dome into horizontal layers to estimate thermal gain through each layer that has a different slope relating to the falling solar radiation.
Source:Author's surveys July 1997.

5.6 SUMMARY

The present chapter discussed the criteria for collecting data and the survey strategy for the new mosque buildings in the Baghdad vicinity, it also presented a definition of the mosque, *musalla* and determined the architectural and constructional details of the new mosque envelope as well as thermal comfort response for the praying people in those fifty new mosques.

The output of the survey comes from the analysis of collected data and statistics that are listed in Tables (5.1,5.2,5.3,5.4,5.5,5.6,5.7,5.8 and Fig.5.1).

The conclusion of the output gave the architectural characteristics and other constructional details of the typical new mosque in the Baghdad vicinity the "Model *Musalla*", which is considered as representative of the new mosques for use in the thermal assessment and computer simulation.

Thermal assessment depends on the heat flow through the parts of the *musalla* envelope. It is proposed that the inner environment of the "Model *musalla*" is in thermal balance to estimate the actual ability of the *musalla* envelope to maintain that balance. The present chapter discussed, by means of geometrical analytical study, all parts of the *musalla* envelope to highlight the role of each, area of opaque and transparent parts, detailed study for the dome parts as well as defining the air cubage.

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 has been arranged with the Building Research Center in Baghdad to get the outputs of some tests carried out by the center's instruments, which help in furnishing this research with some important information.

The heat exchange estimate by heat flow mean per sq.m through walls, windows and roof as well as heat flow mean by ventilation per sq.m owing to the successful results from thermal computer simulations and approach, which have been considered.

[1] Source: Ministry of *Awqaf* and Religious Affairs- Engineering Office, Baghdad, Iraq.

[2] *qibla* direction is fixed for every location, and it varies from one location to another

3 See Fig.4.1,Ch.4.

4 See Figs.5.4, plan of "Model *Musalla*", and Fig.5.3.

CHAPTER SIX

CHOOSING OF VARIABLES AND COMPUTER SIMULATIONS FOR THE " MODEL MOSQUE "

6.1 INTRODUCTION

By following the CIBSE Manual (1975), the rates of the heat flow through the construction components can be theoretically estimated . That will help to define the influence of each component of the construction on the total ability of the *musalla* building envelope to protect the inner environment from climatic fluctuations .

Generally speaking, the minaret does not have a direct impact on the building behavior till now, whereas the dome has the impact of rebalancing by facilitating air circulation through its windows, especially by hot air removal and air circulation which happens due to the variation in air temperature between the external and internal environment. Therefore, the dome was chosen (with the roof) in accordance with the calculations and evaluation steps mentioned in Chapter five as an important element in enhancing the inner environment and contributing in keeping the temperature at a constant level inside the *musalla* at 25C° in summer and 18.5C° in winter, which is the required level .

Since the summer season in Iraq is very long (more than seven months), the need for cooling is very important, and it is necessary to get good thermal isolation of the envelope in its components and behavior to prevent the heat from entering the building. For this reason,the typical new mosque in Baghdad, which is represented by the "Model Mosque" in that city , is used to determine the problems which are related to the weak thermal behavior of section materials in the building of the *musalla*.[1]

The building simulation program is employed in the assessment of the "Model Mosque" to show the environmental impact on the inner environment of the *musalla*. The BLAST program provides the engineering and architectural community with a tool for estimating the behaviour of the *musalla* envelope with different variables of construction materials, specifications and building design under climatic fluctuations in the Baghdad region.

6.2 STRATEGY FOR CHOOSING VARIABLES

The basis of this research would be how close we can get to the optimum temperature, and one of the major aims of this research is to make use of changing the characteristics of the members of the envelope and using it to get thermal comfort, or to be near that aim. Therefore, the heat flow unit for one sq.m of the envelope of the *musalla* building will be according to the following changes: Changing the wall thickness from 0.24m to 0.36m, i.e., increasing the thermal resistance of the walls as well as the thermal capacity (thermal mass),taking into consideration the *time lag* factor.[2]That will be possible through the implementation of the following alternatives (variables);

i Providing insulation material, like foam sheets or polystyrene as an additional layer to the envelope .

ii Changing the gross area and situation of windows, taking into consideration the minimum optimum size in each direction.

iii. Studying the choice of the optimum color and texture for exterior surfaces.[3]

iv. Studying the shaded areas around the praying area (*musalla*) and providing arcades on each side according to need and orientation.

v. Studying the vegetation and types of trees to provide the optimum microclimate and shade around the *musalla* building.

vi. Trying more variables (more alternatives) for walls and roof, and testing the impact of each with the assistance of computer simulations .

This research considered the following proposals to facilitate the stepes of the calculation without imposing major effects on the final output:

i. Assuming the envelope as one homogeneous layer. Since the temperature gradient through a composite wall is different from the gradient for a homogeneous layer, to facilitate the calculations it is proposed that one K-value (thermal conductivity)is due to the following:.[4]

K = K / dxc (W/m C°) d = density (kg/m^3)

c = specific heat (J/kg C°) and that has an impact on the time lag (See Energy Efficient Design,(1995:80),and Fig.40.)

ii. Assuming the heat flow in the perpendicular direction to the section (the envelope surface).

iii. Assuming that complete air ventilation for the *musalla* building happens once per hour.

iv. Since the flooring of the *musalla* is usually covered with thick isolating material (typical specifications of carpet in most of Baghdad's mosques), the calculation of heat flow through this part of the floor is neglected.

v. Assuming that the doors have the same specifications for heat flow as the windows and the same u-value (thermal transmittance).

vi. Assuming that the average number of people praying at each prayer time is 30 persons, and that their average stay is 30 minutes. This is equivalent to 15 persons per hour. The metabolic rate for each person praying as a result of the biological activities of the person's body is equal to the metabolic rate released by a human body in the case of walking 2 miles per hour, That is equivalent to 212 W.[5]

6.2.1 THE ANALYSIS OF THE THERMAL CONDITIONS IN THE "MODEL *MUSALLA* " DUE TO THE MODIFICATIONS OF THE ENVELOPE

Many basic correction alternatives can be applied to the building of the new typical *musalla* in Baghdad to assess their influence on the general thermal balance of the inner environment of the *musalla* building. They are as follows:[6]

i. Thermal testing for the window orientation in the following directions:

1.West 2.South 3.South-west 4.East

That is essential for the proposition of getting suitable solutions and details – as well as the area – for each opening in these directions. For example, the ability to optimise to supply suitable heat during the wintertime; and the prevention of solar radiation and reflected heat from the surroundings entering the *musalla* during the summertime, through the window openings.

This helps to pay attention to the following items:

1. The size of each window according to its direction.
2. The dimensions and proportion of the window and its fixed and mobile parts.
3. The type of glazing and its thickness, in addition to its efficiency in reflecting solar radiation and heat.[7]
4. The height of each window related to the ground level.[8]
5. The determination of the shading devices.

ii.Thermal testing for the walls and roof of the *musalla* building after implementation of the following alternatives;

1. Increasing the thickness of the walls, using cavity type etc.
2. Providing the roof section with an isolating layer (normally polystyrene, which is commonly used in Baghdad) to assess the thermal reflectivity and thermal capacity of the roof.
3. 3. Changing the color of the external surfaces of the *musalla* building from dark colors to light colors to increase their reflectivity and minimize the

absorption of solar energy (heat), which has a clear effect as shown in Tables (A3.1, A3.2 and A3.3, App.A3.)

This research has also taken into consideration the process and results of the previous project at Sheffield University which conducted an assessment for a "chamber test" under a similar environmental impact as Baghdad (Dawud, Azhar.J, 1983;Al-Riahi; 1987) and the tests of the BRC in Baghdad[9], as well other field tests done by the BRC (Building Research Centre in Baghdad), see Appendix A3.

To maintain comfort conditions requires cooling and heating. Therefore, this is not feasible in Baghdad for mosques presently. It is instructive to see potential savings.

Studies and tests had been carried out by the BRC to determine the extent to which energy saving could be achieved by the use of passive design features. Since it is clear that the extensive use of centralised heating and air conditioning plants has not been possible in the past it will also not be possible in the foreseeable future because of the economic crisis in Iraq. The results of this study will indicate the significant savings possible that the new *musalla* needs to make in the equivalent improvement in thermal comfort for passive buildings.

All of the other information and tables presented by the BRC in Baghdad and the analysis of the results are given in App.A3.

6.3 COMPUTER SIMULATIONS

6.3.1 Computer Tools and Approach

Computing the thermal performance of the building before it is even built has several advantages. It becomes possible in the pre-construction stages to refine the thermal properties for each building element.

Heat transition occurs by conduction ,convection and radiation .The analytical methods for heat transfer calculations are not sufficient when it comes to complex composite structures with thermal bridging, thus increasing the thermal transmittance (denoted as U-value) of the *musalla* building structure. Just how much energy flows through the thermal bridge is difficult to determine using conventional analytical methods, but with numerical computer calculations it becomes possible[1°].

The typical mosque building has been simulated for the four different roof structures and five different walls as shown in the graphs. To make the simulations comparable , the size of one huge space *(musalla)* and its direction to Mecca at 10 degree south-west has been treated as a constant. The input data for the "Model" *musalla* are very extensive and will only be presented here in general terms. Weather data for the Baghdad region is obtained from the Iraqi Meteorological station. The location of Baghdad is on Longitude 44° , Latitude 33°.

6.3.2 Measurments

Since Baghdad city has become hotter during the past 10 years , this general increase in temperature is denoted as the "urbanisation effect" and it occurs when the natural

Table 6-1: Masurement Units for Computer Simulation.

Parameters (hourly)	Units
Cloud Cover	Oktas
Dry Bulb Temperature	C°
Wet Bulb Temperature	C°
Relative Humidity	%
Global Solar Radiation	MJ/sq.m
Sunshine Hours	Hours
Wind Direction	Deg.
Wind Speed	m/s

environment is transformed into that of the city (see Shaaban;1975 and App.A3). A number of temperature measurements were taken in and around the "Model" mosque to shed light on this phenomenon. Morever , the measurements were used as a reference for the computer simulation.

The "BLAST" walls and roof simulations were carried out to determine the u-value of the roof and walls of the existing "Model" *musalla*, and computations were also performed for a new insulated panel roof and pitch roof (which is not usually used in Baghdad for no serious environmental reason) which may be used in the future. All charts include a list of the properties of the materials used for the computer simulations, (more details regarding the thermal capacity, conductivity, density and solar absorption of those materials can be found in Appendix A3 and Tables B-1, B-2 APP.B).

6.3.3 Review of the Capabilities of Some of the Softwares Used in the Thermal Assessment Simulation

Through this review ,the approach of the selection of a certain software tool (BLAST) to be used for *musalla* thermal assessment simulation will be discussed. The following criteria are considered;

*Obtained of four common mainstream tools for detailed comparisons.

*Looked at their ability to consider various technologies or issues.

*Compared them to the "best available" specialty tools.

**Broad Spectrum of Software Tools Related to Buildings, Passive Design and Energy.

*What are the capabilities of each tool?

*Who uses them and for what purposes?

*Building designers (sizing / thermal assessment / design.

-ESCO or utilities

-Researchers.

*Who created or promoted the tool and for what purpose?

-Assist designers

-Promote technology / products.

-Promote energy efficiency

-Environmental Impact (which is the current research area).

-Evaluate building science.

***Software Tool Taxonomy

*Comparison of schedules to show list of tools which have been“self-classified” (e.g.tool list).

*We will look at who uses (or is likely to use) each tool in conclusion.

*What tools are currently used by “Design Practitioners”;

*What tools require expert “knowledge“or complex input data; and why is BLAST selected to be the software tool for doing the thermal assessment of the new *musalla* building in Baghdad?

6.3.4 Other Specifications of the BLAST Program

1.Blast and EnergyPlus both use heat balance in passive designed buildings, which is the best available thermal assessment simulation tool. EnergyPlus currently has no user interface. BLAST is a more mature program with an interface.

2. *'There are only two programs that use a true dynamic heat balance and they are BLAST and EnergyPlus. BLAST currently has a graphical interface and EnergyPlus does not' (Dr.Richard Liesen;Support@blast.bso.uiuc.edu.).*

Based on that and the previous comparison, the best program with reference to *musalla* thermal assessment conditions is one that uses a heat balance, or basic thermodynamics, to determine control volumes and all the energy streams that cross into or out of that volume. This is the BLAST program.

3.There is also a bibliography of related articles, which would give a very good idea of what research took place and some verifications of the heat balance at http://www.bso.uici.edu/BLAST/nibliography.html. This bibliography contains a list of BLAST related publications. It is meant to serve two functions. The first is to provide references which contain information and methodologies which were either directly or indirectly incorporated into BLAST algorithms. The articles, books, and conference proceedings describe the heat transfer algorithms.

6.2 Comparison of software tools used for building thermal assessment simulations.

TOOL	KEYWORDS APPLICATIONS	EXPERTISE REQUIRED	AUDIENCE	INPUT	OUTPUT	STRENGTHS
BLAST; Performs hourly simulations of buildings, energy and architectural engineers with accurate estimates of a building's energy needs. The zone models of BLAST (Building Loads Analysis and System Thermodynamics), which are based on the fundamental heat balance method, are the industry standard for heating and cooling and calculations. BLAST output may be utilized in conjunction with the LCCID (Life Cycle Cost in Design) program to perform an economic analysis of the building/system.	Energy performance, design, Retrofit, research, Residential, public and commercial buildings.	High level of computer literacy not required.	Energy, and architectural engineers working for architect/engineer firms; consulting firms, research universities, and research laboratories.	Building geometry, thermal characteristics.Readable, structured input file may be generated by HBLC.	More than 50 user-selected, formatted reports printed directly by BLAST; also the REPORT WRITER program can generate tables or spreadsheet-ready files for over one hundred BLAST variables.	PC format has windows interface as well as structured text interface; detailed heat balance algorithms allow for analysis of thermal comfort, passive solar structures, almost 400 weather files.

Doe-2; *Energy analysis program calculating energy performance.* Can be used to analyse energy efficiency of given designs, other uses include utility demand and training new corps of energy-efficiency conscious building professionals in architecture and engineering schools.	*Energy performance, design, retrofit, research,* Residential and commercial buildings.	*Recommended few days of formal training in basic and advanced DOE-2 user. High level of user* knowledge.	*Architects, engineers in private A-E firms, university school of* architecture and engineering.	*Building description language input describing* geographic location, HVAC equipment and controls and utility rate schedule.	*20-user-selectable input verification reports;50* user selectable monthly/annual summary reports.	*Whole-building energy analysis of* multiple zones in buildings of complex design

EnergyPlus; *Building energy simulation program that builds on the most popular features and capabilities of BLAST and DOE-2.* EnergyPlus includes innovative simulation capabilities including time steps of less than an hour. Other planned simulation capabilities include solar thermal, multizone airflow, and electric power simulation including photovoltaic systems and fuel cells.	*Energy simulation, load calculation, building performance,simulation ,energy performance, heat balance, mass* balance.	*High level of computer literacy not required; engineering background helpful for analysis portions.* Difficult to use without graphical interfaces.	*Mechanical, energy, and architectural engineers, engineer firms, utilities, research universities, and research laboratories.*	*It is envisioned that private developers will wish to develop more targeted / domain specific user interfaces.*	*Basic EnergyPlus program will have several simple ASCII output files - readily adapted into* spreadsheet form for further analysis.	*Detailed simulation capabilities through complex modeling capabilities.*

Energy-10; Conceptual design tool for buildings that are less than 10,000 ft^2 floor areas, including dynamic thermal and delighting calculations. Specifically designed to facilitate the evaluation of energy-efficient building features in the very early stages of the design process.	*Conceptual design, residential buildings, small commercial buildings*	*Moderate level of computer literacy required; two days of training advised.* Limited to smaller buildings and HVAC systems that are most often used in smaller buildings.	*Also HVAC engineers, utility companies, university schools of architecture and architectural engineering.*	*User adjusts descriptions as the design evolves, using fill-in menus, including utility-rate schedules, construction details, materials.*	*Summary table and 20 graphical outputs available, generally comparing current design with base case.*	*Rank-ordering of results; integration of delighting thermal effects with thermal simulation; menu display and modification of all building-description.*

Source:http//www.support.edu.

It also contains a long list of references where BLAST was the primary tool for some type of energy related analysis. They include involving passive solar design strategies and the effect of thermal mass. The computer bibliographic search was completed at the engineering library at the University of Illinois .The list was narrowed down by finding articles which also contained such key phrases as heating load, cooling load, energy consumption, building energy and simulation.

6.3.5 The "BLAST" Program

The BLAST (Building Loads Analysis and System Thermodynamics) system is a set of computer programs for predicting heating and cooling energy consumption in buildings. It was developed by the U.S. Army Construction Engineering Research Laboratory (USACERL). The original release of BLAST was called BLAST Version 1.2. The BLAST program offers a substantial number of features, which allow engineers and architects to obtain the necessary information for design and energy analysis tasks. Some of these features include: a readable input language, two sophisticated input file processors, and readily accessible libraries of common building elements, and accessory programs which greatly simplify the task of processing weather data and generating customized input parameters and output reporting. One of the BLAST preprocessors, the Heat Balance Loads Calculator (HBLC), is used to interactively create BLAST input files with a minimum of input required from the user. The BLAST program contains three major sub programs:

1. The Space Loads Prediction subprogram computes hourly space loads in a building based on weather data and user input detailing the building construction and operation.

2. The Air System Simulation.
3. The Central Plant Simulation.

The HBLC (Heat Balance Loads Calculator) is a windows-based graphical interface for producing BLAST input files. It is a powerful software tool for calculating heating and cooling loads for buildings. It allows the users to access complex heat-balance algorithms using a windows interface. Geometric inputs are entered graphically, an approach which is both quick and easy to understand. The HBLC creates an input file for the Building Loads Analysis and System Thermodynamics Simulation Program (BLAST), making some of the most powerful and accurate algorithms for calculating heating and cooling loads available through a simple, easy-to-use, Windows-based program. BLAST is a very powerful energy analysis program, which calculates thermal loads using an implementation of the heat balance method. As a result, a simpler yet more accurate method of performing loads calculations is made available through the Heat Balance Loads Calculator (www. Support@blast.bso.uiuc.edu.).

i. Weather Files; The BLAST package includes a complete set of weather files in both raw and processed weather data formats. The Weather Information File Encoder (WIFE) program is utilized to process raw weather data into a format, which can be read by the BLAST program. WIFE can automatically read several standard weather data tapes (TMY, TRY, SOLAR Z80…. etc) and allows any other type of weather data tape to be processed by means of a user-written routine. Among the options to user input are holiday periods, type of units in output reports, and hourly reporting periods. During raw weather data input, WIFE attempts to fix (by means of curve-fitting techniques) any missing data points for various types of input (e.g., dry-bulb temperatures, barometric pressure, etc.).The Weather File Reporting Program, a supplemental program to WIFE, has been developed to read processed BLAST weather data files. The standard report produced by the weather File Reporting Program shows monthly and daily averages as well as design temperatures. The information provided by the program is in a format that can be readily used by the designer for system sizing.

ii. Environment Selection; Selecting both a location and weather information from the HBLC libraries specifies the outside environment. Over a hundred locations are available from the on-line locations library, and the user may define new locations by inputting the latitude, time zone, and monthly ground temperatures of the site. Design day weather information is available for each of the library locations, and design days for other locations may be defined by the user. Additionally, weather files with hourly data in TMY and TRY format are available separately for over 350 locations.
iii.Building Geometry;_ The HBLC is a Windows-based graphical interface for producing BLAST input files. The HBLC allows the user to visualize the building model as it is developed and modify previously created input files. Within the HBLC, each story of the building is presented as a floor plan which may contain several separate zones.Numerous other building details may be investigated and accessed through simple mouse operations. The HBLC is an excellent tool which makes the process of developing BLAST input files much more intuitive and efficient. Perhaps the most convenient feature of the HBLC is the method of defining the building's walls, floors and roofs. Up to fifty simultaneous thermal zones at various elevations may be defined for a single building.When subsurfaces are added to a wall,an elevation view of that wall will appear.Windows and doors and overhangs are added by clicking screen buttons,and they are sized by clicking and dragging the surface's edge.Surface construction are easy to specify in the HBLC. Each surface type (walls,roofs,floors,windows,and doors) has an easily-accessible library from which pre-defined building elements can be selected. The library is actually a dynamic database containing layer-by-layer material information for each element. If the desired element is not in the library ,the user may define the element by specifying its different material

layers. The Report Writer Program is an extremely useful engineering tool designed to be used in conjuction with output from the BLAST program. It has the ability to produce files which can be read directly into *L0TUS* and *EXCEL*. Users of Report Writer will get two major benefits from the program: the customization of reports and detailed hourly simulation results. The "Blast" computer program can calculate two-directional heat flows through the envelope. The program contains a large material library with thermal properties for different building materials: The result of simulations can be displayed in a multitude of numerical modes (as well as graphically) as shown in the attached graphs. The areas of focus for the simulations of this research are as follows;

1. U-value of the roof and walls. 2. Mapping of heat gain to the inner environment.

A Simulation has been performed for four different types of roof and five different types of wall structures as shown in each of the graphs (see the attached graphs).

6.4 COMPUTER SIMULATION ANALYSIS FOR THE *MUSALLA*

6.4.1 Walls Summertime Simulation

The simulations for "*musalla* model" building concentrate on an investigation of the walls in the case of two major factors of the *musalla* envelope,which concern the direct climatic impact on the internal air temperature of the *musalla* that affects thermal comfort . Those two factors are the trasparent area and the wall section (including thickness and material characteristics).

Based on that, the Half Glass (HF) simulation graphs show that the wall type of 0.12m thickness is influenced by variations in the external environment more than other types of walls; the inner environment temperatures drop at 1.00am and gradually become higher. As a result of sunshine and the gradual increase in the external environment temperature the inner environment temperature rises until 1.00pm.. After that it starts to drop again after 6.00 pm until 12.00 pm because of the low thermal mass envelope of 0.12m thickness, which is so thin that it cannot protect the inner environment from getting heat through it ,so the inner environment temperature becomes 35°C to 38°C compared with Full Glass (FG) which becomes 35°C to 42°C for the same period, and that reflects the lower heat gain in the case of (HG). Since the same phenomenon occurs in (FG) and there is no significant difference between all other brick wall types 0.45m and cavity wall as shown in the graph, the 0.36m brick wall becomes the best in terms of cost and labour skill, as well as heat exchange.The graphs show that the heat gain is more in the case of (FG) and also compared with (HG), the case of (FG) becomes 35°C to 42°C. Since solar radiation between 8.00 am and 1.00 pm causes heat gain to increase more and more, the gain is stored inside. Thus, within that period ,when it is not reflected again toward the outside, the massive envelope that has high thermal mass and cavity wall type of construction assists in keeping heat inside the building.These construction types work like a "thermos flask",but those types of wall are not always approprate in summer,(see Figs.6.2,6.3,6.4,6.5,6.6,6.7 and App.B1.)

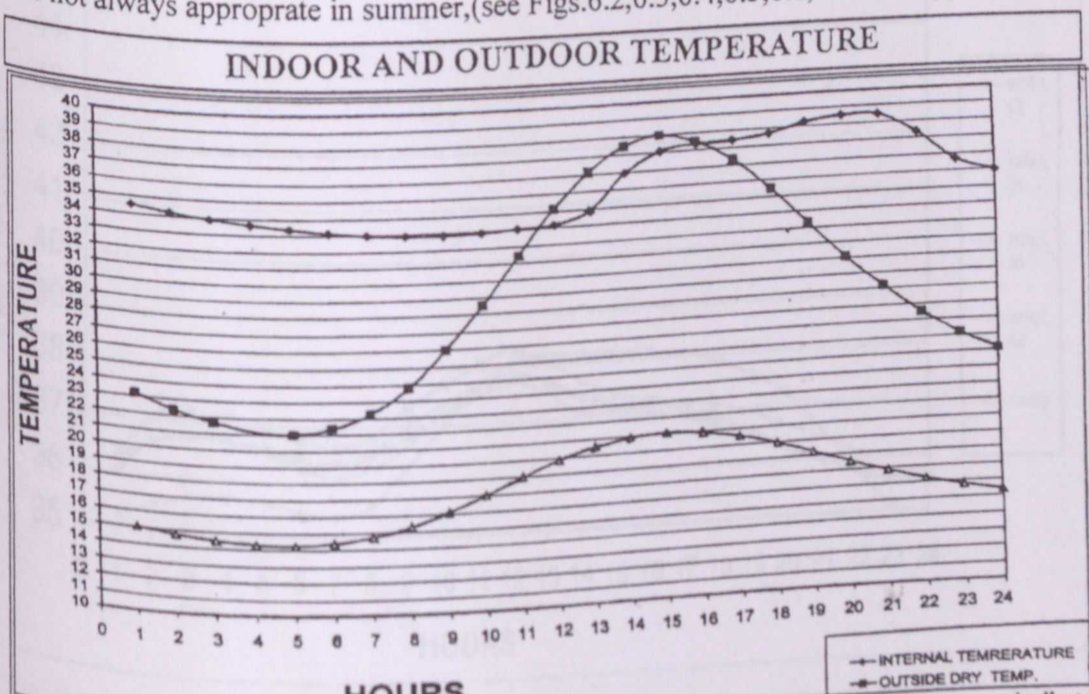


Fig.6.1 This graph shows that the radiation peak time in Baghdad starts at 10.30 am and increases gradually to reach a maximum at 3.00 pm, and reduces gradually after that to reach starting point at 7.00pm. However, the inner temperature increases from 1.00 pm gradually till 10.00 pm, that indicates the important role of the envelope in delaying the heat gain from reaching the inner space, or what is called –Time lag period–which depends on the envelope section in terms of the specifications of material and constructional details.

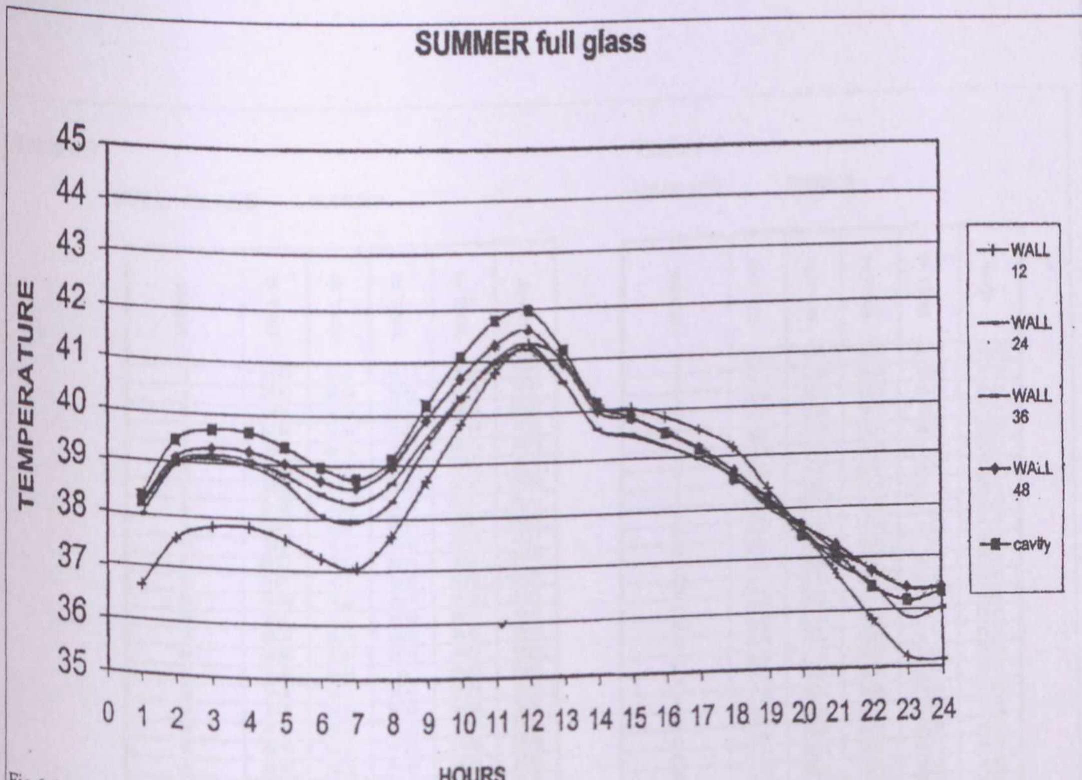


Fig.6.2 This graph shows that 0.12m wall heat loss and gain happen more quickly than others; it is influenced more than them by weather fluctuations. Cavity and 0.48m envelopes have the ability to maintain the heat of the inner environment more than others respectively, but 0.36m envelope is the best in terms of heat gain particularly from 12.00 noon to 9.00 pm when four prayer times occur inside the *musalla*.

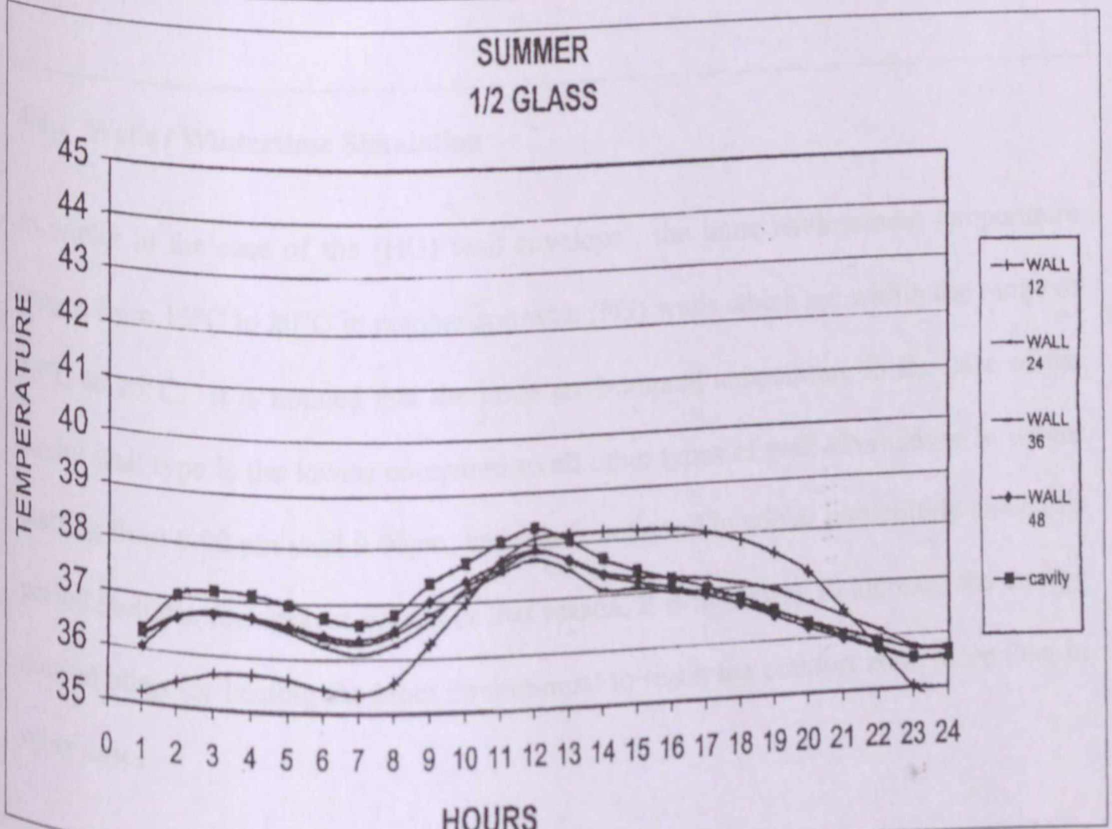


Fig. 6.3.High solar radiation impact on the envelope in summer, during the period from 8.00 am to 1.00 pm causes a high amount of heat gain transition to be stored inside the *musalla*. That heat gain is conserved inside for a long time if the envelope is thick or highly insulated, such as 0.45m wall and cavity wall types .Based on that the inner temperature rises.

Table 6.3

FULL GLASS SUMMER

HOURS	WALL 12	WALL 24	WALL 36	WALL 48	cavity
1	36.66	37.97	38.14	38.21	38.34
2	37.57	38.94	39.01	39.11	39.44
3	37.8	39.09	39.17	39.31	39.67
4	37.81	38.97	39.06	39.26	39.63
5	37.6	38.66	38.81	39.03	39.36
6	37.25	38.06	38.45	38.71	38.96
7	37.07	37.93	38.28	38.57	38.74
8	37.67	38.31	38.66	38.97	39.11
9	38.71	39.37	39.54	39.88	40.16
10	39.8	40.28	40.32	40.67	41.07
11	40.77	41.01	40.94	41.3	41.76
12	41.3	41.3	41.2	41.58	41.95
13	40.99	40.58	40.55	40.92	41.17
14	40.1	39.64	39.64	39.96	40.12
15	40.02	39.48	39.51	39.82	39.85
16	39.83	39.27	39.28	39.55	39.53
17	39.57	39.01	39	39.23	39.18
18	39.2	38.65	38.64	38.74	38.81
19	38.4	38.04	38.12	38.23	38.21
20	37.81	37.64	37.73	37.71	37.52
21	36.76	36.96	37.21	37.33	37.15
22	35.91	36.58	36.86	36.82	36.53
23	35.2	35.83	36.48	36.5	36.26
24	35.13	36.11	36.48	36.51	36.41
AVARAGE 24	38.28	38.66	38.80	39.00	39.11
AVARAGE/USE	38.81	38.84	38.93	39.14	39.23

Table 6.4

1/2 GLASS SUMMER

HOURS	WALL 12	WALL 24	WALL 36	WALL 48	cavity
1	35.21	36.3	36.24	36.05	36.37
2	35.46	36.66	36.64	36.63	37.04
3	35.64	36.77	36.77	36.73	37.15
4	35.67	36.88	36.7	36.7	37.11
5	35.6	36.46	36.54	36.57	36.95
6	35.43	36.21	36.34	36.41	36.73
7	35.34	36.07	36.24	36.33	36.8
8	35.56	36.34	36.42	36.51	36.76
9	36.25	36.64	36.78	37.02	37.34
10	36.86	37.25	37.16	37.36	37.69
11	37.71	37.57	37.49	37.86	38.06
12	38.1	37.85	37.7	37.59	38.29
13	38.15	37.88	37.48	37.66	38.03
14	38.16	37.41	37.08	37.35	37.65
15	38.15	37.29	37.08	37.19	37.41
16	38.13	37.25	36.96	37.06	37.22
17	38.04	37.19	36.88	36.89	37.03
18	37.86	37.07	36.71	36.68	36.81
19	37.58	36.91	36.52	36.44	36.55
20	37.2	36.95	36.31	36.19	36.28
21	36.48	36.38	36.11	35.96	36.02
22	36.77	36.09	35.82	35.74	35.76
23	35.03	35.78	35.73	35.64	35.56
24	34.71	35.68	35.75	35.57	35.58
AVARAGE 24	36.59	36.75	36.65	36.67	36.92
AVARAGE/USE	37.19	36.95	36.76	36.79	37.01

6.4.2 Walls / Wintertime Simulation

In winter in the case of the (HG) wall envelope , the inner environment temperature ranges from 15°C to 20°C in comparison with (FG) walls which are within the range of 15°C to 25°C. It is noticed that the inner environment temperature in the case of the cavity wall type is the lowest compared to all other types of wall alternatives in winter starting from 6.00 pm until 9.00pm, and this is not good in winter particularly since this period includes four prayer times.For that reason, it is necessary to increase the energy consumption for heating the inner environment to reach the comfort zone more than in other cases.

Similarly, the 0.36 m wall is the best of all the types in winter in the case of (HG). since it maintains the heat inside the *musalla* and requires lower costs in building materials, labour and energy consumption .

For (FG) construction in winter , it is noticed that the desired wall types are cavity walls(CW) and 0.48m wall thichness in terms of highest heat flow to the internal environment during the coldest periods of day and night from 1.00am to 2.00pm,and from 4.00pm to 12.00am. However, in the case of the 0.12m wall ,the inner environment temperature becomes lower since the envelope (walls) is so thin that it is unable to maintain the inner environment temperature. In addition, it is influenced more than other wall types by external environmental variations. However,the walls (0.24m,0.36m0.48 and cavity wall type respectively) follow the same base in terms of heat exchange. The impact of the external environment on the last three types is almost similar within the important period in winter from 12.00 noon untill 1.00am which includes four prayer times and represents the coldest time in winter. So the optimum envelope will be the 0.36m wall, compared to other types of wall in terms of cost and labour in Baghdad (see the attached graphs Figs.6.1,6.2,6.3,6.4,6.5).

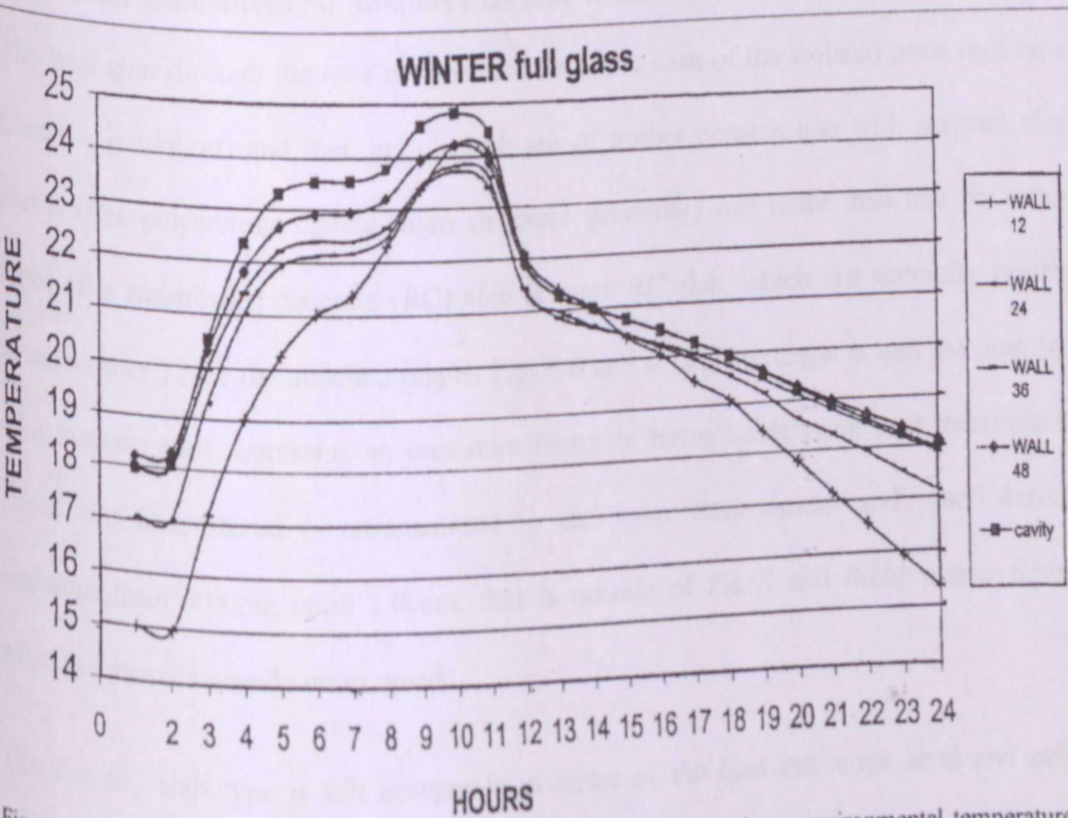


Fig. 6.4.It is found that cavity wall and 0.48m wall types maintain the inner environmental temperature in the lowest temperature during the day in winter from 1.00 am to 12.00 pm ,and that is desirable in winter, and that 0.12m wall are influenced more by the climatic fluctuations and 0.24m wall respectively, but 0.36m wall is still moderate as shown in this chart.

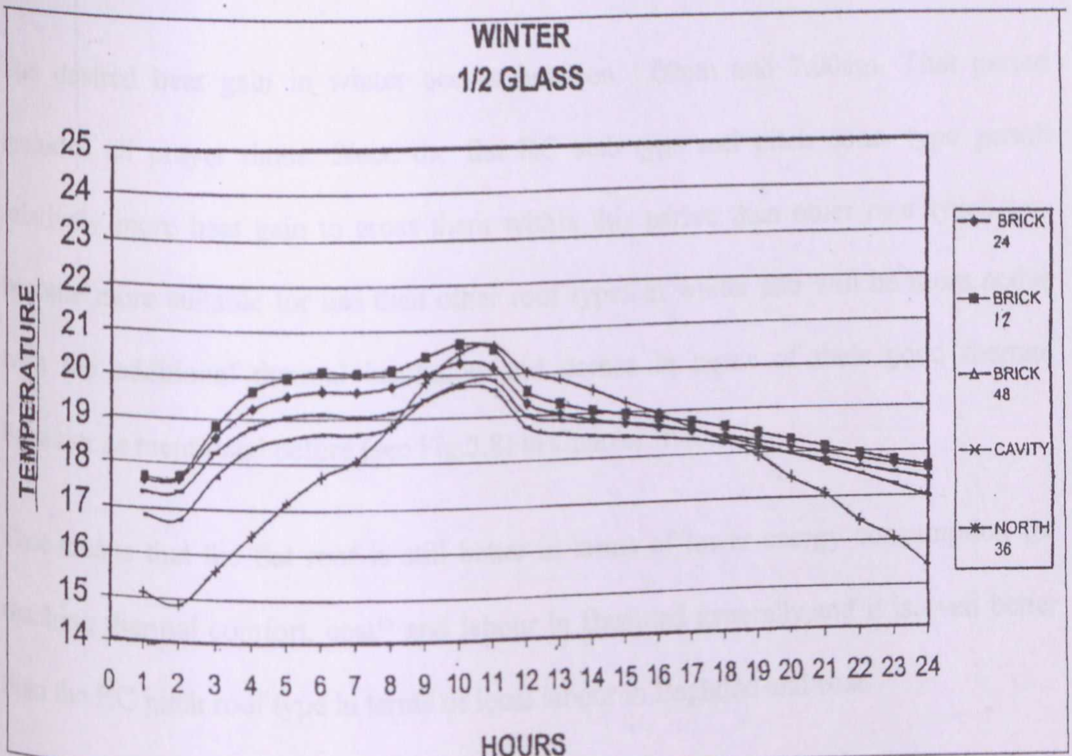


Fig. 6.5 It is noticed that 0.12 wall thickness is affected more than other types by climatic fluctuations. Cavity walls of, 0.45m type and 0.36m type are respectively more efficient in terms of internal heat conservation, but still there is a slight difference of not more than 1°C. This is a positive condition in winter particularly for the period from 6.00 am to 6.00 pm when all the prayer times occur.

6.4.3 Roof Simulations for Summertime and Wintertimes

The heat gain through the roof in summertime in the case of the isolated pitch roof type (2inch – insulation) and (6in. ins.) ,which are of timber construction with ceramic tiles and a false polystyrene ceiling (light structure generally) was more than that for other types (flat rreinforced concrete (RC) slab & pitch RC slab, which are generally similar to each other) (see the attached graphs Figs.6.6 and 6.7). The reason is that the time lag of a massive roof represents an important factor in terms of delaying heat transmision ,when the heat stored is retransmitted to the inner environment and outer during nighttime,from 9.00pm untill 5.00am, that is outside of *FAJR* and *ISHA* prayer times when the musalla usually unoccupied .

The flat RC slab type is still acceptable in terms of the heat exchange level and cost related to others, with the additional enhancement of active thermal insulation .

The desired heat gain in winter occurs between 1.00pm and 7.00am. That period includes all prayer times. Since the flat RC slab type and pitch conc. type permit relatively more heat gain to cross them within this period than other roof types,they become more suitable for use than other roof types in winter and will be more active with the additional thermal insulation and domes in terms of their good thermal behavior as mentioned before (see Fig.5.8) in Chapter five.

That means that the flat roof is still better in terms of lower energy consumption for reaching thermal comfort, cost[13] and labour in Baghdad generally,and it is even better than the RC pitch roof type in terms of local labour in Baghdad and cost.

By the way, it is good to mention that the pitched roof type particularly the timber pitched roof is not used in Baghdad as well as RC pitched roof . The traditional roofing systems depended on mud, mat and timber. Jack Arching which commonly used after Second World war was left gradualy in the beginning of 1960's and replaced by RC.

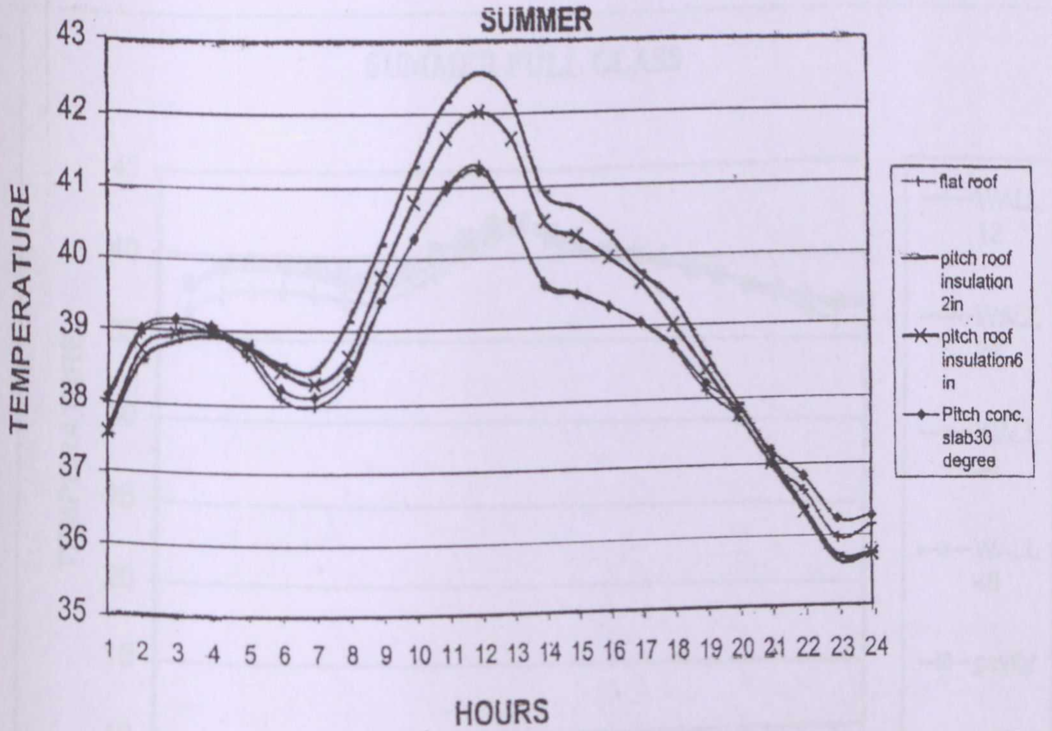


Fig.6.6. Pitch roof (2 inch-insulation material) and (6 in.ins. made from timber) heat gain allowal greater than other roof types respectively as shown in the chart. The curves of flat RC and pitched RC roof types seem typical because of the higher time lag of massive insulated characteristics of each that delay the transition of heat gain through them till 9.00 pm. The radiation from their inner surfaces to the inner environment continuues till 5.00 am and heats it when there is no prayer time at all. This is acceptable in summer, since we can use the natural ventilation to enhance the inner environment, if necessary

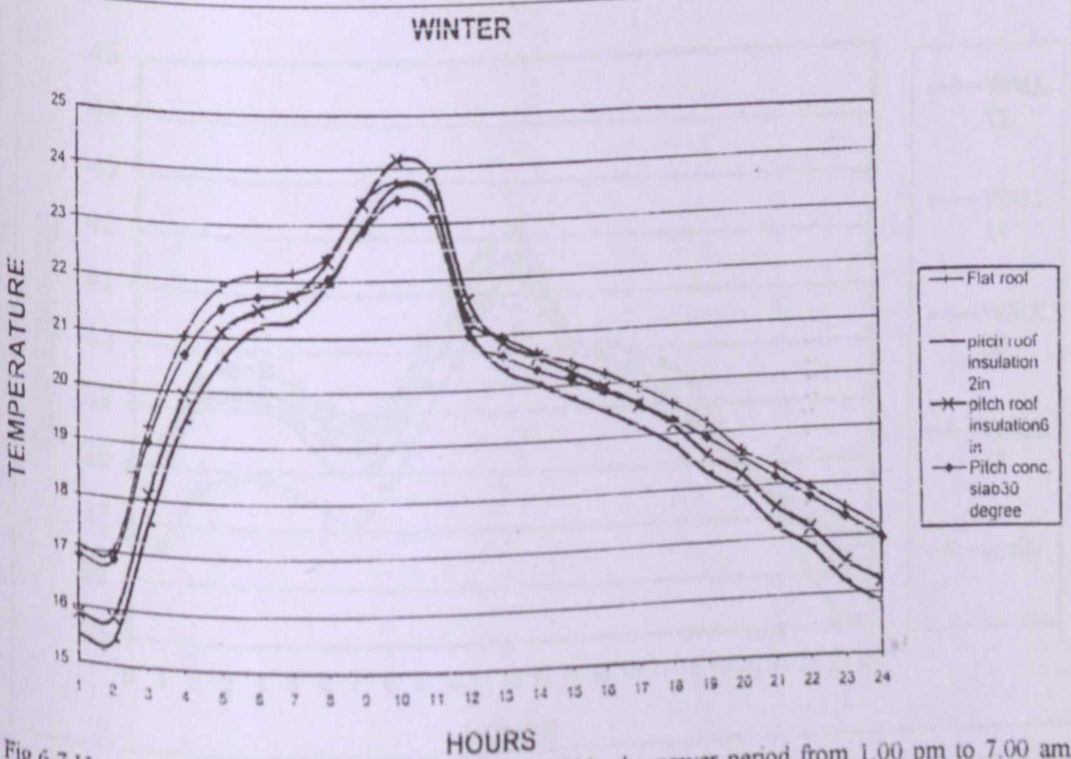
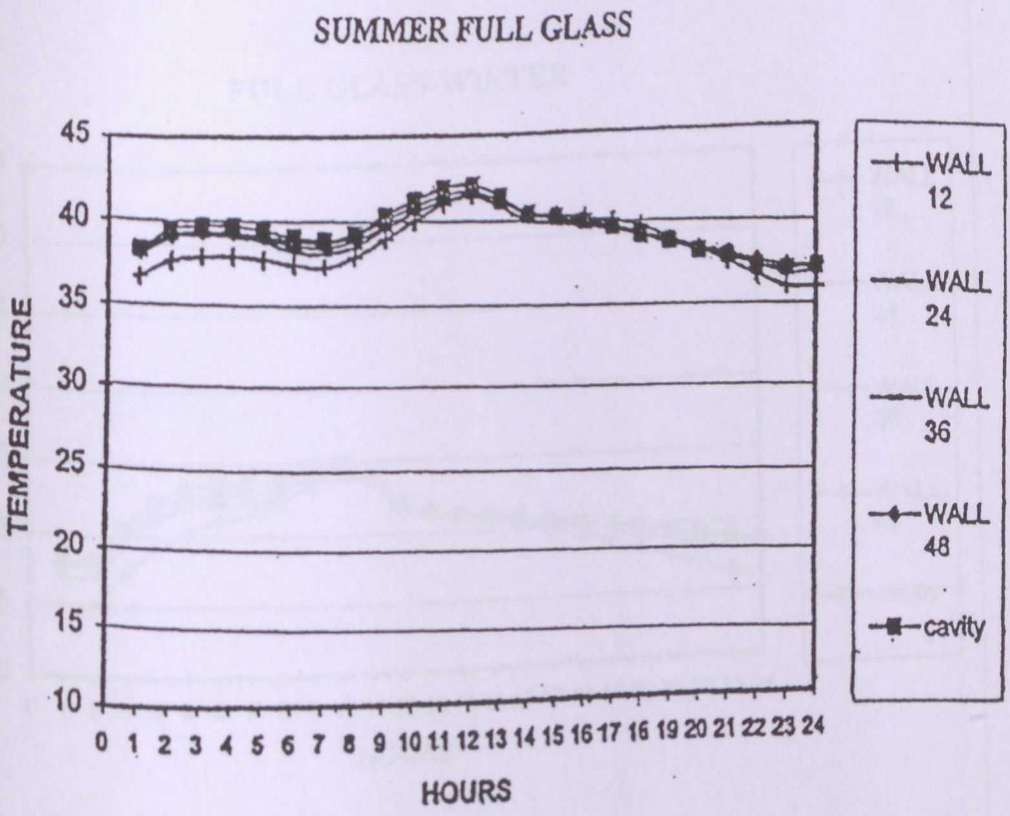


Fig.6.7.Heat gain is desirable in winter particularly within the prayer period from 1.00 pm to 7.00 am, which includes all the five prayer times ,*Fajar,Zuhur,Asar,Maghrib* and *Ishaa*. The flat RC roof and RC pitched roof have the highest capability in terms of heat gain transition through them, particularly the flat RC which is best. Therefore they are more positive in thermal behaviour in winter .The addition of domes and further insulation materials will enhance their positive thermal behavior further in summer.



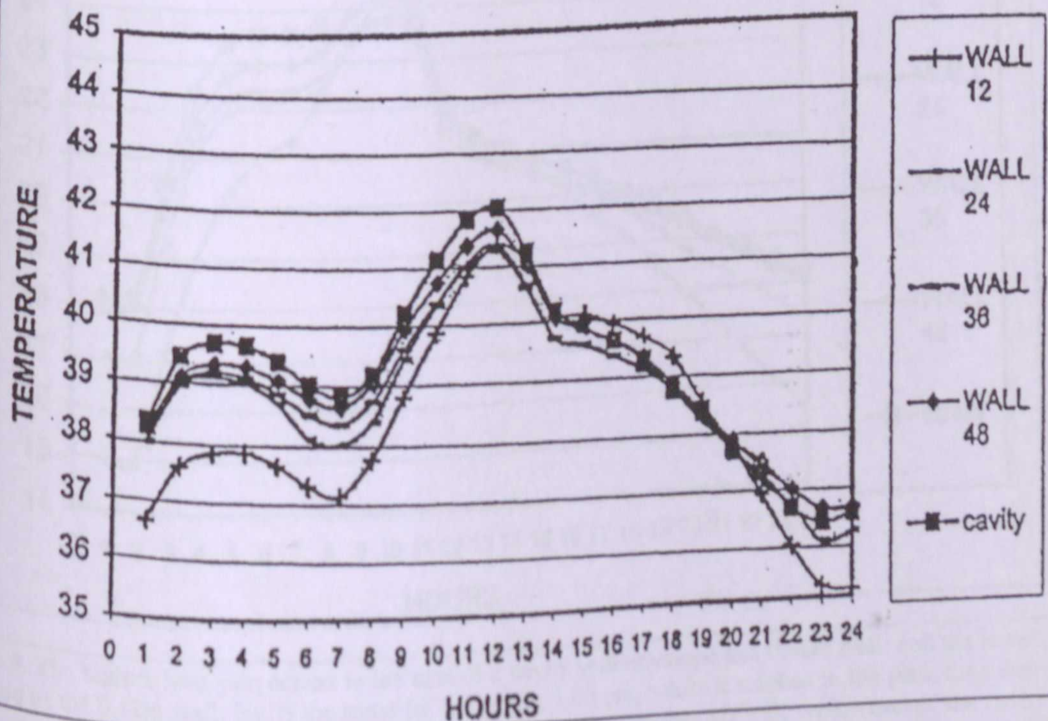
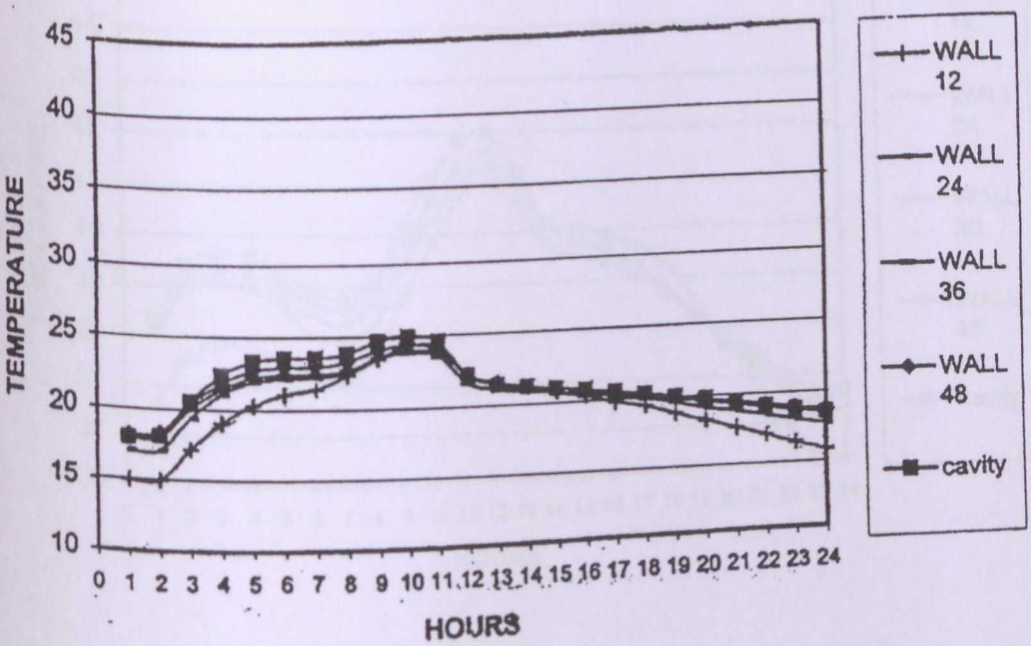


Fig.6.8 Those graphs are shown from two angles to realize the differences clearly for all envelope types in terms of heat gain in summer which is still from 11.00 am to 1.00pm.

FULL GLASS-WINTER



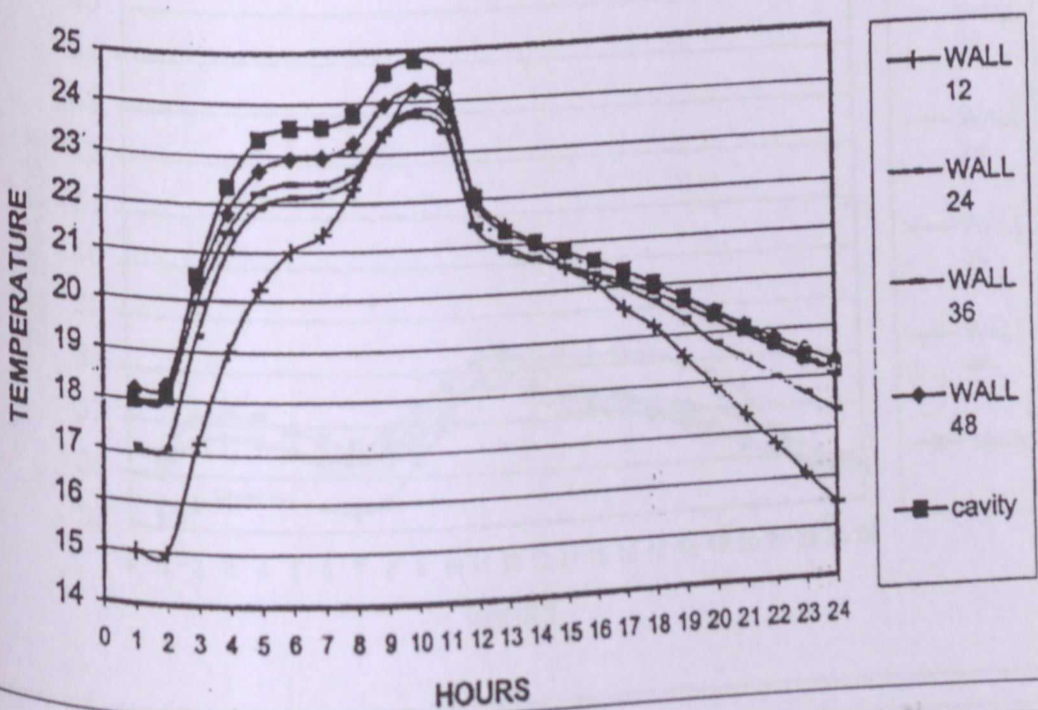
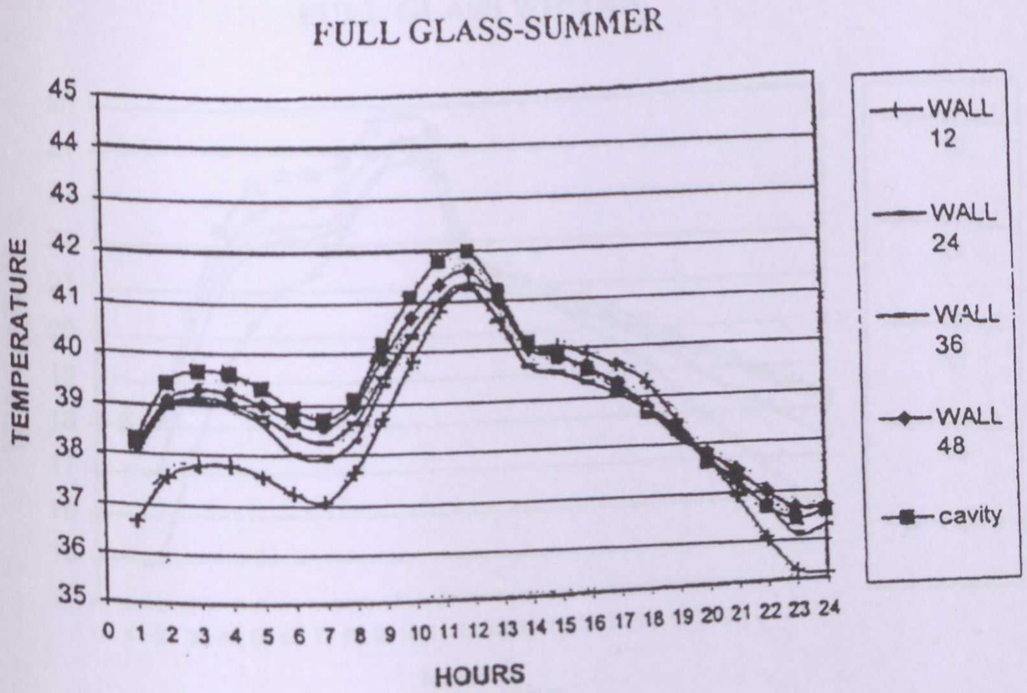


Fig.6.9. The highest heat gain occurs in the case of a cavity wall envelope and 0.48m wall: and the lowest in case of the 0.12m wall; but is the same for the rest at 1.00 pm, while it reaches in the peak time from 9.30 to 11.00 am period. At 7.00 pm, the inner temperature decreases all wall types (except the cavity wall and 0,48m wall types because of their capability to maintain the inner temperature till 11.00 am of the next day as shown in the graph). That behaviour of the cavity wall and 0.48m wall types is desirable in winter because there are two prayer times within that period (*Ishaa & Fajar* prayers) but still a half glass envelope is more efficient and suitable for the Baghdad climate (see half glass graph Fig.6.3).



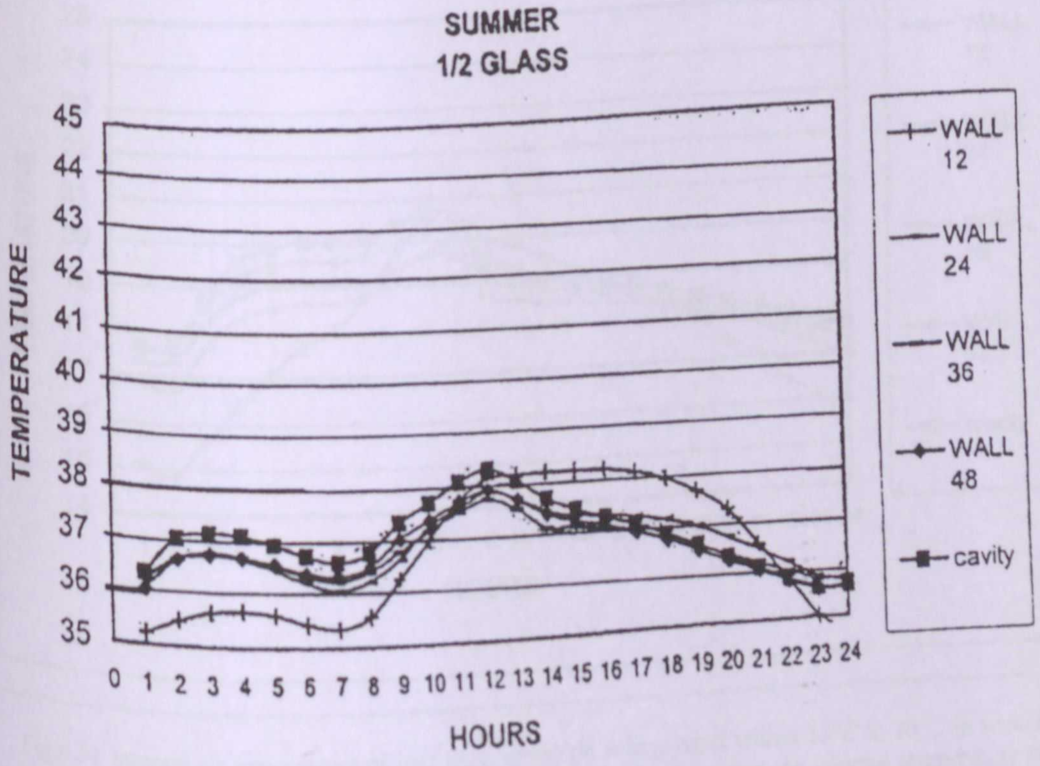
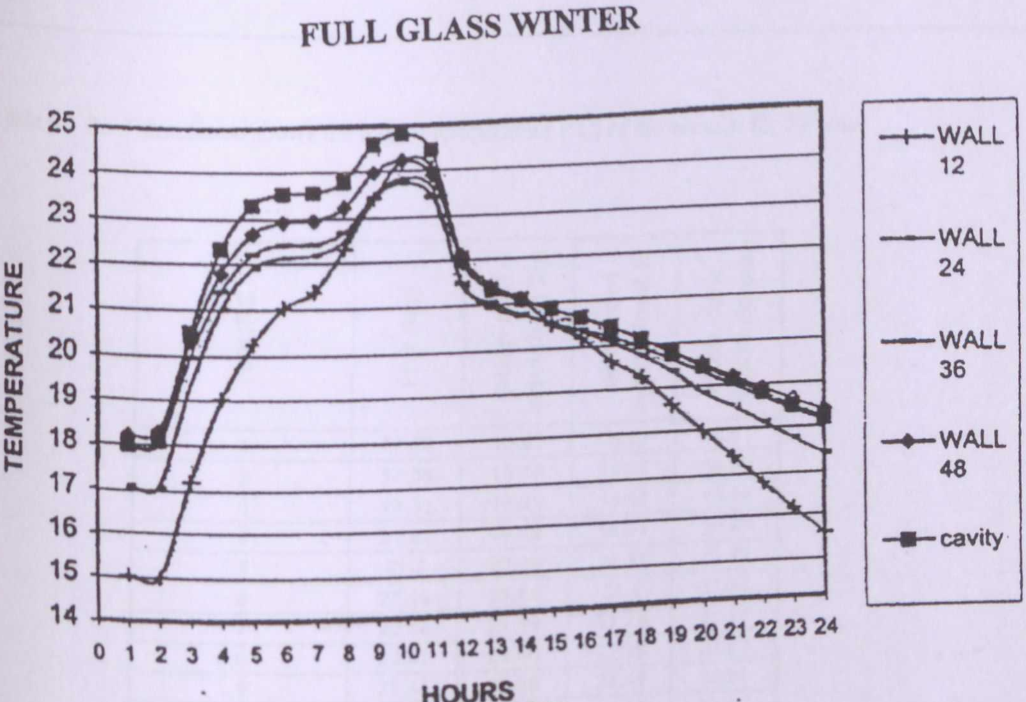


Fig.6.10. Highest inner temperature in case of full glass envelope of cavity wall is 42°C and the lowest is 41.2 for 0.36m walls. For cavity wall the temperature is 42°C, and for 0.36m walls the temperature is 37.6°C respectively in case of a half glass envelope. The peak time of inner temperature in case of a full glass envelope is from 10.30 am to 1.00 pm, but from 11.00 am to 1.00 pm in the case of a half glass envelope. The lowest inner temperature occurs with a 0.36m wall, and is from 12.00 noon to 9.00 pm. This represents the advantage of using a 0.36m wall envelope, because there are four prayer times which happen normally within this period (*Zuhor,Asar,Maghrib* and *Ishaa*). That period also represents the peak radiation time in Baghdad as shown in the chart.



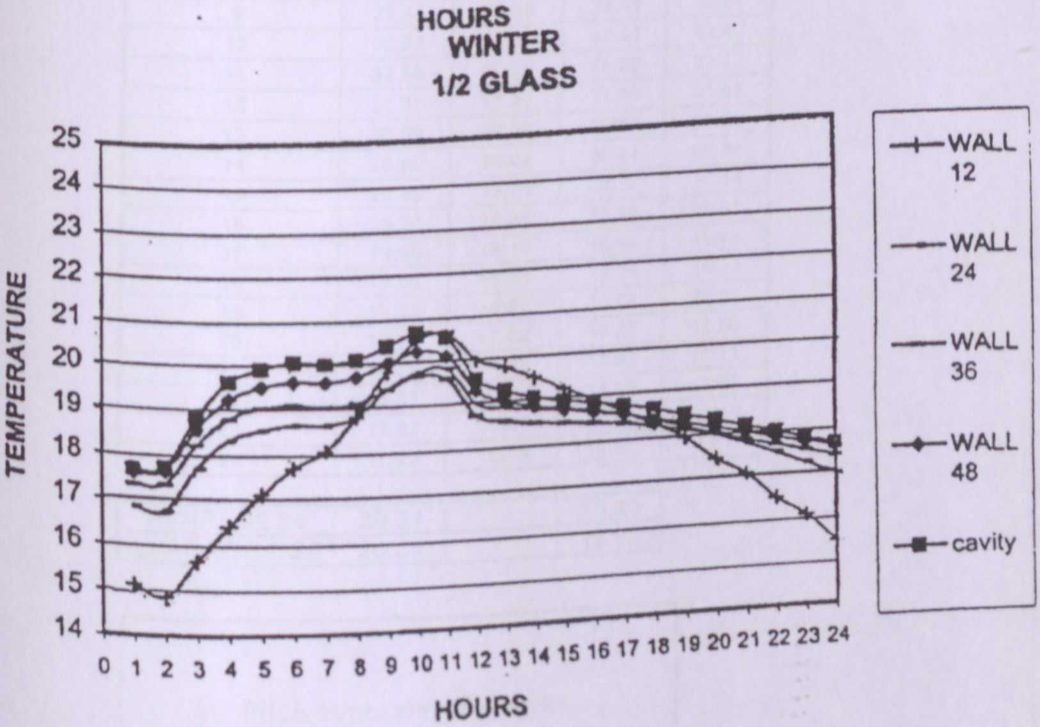


Fig.6.11 Internal air temperature of half glass envelope is in general within 15°C to 20°C in winter compared_with a range for full glass of 15°C to 25°C. It is noticed that the internal temperature is in general within the range 15°C to 21°C. In case of using cavity walls, the heat gain will be the lowest compared to all wall types for the period from 6.00 pm to 9.00 am. Highest inner temperature happens in the case of a full glass envelope, and is 25°C for cavity wall and 23.5°C for 0.36m. In the case of a half glass envelope it is 20.5°C for cavity wall, and 19.5°C for 0.36m respectively; this indicates the advantage of using half glass envelope and the good thermal behaviour of 0.36m wall type. On other hand , it indicates the instability of the 0.12m envelope because the impact of the climatic fluctuations on it is more than for other envelope types. It is the thinnest among them. This chart indicates also the peak time period of heat gain in this case, that is, from 10.00 am to 12.00 noon.

Table 6.5 Roof simulation shows the indoor temperature (°C) of the *musalla* for 24 hour.

HOURS	Flat roof	pitch roof insulation 2in	pitch roof insulation6 in	Pitch conc. slab30 degree
1	17.08	15.29	15.87	16.91
2	17.06	15.18	15.86	16.89
3	19.32	17.28	18.08	19.04
4	21.02	19.19	19.94	20.67
5	21.9	20.38	21.11	21.52
6	22.12	21.03	21.5	21.73
7	22.16	21.19	21.74	21.77
8	22.47	21.84	22.38	22.07
9	23.45	22.88	23.42	22.91
10	23.82	23.64	24.21	23.49
11	23.58	23.38	23.95	23.17
12	21.37	21.07	21.66	21.03
13	20.99	20.29	20.89	20.64
14	20.69	20.02	20.61	20.36
15	20.48	19.74	20.3	20.14
16	20.24	19.47	19.98	19.91
17	19.96	19.17	19.64	19.64
18	19.63	18.81	19.24	19.33
19	19.25	18.22	18.65	18.97
20	18.72	17.82	18.27	18.59
21	18.39	17.19	17.66	18.21
22	18.01	16.6	17.28	17.83
23	17.62	16.21	16.67	17.46
24	17.25	15.59	16.31	17.1
AVARAGE 24	20.27		19.80	
AVARAGE/USE	20.33		19.93	

Pitch conc. slab30 degree
CLAY TILE 1 CELL - 1 IN
E3 - 3 / 8 IN FELT AND MEMBR
B6 - 2 IN DENSE INSULATION
B6 - 2 IN DENSE INSULATION
B6 - 2 IN DENSE INSULATION
AIRSPACE - SLOPE DOWN
E4 - CEILING AIRSPACE
CONCRETE SLAB 6 IN
BLBD - GYPSUM PLASTER 1 / 2
BLBD - GYPSUM PLASTER 1 / 2

6.4.4 Conclusion of Computer Simulations

The analytical study by computer simulation, as shown in the graphs reflects the thermal behaviors of the "Model *Musalla*" envelope and other modifications of the envelopes after applying "alternatives" in terms of the employment of different materials and areas of opaque and transparent parts of the *musalla* envelope and also indicates the resulting energy consumption.

Indeed, the computer simulation proved that the massive envelope behaves as a "Thermos flask" .So, there is no actual enhancement of the condition of the inner environment thermally by increasing wall thickness to more than 0.36 m or even using cavity walls with the same specifications of the envelope of the "model Mosque" in terms of opening areas and other envelope section features.

Therefore, in the light of the findings, we can conclude that, for a climatically balanced structure in a hot-dry climate region, the external walls of the *musalla* envelope should be 0.36m thick.

In addition, it is recommended that the occurrence of the inner maximum environmental temperature be delayed to a time when the building is not occupied. This time occurs from 8.00am to 12.30 pm in summer as shown by the simulation, when the inner maximum environmental temperature at 12.00 noon is 42°C, and in winter is 25°C at 10am.Thus the envelope keeps the inner environment warm untill the *zuhur* prayer at 12.30 (22°C), but starts again warming continually from 5.00pm to 8.30 pm (19.5°C-20.5°C) respectively.This range includes three prayer times, until the *fajar* prayer time at 6.00am ,when the temperature is 23.5°C. This is an acceptable comfortable temperature in winter and needs low energy consumption to maintain thermal comfort. The computer simulation showed that this could be achieved by using half glass and a 0.36m envelope. The computer simulation also indicates that the traditional RC flat roof is still the best thermally in terms of cost, labor, and heat exchange after applying additional insulation materials (6 inch insulation),see more details in App.B1.

In addition, reducing the numbers and size of windows and other openings on the west and east walls to the minimum, or blocking them totally, will enhance the inner environment thermally. It is found that the *musalla's* building is dialectically balanced with the outside climate when the wall thickness is 0.36m, and is influenced more by climatic fluctuations when there is a thin envelope of 0.12m.

Table 6.6 Roof types simulation shows the indoor temperature (°C) for 24 hour.

HOURS	flat roof	pitch roof insulation 2in	pitch roof Insulation6 In	Pitch conc. slab30 degree
1	37.97	37.09	37.4	38.07
2	38.94	38.39	38.49	39.01
3	39.09	38.7	38.76	39.16
4	38.97	38.89	38.82	39.06
5	38.65	3R.85	38.66	38.76
6	38.06	38.67	38.36	38.19
7	37.93	38.63	38.21	38.07
8	38.31	39.34	38.82	38.43
9	39.37	40.41	39.84	39.41
10	40.28	41.46	40.87	40.27
11	41.01	42.32	41.74	40.96
12	41.3	42.66	42.1	41.22
13	40.58	41.94	41.72	40.53
14	39.64	40.7	40.5	39.59
15	39.48	40.45	40.28	39.45
16	39.27	39.87	39.92	39.26
17	39.01	39.56	39.52	39.03
18	38.65	38.87	38.87	38.7
19	38.04	38.19	38.21	38.15
20	37.64	37.44	37.51	37.78
21	36.98	36.69	36.82	37.17
22	36.59	35.92	36.11	36.79
23	35.93	35.16	35.41	36.19
24	36.11	35.22	35.47	36.23
AVARAGE 24	38.66		38.85	
AVARAGE/USE	38.84		39.20	

2 inch insulation	6 inch insulation
CLAY TILE 1 CELL - 1 IN	CLAY TILE 1 CELL -1 IN
E3 - 3 / 8 IN FELT AND MEMBR	E3 - 3 / 8 IN FELT AND MEMBR
B6 - 2 IN DENSE INSULATION	B6 - 2 IN DENSE INSULATION
AIRSPACE - SLOPE DOWN	B6 - 2 IN DENSE INSULATION
E4 - CEILING AIRSPACE	B6 - 2 IN DENSE INSULATION
BLBD - GYPSUM PLASTER 1 / 2	AIRSPACE - SLOPE DOWN
BLBD - GYPSUM PLASTER 1 / 2	E4 - CEILING AIRSPACE
	BLBD - GYPSUM PLASTER 1 / 2
	BLBD - GYPSUM PLASTER 1 / 2

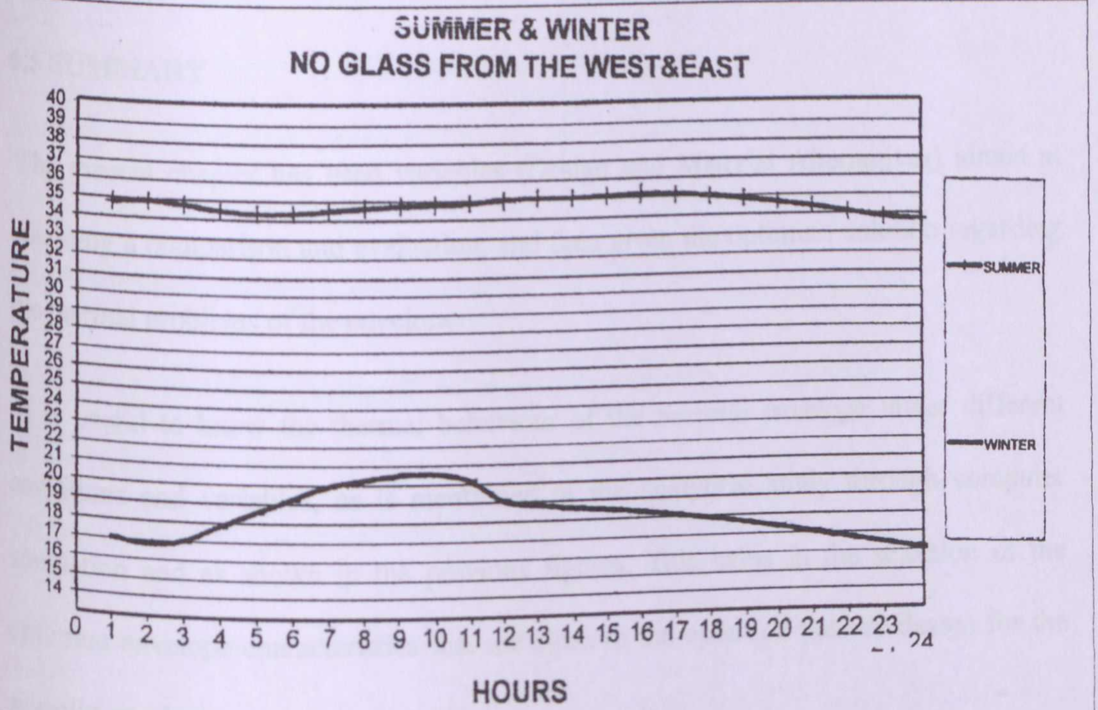


Fig.6.12. This graph shows that the inner environment temperature of the *musalla* becomes 4.5°C lower in this case than when FULL GLASS is used for west and east walls orientation where the temperature is 41.5°C. This is 2.0°C lower than when HALF GLASS is used, when the temperature was 38°C. When NO GLASS is used for the west and east walls the temperature is 36°C. This is positive condition in terms of reducing energy consumption for cooling in summer. But in winter, the inner temperature when FULL GLASS is used becomes 24°C, which is 3°C less than in the case of NO GLASS, and 1°C less than in the case of HALF GLASS. This occurs because of the lowest ability of the envelope area of windows to maintain the inner environment temperature, thus, a reduction in window area on the east and a west wall gives additional thermal advantage.

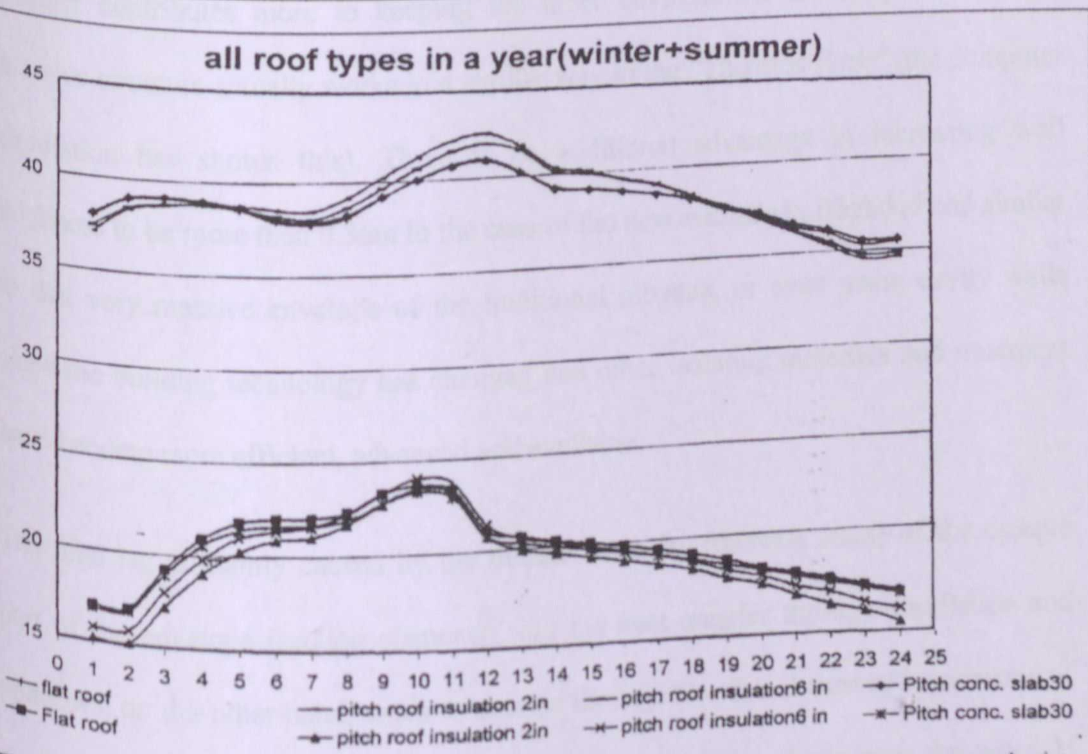


Fig.6.13 This graph explains the big gap of heat gain through the envelope between summer and winter. The maximum inner temperature in summer as shown in the chart is 43°C while it is 24°C in winter. The maximum the heat gain in summer is of pitch roof (insulation 2 in.) and peak time occurs from 11.00am to 1.00 pm. But the maximum heat gain is of the flat roof in winter. So, the flat roof is the best in terms of its lowest heat gain in summer and highest heat gain in winter particularly within the period of prayer times inside the *musalla*,and this is desirable in the Baghdad climate.

6.5 SUMMARY

The present chapter has used variables (Design and Material Alternatives) aimed at obtaining a comparison and evaluation, and then given the optimum solution regarding the thermal problems of the envelope.

It is useful to know the thermal behaviour of the *musalla* envelope under different conditions and variables, as is mentioned in the analytical study through computer simulation and as shown in the previous figures. This helps in the selection of the optimum envelope characteristics that are close to the optimum passive design for the *musalla* envelope.

The appreciation of the massive structure of the traditional old mosque in Baghdad is still considered in terms of good thermal behaviour and energy conservation. That manner contributes more to keeping the inner environment thermally stable. That massive structure actually works in a similar way to the "Thermos flask" (the computer simulation has shown this). There is no additional advantage in increasing wall thickness to be more than 0.36m in the case of the new *musalla* in Baghdad and similar to that very massive envelope of the traditional mosque, or even using cavity walls since the building technology has changed and other isolating materials and treatment have become more efficient, advanced and available.

The time lag is mainly caused by the thermal capacity (thermal mass) of the opaque part of the envelope (section 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. If the conductive heat gain is more dominant than that of ventilation and fenestration, the time lag will be longer and vice versa. It seems that conductive heat gains dominate at wall thicknesses lower than 36cm in the building under consideration. However, at thicknesses greater than 36cm, ventilation and window gains combined dominate and thus shift the temperature of the inner environment maximum closer to that of outside maximum air temperature.

In studying the effect of conductance on the thermal environment, when the thickness of the external elements is fixed at 36cm, and the thermal conductance decreases, inside maximum temperatures increase along with amplitude.

This could be explained by the fact that heat gain through the window and air infiltration is of a higher value than that gained through the envelope. On the other hand, the high thermal resistance of the envelope seems to act as a trap for the heat that has already been transferred to the inner environment, resulting in an increase in the maximum indoor temperature, (see Tappuni & Ahmad; 1982.)

Therefore, in the light of the findings, it is concluded that, for a climatically balanced structure in this region (hot-dry), the external wall elements should be 36cm thick. In addition, $1.7 Wm^{-2}C^{-1}$ seems to be optimum thermal conductance of the envelope and the solar absorption should be as low as possible.

In addition, it is recommended that the occurrence of the inner maximum environmental temperature be delayed to a time when the building is not occupied. This time occurs from 8.00 am to 12.30 pm in summer as the computer simulations show, when the inner maximum environmental temperature at 12.00 noon is 45°C, and in winter it is 25°C at 10am. Thus, the envelope keeps the inner environment warm until the *Zuhur* prayer at 12.30 pm (22°C), and starts again to warm continually from 5.00pm to 8.30pm (19.5°C-20.5°C respectively). This range includes three prayer times, *Asar,Maghrib* and *Ishak* until the *Fajr* prayer at 6.00am,when the temperature is

23.5°C. This temperature is acceptable in winter to feel comfortable with low energy consumption.

The thermal capacity, which increases with the mass and thickness of the external elements, has a non-linear effect on the internal thermal environment. It is noticed that the indoor maximum temperature decreases as the envelope thickness increases with the lowest maximum reached at a thickness of 36cm.

It appears that the building is dialectically balanced with the outside climate for a wall thickness of 36cm because as the wall thickness decreases below 36cm its effectiveness in dampening outside temperature fluctuations also decreases. On the other hand, for wall thicknesses of more than 36cm, the heat received during the long summer day cannot be released during the shorter nighttime in summer, and that is what was stated about the bad envelope behaviour in terms of the "Thermos flask" manner. In this case, there is overlapping heat gain occurrence.

[1] See the typical new mosque- "Model *Musalla*"- in Baghdad in Chapter Five.

[2] See the detailed sections for each type A and B, Figs.B.2.,B.3 and B.4 in Appendix B.

[3] See Tables.B-1,B-2,App.B.

[4] See Energy Efficient Design,(1995) for more explanation.

[5] See Fanger's Classifications Table 4.2.

[6] See the changes after using alternatives related to the original envelope of the common new mosque in the attached graphs..

[7] See the optimum types of window glass for each orientation in Baghdad,App.A1.

[8] See APP.A.

[9] See Tables in App.A3.

10 "Typical U-values are :220mm solid brick wall with 16mm plaster on inside face-1.4;260mm cavity wall (unventilated)with brick outer skin,lightweight concrete block inner skin and 16mm plaster on inside face-0.96;and,as last but with 13mm expanded polysterene board in cavity –0.70.The additional cost of the latter form of construction would be in the order of 50 to 60 p/sq.m in 1975.,and to inject urea formaldehyde foam in to the cavity would be two-and-a half to three times as expensive."The cost is similar to those in Baghdad for the same time period,this mentioned the advantage of choosing 36cm wall thickness and that roof type.

"When comparing the cost of alternative insulating materials both the cost per square meter and u-value must be taken into account.The unit cost multiplied by the U-value will give an index for comparison purposes.Adopting this approach ,expanded polysterene generally compares very favourably with insulating plaster board,fiberboard or insulating screeds."

(SEELY.IVOR H."1981"BUILDING ECONOMICS"The Macmillan Press LTD,London.pp51,54.)

CHAPTER SEVEN

FINDINGS , CONCLUSIONS AND RECOMMENDATIONS

7.1 I NTRODUCTION

Passive design in Iraq is still relatively new. Since the economic crisis after the first Gulf War, people have become more aware of the need for energy conservative buildings and architects capable of designing them.

Controlling the heat, which a *musalla* building gains from its environment is what passive cooling, is all about. It has sometimes been defined as strategies that introduce cool or heat into the new *musalla* building without mechanical assistance.

Baghdad weather conditions are such that heating needs in winter are small but do exist if the *musalla* temperature is expected to reach 19-20 °C and that cooling needs in summer are large. Using climatic resources may satisfy these needs: solar energy heating and evaporative cooling in summer. But to take the best advantage of these resources for five short times a day during prayers in the *musalla* building, an appropriate thermal design of the envelope is necessary.

In previous chapters, the effect of new *musalla* building design in Baghdad (type of material used in construction, heat gain to inner environment and heat flow through the envelope, orientation, climatic impact and envelope design) on the internal air temperature were studied.

A typical ground floor *musalla* building in Baghdad is used for thermal assessment by computer simulation, which represents a typical praying space *"musalla"* building within the typical new mosque complex in the Baghdad region.

The *musalla* building dimensions are 21.0mx11.0m with a height of 6.0m. Four walls of the *musalla* building are taken as external. The walls are constructed of brick. Three wooden doors are assumed to be in one of the walls, which face 10-degrees northeast orientation. The structural details are given in Chapter three & Chapter four. It is constructed using a skeletal frame. The roof is constructed of reinforced concrete, a single glazing window of varying dimensions is considered with the total glazing area given in the manual thermal analysis in Chapter five also.

A simulation assessment for thermal behaviours of the envelope of the selected "*musalla* model" between winter and summer conditions, was made using the "BLAST" energy program.

The computer simulation represents the dynamic behaviour of the *musalla* envelope as a function of its geometry, the thermal characteristics of the walls and roof, the occupation times, and as a response to outside weather conditions. The simulations run hour by hour and the program required detailed weather data and other geometrical and constructional details.

7.2 DISCUSION OF FINDINGS

7.2.1 *Musalla* Building Orientation and Envelope Components

Since the *qibla* (direction to Mecca) is a constant factor in the design process for the *musalla*, it must provide high protection for the *musalla* envelope from the impact of climatic fluctuations using suitable envelope section and material specifications that become important because 90% of the new Baghdad's *musalla* are of the detached type. This protection comes from the following considerations:

i. Using suitable types of vegetation for each of the *musalla's* wall orientations to reduce the impact of solar radiation by providing shade. Using some climbers and shrubs, which help in covering the walls, which face west, southwest, east and northeast to reduce the impact of solar radiation as well as to prevent glare from the surroundings (as shown in Fig.7.3).

ii. Using shading devices (louvers), which are of selected types according to the orientation (horizontal type for north and south –*Qibla*-wall orientation, and vertical type for the orientation of *musalla* walls at the west, east, and southwest orientation). Orientation suggested shading type is: North; fixed or adjustable shading placed horizontally above window, E & W; adjustable vertical screens outside window. NE & NW; adjustable shading, and SE & SW; planting.

Obviously, one cannot provide a perfect solution by using louvers. One must reach a compromise at the expense of part of the overheated period and part of the cold period. (Shabaan , M.Al-Jawadi, A.Jawad; 1975:9, 10).

Three solutions are discussed in Chapter four. The final decision will have to be made by the architect. It obviously depends on the circumstances and the specific type of building. In the case of the *musalla* building where no summer sun is tolerated for such an open majestic space, the first suggestion might be applicable, (see Fig 4.4) in Chapter four. Increasing window recess will decrease the summer load due to the decrease in solar radiation received by the window. The reverse is expected during winter.

For south oriented windows the C.H. value during winter (the seasonal C.H. values represents the undesirable internal temperature of the building that is to be cooled or heated by active means), when no window recess is used, is 38 % less than when a 0.5m window recess is used for the same orientation. The reverse happens during summer, in the case of using window blinds, the C.H. value, with no window recess, is 2% higher than when a 0.5 m window recess is used for the south orientation (Al-Azawi; 1984:185). So, it is preferable to use a recess for more protection in summer, which is the longest season in Baghdad.

At the same time, walls which face 10 degrees south-west and north-east (longitudinal mosque elevations), which represent the wall of the *qibla* (that face southwest); and the wall which faces or which is parallel to the wall of the *qibla* (north-east direction, that faces the prevailing air direction in Baghdad) can get more natural ventilation through wide enough openings shaded by *Riwaq* as well as enhancing the open spaces nearby them when, fountains, suitable vegetation and water surfaces, especially at the north and north-west and east orientations (within a certain range)are used. Further axes of air circulation should be created in order to benefit from natural ventilation at night during summer, and use natural ventilation in the day during winter to reach the thermal comfort level. This "stack ventilation" is a slow moving air current of negative and positive air pressures throughout the *musalla* building created by cross ventilation. This is particularly applicable when there is a courtyard (outdoor *musalla*) which is usually used.

iii. The negative role of wide windows (at south-west orientation particularly) is to create a "Green House" effect by allowing short waves of solar radiation to enter and preventing long waves from exiting. This has the effect of raising the air temperature of the inner space of the *musalla* building to higher than the external air temperature during summer.

To limit solar heat gain, Heat Filter Glass could be used, which reduces sol-heat gain

according to the following recommended glazing:

-10% & 20% glazed area for east, west and southwest *(Qibla) orientation.*

-20% and 30% for west and south orientation.

-40% for north orientation.

- 60% glazing may be recommended for south oriented window when a windows blind is used during the summer season or when a window recess is used to shade the summer sun, (for more details see Al-Azawi, 1984:185.)

It is established that the optimum orientation regarding the size and location of the windows is on the north and south facades that, like other parts of the envelope are under the impact of two heat influences, solar radiation and thermal temperature of external air which are expressed by sol-air temperature. Its impact depends on solar radiation and *musalla* envelope specifications. The manual reference of (Al-Jawadi-Dr.Muqdad, Proceeding of Building Research Centre, and Baghdad1973) sets out the optimum treatments for windows in Baghdad for all orientations in terms of heat exchange.

It is concluded that a 10-degrees southwest oriented rectangular *musalla* building requires less annual load, but buildings with west, southwest and east orientations demand the highest load. This is because solar radiation received by south windows is at its maximum during the winter season, and its minimum during summer for the same window area while the annual solar radiation received by west and east facing windows is the highest, (see Al-Azawi, 1984:183).

However, the areas of doors and windows should be reduced to the minimum in terms of number and size on the west and east elevations (walls) since these are the worst directions thermally. Double-glazed windows of reflecting glass may also be used to increase the reflectivity of the solar radiation and decrease its ability to cross the glass and enter the inner space of the *musalla*.

7.2.2 *Musalla* Envelope Components and Materials

Low thermal transmittance (low U-value) materials for the *musalla* envelope help prevents heat from crossing it to get faster cooling. It depends on the specific heat (Cp) and the density (kg/m) of the material of the section.

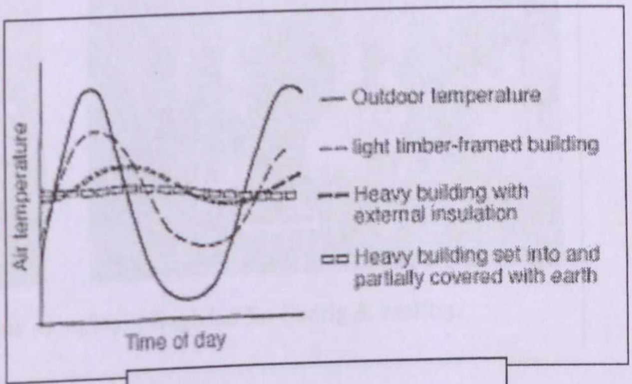


Fig.7. 1Thermal mass of envelope.
Source:www.bom.gov.au.

It is expressed in T/M, which is *the amount of heat needed to raise the temperature of* $1m^3$ *of a given material through IK (1C)* – (Al-Azawi; 1984). Selection of the optimum types of materials for all members of the envelope should be considered as follows:

-The most available building material for walls construction in the Baghdad region is fired brick. Roofs and floors are generally constructed of reinforced concrete. Traditional roofs were made of timber and topped with mud and straw in rural areas and brick jack arching with *Juss* (Local Gypsum and *Nora* also as mortar) was a common roofing method during the first half of the 20th century. The materials used in Iraq before that, by so many civilizations in the Mesopotamian area, such as famous fired bricks with dimensions of (0.30 x 0.30 x 0.05 m), which were used in Babylon give good practical examples of thermally optimum materials. Moreover, using cavity wall could be of benefit to face the worst orientations in Baghdad (west and south-west) with regards to the solar radiation density. The thickness of a cavity should be between 50 and 70 mm, and the aperture for vertical airflow should be more than 40% of the cavity section. This method performs as a compact shading structure (Homma, 1984:43).

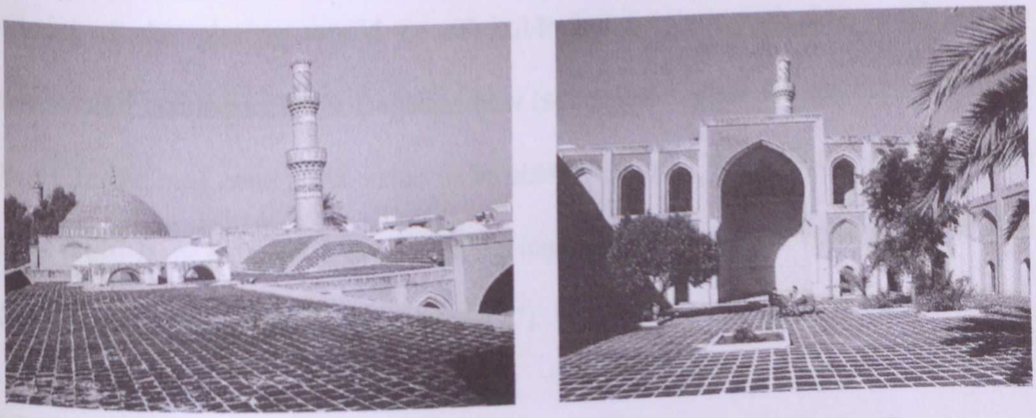


Fig.7. 2 Using "*Fershi*"in traditional mosque *(A'safia)* in Baghdad for floorig & roofing.

-Polystyrene foam is primarily used in structures for insulation for roofs/ceilings in the Baghdad region. Thermal insulation inside the walls (near the outer surface, which receives the direct climatic impact) is used to prevent most of the heat flow through the envelope. To prevent the accumulation of vapour, a thin partition is necessary near the inner surface in case of vapour condensation to prevent moisture condensation in the section and its appearance on the inner surface.

- Other types of traditional mortars (such as *Juss* (local gypsum) and *Nora* (local lime mortar) which have good thermal specifications and which have been found through experience to be the optimum materials used in the traditional buildings in Baghdad, could be used in the new *musalla* building (for more details see Appendix. B).

In the Baghdad region, outdoor air temperatures during summer time vary considerably and the temperatures at night often cool down from 45°C during the day to 18°C. Thermal mass is particularly beneficial in such a hot-dry climate as Baghdad where there is a big difference between day and night outdoor temperatures. Design with massive building components that have a heat storing effect due to their mass reminds us of the traditional treatment of massive walls and roof in the traditional Baghdad mosques (see more explanations in Chapter three and Chapter four). The use of insulating double-glazing would be advisable but insulating glazing could not be manufactured economically in Baghdad now (see selected glass for each orientation in App.A). In the roof zone the k-value to be obtained should be about 0.5 W/mK. In the case of multi-layer external components the insulating layer should be arranged outside and the storing layer inside (Gertis, 1981:127).

7.2.3 Impact of the *Musalla* Microclimate

Musalla siting and microclimate planning controls can have a major influence over the *musalla* envelope design. In addition to the form of the *musalla* building, the hard and

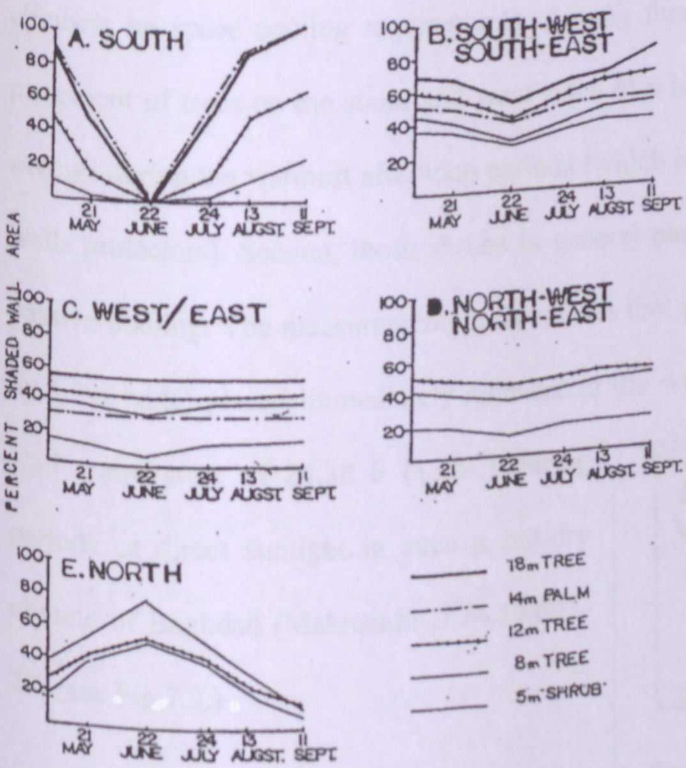


Fig.7.3 Shading efficiency of selected vegetation for the different orientation of the *mussalla* building in the Baghdad region.

Source; Developed idea from Makhzumi. M;1982.

soft landscape treatments, and the water elements affect the mosque complex microclimate (Fig.7.3). This includes the use of bricks (high thermal mass) in the flooring of the courtyard, passages and façades (fair face brick elevation as well as treatment of other open spaces, like the car parks; *Fershi* (local fired brick) paving, with suitable arrangement and patterns to let the vegetation grow among the units, such as the porous bricks or grass stone to minimize glare and thermal absorption of the surfaces close to the *musalla* envelope, particularly its openings. Materials used externally should be chosen carefully in terms of colour, texture and other physical factors, which help in enhancing the microclimate of mosque complex that consequently influences the external envelope of the *musalla*. Some examples of this include using dark surfaces near the building to absorb solar radiation, and light external surfaces for the *musalla* envelope to reflect solar radiation.

It has been illustrated in one study (McPherson; 1981) that dense shading cast on the east or west elevation of a building can cut cooling costs by one half compared to an unshaded one. Other findings (Parker; 1981) compare the effect of trees, shrubs, and climbers on space cooling requirements. Among them is the effect of the precision placement of trees on the south and west sides of a building in optimising the energy savings during the warmest afternoon periods (which is useful to implement as *musalla* walls protectors). Second, those shrubs in general play a major role in the process of passive cooling. The measurements have shown that moderate size shrubs (1.5m high by 1.2m wide) placed immediately adjacent to the wall yield an average reduction in wall temperature of 24.30 F (13.5C) during periods of direct sunlight in such a hot-dry climate of Baghdad (Makhzumi .J M.1982:2-24) (see Fig.7.3.)

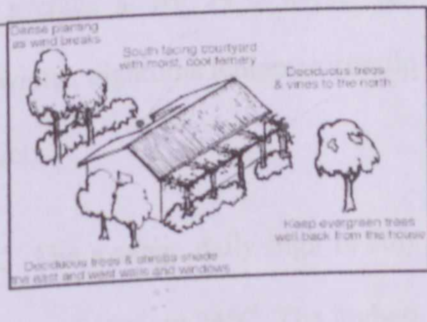


Fig.7.4 *Musalla* microclimate

The replacement of the flat roof type by a domed roof, or increasing the domed area of the roof of the *musalla* is a good solution to reduce the area of flat roof to the minimum in relation to the domed area of the roof of the *musalla* since, as shown by the computer simulations, the flat (horizontal) roof and pitched roof convey high thermal energy to the inner space of *musalla* more than the domed one. The behaviour of the shape of the dome helps in reducing the gained heat to the lowest level related to the flat roof of the *musalla*, (see Fig.5.5 in Ch.5). It is interesting to note that using a traditional brick roof (Jack Arching System, which is used in the intermediate mosque type in Baghdad) instead of a reinforced concrete roof makes hardly any change in energy consumption. This is likely to be due to the thermal bridges through (I- Beam) used in the first type of roof (see Shaaban; 1973.)

Roof shading using common palm trees adjust to the envelope of the new *musalla* in Baghdad could contribute to reducing thermal gain through the *musalla* envelope. It is found that when shading of direct solar radiation received by the roof is increased 25% of roof surface, the summer C.H. values are decreased by 8%. As expected the reverse happens during winter when the sun is more inclined and the seasonal radiation received by the roof is less, C.H. values are increased by 4.5%. (See Al-Azawi; 1984:166-186).

7.3 CONCLUSIONS DRAWN FROM RESEARCH

i. In general, the climate of Baghdad is hot and dry in the summers, cool and a bit rainier in the winters. Daytime high temperatures average above 34°C during the summer and often remain above 24°C at night. In the winter, nighttime temperatures dip to –1 and 4°C, but only rarely drop below freezing point.

The July average monthly temperature range is 29°C. The average daily high in July ranges from about 33°C to 40°C with average daily lows of 19°C to 24°C. The highest temperatures recorded range from the 39°C to 44°C.

Dew points and humidities are usually quite low. The low rainfall in Iraq qualifies it as a desert. Iraq's average rainfall is generally between four and seven inches a year. Ninety percent of this rain falls between November and April. Another unique climatic feature in Iraq are the winds. Specifically, the summer months are marked by two kinds of wind phenomena: The southern and Southeasterly *Sharji*: a dry, dusty wind with occasional gusts of 80 kilometers per hour, occurs (from time to time) from April to early June and again from late September through The November. Northwesterly *Gherbi*: From mid-June to mid-September the prevailing wind is from the north and northwest. It is a steady wind. It permits intensive sun heating of the land surface, but the breeze has some cooling effect (Climatological Atlas No.II for Iraq) .

ii. Baghdad's historical urban form evolved as a compact aggregation of small and large quarters. The result was an organic and "animated" urban structure , obviously different from the new rigid grid-iron uniformity produced by more mechanical modes of urban planning that applied after World War II. The historical city of Baghdad does not conform to the later geometric symmetry of urban planning that is characteristic of its new districts after World War II. The traditional Islamic Baghdad city evolved gradually, its boundaries delineated by fortified walls, with the mosque acting as the religious, social and political centre of the community.

The compact nature of this layout allowed inhabitants to walk around the narrow and shaded streets without any difficulties. The structure of this urban pattern was based on hierarchy of roads, spaces and attached buildings in such compact system that gives high protection from environmental impact for the inhabitants. For instance, the attached massive envelope of the mosque with use of a courtyard represents a high response to the environment. The compact urban fabric of the traditional city of Baghdad ensured a network of narrow cool alleyways and squares, creating an agreeable microclimatic condition (Antoniou: 1981.)

The radiative heat exchange in the courtyard, its high thermal capacity floor, being well shaded from the sun, and having good exposure to the sky, act as a good mediator in

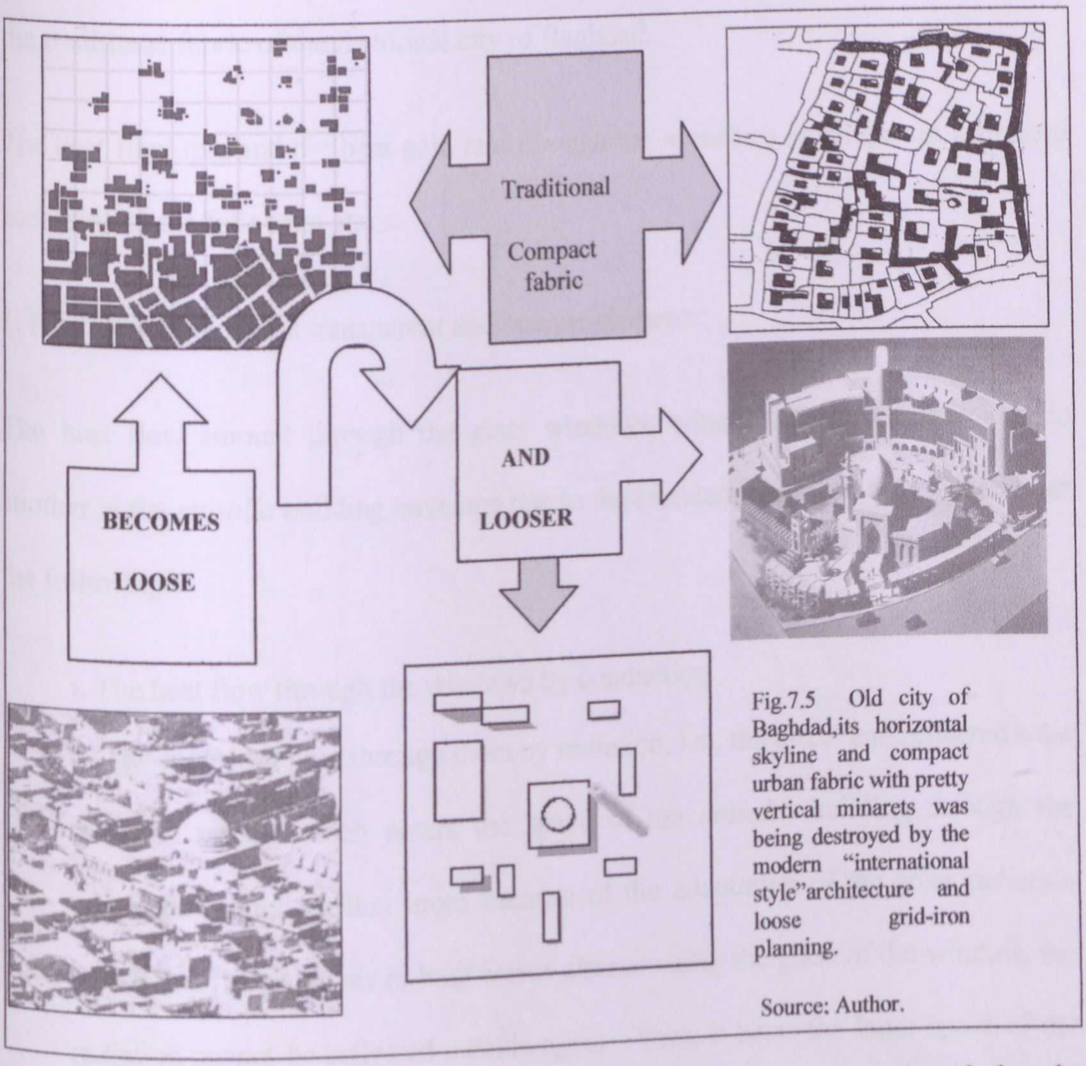


Fig.7.5 Old city of Baghdad,its horizontal skyline and compact urban fabric with pretty vertical minarets was being destroyed by the modern "international style"architecture and loose grid-iron planning.

Source: Author.

long-wave radiative heat exchange between facades in the courtyard and the sky (Tappuni: 1981.)

The city is composed of three main urban areas-public, semi-public and private spaces. The main public areas of the city are the mosque complex and other commercial and public facilities. From this central space, the main streets branch off to the different districts. From these main streets stem other narrow and blank-walled alleys and cul-de-sac outto, which open the doorways of individual houses (Michell: 1978).

The New geometrical grid-iron planning of Baghdad with wide streets, open spaces, loose urban fabric of individual separated buildings, contributes to exposing the *musalla* building envelope to solar radiation and other environmental impacts more than that of the traditional fabric of the historical city of Baghdad.

The heat flow rate and the heat gain rate through the *musalla's* envelope are estimated according to the following steps:

1. Heat flow through the transparent and opaque elements:

The heat flow amount through the glass windows, which differs from one side to another in the *musalla* building envelope due to the orientation of each wall, depends on the following:

i. The heat flow through the windows by conduction.

ii. The solar heat gain through them by radiation, i.e., the direct and reflected solar radiation effect, which enters the space of the *musalla* building through the transparent parts. Farther more because of the adaptation of the solar radiation waves from short waves to long waves after crossing the glass of the window, the radiation cannot be reflected outside again. Thus, it heats the inner space of the *musalla* since the radiation conveys the heat to the inner space of the *musalla* .

2. The heat flow through the (opaque elements) walls, roof and dome: Through (conduction).

3. The heat flow by ventilation: Through ventilation (convection method).

The cooling and heating load (energy consumption) of the *musalla* building are highly affected by factors related to the *musalla* building design also. These factors considered

4. Activities of *musalla* occupants. (Almost constant)

5. *Musalla* building size (affected by proposed number of occupants).

6. Ventilation rate and wind direction.

7. *Musalla* microclimate and site treatments of mosque complex.

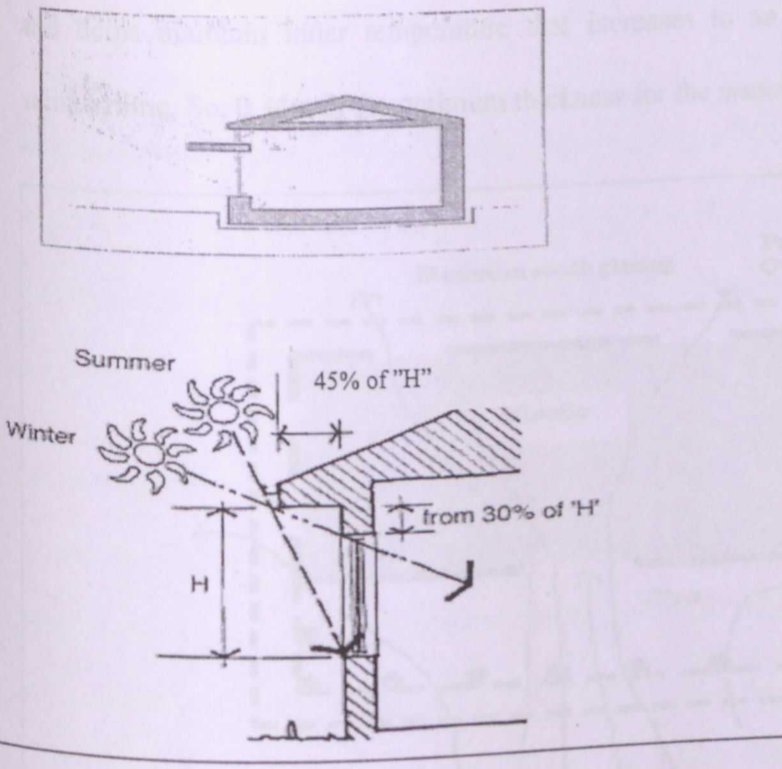


Fig.7.6 The light shelf is an extremely useful tool when used in conjunction with side lighting strategies. This mechanism can achieved by embracing of the *musalla* zone by the *Riwaq* . A horizontal surface at or above eye level, serves to reflect light falling above the vision window up onto the ceiling and therefore deeper into the *musalla*. At the same time, it reduces illumination immediately adjacent to the window, where illumination levels are typically too great to work comfortably.

In the previous estimation in Chapter five, the "quantity thermal assessment" procedure for the mean heat flow through the *musalla* envelope has been followed. It is assumed that the inner environment is in stabilised thermal balance in order to estimate the actual ability of the *musalla's* envelope to maintain the thermal balance of the inner environment.

According to what is mentioned above, it is found that the annual mean of heat flow and heat gain reduced due to the increase in thermal capacity (thermal mass) of the *musalla* building's envelope. So, that leaves the inner air temperature nearer to the heat balance. In spite of depending on approximate results in this assessment, it is still useful in understanding the thermal behaviour of the *musalla* building envelope.

It is found that the building is balanced with the outside climate when the wall thickness is 0.30 to 0.36m. As the wall thickness decreases below 0.30m its effectiveness in damping outside air temperature fluctuations also decreases. On the other hand, for wall thickness greater than 0.36m, the heat received during the long summer day cannot be released during the shorter night time, then the envelope works as a “Thermos flask” and helps maintain inner temperature that increases to an uncomfortable level in summertime. So, 0.36m is the optimum thickness for the *musalla* envelope.

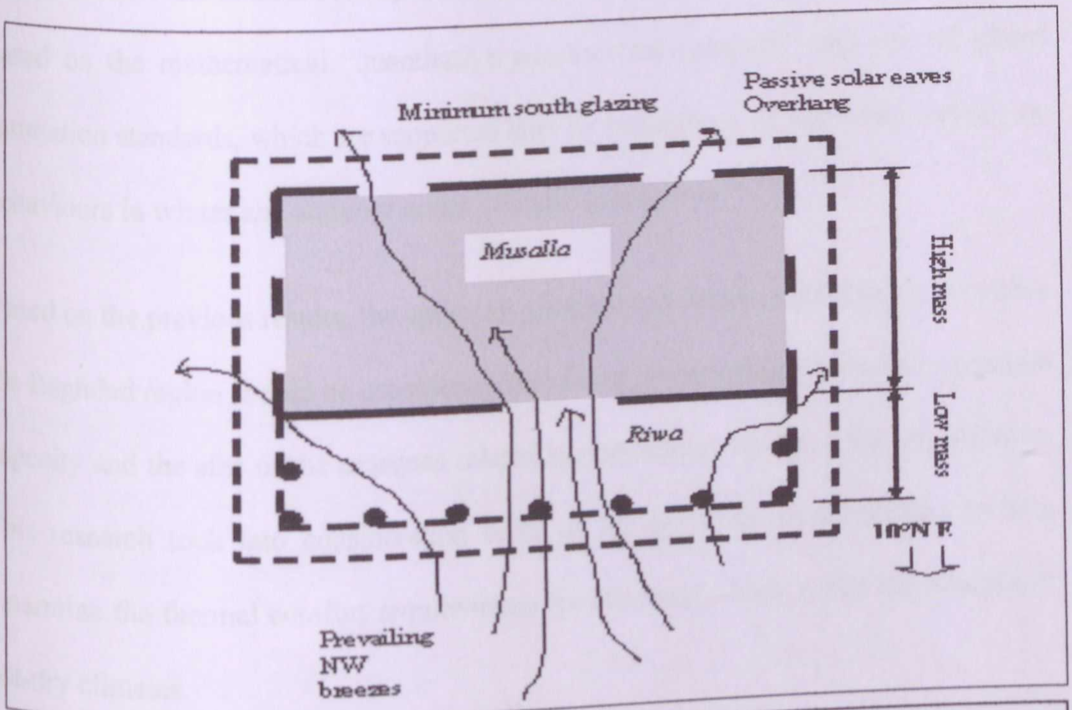


Fig.7.7 Minimum east & west glazing or providing adjustable external shading. High mass *musalla* areas are more comfortable during day time.Low mass *Riwaq* (used as outdoor *musalla* sometimes in winter and summer and mostly in autumn and springtime) cool quickly at night , as well as high insulation prevents summer heat gain.

18.5°C is chosen as a thermal design degree for inner environment of the *musalla,* in spite of its being lower than the comfort level 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. This happens from the impact of the metabolic rate temperature, and this is what has been discussed in the thermal comfort requirements for the human body related to the biological activities in Chapter four. While the temperature during summer is 25°C (it could be made less for the same reason), the aim is to let praying people feel comfort inside the *musalla* building during the long summer in Baghdad.

7.4 RECOMMENDATIONS

The procedure and criteria of the previous analysis and estimation of *musalla* design are based on the mathematical "quantitative conventional approach" and general global estimation standards, which are supported later by simulations for the *musalla* envelope behaviours in winter and summer under climatic fluctuations. .

Based on the previous results, the optimum geographical distribution of mosques within the Baghdad region should be considered in terms of environmental criteria, occupation capacity and the size of the mosques related to population density of the city districts. This research took into consideration some of the previous similar studies to help determine the thermal comfort requirements for the human body inside the *musalla* in hot-dry climates.

Since there are many activities, which occur, daily, weekly, and yearly inside the mosque complex, I recommend continuing the research to determine thermal design parameters of other spaces and facilities for the religious and social functions inside the mosque complex. Based on that, the recommendations for future research should consider the criteria listed below:

i. Defining the thermal design parameters, thermal properties and behaviours of the *musalla* building envelope in conditions of congregational prayers and other similar mass activities and congregational celebrations inside the *musalla*.

ii .Determining the thermal comfort requirements inside the *musalla* during the congregational optional prayers particularly in the holy month in Islam *(Ramadhan)* , as well as the Friday congregational weekly prayer.

iii. Determining the thermal comfort requirements for congregational activities inside the annex spaces of the mosque complex throughout the different seasons in Baghdad according to the nature of each activity, such as the congregational hall and so on.

iv. Starting research to define the thermal comfort limits in the case of the *musalla* and the occasional hall unit (as one space, since they are almost attached individual spaces in the new mosque complexes in Baghdad) at one congregational time to specify the suitable architectural and constructional treatments with regard to that.

v. Extending the study of the thermal comfort in case of proposed essential treatments to give high architectural design flexibility and suitable passive design to the *musalla* building as shown below:

1. Evaluation of the effect of having a flexible split of the interior space of the *musalla* building into two, rather than one majestic space, so that any size can be used according to the number of people praying at each prayer time in order to control the environmental impact by defining the space due to the actual need of occupation size. That encourages us to get the proposed cubic modular size, which is the optimum in terms of heat exchange as mentioned in Chapter five.

2. Using materials, which have low thermal transmittance (low U-value) and high thermal mass. This is the product of the specific heat (cp) and the density (kg/cubic m.) of a material, and it is expressed in T/M (see definition in 7.2). Consideration of that will help prevent heat from entering the building but will allow it to cool down quickly. In the hot-dry climate of Baghdad, the high thermal capacity of the envelope will help reduce the unsuitability of inner thermal temperature and delays heat to prevent it from

reaching the maximum level. This is one of the advantages of the traditional mosque envelope in Baghdad (see many examples in Ch.3). Thermal mass is beneficial for the *musalla* building envelope in Baghdad where there is big difference between day and night outdoor temperatures. 0.36m thickness for the *musalla* envelope, correct use of thermal mass (as shown in simulations in Chapter six) can delay heat flow by as much as 8 to 14 hours for walls and 20-30 for the roof. A greater time lag than this range will not enhance the inner environment thermally to reach comfort level because of overlapping occurrence with the heat gain of the roof by ventilation,(see Evans (1980-62). A high thermal mass

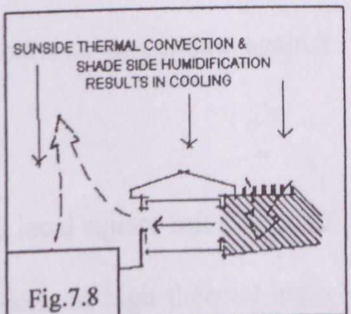


Fig.7.8

of traditional *musalla* in Baghdad needs to gain or lose a large amount of energy to change its internal temperature, whereas the light weight of typical new *musalla* buildings requires only a small energy gain or loss. Thermal mass is not a substitute for insulation. The components of the *musalla* envelope must be heat insulating and heat storing. The external walls should have k-values of about 0.5 to 1.0 W/sq mK. In the roof zone the k-value to be obtained should be about 0.5 W/sq mK. The necessary heat storing capacity must be ensured by massive internal components (concrete components of the roof and external brick walls).

3.Designing well-shaded walls and windows to reduce internal heat gain helps reducing insulation requirements, and the choice of optimum types of window glass that are suitable for each orientation in the Baghdad region contributes to that (according to provided data in Appendix A1.). Because of the necessary sun shading measures, small windows and relatively compact external facades are correct. The *musalla* building should open onto (shaded) inner courts. If this basic principle is dropped, highly efficient sun shading devices must be attached to the windows (external roller blinds resp. awnings). Use of insulating double-glazing would be advisable if insulating glazing could be manufactured economically in Baghdad (see App.A1 for more details).

4. Microclimate planning controls can have a major influence over the *musalla* design. In addition to providing shade, plants can assist cooling by transpiration and create pleasant filtered light. Deciduous plants allow winter sun through and exclude summer sun. Palm trees, which are commonly planted in Baghdad with high canopies, are useful for shading the roof and large portions of the building structure. Shrubs are appropriate for more localised shading of windows and wall vines and ground cover insulate against summer heat and reduce glare around the *musalla* envelope.

5. Constructed insulated materials for finishing (like the tried local square bricks (*fershi* 30 cm x 30cm x 5 cm) which have good thermal specifications of high thermal mass and low thermal transmittance. In addition, available-expanded polystyrene (11 cm thickness) that gives the best performance thermally can be used. Raising the roof also helps; this enables cooling by ventilation and helps by enhancing air movement.

There are other ideas for reducing heat gain through roof. One of them is idea on sun shading, double roof and the early development of ideas on" Filter "architecture, and the concept of building enclosures as environmental filter (see Powell; 1989:25).

6. Designing the *musalla* to be in contact with the earth by making it lower than the ground surface (Sub ground level *Sirdab*-basement-) 1.4 to 1.7m (or more) according to the tried traditional buildings in Baghdad. Earth-integrated or underground construction takes advantage of attenuating extreme air temperatures and thermal time lag (See Figs. 7.8,7.10 and 7.14).

7. Preventing air getting through a variety of cracks or small-uncontrolled openings into

the building and other sub parameters. The equations and treatments to deal with these conditions for estimation of such amount of air getting through cracks are given in Chapter Five.

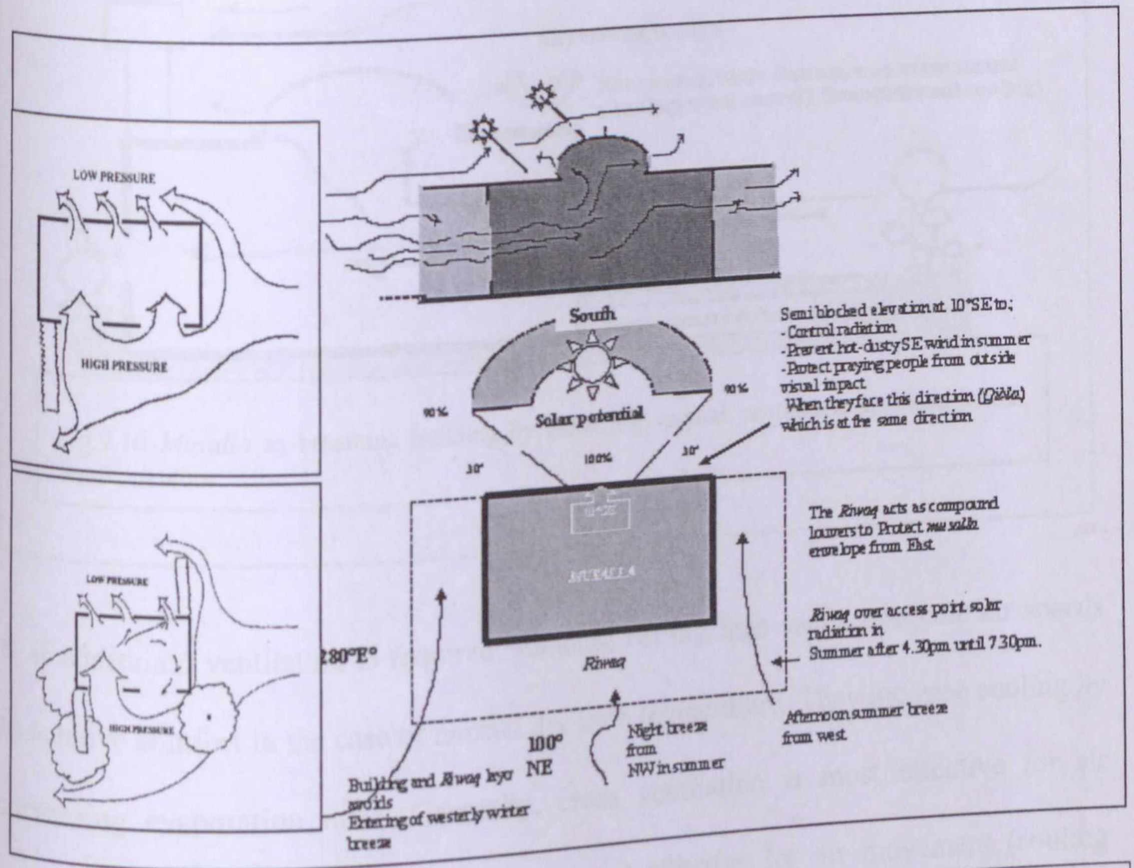


Fig.7.9 Key considerations regarding passive design of the *musalla* building are determined by the characteristics of the building site. The most effective designs are based on a specific understanding of a building site's wind patterns, terrain, vegetation, solar exposure and other factors often requiring professional architectural services. However, a basic understanding of these issues can have a significant effect on the energy performance of the *musalla* building in the hot-dry climate of Baghdad. The rule for ventilation with regards to building orientation is that air flow is often better captured when the *musalla* is placed off the cardinal (north-south) directions within 30 degrees approximately.

Source; Author.

In combination with passive envelope design for cooling climates and prayer activities, air movement, evaporative cooling and earth coupled thermal mass can provide adequate thermal comfort. Air movement is the most important element in the passive cooling of the *musalla*.

If additional ventilation is required, a three-bladed propeller fan (punkah fan) is used for this purpose. Performance of a typical 1350mm diameter fan installed in a spacious vertical duct of low resistance indicates a flow rate of about 0.7m/s when the fan runs quietly at about 80 rev/min, see Randal (1992:133).

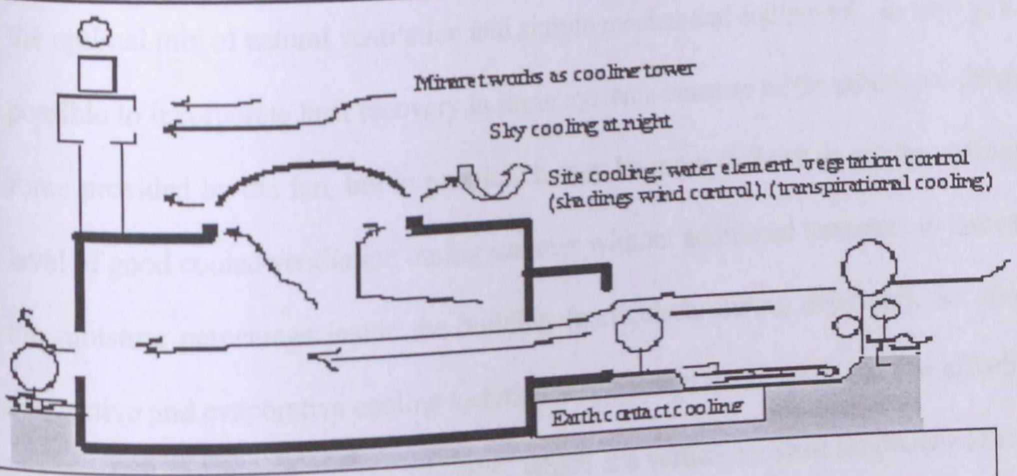


Fig.7.10 *Musalla* as breathing building by enhancing natural ventilation & microclimate. Source;Author.

8. If additional ventilation is required, standard ceiling fans create adequate air speeds to achieve comfort in the case of normal dry bulb temperature. They increase cooling by increasing evaporation rates. Generally, cross ventilation is most effective for air exchange *(musalla* cooling) and fans are most effective for air movement (cooling praying people). An air speed of 0.5m/sec equates to a 3-degree drop in temperature at an average relative humidity of 50 percent in summer in Baghdad. The design maximizes beneficial cooling breezes by providing multiple flow paths and minimising potential barriers around the *musalla* zone within mosque complex. Windows on walls with the best exposure to common cooling breezes northwest are part of *musalla* design for effective cross flow of air through the *musalla* building.

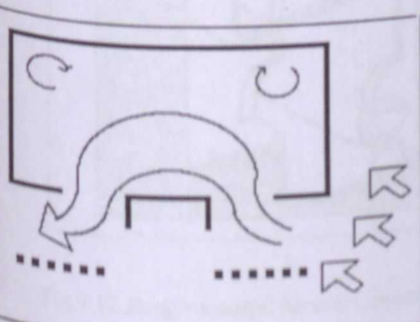


Fig.7.11 The pressure differences created by the *Riwaq* designed to get the same function of wing walls will accelerate the natural entilation through the *musalla* as shown in the following figure.

These assisted natural systems can be beneficial particularly for nighttime and for daytime cooling in Baghdad especially in shaded spaces. Further research is needed on the optimal mix of natural ventilation and simple mechanical equipment. 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 treatment to increase the moisture percentage inside the building (particularly during day-time). So, using convective and evaporative cooling techniques can obtain the best results. The effective passive cooling systems are the "*Badgir*"; which is a vertical air shaft sandwiched in the mass of the external wall (or minaret) connecting a breeze catcher at roof level or higher, oriented towards the prevailing pleasant northwest wind to an opening of the *musalla* minaret. A water jug or small pool is placed at the inlet to provide evaporative cooling. Development of this system by the provision of a movable air scoop and outlet and more elaborate evaporative techniques is proposed as shown in (Fig.7.14), (for more details, see Tappuni, 1981) see the developed cool tower mechanism Fig.B.5,App.B.

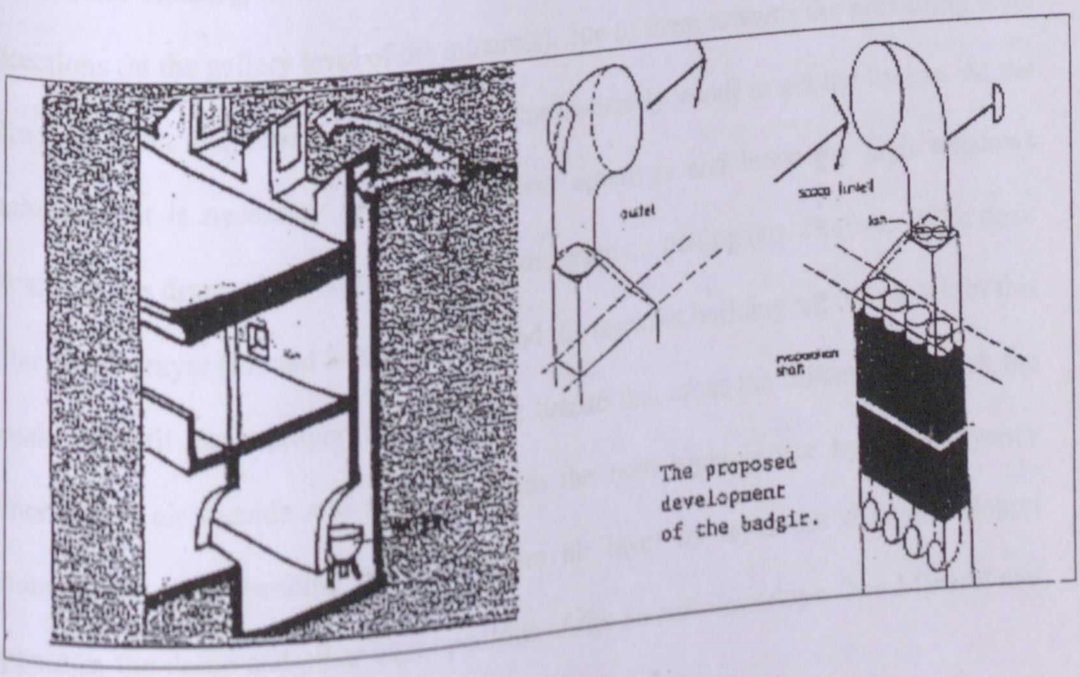


Fig.7.12.*Badgir*concept. Source:Tappuni;1981;15-32

9. Applying alternatives on the basic *musalla* model gives flexibility to choose the optimum envelope constructional section as well as the optimum architectural design to optimize the inner environment and approaching thermal comfort for praying people.

It is possible to reach the comfort zone in winter as explained in the computer simulation (Graphs 6.11 and 6.13 in Ch.6),using Half Glass walls of 360mm thickness and a 6-inche RC flat roof.

Adding other treatments, as well as other microclimate enhancement, as mentioned in previous categories contribute to an improvement of comfort inside the *musalla* during summer.

Depending on the "Flushing" mechanism, it makes a high contribution to approaching the comfort zone in summer too. That happens using nighttime ventilation for the inner environment of the *musalla.*

Referring to the proposed mechanism of ventilation for the *musalla* building Fig.7.14, it will be preferable to have two (or even four) minarets (or air tunnels) at each corner of the *musalla* building, to have mechanically controlled openings (air scoops) open in two directions (at the gallery level of the minarets), one of them towards the prevailing wind direction in the Baghdad region (*Gherbi*- Northwesterly wind) to get the breeze. At the same time it is necessary to close all lower openings and leave the high windows located at the drum of the dome open to let the warn air getting out. That should be done after *Ishak* prayer (around 8.30-9.00 pm),and the *musalla* building should be left in this condition until *Fajar* prayer (5.30am). The breeze that cross the minaret will suck the inner warm air outside and replace it with the cold night breeze by the buoyancy phenomenon, then pushing the inner warm air layer by layer out through minaret openings, the dome and other high openings of the *musalla* envelope. The Minaret and dome openings should be closed after *Fajar* prayer until *Zuhur* prayer (1.00pm) to maintain the cooled inner environment that is obtained from this "Flushing" method.

10. Based on basic design criteria that determine the level of the system's energy used, which are: the building's configuration and orientation; interior space arrangement and building envelope, the most common means of simple mechanical cooling that is the simple electrically operated air cooler has proved to be an effective low energy cooling method. Its major drawback is the continuous need for maintenance due to the concentration of water impurities and high content of sulphates.

11. It is possible, of course, to put a second "skin" or envelope around the first one. This can help reduce the heat loss and heat gain while maintaining most of the benefits of the solar gain directly into the building in wintertime. It can also trap potential useful heat between the skins, or use a partial second skin in a defined direction-(west, south-west and east particularly for the *musalla* building in Baghdad). At the same time, it can use this partial skin for a special aesthetic architectural treatment.

12. The most available and economical thermal insulation material widely used for external brick wall and RC roof of new buildings in Baghdad is polystyrene. It could be used in the *musalla* building in (11cm) thickness for the roof; (7cm) in the composition for south and southwest walls; (8cm) for walls that face southeast orientations and (10cm) for walls that face the other orientations. The location of insulation material should be near the external layer of the wall, and there should be a gap for ventilation between it and the layer, which is beyond it to prevent water vapour condensation (for further details in the hot-dry climate of Baghdad, see Husain; 1984:4). The most important properties in the selection of the insulation materials are (1) low thermal conductivity, (2) low density, (3) low initial and labour costs, and (4) long thermal life.

So, polystyrene *(styropor* –the common local name in Baghdad) has been selected according to the previous properties. *Styropor* insulation sheets should be coated with plastic sheets to protect them from moisture. In addition to what is mentioned before, foaming a Portland cement mixture with a foaming agent such as aluminium dust can also make insulating concrete. This agent causes a chemical reaction that evolves gas producing a closed cell porous material having some strength. A wide range of density is possible, and is a function of the amount of evolved gas (see Gertis; 1981:126-129).

13. A square plan for the *musalla* with a cubic size or one approximating that shape has the best characteristics for preserving heat in winter and maintaining cool in summer as explained in the Chapter five. Lippsmeir (1969) proposed the optimum proportion for that shape to be 1:1.3 with regard to width and length.

This is based on the fact that it is a practical size with the smallest outside surfaces. It can be used in the modification of a new *musalla* type to a *cubic* form by increasing its height to make it a double (or maybe triple) storey *musalla* .In this way, the second level becomes (U– shaped mezzanine) a women's *musalla*. So, the central part of the *musalla* space will be like a courtyard covered by a central dome, to approach a compact cubic shape (Figs.7.12b and 7.15.)

According to what is mentioned in the previous chapters, the rectangular *musalla* shape is the most familiar in Baghdad. Olgyay evaluated the relationship of proportions for buildings in different climatic regions; he found that the optimum orientation for a rectangular building shape in a hot-dry climate (the Baghdad region climate) is to situate the longitudinal sides of it towards the South-west (for more details, see Lippsmeir (1969) also.

Based on that, Southwest building orientation is a well oriented building in Baghdad.

The *Qibla* direction in Baghdad locates within this range. That means a rectangular shape of the new *musalla* is acceptable in relation to Islamic jurisprudence and climatic criteria (see Al-Rawi, 1988:46-47), but we have to consider the proportion of the *musalla* as being as optimum as possible.

As a consequence, a rectangular shape could be employed by repetition of cubic size, which is thermally the best due to the previous criteria. Getting the optimum size (or similar to it) comes from the repetition of cubic size to approach a rectangular size, which is also favourable in the Baghdad climate as well as in Islamic teachings,(see Fig.7.15.)

14. Employment of an L-shape *Riwaq* (semi covered arcade area) around the *musalla*, or U-shape, gives more shade to the *musalla* envelope and contributes to enhancing the microclimate around it.

Traditional spaces are used to provide outdoor semi-protected areas for climatic moderation also e.g. atriums, veranda ways, corridors, plazas, terraces, and balconies. (see Powell; 1989:104).

The basis would be how close we can get to the optimum internal air temperature, which is closest to thermal comfort level. One should attempt to perform the control task by passive controls (i.e by the building itself), and resort to active controls (i.e. by energy-based heating or cooling systems) only when passive controls cannot ensure comfort. This approach is suggested for three main reasons:

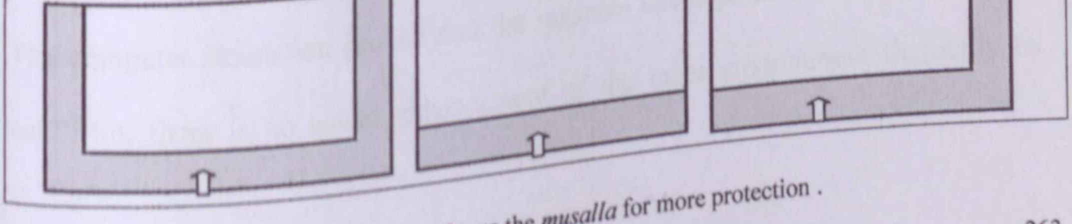


Fig.7.12a Three shapes of *Riwaq* which embrace the *musalla* for more protection .

7.5 FINAL CONCLUSIONS AND RECOMMENDATIONS

During the past twelve years it has not been economically possible to either invest in HVAC plant for mosques or meet the running costs. It is not likely that this economic position in Iraq will change in the near future and undoubtedly many mosques will have to be built with these economic constraints. So, this study has not considered the use of centralised HVAC systems as part of any strategy to achieve thermal comfort.

This thesis concerns the optimum architectural passive design and constructional treatments of the new *musalla* in Baghdad under the environmental impact, to provide thermal comfort for the inner environment of the *musalla* in the Baghdad region taking into consideration, urban planning, available materials, skill and other religious criteria.

The thesis findings are concluded as follows:

1. Design of the present new *musalla* envelope is thermally inefficient according to the previous analytical assessment and computer simulation.

2. Materials used in the construction of the present new *musalla* are not efficient in protecting the inner environment from climatic fluctuations.

3. Then, the inner environment of the present new *musalla* is not recently within thermal comfort level.

4. So, achieving as well as maintaining thermal comfort for the inner environment of the present new *musalla* should come from controlling heat gain.

5. The Computer simulation shows that it is possible with the proposed alternatives (as mentioned below) for the new *musalla* envelope to approach the comfort range for the inner environment which is within 20 °C to 30 °C as mentioned in item 4.2.1.

6.The computer simulation proved that the massive envelope behaves as a "Thermos Flask". So, there is no actual enhancement of the inner environment thermally by increasing wall thickness to more than 360mm or even using cavity walls with the same specifications of the basic "Model *Musalla*" envelope.

It appears that the *musalla* building is dialectically balanced with the outside climate for a wall thickness of 360mm because as the wall thickness decreases below 360mm its effectiveness in damping outside temperature fluctuations also decreases. On the other hand, for wall thickness of more than 360mm, the heat received during the long summer day cannot be released during the shorter nighttime, and that is what was stated concerning the bad envelope behaviors in terms of "Thermos Flask" effect.

The computer imulation also indicates that the RC flat roof is the bestthermally in terms of cost, labor skill, and positive heat exchange after the application of an additional 6 inches of insulation material.

The following factors, which contribute to this, should be taken into consideration as recommendations and techniques to apply:

i. Since many different facilities are added from time to time inside the mosque complex, the research should continue to determine the thermal design parameters of other spaces and facilities. The subdivision of the *musalla's* interior space should be studied to give flexibility in controlling the environmental impact and thermal comfort limits in the *musalla* as well as trying to unite the congregational hall with the *musalla* space to be one space at one congregational time.

ii. Selecting materials and the construction system on the basis of low thermal transmittance (low U-value) and high thermal mass in addition to the implementation of constructional treatments to get a desired time lag within 8 to 14 hours for walls, and 20 to 30 hours for the roof. Using well-insulated roofing materials to provide high time lag, low thermal transmittance and high thermal capacity (like local *fershi* brick

30cmx30cmx5cm) and 0.36m walls thickness to replace 0.24m walls, or foaming a Portland cement mixture with a foaming agent such as aluminium dust to make insulated concrete roof slab can be done.

iii. Using the most common economical thermal isolation materials in Baghdad, that is, polystyrene (11 cm) thick for the roof; (7 cm) thick for south-facing walls;(8 cm) for southeast walls; and (10 cm) for other orientations. Insulation material should be located near the external layer of the walls, which should be smooth and painted externally in light colours.

iv. Designing well-shaded walls and windows, selecting suitable window glass and size for each orientation in Baghdad from provided data in App.A1. These areas should be minimal on the east and west elevations.

v. Raising the roof enables cooling by ventilation; the best result of U-value for the whole roof and ceiling construction should be 0.8 W/sq.mc.

vi. U sing d ouble r oof, d ouble walls skin and the early development ideas on "Filter" Architecture" to get high thermal protection.

vii. Designing the *musalla* to be in thermal contact with the ground, the idea of (sub ground level–basement) enables benefits from the cooled humid space more than is possible at ground level.

viii. Additional ventilation is required in summer by using fans. This can be beneficial, particularly at nighttime, and daytime in shaded spaces. Further research is needed on the optimal mix of natural ventilation and the simple mechanical fan, and water nozzle fan and other levels of mechanical equipments.

ix. Employing of minarets as external breeze catchers. The minarets should face the prevailing pleasant northwest wind in Baghdad and have openings, "vertical air shafts" (as shown in Fig.7.14) to promote airflow into the *musalla,* using the convective and evaporative cooling techniques.

x. For more optimization of the inner comfort level for the "*musalla*" building in summer, "Loading" the *musalla* with night coolness that is retained in the inner environment of the *musalla*. The cool summer night breezes are used to "Flush "the *musalla* building of heat that has accumulated during the hot summer days in Baghdad.

Both the "Loading" and "Flushing" effects have ample applications in day cooling and ventilation strategies as well as in keeping the inner environment of the *musalla* cool during the daytime that help to improve the comfort level to approaching comfort zone.(see category 9,p.263 and Fig.7.14).

xi. Using the common means of simple mechanical cooling (for limited conditions) such as simple electrically operated air coolers. They are an effective, low energy cooling method, where air temperature and relative humidity are constant.

xii. Since the rectangular shape of the new typical *musalla* in Baghdad is acceptable in relation to the previously mentioned criteria, and the cubic shape is the optimum one for hot-dry climates, it is recommended to combine them by getting repetition cubic size in a ratio 1:1:1 to reach the optimum rectangular shape, (see Figs.7.12b,7.13 and 7.15.)

xiii. Employment of an L-shape or U-shape *Riwaq* (semi-covered arcade area) attached to the *musalla* envelope gives it more shade, and enhances the microclimate. In addition, an increase in the numbers of domes is thermally desirable as mentioned before and shown in Fig.7.12a and 7.15.

xiv. Microclimate planning controls can have a major effect over the *musalla* design. In addition to providing shade, plants can assist cooling by transpiration. Plants also enhance the visual environment and create pleasant filtered light.

xv. The study will be transferable for other parts of Iraq with certain limitations. For example, in the south part of Iraq increase in temperature could be consummated either by introduction of some cooling or an increase in the thermal mass. In the north, which is generally cool, this may be consummated of some heating or an increase in insulation and a reduction in glazed area.

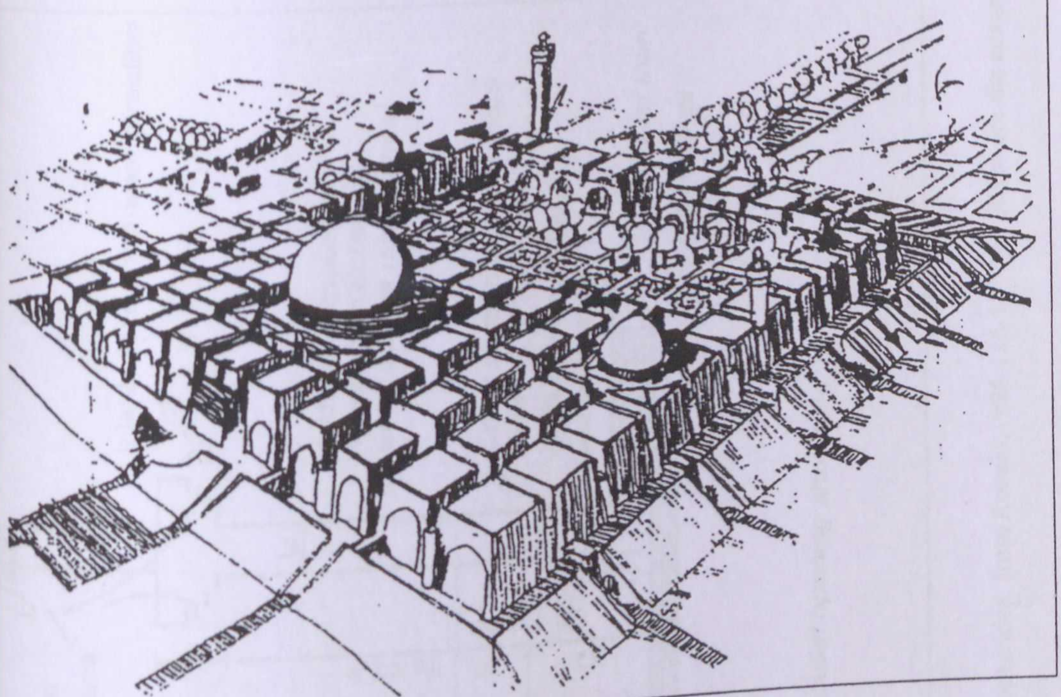


Fig.7.12b Architect Rasim Badran; semi cubic shape as modular.

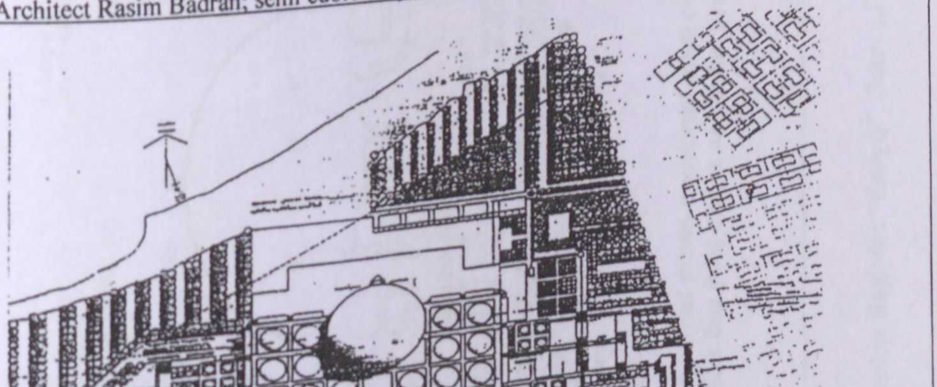


Fig.7.13 Architect Mohd.Makiyya. Domed cubic shape as modular. State mosque competition-Baghdad.
Source; Brochure of the competition; Municipality of Baghdad;1983.

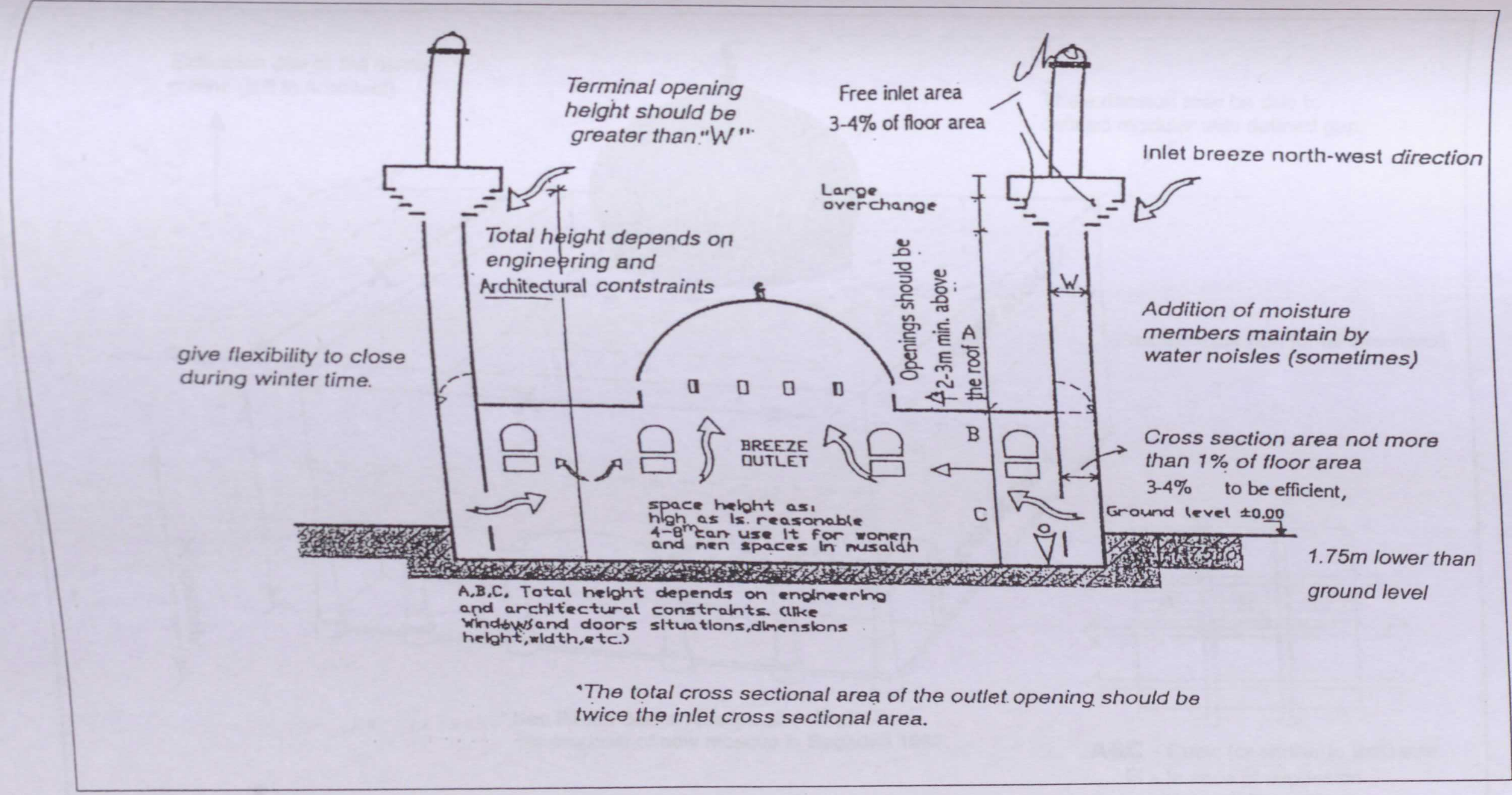


Fig.7 .14 Developed idea from traditional vertical air tunnel in Baghdad "*Badgir*". Source;Developed idea from Ronald;1996:126-127 and others,see the advanced Cool Tower Fig.B.5 n App.B.

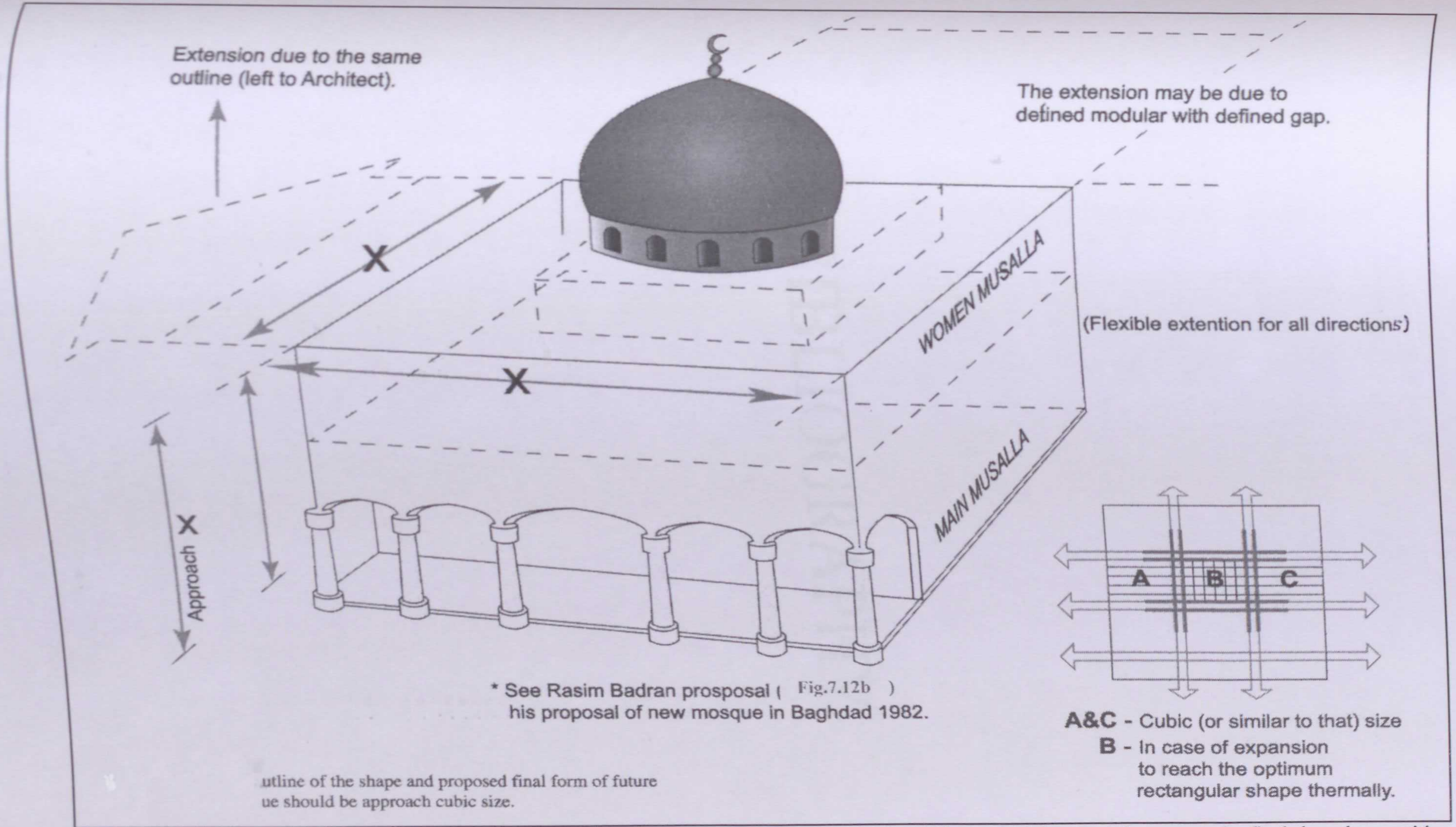


Fig.7.15 Proposed external envelope for future *musalla* that approaches cubic size and gives the flexibility as modular to get the rectangular final shape by repetition.

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Appendices

Appendix A

Proposed Glass for Each Orientation in Baghdad:

Heat-absorbing glass: This generally contains a small amount of iron, and the glass tends to be greenish-blue or greenish-brown in color. Daylight penetration through it is reduced; the glass heats up and about one-third of the absorbed heat are transmitted inwards. Radiation from such glass can produce thermal comfort indoors. (It can be used for windows in the north or northeast orientations).

Reflective glass: This has a very thin metallic film on the glass. The reduction in the transmission of infrared radiation is accompanied by a reduction in daylight. Better performance may be obtained by reducing the area of clear glass. Moreover, there are problems resulting from external reflection, and internal reflection in uncurtained windows (can be used in the northeast or southeast orientation).

Glare control glass: Color is injected electrically out to the surface of this glass on the "float" line. This provides some filtering of solar heat as well. Light transmission may be reduced to such an extent that permanent artificial lighting may be needed, with its consequent heat output and extra power consumption (can be used in the southwest).

Modifications of clear glass: Two methods are available with this glass. The older method uses lacquers, which is difficult to apply smoothly and in the desired thickness. A more recent method uses an aluminized polyester film. Both methods are used when clear glass has been installed and a reduction in both heat and light transmission is found to be necessary (Can be used for south-west orientation).

New coatings are being developed that are wavelength selective, i.e., they will reflect part of the spectrum of radiation, but transmit other wavelengths. The usual aim is to transmit visible wavelengths, i.e., daylight, and to reduce either the entry of short wave infrared radiation or the egress of long wavelength infrared radiation (depending on whether the building is in a hot or a cool climate). These coatings are very thin and delicate, and usually have to be applied to the protected inside faces of double-glazing units (it can be used in south-west orientation).

'Smart" glass: photo chromic glass employs silver haloes which dissociate when irradiated with strong light causing darkening in shade. The haloes reform and the glass clear. Thermo chromic glass undergoes a color transmission at a specified temperature. As the coating heats up, it switches to a metallic state and reflects the infrared component of solar radiation. Electro chromic materials change their color reversibly in response to an applied electric potential. Current research shows that electro chromic coating holds the greatest promise for future solar energy filtering applications (it can be used on the west and northwest walls).
Sunlight filtering glass: This is used in fixed external shades. In this application, heat absorbed in the glass is dissipated to the outside air and little will be transmitted through the window glazing' (Energy Efficient Design, 1995:68-69", with additions).

Table A.1 shows the classification of the responses of the surveyed prayers in the new mosques .

Mosque No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1	7	7	7	7	4	3	4	4
1	3	7	3	3	4	3	7	4
1	1	7	3	1	4	3	7	4
2	7	7	3	3	4	3	4	4
2	3	7	3	7	4	3	7	4
2	3	3	3	3	3	3	7	4
3	7	7	3	7	5	7	4	3
3	3	3	7	5	3	3	4	4
3	1	3	1	3	5	3	3	4
4	7	7	3	7	3	7	7	4
4	7	7	3	7	3	7	7	4
4	7	7	3	7	3	7	7	4
5	7	7	7	7	3	7	4	5
5	3	7	7	7	3	7	4	5
5	7	7	7	7	3	7	4	5
6	7	7	3	3	4	3	4	4
6	7	7	3	3	4	3	4	4
6	7	7	3	3	4	3	4	4
7	2	7	3	3	3	3	5	4
7	3	7	3	7	4	3	3	4
7	3	3	3	7	4	3	3	4
8	7	7	3	3	4	3	4	4
8	3	7	3	1	4	4	4	4
8	1	2	3	3	4	3	4	4
9	7	3	7	4	4	3	4	5
9	1	7	3	3	4	3	4	5
9	1	3	1	3	5	3	4	4
10	7	7	3	3	5	7	4	5
10	7	3	3	3	3	3	4	3
10	1	3	3	3	4	7	4	3
11	3	1	3	1	4	3	7	4
11	3	1	4	3	5	3	7	5
11	3	7	3	3	5	1	4	5
12	3	7	4	3	5	3	4	4
12	3	3	7	7	4	7	2	4
12	7	7	3	3	4	3	7	4
13	7	7	3	3	3	3	7	3
13	2	7	3	3	4	3	4	4
13	3	3	2	3	4	7	7	4
14	7	3	3	1	3	3	7	4
14	3	1	3	3	4	3	7	5
14	3	7	3	3	4	1	4	5
15	3	3	3	1	4	3	7	4
15	3	1	4	3	4	3	7	5
15	3	7	3	3	5	1	4	4
16	7	3	3	3	5	3	7	5
16	3	7	7	3	5	3	4	4
16	3	1	7	7	4	7	2	4
17	7	7	3	3	3	3	7	5
17	3	7	3	3	4	3	4	5
17	3	3	2	3	4	7	7	4
18	3	7	3	3	5	3	7	5
18	3	7	3	3	4	3	4	5
18	3	3	2	3	4	7	7	4
19	7	3	3	3	5	3	7	5
19	3	7	7	3	5	3	4	5
19	3	1	7	7	4	7	2	5
20	3	7	3	3	4	3	7	5
20	3	7	3	3	4	3	4	4
20	3	3	3	3	4	7	7	4

21	7	3	3	1	3	3	7	3
21	3	7	7	3	5	3	4	3
21	3	1	7	7	4	7	7	4
22	7	3	3	3	5	7	7	4
22	3	7	3	3	5	3	4	4
22	3	1	7	7	4	7	4	4
23	3	3	3	1	4	7	7	4
23	3	1	4	3	4	3	7	5
23	3	7	3	3	5	1	4	4
24	3	7	3	3	3	3	7	3
24	3	7	7	3	5	3	4	4
24	3	1	3	7	4	7	2	4
25	3	3	3	3	5	3	7	5
25	3	3	3	3	4	3	4	5
25	3	3	2	3	4	7	7	4
26	3	7	3	3	4	3	4	5
26	3	3	3	3	4	3	4	4
26	3	7	3	3	5	3	3	4
27	3	7	3	3	4	3	4	5
27	3	3	3	3	5	3	3	4
27	1	7	3	1	3	3	4	4
28	1	3	3	3	3	3	4	5
28	3	3	3	3	4	3	4	4
28	1	3	4	3	4	3	5	5
29	3	7	3	3	3	3	4	3
29	1	7	3	3	3	3	4	4
29	3	3	3	3	4	4	4	4
30	3	2	7	3	3	3	4	4
30	3	7	3	3	4	3	4	5
30	1	7	3	3	4	3	3	4
31	1	7	7	3	3	3	4	3
31	1	7	3	3	3	3	4	3
31	3	3	3	3	3	3	4	3
32	3	3	3	3	4	3	4	5
32	3	7	3	3	4	3	4	4
32	3	3	3	3	3	3	4	4
33	3	3	7	3	4	3	4	5
33	3	7	3	3	4	3	4	5
33	3	3	3	3	4	3	4	5
34	3	7	3	7	4	3	3	4
34	3	3	7	3	4	3	3	5
34	3	3	7	3	4	3	4	4
35	7	7	7	7	5	7	4	5
35	3	3	7	3	4	3	4	4
35	3	3	3	3	4	3	4	4
36	3	7	4	3	4	4	4	5
36	3	7	4	3	4	3	4	4
36	3	3	4	4	4	4	4	4
37	7	1	3	1	3	7	4	4
37	7	1	3	1	3	7	4	4
37	3	3	3	3	3	3	4	4
38	3	2	3	3	5	7	4	5
38	3	2	3	3	4	3	4	4
38	3	7	7	3	5	7	4	4
39	1	7	7	3	4	7	4	4
39	1	7	7	1	3	3	4	4
39	3	3	3	1	3	3	4	4
40	3	7	3	3	4	7	4	5
40	3	7	3	3	4	4	4	4
40	1	2	3	3	4	7	7	4
41	2	1	3	1	4	7	7	4
41	3	1	3	1	3	7	4	4

41	2	3	3	3	3	3	7	4
42	1	1	3	1	5	3	3	5
42	1	1	3	1	5	3	4	5
42	1	3	7	1	5	3	3	5
43	3	7	3	3	4	7	4	4
43	7	7	3	3	5	3	4	4
43	3	7	3	3	5	7	4	4
44	3	1	3	3	4	7	4	4
44	1	1	7	3	4	7	5	4
44	1	7	3	3	4	3	4	4
45	3	7	4	1	4	7	5	4
45	3	1	3	1	3	7	4	4
45	3	1	3	3	3	3	4	4
46	1	1	2	3	4	7	4	4
46	1	1	3	1	4	7	4	4
46	1	3	2	1	4	3	4	4
47	1	7	3	1	4	7	4	4
47	3	3	3	1	4	7	4	4
47	3	3	3	3	4	3	4	3
48	3	2	3	1	3	7	5	3
48	3	2	3	3	3	7	4	3
48	3	3	3	1	4	3	4	4
49	3	3	3	3	4	4	4	4
49	3	3	3	3	4	3	4	4
49	3	1	3	3	3	7	4	4
50	2	1	3	1	3	7	4	3
50	3	1	3	1	3	7	4	4
50	2	1	3	1	4	3	4	3

Appendix A1

*To be more precise in our calculation, we can add + [(U (teo – Tao)]. If the indoor temperature is assumed to be constant (a reasonable assumption in controlled environments), the momentary rate of flow can be calculated fairly simply if it is split into two parts.

a. First, the average heat flow rate is found for the full cycle (one day). Using the steady state equation, except that the temperature difference is taken between the daily mean outdoor temperature and the indoor temperature:

   $Q = A \times U \times (Tm - Ti)$

b. The momentary deviation from the average heat flow rate is found. If the time lag of the wall is O hours, then the heat flow now will depend on the outdoor temperature O hours previously: To. The deviation is found by using a temperature difference value between this To and the mean. The transmittance or U-Value is modified by the decrement factor (u).

   $Q = A \times U \times u\,(To - Tm)$

   The two equations can be added to get the equation describing the periodic heat flow rate:-

   $Q = A \times U \times [(Tm - Ti)] = u\,(To - Tm)]$

   Where Q= momentary heat flow rate in W

   A= area in sq.m

   U=transmittance W/sq.m

   Tm=daily mean outdoor (sol-air) temperature-°C.

   Ti=indoor temperature (constant), °C.

To=outdoor (sol-air) temperature

Q hours earlier, °C

U= decrement factor and Q= time-lag in hours.(Olgyay,1992:13).

*Conduction heat flow rate through a wall of given area can be described by the equation:

Qc = A x U x T

Where:

Qc = conduction heat flow rate, in W

A = surface area, in m.sq

U = transmittance value, in W/m.sq degree

T = temperature difference

So:

T = Ti – To

Ti = inside air temperature

To = outside air temperature

For the whole building, enclosed by various elements and possibly with the temperature varying from side to side, the above equation is solved for each element and the results are added. (Olgyay, 1992:76).

*The interior heat effects C are calculated (also) with the periodic heat-flow method using the following equation in the case of opaque materials:

C = U (tm – ti) - U (te – tm)

In the case of glass surfaces the solar – heat-gain method was used with the following equation.

$C = ID\,(TD \times Ad) + Id\,(Td \times ad) + U\,(to - ti)$

Where the symbols in the equations designate:

U = overall coefficient of heat transfer Btu/ft²/hr

to = outdoor air temperature

ti = indoor air temperature

tm = 24-hr cyclic average sol-air temperature

te = sol-air temperature earlier to time lag

u= Amplitude decrement factor

a = absorbtivity of weather side of wall. Subscripts D and d refer respectively to direct and diffuse incident solar radiation

I = incident solar radiation, Btu/ft2/hr. subscripts D and d refer to direct and diffuse

T = transmittance coefficient of solar radiation. Subscripts D and d refer to direct and diffuse. (Olgyay, 1992:87)

Appendix A2

i- To estimate sol-air temperature and the rates of heat exchange requirements we should get the daily rates of solar intensity for the months of the year in different directions according to the categories which are listed below:

1. Daily rates of solar radiation for the months for vertical and horizontal surfaces (in different directions) (Dawud, 1983)

2. Daily rates of solar radiation of months of the year for inclined surfaces (for different directions) are obtained in accordance with Al-Riahi, (1985:12-13) research, and based on the following steps:

A- Getting the rates of solar radiation for .Jan, Feb, March, June and September, for the required inclined surfaces, 30°,45°,65°,82° from Al-Riahi (1985):Fig.(A2.1).

B- Getting other monthly and daily rates for all months of the year for solar radiation intensity values by redrawing the curves. By putting the curves of the same direction on one curve, we can obtain the solar radiation intensity for other months with the assistance of the estimated rates and angles of the known months. This method assists us to calculate the rates for all months approximately (Al Riahi, 985:Fig.A2.1).

Due to differences in the emmissivity of horizontal surfaces and inclined surfaces, I depended on the same reference to find emmissivity values from certain inclined surfaces.

ii- Daily mean for thermal sol-air temperatures for different orientation were calculated by means of the following equation;

teo = tao = Rso (alt –EIL), see Chapter Four, p.137-138.

That equation depends on the daily sol-air temperature for the months of year. I considered the absorptivity factors also as:

0.5 For light surfaces and 0.8 for dark surfaces.

iii-Which are equivalent to:

Rs1 = thermal resistance of internal surfaces

Rso = thermal resistance of external surfaces

Another formula (equation), which assists us to estimate the U-Value also, is as follows:

$$U = \frac{1}{Rs1 + Rso + RA + R1 + R2 + R3}$$

RA= thermal resistance of air space within construction, R1, R2, R3 etc = thermal resistance of successive components,

$$R = \frac{1}{\text{K-Value}} \text{ X } \frac{\text{thickness of material mm}}{1000}$$

or –the U-Value is the reciprocal of this;

$$\frac{1}{\text{Sum of resistance}}$$

(Baden; 1997:112).

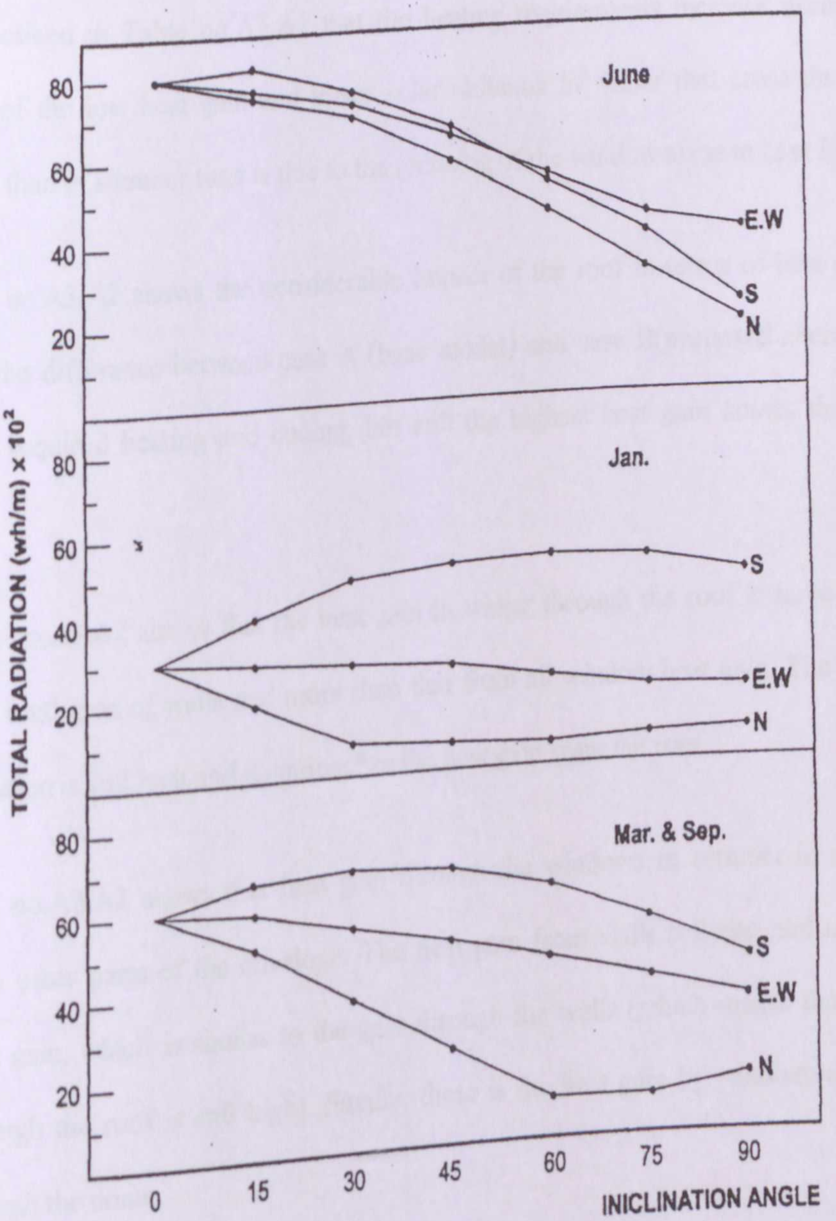


Fig. A2.1 Rate of solar radiation intensity on the inclined surfaces in the Baghdad region.
Source, Al-Riahi; 1985.

APPENDIX A3

A3.1 ANALYSIS OF THE FIELD TEST RESULTS SHARED WITH BRC

I. It is noticed in Table no.A3.A1 that the heating requirements increase during winter because of the low heat gain and lower solar radiation in winter that cross the building envelope than in summer time is due to the reducing of the window areas in case B.

ii. Table no.A3.A2 shows the considerable impact of the roof in terms of heat exchange through the difference between case A (base model) and case B(proposed alternative) in terms of required heating and cooing, but still the highest heat gain comes through the roof.

iii. Table no.A3.A2 shows that the heat gain in winter through the roof is more than that from the total area of walls and more than that from all window heat gain. The heat gain by ventilation is still high and it approaches the heat gain from the roof.

iv. Table no.A3.A2 shows that heat gain through the windows in summer is more than that from other parts of the envelope. The heat gain from walls follows, and next is the roof heat gain, which is similar to the gain through the walls (which means that the heat gain through the roof is still high). Finally, there is the heat gain by ventilation and heat gain through the dome.

v. Table no.A3.A5 shows that the heating requirements are lower in the winter when the exterior surface colour of the envelope is dark, because it contributes by adding absorbed heat to the internal environment because of its high absorptivity factor. However, that has a negative influence in summer.

vi. All previous tables show that the reduction of window areas reduces solar radiation to the inner environment. As a result of that, the inner environment receives lower heat gain than wider openings. Based on that, the cooling requirements will be less and the energy consumption is in proportion.

Table. A3.A1 The heat gain 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. A3.A2: The heat gain 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	5.16
The ventilation	16925	14.4

Source: Qadir; 1990, with the assistance of "BRC-Baghdad" July 1997.

Table. A3-A3. Heating and cooling requirements for A&B cases explain the heat reduction in case A and reducing of cooling in case B.

The case	Heating requirements KWh	Cooling requirements KWh	Reducing %
(A) Typical mosque	22459	117022	---
(B) Proposed corrected mosque (after reducing the area of the windows from 30% to 20% of the area of the *musalla* walls)	31242	92678	11.25%

Table.A3.A4. The requirements of annual energy for cooling and heating in the case of (A) the "Model" mosque, and (B) the corrected proposed type.

Case	Envelope elements		(+)Heating KWh		(-)Cooling KWh	
	Walls	Roof	Energy	Decreasing	Energy	Decreas--ing
A	0.24m bricks	Reinforced concrete without thermal insulation	22459 12	---	117022	---
B	0.36m bricks	Reinforced concrete with thermal insulation	8812	60.8%	7779.7	33.5%

Source: Qadir; 1990,with the assistance of Building Research Center-Baghdad.

Table. A3.A5: Cooling and heating requirements for the typical and proposed "Model" mosques (A and B) in condition of two types of envelope external surfaces colors.

Case of "Model" (mosque)	Heating requirements KWh		Cooling requirements		Difference percentage (%)
	Dark color a = 0.8	Light color a = 0.5	Dark color a = 0.8	Light color a = 0.5	
A	20086	22459	124025	117022	3.32%
B	6234	8690	83281.3	77797	3.8%

Source: Qadir; 1990. Documented with the assistance 0f "BRC-Baghdad" July 1997.

Table A3.A6 Daily total rates of solar radiation intensity for inclined surfaces in the Baghdad region KWh/day.

Month	North				East & West				South			
	30°	45°	65°	82°	30°	45°	65°	82°	30°	45°	65°	82°
Jan.	0.9	0.8	0.7	0.8	2.8	2.8	2.5	2.5	4.7	5.2	5.2	4.9
Feb.	2.4	1.7	0.8	1.0	4.2	4.0	3.4	3.0	5.7	6.0	5.7	4.9
Mar.	3.9	2.6	0.9	1.3	5.7	5.1	4.3	3.6	6.8	6.8	6.0	5.1
Apr.	4.5	3.6	2.0	1.5	6.2	5.5	4.5	3.8	7.1	6.6	5.6	4.4
May.	5.7	4.7	3.0	1.6	6.6	5.8	4.8	4.1	7.5	6.6	5.3	3.6
Jun.	6.8	5.7	3.9	1.7	7.1	6.2	5.2	4.2	8.1	6.5	4.8	3.2
Jul.	5.7	4.7	3.0	1.6	6.6	5.8	4.8	4.1	7.5	6.6	5.3	3.6
Aug.	4.5	6.3	2.0	1.5	6.2	5.5	4.5	3.8	7.1	6.6	5.6	4.4
Sep.	3.9	2.6	0.9	1.3	5.7	5.1	4.3	3.6	6.8	6.8	6.0	5.1
Oct.	2.4	1.7	0.8	1.0	4.2	4.0	3.4	3.0	5.7	6.0	5.7	5.0
Nov.	0.9	0.8	0.7	0.8	2.8	2.8	2.5	2.5	4.7	5.2	5.2	4.9
Dec.	0.4	0.2	0.5	0.6	1.9	1.9	1.6	1.9	3.6	4.6	4.8	4.9

Source:(Al-Riahi; 1985).

Table A3.A7 Solar radiation on vertical surfaces of the *musalla* envelope that are oriented 10degree southwest toward "*Qibla*" in the Baghdad region KWh/day.

Months	10°	100°	190°	280°
Jan.	0.80	2.06	3.82	1.52
Feb.	1.0	2.46	4.0	1.93
Mar.	1.27	2.89	3.61	2.44
Apr.	1.61	3.20	3.11	2.94
May.	2.08	3.49	2.71	3.27
Jun.	2.38	3.81	2.51	3.78
Jul.	2.25	3.77	2.64	3.70
Aug.	1.80	3.66	3.19	3.42
Sep.	1.38	3.40	3.96	2.95
Oct.	1.06	2.86	4.33	2.78
Nov.	0.94	2.33	4.24	1.73
Dec.	0.72	1.87	3.64	1.35

Source: (Al-Riahi; 1985)

Table A3.A8 Sol- air temperature for light and dark surfaces in Baghdad.

Light surface

Month	Horizontal surface	Vertical surface			
		10°	100°	190°	280°
Jan.	10.00	10.34	11.90	13.60	11.40
Feb.	12.40	13.34	14.70	16.15	14.20
Mar.	17.00	17.49	19.00	19.70	18.60
Apr.	23.60	23.41	24.90	24.80	24.70
May.	34.10	30.25	31.60	30.80	31.50
Jun.	36.20	35.20	36.60	35.40	36.50
Jul.	38.10	36.91	38.30	37.30	38.30
Aug.	37.10	36.10	37.80	37.39	37.60
Sep.	32.40	31.89	33.80	34.30	33.40
Oct.	25.00	25.50	27.20	28.60	26.64
Nov.	17.00	17.90	19.20	20.90	18.60
Dec.	11.00	11.80	12.90	14.50	12.40

Source: (Al-Riahi; 195)

Table A3.A8 Sol- air temperature for light and dark surfaces in Baghdad,continued.

Dark surface

Month	Horizontal surface	Vertical surface			
		10°	100°	190°	280°
Jan.	10.00	11.20	13.10	15.80	12.30
Feb.	12.40	13.30	16.10	18.40	15.30
Mar.	18.10	18.20	20.60	21.70	20.00
Apr.	25.10	24.30	26.70	26.60	26.31
May.	33.30	31.40	33.50	32.40	33.40
Jun.	39.60	36.57	38.70	36.80	38.70
Jul.	39.80	38.20	40.70	38.70	40.40
Aug.	37.60	37.10	39.90	39.20	39.50
Sep.	32.90	32.70	34.90	37.10	34.00
Oct.	24.50	26.10	28.90	28.00	27.00
Nov.	17.00	18.40	20.50	23.40	19.60
Dec.	11.10	12.20	13.90	16.60	13.10

Source: Qadir; 1990 supported by Building Research Center- Baghdad/1997.

Table A3-1 Daily rate of heat flow through the walls (kWh/day).
$U = 1.94\ W/m^{2.o}C \ \ = 0.5$

Light surface:

Orientn. of wall	Area	Heat loss						Heat gain					
		N	D	J	F	M	A	M	J	J	A	S	O
10°	112	3.1	34.7	40.1	26.7	5.2	8	27.2	52.8	61.5	57.5	35.7	3.5
100°	57	68	16.7	17.8	10.8	0	68	17.8	32.8	34.5	33.6	28.6	3.1
190°	126	80	24.0	29.4	2.35	0	0	34.8	63.0	73.8	74.3	55.8	9.8
280°	57	0.4	17.0	22.3	12.1	0	0	81.1	32.2	34.5	33.8	23.3	4.5
Total		3.1	97.0	114.0	55.7	5.2	0	105.8	191.5	222.7	215.0	147.8	26.0
		238.7						851.7					

Dark surface:

Orientn. of wall	Area	Heat loss						Heat gain					
		N	D	J	F	M	A	M	J	J	A	S	O
10°	112	0.5	32.6	37.8	26.4	1.6	0	33.1	60.0	68.3	62.6	39.9	5.7
100°	57	0	15.1	17.7	7.9	0	4.5	27.9	44.9	51.5	48.8	32.5	12.5
190°	126	0	11.4	16.1	0.6	0	9.6	44.2	70.5	81.9	64.9	72.6	17.9
280°	57	0	17.73	20.3	10.5	0	4.3	27.5	44.9	50.5	47.5	29.5	9.5
Total		0.5	76.8	82.0	45.4	1.6	58.9	132.7	220	252.2	243.0	174.5	45.6
		250.3						1003.7					

$U = 1.94\ W/m^{2o}C \ \ = 0.8$ Source: Obtained with the assistance of (Qadir; 1990)

Table A3-2: Daily heat flow through the walls (kWh/day)
U = 0.5 W/m^2.°C

Light surface:

Orient of wall	Area	Heat loss						Heat gain					
		N	D	J	F	M	A	M	J	J	A	S	O
10°	112	0.8	8.9	10.3	6.9	1.3	0	7.0	13.6	15.9	14.8	9.2	0.9
100°	57	0	4.0	4.9	2.8	0	0	4.9	8.6	9.0	9.3	6.4	1.3
190°	126	0	6.2	7.6	0.6	0	0	8.9	16.2	19	19.1	14.4	5.6
280°	57	0.8	4.3	5.2	0.8	0	0	4.9	8.6	9.8	9.2	6.1	1.2
Total		0.8	25	29.5	11.6	1.3	0	27.0	35.7	41.2	40.5	38.1	9.8
		64.6						259.2					

Dark surface

Orient of wall	Area	Heat loss						Heat gain					
		N	D	J	F	M	A	M	J	J	A	S	O
10°	112	0.1	8.4	30.3	19.1	0.4	0	8.5	15.5	17.6	16.1	10.2	1.5
100°	57	0	3.1	10.6	4.3	0	1.2	6.5	10.1	10.6	10.2	7.1	2.9
190°	126	0	2.9	14.7	1.46	0	2.5	11.4	18.2	21.1	21.9	18.8	4.6
280°	57	0.1	4.1	14.0	7.2	0	1.0	6.3	2.9	11.4	10.4	8.7	2.2
Total		9	19.8	5.2	0.7	0.4	5.3	34.2	48.4	65	62.5	47.4	42.3
		23.6						484.8					

Source:Dawud;op.cit.

Table A3-3 . (cont.).
Light surface:
U = 0.794 W/ m^2°C

Orient. of wall	Area	Heat loss						Heat gain					
		N	D	J	F	M	A	M	J	J	A	S	O
10°	119.2	3.58	35.76	42.9	28.61	56.02	0	29.8	57.22	66.75	61.98	38.14	3.78
100°	94.4	0	24.54	29.26	12.0	0	0	29.26	50.98	58.53	55.7	38.7	9.44
190°	122.8	0	23.33	28.24	2.46	0	0	33.16	60.17	71.22	71.22	54.03	9.82
280°	94.4	0	27.4	31.15	18.9	0	0	28.32	50.9	58.5	55.7	36.82	7.55
	530.8	3.58	111.0	131.5	67.0	56.02	0	128.5	219.2	255	244.6	167:7	38.6
Total	369.10							1037.71					

Dark surface

Orient of wall	Area	Heat loss						Heat gain					
		J	F	M	A	M	J	J	A	S	O	N	D
10°	17.2	10.5	13.1	16.6	21.1	27.2	31.1	29.4	35.5	18	13.9	12.3	9.4
100°	25.2	39.5	47.1	55.3	61.3	66.8	72.9	72.2	70.1	65.1	54.8	44.6	35.8
190°	7.2	20.9	21.9	19.8	17	14.8	13.7	14.5	17.5	21.7	23.7	23.2	19.9
280°	25.2	29.1	36.9	46.7	56.3	65.5	72.4	70.9	65.5	56.5	43.7	33.1	25.9
	74	100	119	138	155.7	174.3	190.1	187	176.6	161.3	136.1	113.2	91
Total	717.3							1025.4					

Source:Qadir;op.cit.

Table A3-4: Areas and dimensions of the opaque and transparent members of the"Model" mosque envelope.

Vertical walls	Net area sq.m	Doors	Windows	Total areas sq.m	The volume m^3
Musalla 10°	100	12.0	8	120	--
100°	57.0	--	20	76.0	--
190°	120	--	6	132	--
280°	57	--	20	76.5	--
Drum 10°	12.8	--	1.2	14	--
100°	12.8	--	1.2	14	--
190°	12.8	--	1.2	14	--
280°	12.8	--	1.2	14	98.00

Source: Author Calculation

Table.A3-5: The solar heat gain through one square meter from the walls kWh/m^2.day in Baghdad.

Orient	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10°	0.6	0.76	0.97	1.23	1.58	1.81	1.71	2.1	1.1	0.81	0.72	0.55
100°	1.57	1.07	2.19	2.4	2.65	2.89	2.87	2.78	2.58	2.18	1.77	1.42
190°	2.9	3.04	2.75	2.36	2.05	1.9	2.0	2.43	3.01	3.29	3.22	2.76
280°	1.16	1.46	1.85	2.23	2.60	2.87	2.81	2.6	2.24	1.74	1.74	1.03

Source: Qadir;op.cit.

Table.A3-6: Daily rate of heat flow by ventilation over the year (kWh).

Vol. m^3 1955	Heat loss					Heat gain					
	N	D	J	F	M	A	M	J	J	A	S	O
	3.58	112.5	126.7	91.9	929	-	50.8	121.1	150.3	149.0	88.3	-
	399.5						559.5					

Source:Qadir;1990.

Table A3-7: The solar gain through the *musalla* walls, and the drum of the dome. Solar gain factor is 76 KWh. $U = 0.6\ W/m^2\ °C$

Orient	Area m^2	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10°	17.2	10.5	13.1	16.6	21.1	27.2	31.1	29.4	23.5	18.0	13.9	12.3	9.4
100°	25.2	39.5	47.1	55.3	61.3	66.8	72.9	72.2	70.1	65.1	54.8	44.6	35.8
190°	7.2	20.9	21.9	19.3	17.0	14.3	13.7	14.5	17.5	21.7	23.7	23.2	19.9
280°	25.2	29.1	36.9	46.7	56.3	65.5	72.4	70.9	65.5	56.5	43.7	33.1	25.9
	74.8	100.0	119.0	138.4	155.7	174.3	190.1	187.0	176.6	161.3	136.1	113.2	91.0
		717.3				1025.4							

Source: Qadir;1990 with the assistance of Building Research Center-Baghdad.

Table A3-8a: Heat loss and gain for all walls at all orientations. kWh.

Orient	Area m^2	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10	9.2	5.52	7.8	9.8	11.3	14.5	16.7	15.73	19.3	18.12	7.5	6.62	5.1
100	1.2	1.9	2.2	2.63	2.88	3.19	3.47	3.44	3.34	3.1	2.62	2.12	1.7
190	12.8	37.12	38.91	35.2	38.2	26.24	24.32	25.6	31.18	32.53	42.11	41.22	35.33
280	1.2	1.4	1.75	2.22	2.68	3.12	3.44	3.37	3.12	2.69	2.89	1.57	1.24
Total	24.4	45.94	49.86	49.1	47.1	47.1	95.8	48.14	56.9	54.4	54.32	51.5	43.4
		286.9				355.86							

Source;Qadir;1990.

Table.A3-8b: Daily rate of the heat flow through the Roof (kWh/day).

Light surface: U=2.1

Area m^2	N	D	J	F	M	A	M	J	J	A	S	O
291.1	21.9	110.0	124.0	89.5	21.9	0	133.7	164.2	192.6	177.5	108.6	0
	367.3						**776.5**					

Dark surface: U =2.1 W/m^2°C

Area m^2	N	D	J	F	M	A	M	J	J	A	S	O
291.1	0	67.6	74.9	0	0	68.9	168.8	273.1	295.7	278.9	198.4	79.3
	142.5						**1363.1**					

Light surface: Roof U=0.479 W/m^2°C

Area m^2	N	D	J	F	M	A	M	J	J	A	S	O
291.1	5.0	25.1	28.3	20.4	5.0	0	30.5	37.5	43.9	40.5	24.8	0
	8.38				**177.2**							

Dark surface U=0.479 W/m^2°C

Area m^2	N	D	J	F	M	A	M	J	J	A	S	O
292	0	15.4	17.1	0	0	15.7	38.5	62.3	67.4	63.6	45.3	19.1
	32.5						**295.2**					

Source;Qadir;1990.

TableA3-8: Heat flow mean for each cubic.m by ventilation, KWh/cubic.m/day.

Volume	Heat loss (-)						Heat gain (+)					
M³	N	D	J	F	M	A	M	J	J	A	S	O
1	0.019	0.058	0.065	0.047	0.015	-	0.026	0.062	0.077	0.076	0.045	-

Source:Qadir;1990.

Table.A3-9: Daily rate of heat flow through the dome (kWh/day)

Orientn.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	07	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	49	5.3	4.3	2.7	.0
	65	5.78	0.7	3.3	3.9	2.7	1.0	0.0	1.6	42	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	125	8.6	3.1	0.0	6.6	15.5	17.0	15.4	10.7	0.0
West & east	30	4.16	8.5	2.4	28	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	42	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	34	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	28	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	25	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	33	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	27	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	19	1.2	0.0	0.0	2.1	3.3	4.3	3.9	2.8	0.9
			0.2	9.8	104	6.3	0.0	0.0	10.62	17.3	20.8	19.8	13.7	8.2
		69.82							81.12					
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	0.15	0.0	2.7	4.2	4.9	4.1	2.5	8.8
	45	6.24	0.7	3.6	2.8	1.9	08.5	0.0	3.6	62	6.9	5.6	3.1	8.8
	65	5.78	0.7	3.3	3.9	2.7	1.8	0.0	2.4	50	5.2	4.5	2.5	8.8
	82	4.46	0.6	2.5	3.0	2.1	0.7	0.0	1.3	3.1	3.6	3.4	2.1	8.8
			2.5	11.8	125	8.6	2.35	0.0	10.0	18.5	20.6	17.6	10.2	8.8
West & east	30	4.16	0.5	2.4	25	2.1	0.0	0.4		4.9	5.2	4.9	3.4	0.7
	45	6.24	0.83	2.4	37	3.0	0.0	0.7	4.3	6.8	7.4	7.1	4.9	1.2
	65	5.78	0.1	3.3	31	3.0	0.0	0.4	3.4	3.7	6.5	6.2	4.9	1.2
	82	4.46	0.0	2.2	22	1.5	0.0	0.15	4.5	4.9	4.6	4.3	3.0	0.0
			0.9	18.3	115	9.6	0.0	1.65	15.2	28.3	23.7	22.5	13.2	3.1
South	30	4.16	0.0	3.1	24	8.36	0.0	1.3	3.6	5.5	5.6	5.3	4.0	3.8
	45	6.240	0.0	3.1	19	0.1	0.0	1.2	4.9	2.1	7.6	7.9	6.2	1.5
	65	5.78	0.0	1.2	15	0.0	0.0	1.3	4.8	5.8	6.8	6.5	5.5	2.6
	82	4.46	0.0	0.7	10	0.15	0.0	0.5	2.5	3.9	4.7	5.0	4.0	2.6
			0.0	8.1	68	8.61	0.0	4.4	15.8	17.3	24.7	24.7	19.7	10
		27.91							111.0					

Source: Conducted with assistance of Building Research Center-Baghdad and (Qadir;1990) approach.

Table .A3-10: The solar gain for the walls of the *musalla* and drum of the dome. kWh.

Orient	Area m^2	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10°	17.2	10.5	13.1	16.5	21.1	27.2	31.1	29.4	23.5	18.0	13.9	12.3	9.4
100°	25.2	39.5	47.1	55.3	61.3	66.8	72.9	72.2	70.1	65.1	54.8	44.6	35.8
190°	7.2	20.9	21.9	19.8	17.8	14.8	13.7	14.5	17.5	21.7	23.7	23.2	19.9
280°	25.2	29.1	36.9	46.7	56.8	65.5	72.4	70.9	65.5	56.5	43.7	33.1	25.9
	74.8	100.0	119.0	138.4	155.7	174.3	190.4	187.0	176.6	161.3	136.1	113.2	91.0
				717.3			1025.4						

$U = 5.6\ m^2 °C$

Table.A3-11-The solar gain of the windows including the windows of the dome drum after the correction of the window areas from 30% to 20% of the area of the *musalla* and shifting them to face the *qibla*, kwh.

Orient	Area m^2	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10°	9.2	5.52	7.8	9.8	11.3	14.5	16.7	15.73	19.3	10.12	7.5	6.62	5.1
100°	1.2	1.9	2.2	2.63	2.88	3.19	3.47	3.44	3.43	3.1	2.62	2.12	1.7
190°	12.8	37.12	38.91	35.2	30.2	26.24	24.32	25.6	31.0	38.53	42.11	41.22	35.33
280°	1.2	1.4	1.75	2.22	2.68	3.12	3.44	3.37	3.12	2.69	2.09	1.57	1.24
Total	24.2	45.94	49.86	49.1	47.1	47.1	95.0	48.14	56.9	54.0	54.32	51.5	43.4
			286.9				355.46						

Source: Qadir;op.cit

Table .A3-12 The heat flow through the windows by conduction before and after decreasing their areas of them from %30 to %20 of the area of the *musalla*. kWh/sq.m

Area	Heat loss								Heat gain			
m^2	N	D	J	F	M	A	M	J	J	A	S	O
74.8	15.0	64.0	85.0	61.0	22.0	0	33.0	80.0	90.0	94.0	50.0	-
	247.0						347.0					

Area	Heat loss								Heat gain			
m^2	N	D	J	F	M	A	M	J	J	A	S	O
24.9	4.88	30.9	21.8	20.0	7.1	-	10.7	26.1	29.3	30.5	16.35	-
	80.7						112.95					

Source: Qadir,op.cit.

Table.A3-13: Heat gain mean of 1 sq.m through the windows, kWh/sq.m°C.

Orient	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10°	0.6	0.76	0.97	1.23	1.58	1.81	1.71	2.1	1.1	0.81	0.72	0.55
100°	1.57	1.87	2.19	2.4	2.65	2.89	2.87	2.78	2.58	2.18	1.77	1.42
190°	2.9	3.04	2.75	2.36	2.05	1.9	2.0	2.43	3.01	3.29	3.22	2.76
280°	1.16	1.46	1.85	2.23	2.60	2.87	2.81	2.6	2.24	1.74	1.71	1.03

Source: Qadir'op.cit.

Table.A3-14: Heat flow mean through 1sq.m by conduction through the windows kWh/sq.m

Qg=A.U.(teo-tei)

Area	Heat loss							Heat gain			
M^2	N	D	J	F	M	A	M	J	J	A	S	O
Per M^2	0.20	0.86	1.14	0.82	0.29	-	0.44	1.07	1.20	1.25	0.67	-

Table.A3-15: Heat flow mean through 1sq.m by convection through the walls, kWh/sq.m/day

Qg=A.U.(teo-tai)

Orientn	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
10°	0.03	0.30	0.36	0.24	0.47	-	0.25	0.48	0.56	0.52	0.32	0.03
100°	-	0.26	0.31	0.18	-	-	0.31	0.54	0.62	0.59	0.41	0.10
190°	-	0.19	0.23	0.02	-	-	0.27	0.49	0.58	0.58	0.44	0.08
280°	-	0.29	0.33	0.20	-	-	0.30	0.54	0.62	0.59	0.39	0.6

Table.A3-16: Heat flow mean through 1 sq.m of the roof, kWh/sq.m/day.

Qg=A.u.(teo-tei)

Area	Heat loss							Heat gain			
M^2	N	D	J	F	M	A	M	J	J	A	S	O
1	0.08	0.38	0.43	0.31	0.08	-	0.46	0.56	0.66	0.61	0.37	-

Source:Al-Riahi;1985

Table.A3-17: Heat flow mean through 1sq.m of the dome, kWh/sq.m/day.

U=306 W/m²°C

Orientn	Slope	Area	Heat loss (-)						Heat gain (+)					
			N	D	J	F	M	A	M	J	J	A	S	O
North	30o	1	0.12	0.58	0.57	0.46	0.17	0	0.38	0.89	0.87	0.87	2.5	0
	45o	1	0.11	0.58	0.45	0.30	0.11	0	0.35	0.79	0.85	0.69	0.43	0
	65o	1	0.12	0.50	0.67	0.47	0.18	0	0.28	0.77	0.8	0.74	0.44	0
	82o	1	0135	0.56	0.67	0.47	0.16	0	0.27	0.63	0.76	0.74	0.43	0
West & east	30o	1	0.12	0.58	0.67	0.46	0.04	0	0.47	0.87	1.03	0.94	2.98	0
	45o	1	0.11	0.38	0.67	0.49	0.08	0	0.43	0.83	0.95	0.89	0.58	0.02
	65o	1	0.12	0.58	0.59	0.37	0.05	0	0.44	0.82	0.93	0.88	0.63	0.018
	82o	1	0.49	0.56	0.63	0.40	0.034	0	0.81	0.94	0.89	0.56	0.03	0.07
South	30o	1	0.05	0.58	0.60	0.36	0	0	0.53	0.94	1.18	1.01	0.67	0.09
	45o	1	0	0.49	0.53	0.29	0	0	0.46	0.85	0.98	1.01	0.69	0.14
	65o	1	0	0.05	0.05	0.03	0	0	0.06	0.08	0.096	0.095	0.07	0.018
	82o	1	0	0.36	0.43	0.27	0	0	0.47	0.74	0.96	0.87	0.63	0.20

Source:Qadir;1990.

APPENDIX B

Table B-1 Classification based on solar radiation factors for common materials in Baghdad used for finishing, taking into consideration their nature and surface texture.

Color of Finishing	Very Light >0.70	Light 0.70-0..50	Medium 0.49-0.30	Dark 0.29-0.20	Very Dark <0.20
Smooth Surface(Cladding with sand cement mortar)covered with emulsion paints	0.82	0.63	0.45	0.27	0.12
Facing Materials	*	*	0.41	0.23	0.16
Roofing and Roof finishing Materials	*	0.60	0.39	0.25	0.15
Rough Surfaces Covered (Fine)with emulsion Paints	0.71	0.58	0.44	*	0.12
(Medium)	0.70	0.56	0.42	*	0.09
(Rough)	0.70	0.52	0.40	*	0.07
	0.74	0.60	0.42	0.25	0.12

*Can be considered as average Values.
Source: Thermal Specifications for Building Materials in Iraq; op.cit.., p.32.

Table B-2 Physical specifications of commonly used materials for wall furnishings in Baghdad.

Finishing Materials	Luminance %	Purity %	Wave Length (nm)
Light Yellow Brick	65	32	583
Ordinary Bricks	55	20	560
Yellow Cement Bricks	54	24	545
Grey Cement Bricks	26.6	4	520
Concrete Blocks	58	5	540
Concrete Wall (Fine Gravel)	60.3	4	500
Cement Wall (Coarse Gravel)	63.3	25	498
Stone	72	16	587
Black White Marble	71	47	467
Black Marble	32.8	2	500
Facing Ceramic Tiles:			
Green	65	26	540
Red	15	-	497
Yellow	12.5	-	499
Orange	9.7	-	496
Brown	4.4	-	503
Light Brown	9	-	501

Source: Thermal Specifications for Building Materials in Iraq

Table B.3 A comparison among the common types of roofs and walls in Baghdad.

		Maximum Heat Flow Rate (W/sq.m) (Steady			)(	Unsteady			)
Construction	**U-Value W/sq.m**	**S**	**E**	**N**	**W**	**S**	**E**	**N**	**W**
Wall A	2.14	57.	64.	45.	88. 36	36.	40.	33.	48.
= B	1.63	78	41	37	57. 32	89	45	41	71
= C	1..96	44.	49.	34.	80. 95	23.	27.	12.	29.
= D	1..90	01	06	56	78. 47	80	43	60	99
= E	1. 47	52.	59.	41.	60. 71	32.	36.	29.	42.
= F	1. 17	92	00	55	48. 32	18	02	26	67
= G	0. 87	51.	57.	40.	35. 72	29.	33.	27.	39.
= H	0. 58	30	19	28	27. 92	94	67	25	33
		39.	44.	31.		20.	23.	18.	24.
		69	25	16		64	89	81	87
		31.	35.	24.		19.	21.	17.	24.
		59	22	80		55	53	55	92
		23.	26.	18.		12.	14.	11.	15.
		36	04	34		54	32	33	31
		18.	20.	14.		9. 94	11.	9. 0	12.
		25	35	33			29	0	17
Roof A	3.75	158.25				127.88			
= B	3.14	132.51				98.28			
= C	2.34	98.75				55.93			
= D	0.61	25.91				12.46			
= E	0.99	41.78				20.49			
= F	1.57	66.09				33.67			
= G	1.64	69.33				38.61			

See figs.B.2, B.3. for walls and roof types.

Source: Wasim Y;1984..

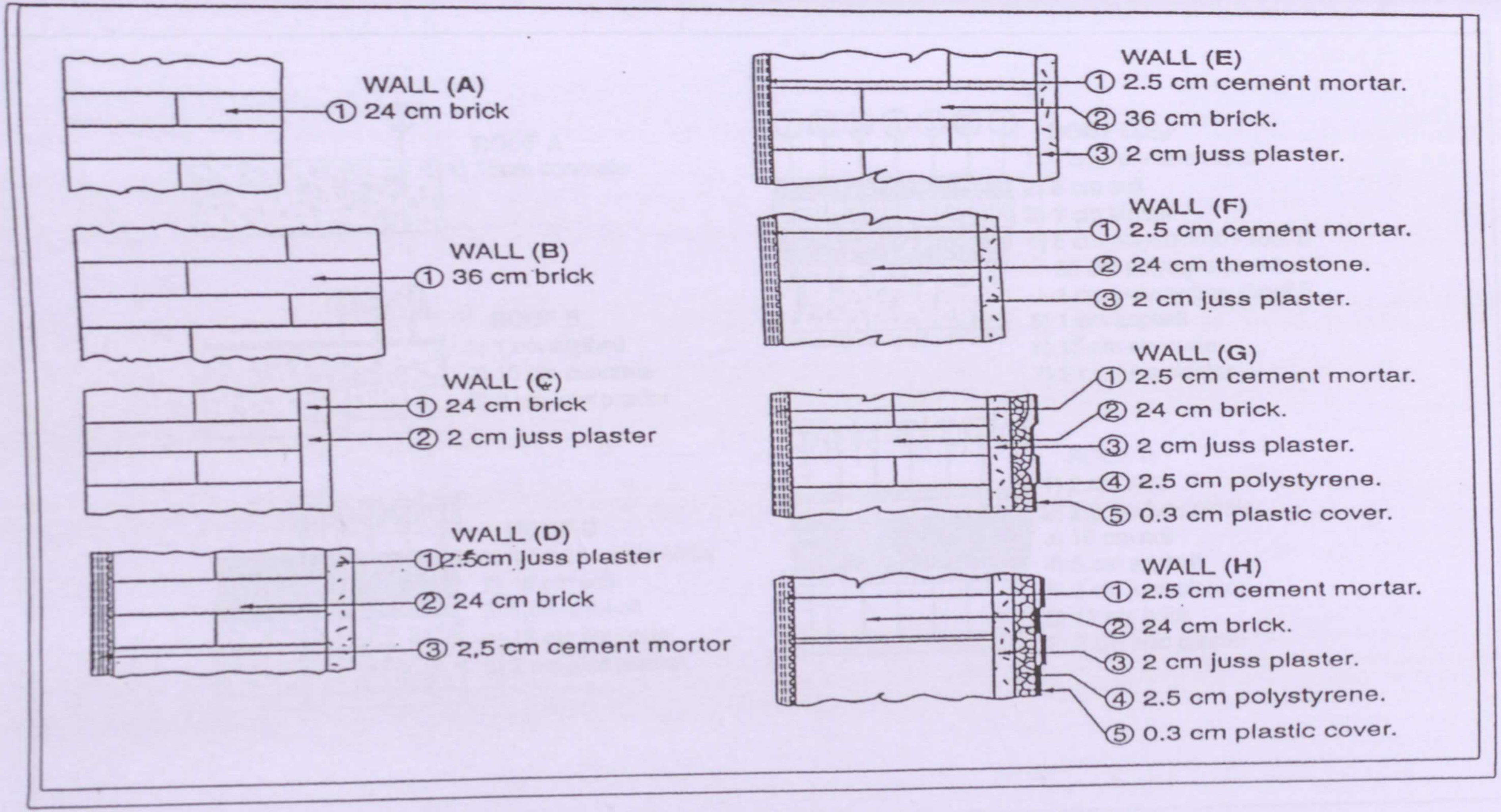


Fig.B.2 Common typical wall sections used in Baghdad. Source; Wasim Y:1984.

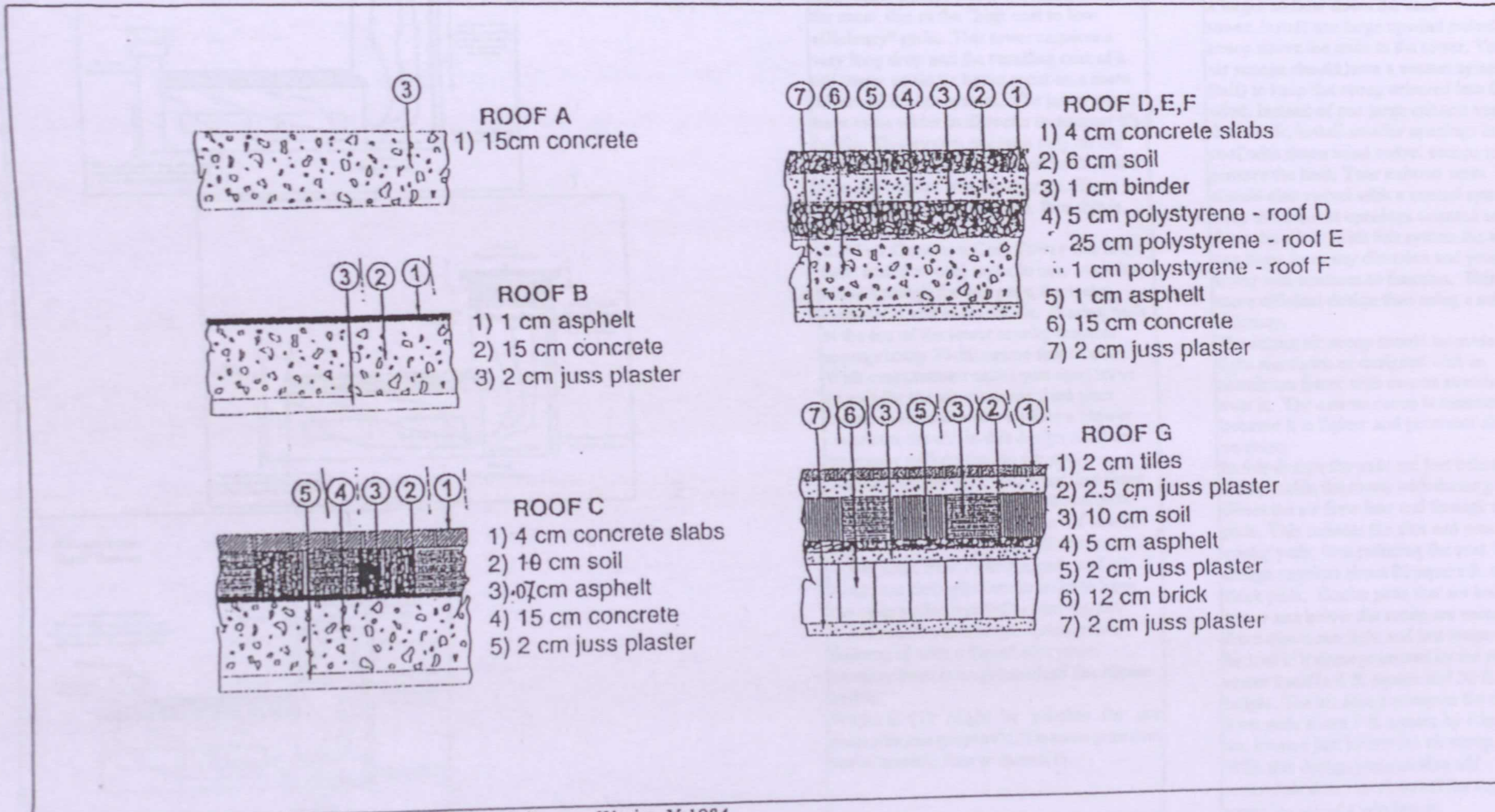
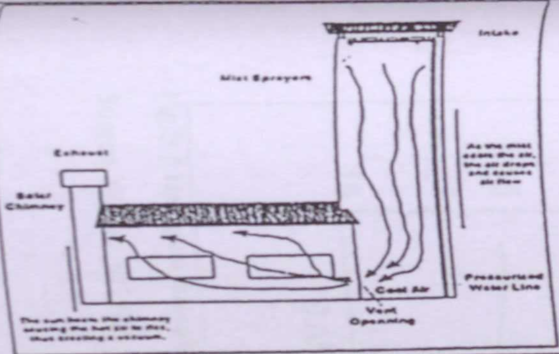


Fig B.3 Common typical roof sections used in Baghdad. Source; Wasim Y:1984.



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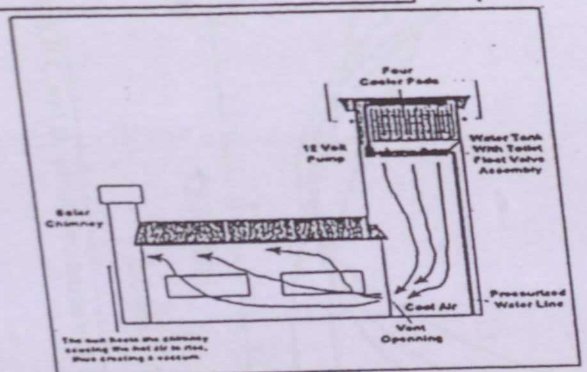

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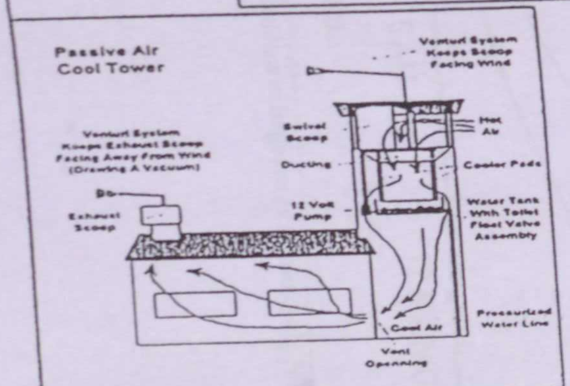

3

1.Basic Cool Tower Design; this is the most basic design and is not recommend for most, due to the "high cost to low efficiency" ratio. This tower requires a very long drop and the resulting cost of a tall tower could be better spent on a more advanced design system. The tower would have to be wider in diameter to support it's height. This system operates only on the Buoyancy Principle described in Ch.4 and does not require wind to operate. If you live in an area with no wind, then this is the tower for you.

2.;Most Common Cool Tower this is the most common cool tower in use. As wind blows through the wet pads, the water evaporates and cools the air. Placing pads at the top of the tower usually requires appropriately 70-80 square feet of pads. With evaporative coolers you must leave an exit for the air to escape from your house. In normal water coolers a blower circulates the air, in this design wind and buoyancy will do the job for you.

Standard cooler pads will work, but there are better, more efficient pads available that have less wind resistance. Of course these higher quality pads will cost more. Water must flow down the pads and air must pass through them in order to have the evaporation needed to cool the air. Vents must have a larger opening than those used with a forced air system because there is no pressurized fan blower in this.

Proposal (1) might be suitable for our *mussalla* ,but proposal (3) is more practical and economic than proposal(1).

3.Advance Cool Tower Design; to create a larger airflow down the cool tower, install one large upwind swivel scoop above the pads in the tower. Your air scoops should have a venturi system (tail) to keep the scoop oriented into the wind. Instead of one large exhaust vent for the hot air, install smaller openings in the roof with down wind swivel scoops to remove the heat. Your exhaust vents should also swivel with a venturi system to keep the exhaust openings oriented away from the wind. With this system the wind can blow from any direction and your cool tower will continue to function. This is a more efficient design than using a solar chimney.

The intake air scoop should be made out of light aluminum or designed with an aluminum frame with canvas stretched over it. The canvas scoop is recommended because it is lighter and generates almost no noise.

In this design the pads are just below the scoop inside the tower with ducting to direct the air flow into and through the pads. This reduces the size and area of the cooler pads, thus reducing the cost. This design requires about 20 square ft. of 4 in. thick pads. Cooler pads that are inside the tower and below the scoop are protected from direct sun light and last longer due to lack of UV damage caused by the sun. The tower itself is 6 ft. square and 30 ft. in height. The air scoop occupies the top 4 ft. Two pads about 3 ft. square by 4 in. thick are located just below the air scoop.

With this design you can also add removable doors to close off the top of the tower incase of a windstorm.

Fig.B.4 Development of the Mechanism of the traditional "*Badgir*" concept "air tunnel" which used in the traditional building in Baghdad. Source; http: Basic Cool Tower Design, An Article Donated By:Tom Elliot.

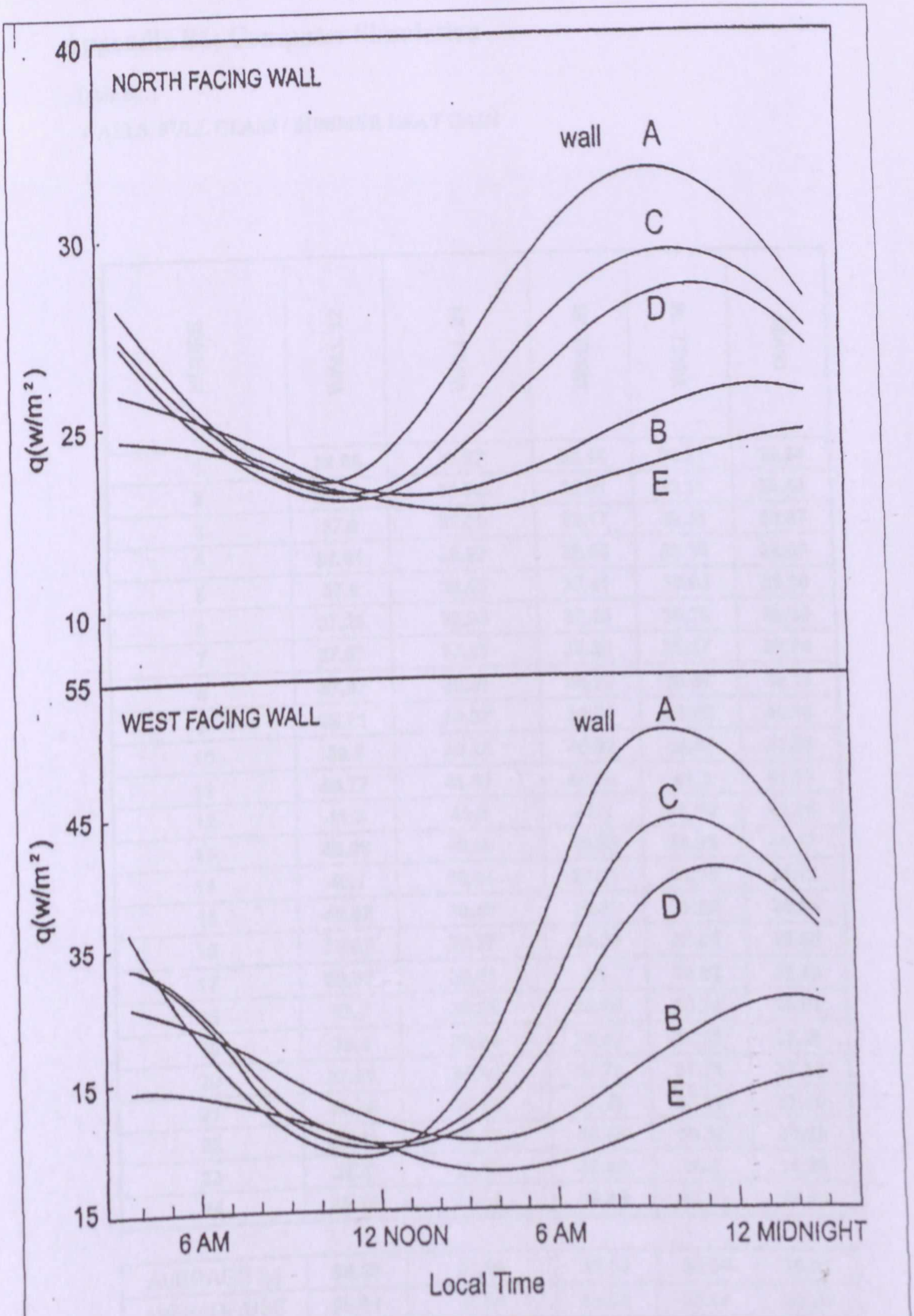

Fig.B.5 Heat gain through A,B,C and D various common wall sections in Baghdad as shown in Fig.B.2.

Source; Wasim Y:1984.

Appendix B1; Computer Simulation

Table B1.1

WALLS, FULL GLASS / SUMMER HEAT GAIN

HOURS	WALL 12	WALL 24	WALL 36	WALL 48	cavity
1	36.66	37.97	38.14	38.21	38.34
2	37.57	38.94	39.01	39.11	39.44
3	37.8	39.09	39.17	39.31	39.67
4	37.81	38.97	39.08	39.26	39.63
5	37.6	38.65	38.81	39.03	39.36
6	37.25	38.05	38.45	38.71	38.96
7	37.07	37.93	38.28	38.57	38.74
8	37.67	38.31	38.66	38.97	39.11
9	38.71	39.37	39.54	39.88	40.16
10	39.8	40.28	40.32	40.67	41.07
11	40.77	41.01	40.94	41.3	41.76
12	41.3	41.3	41.2	41.56	41.95
13	40.99	40.58	40.55	40.92	41.17
14	40.1	39.64	39.64	39.98	40.12
15	40.02	39.48	39.51	39.82	39.85
16	39.83	39.27	39.28	39.55	39.53
17	39.57	39.01	39	39.23	39.18
18	39.2	38.65	38.64	38.74	38.61
19	38.4	38.04	38.12	38.23	38.21
20	37.61	37.64	37.73	37.71	37.52
21	36.78	36.98	37.21	37.33	37.15
22	35.91	36.59	36.86	36.82	36.53
23	35.2	35.93	36.48	36.5	36.26
24	35.13	36.11	36.48	36.51	36.41

AVERAGE 24	38.28	38.66	38.80	39.00	39.11
AVERAGE/USE	38.81	38.84	38.93	39.14	39.23

Note; See the graphs of the following Tables with further details in Chapter Six.

Table B1.2

WALLS;
FULL GLASS
WINTER

HOURS	WALL 12	WALL 24	WALL 36	WALL 48	cavity
1	15.02	17.08	17.96	18.21	17.99
2	14.98	17.06	18.02	18.31	18.09
3	17.17	19.32	19.97	20.31	20.51
4	19.01	21.02	21.4	21.8	22.34
5	20.24	21.9	22.21	22.66	23.29
6	21.01	22.12	22.4	22.9	23.52
7	21.35	22.16	22.4	22.92	23.53
8	22.28	22.47	22.65	23.19	23.76
9	23.36	23.45	23.39	23.94	24.58
10	24.21	23.82	23.71	24.22	24.82
11	24.06	23.58	23.38	23.87	24.44
12	22.07	21.37	21.44	21.89	22.01
13	21.38	20.99	20.87	21.26	21.26
14	21.02	20.69	20.66	21	21.01
15	20.44	20.48	20.48	20.77	20.78
16	20.1	20.24	20.29	20.54	20.55
17	19.54	19.96	20.08	20.29	20.29
18	19.15	19.63	19.81	20.01	20
19	18.49	19.25	19.51	19.69	19.67
20	17.88	18.72	19.19	19.37	19.32
21	17.26	18.39	18.87	19.06	18.98
22	16.64	18.01	18.56	18.77	18.65
23	16.03	17.62	18.27	18.49	18.34
24	15.44	17.25	17.99	18.24	18.06
AVERAGE 24	19.51	20.27	20.56	20.90	21.07
AVERAGE/USE	19.77	20.33	20.54	20.85	20.99

Table B1.3

WALLS
HALF GLASS
SUMMER

HOURS	WALL 12	WALL 24	WALL 36	WALL 48	cavity
1	35.21	36.3	36.24	36.05	36.37
2	35.46	36.66	36.64	36.63	37.04
3	35.64	36.77	36.77	36.73	37.15
4	35.67	36.66	36.7	36.7	37.11
5	35.6	36.46	36.54	36.57	36.95
6	35.43	36.21	36.34	36.41	36.73
7	35.34	36.07	36.24	36.33	36.6
8	35.56	36.24	36.42	36.51	36.78
9	36.25	36.64	36.78	37.02	37.34
10	36.98	37.25	37.16	37.36	37.69
11	37.71	37.57	37.49	37.68	38.06
12	38.1	37.85	37.7	37.89	38.29
13	38.15	37.68	37.48	37.66	38.03
14	38.16	37.41	37.08	37.35	37.65
15	38.15	37.29	37.08	37.19	37.41
16	38.13	37.25	36.98	37.06	37.22
17	38.04	37.19	36.88	36.89	37.03
18	37.86	37.07	36.71	36.68	36.81
19	37.58	36.91	36.52	36.44	36.55
20	37.2	36.65	36.31	36.19	36.28
21	36.48	36.38	36.11	35.96	36.02
22	35.77	36.09	35.92	35.74	35.78
23	35.03	35.78	35.73	35.54	35.56
24	34.71	35.68	35.75	35.57	35.58

AVERAGE 24	36.59	36.75	36.65	36.67	36.92
AVERAGE/USE	37.19	36.95	36.76	36.79	37.01

Table B1.4

WALLS
HALFGLASS
WINTER

HOURS	WALL 12	WALL 24	WALL 36	WALL 48	cavity
1	15.12	16.84	17.33	17.59	17.67
2	14.84	16.74	17.34	17.63	17.7
3	15.63	17.69	18.22	18.58	18.83
4	16.4	18.33	18.81	19.23	19.62
5	17.1	18.55	19.04	19.5	19.91
6	17.68	18.65	19.1	19.61	20.05
7	18.04	18.64	19.03	19.58	20
8	18.82	18.81	19.11	19.69	20.08
9	19.78	19.39	19.39	19.97	20.37
10	20.45	19.74	19.66	20.22	20.65
11	20.61	19.79	19.57	20.09	20.52
12	19.97	18.98	18.72	19.26	19.53
13	19.76	18.84	18.55	18.99	19.23
14	19.49	18.78	18.47	18.83	19.04
15	19.19	18.73	18.42	18.72	18.92
16	18.9	18.64	18.37	18.61	18.82
17	18.56	18.51	18.3	18.5	18.71
18	18.24	18.32	18.19	18.37	18.57
19	17.88	18.12	18.06	18.22	18.41
20	17.36	17.9	17.91	18.07	18.24
21	16.99	17.67	17.76	17.92	18.07
22	16.4	17.42	17.6	17.77	17.9
23	16	17.17	17.45	17.64	17.73
24	15.39	16.91	17.3	17.51	17.58

AVERAGE 24	17.86	18.30	18.40	18.75	19.01
AVERAGE/USE	18.24	18.43	18.42	18.74	19.00

Table B1.5
ROOF / SUMMER
HEAT GAIN

HOURS	flat roof	pitch roof insulation 2in	pitch roof insulation 6 in	Pitch conc. Slab 30 degree
1	37.97	37.5	37.55	38.07
2	38.94	38.56	38.73	39.01
3	39.09	38.84	38.95	39.16
4	38.97	38.92	38.98	39.06
5	38.65	38.79	38.78	38.76
6	38.05	38.53	38.44	38.19
7	37.93	38.44	38.26	38.07
8	38.31	39.12	38.63	38.43
9	39.37	40.2	39.74	39.41
10	40.28	41.29	40.78	40.27
11	41.01	42.19	41.67	40.96
12	41.3	42.57	42.04	41.22
13	40.58	42.19	41.67	40.53
14	39.64	40.91	40.49	39.59
15	39.48	40.68	40.28	39.45
16	39.27	40.31	39.96	39.26
17	39.01	39.74	39.6	39.03
18	38.65	39.35	38.98	38.7
19	38.04	38.57	38.35	38.15
20	37.64	37.83	37.67	37.78
21	36.98	37.1	36.99	37.17
22	36.59	36.35	36.3	36.79
23	35.93	35.69	35.62	36.19
24	36.11	35.72	35.71	36.23

AVERAGE 24	38.66		38.92
AVERAGE/USE	38.84		39.28

2 inch insulation

CLAY TILE 1 CELL - 3 IN
E3 - 3 / 8 IN FELT AND MEMBER
B6 - 2 IN DENSE INSULATION
AIRSPACE - SLOPE DOWN
E4 - CEILING AIRSPACE
BLBD - GYPSUM PLASTER 1 / 2
BLBD - GYPSUM PLASTER 1 / 2

6 inch insulation

CLAY TILE 1 CELL - 3 IN
E3 - 3 / 8 IN FELT AND MEMBER
B6 - 2 IN DENSE INSULATION
B6 - 2 IN DENSE INSULATION
B6 - 2 IN DENSE INSULATION
AIRSPACE - SLOPE DOWN
E4 - CEILING AIRSPACE
BLBD - GYPSUM PLASTER 1 / 2
BLBD - GYPSUM PLASTER 1 / 2

Table B1.6

ROOF
WINTER

HOURS	Flat roof	pitch roof insulation 2in	pitch roof insulation6 in	Pitch conc. slab30 degree
1	17.08	15.47	15.87	16.91
2	17.06	15.43	15.86	16.89
3	19.32	17.55	18.08	19.04
4	21.02	19.44	19.94	20.67
5	21.9	20.6	21.11	21.52
6	22.12	21.21	21.5	21.73
7	22.16	21.33	21.74	21.77
8	22.47	21.96	22.38	22.07
9	23.45	22.98	23.42	22.91
10	23.82	23.75	24.21	23.49
11	23.58	23.49	23.95	23.17
12	21.37	21.18	21.66	21.03
13	20.99	20.4	20.89	20.64
14	20.69	20.12	20.61	20.36
15	20.48	19.82	20.3	20.14
16	20.24	19.54	19.98	19.91
17	19.96	19.23	19.64	19.64
18	19.63	18.87	19.24	19.33
19	19.25	18.32	18.65	18.97
20	18.72	17.94	18.27	18.59
21	18.39	17.32	17.66	18.21
22	18.01	16.93	17.28	17.83
23	17.62	16.3	16.67	17.46
24	17.25	15.92	16.31	17.1

AVERAGE 24	20.27		19.80
AVERAGE/USE	20.33		19.93

This specifications concern also the Previous Table

Pitch conc. slab30 degree slope

CLAY TILE 1 CELL - 3 IN
E3 - 3 / 8 IN FELT AND MEMBER
B6 - 2 IN DENSE INSULATION
B6 - 2 IN DENSE INSULATION
B6 - 2 IN DENSE INSULATION
AIRSPACE - SLOPE DOWN
E4 - CEILING AIRSPACE
CONCRETE SLAB 6 IN
BLBD - GYPSUM PLASTER 1 / 2
BLBD - GYPSUM PLASTER 1 / 2

APPENDIX B2

BLAST Program

```
HBLC) 667 359 25
bag 21minus                                     1 01JAN 31DEC 1 M M
REPORT FILE FROM 01Jan THRU 31Dec
A-JUN-BAGHDAD
 10  12  16  22  28  33  34  34  30  24  17  11
   0
 1  1  0  2  0  0
BAG 21MINUS                                     33.00  -44.00 21
A-JUN-BAGHDAD                                  WEEKDAY   21jun  38.00
21.00  20.00   99351.00     3.50 315.00     1.10
akeel roof                                     2  6
C12 - 2 IN HW CONCRETE
CONCRETE - SAND AND GRAVEL 4 IN
B4 - 3 IN INSULATION
B4 - 3 IN INSULATION
SDNG - ASPHALT INS 1 / 2 IN
C13 - 6 IN HW CONCRETE
akeel24                                        1  4
PLASTER - CEMENT SA 3 / 4 IN
BRICK - COMMON 8 IN
PLASTER - GYPSUM LWA 1 / 2 IN
PLASTER - GYPSUM LWA 1 / 2 IN
Building #1           190.00  1 3  36 0 0


BEGIN INPUT;
   RUN CONTROL:
     NEW ZONES,
     NEW AIR SYSTEMS,
     PLANT,
     REPORTS(FANGER,ANNUAL COMFORT REPORT,96),
     UNITS(IN = METRIC, OUT = METRIC);
     TEMPORARY LOCATION:
       BAG 21MINUS
         = (LAT=33.00,LONG=-44.00,TZ=21);
     END;
     TEMPORARY DESIGN DAYS:
       A-JUN-BAGHDAD
         = (HIGH=38.00,LOW=21.00,WB=20.00,DATE=21jun,PRES=99351.00,
             WS=3.50,DIR=315.00,CLEARNESS=1.10,WEEKDAY        );
     END;
     TEMPORARY WALLS:
       AKEEL WALL36
         = (PLASTER - CEMENT SA 3 / 4 IN,
             BRICK - COMMON 4 IN,
             BRICK - COMMON 8 IN,
             PLASTER - GYPSUM SA 1 / 2 IN,
             PLASTER - GYPSUM SA 1 / 2 IN);
     END;
     TEMPORARY ROOFS:
       akeel roof
         = (C12 - 2 IN HW CONCRETE,
             CONCRETE - SAND AND GRAVEL 4 IN,
             B4 - 3 IN INSULATION,
```

```
      B4 - 3 IN INSULATION,
      SDNG - ASPHALT INS 1 / 2 IN,
      C13 - 6 IN HW CONCRETE);
  END;
  PROJECT="mosque
                                   (HBLC)  667  359 ";
  LOCATION=bag 21minus                                   ;
  DESIGN DAYS=A-JUN-BAGHDAD                                 ;
  GROUND TEMPERATURES=(10.00,12.00,16.00,22.00,28.00,33.00,34.00,
      34.00,30.00,24.00,17.00,11.00);
BEGIN BUILDING DESCRIPTION;
  BUILDING="Building #1";
    NORTH AXIS=190.00;
    SOLAR DISTRIBUTION=0;
    ZONE 1 "Zone 1":
      ORIGIN:(23.10,13.11,0.00);
      NORTH AXIS =0.00;
      EXTERIOR WALLS:
        STARTING AT(0.00,0.00,0.00)
        FACING(180.00)
        TILTED(90.00)
        AKEEL WALL36(22.00 BY 6.00)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(2.00 BY 0.70)
            REVEAL(0.00)
            AT (17.00,2.10)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(2.20 BY 0.70)
            REVEAL(0.00)
            AT (2.00,2.10)
          WITH DOORS OF TYPE
          HOLLOW WOOD DOOR(2.00 BY 2.00)
            REVEAL(0.00)
            AT (17.00,0.10)
          WITH DOORS OF TYPE
          HOLLOW WOOD DOOR(2.00 BY 2.00)
            REVEAL(0.00)
            AT (9.50,0.10)
          WITH DOORS OF TYPE
          HOLLOW WOOD DOOR(2.20 BY 2.00)
            REVEAL(0.00)
            AT (2.00,0.00)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(0.70 BY 1.00)
            REVEAL(0.00)
            AT (9.50,2.90)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(0.70 BY 1.10)
            REVEAL(0.00)
            AT (10.80,2.90)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(1.10 BY 3.90)
            REVEAL(0.00)
            AT (7.50,0.00)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(1.10 BY 3.90)
            REVEAL(0.00)
```

```
    AT (7.50,0.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (12.20,0.00),
STARTING AT(22.00,0.00,0.00)
FACING(90.00)
TILTED(90.00)
AKEEL WALL36(11.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (4.00,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (6.30,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(0.70 BY 1.00)
    REVEAL(0.00)
    AT (5.40,4.50)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (6.30,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (6.30,4.90),
STARTING AT(22.00,11.10,0.00)
FACING(0.00)
TILTED(90.00)
AKEEL WALL36(10.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.40,4.80)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (4.40,0.70),
STARTING AT(11.90,11.10,0.00)
FACING(90.00)
TILTED(90.00)
AKEEL WALL36(1.50 BY 6.50),
STARTING AT(11.90,12.60,0.00)
FACING(0.00)
TILTED(90.00)
AKEEL WALL36(1.80 BY 6.50),
STARTING AT(10.10,12.60,0.00)
FACING(270.00)
```

```
    TILTED(90.00)
    AKEEL WALL36(1.50 BY 6.50),
    STARTING AT(10.10,11.10,0.00)
    FACING(0.00)
    TILTED(90.00)
    AKEEL WALL36(10.10 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.10)
        REVEAL(0.00)
        AT (4.70,0.60)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.20 BY 0.60)
        REVEAL(0.00)
        AT (4.70,4.90),
    STARTING AT(0.00,11.10,0.00)
    FACING(270.00)
    TILTED(90.00)
    AKEEL WALL36(11.10 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (3.30,0.40)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (6.40,0.40)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 0.60)
        REVEAL(0.00)
        AT (3.40,4.80)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 0.60)
        REVEAL(0.00)
        AT (6.40,4.80)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(0.70 BY 1.00)
        REVEAL(0.00)
        AT (5.10,4.40);
  SLAB ON GRADE FLOORS:
    STARTING AT(0.00,0.00,0.00)
    FACING(90.00)
    TILTED(180.00)
    SLAB FLOOR(15.70 BY 15.70);
  ROOFS:
    STARTING AT(0.00,0.00,10.00)
    FACING(180.00)
    TILTED(0.00)
    akeel roof(15.70 BY 15.70);
  RELATIVE VELOCITY= 0.137 ,Constant,
    FROM 01JAN THRU 31DEC;
  RELATIVE HUMIDITY= 0.5 ,Constant,
    FROM 01JAN THRU 31DEC;
  METABOLIC RATE= 1 ,Constant,
    FROM 01JAN THRU 31DEC;
  WORK EFFICIENCY= 0 ,Constant,
    FROM 01JAN THRU 31DEC;
  CLOTHING INSULATION= 1 ,Constant,
    FROM 01JAN THRU 31DEC;
END ZONE;
```

```
  END BUILDING DESCRIPTION;
 END INPUT;


BEGIN INPUT;
  RUN CONTROL:
    NEW ZONES,
    NEW AIR SYSTEMS,
    PLANT,
    REPORTS(FANGER,ANNUAL COMFORT REPORT,96),
    UNITS(IN = METRIC, OUT = METRIC);
    TEMPORARY LOCATION:
      BAG 21MINUS
        = (LAT=33.00,LONG=-44.00,TZ=21);
    END;
    TEMPORARY DESIGN DAYS:
      A-JUN-BAGHDAD
       = (HIGH=38.00,LOW=21.00,WB=20.00,DATE=21jun,PRES=99351.00,
          WS=3.50,DIR=315.00,CLEARNESS=1.10,WEEKDAY        );
    END;
    TEMPORARY WALLS:
      akeel 12
        = (PLASTER - CEMENT SA 3 / 4 IN,
           BRICK - COMMON 4 IN,
           PLASTER - GYPSUM LWA 1 / 2 IN,
           PLASTER - GYPSUM LWA 1 / 2 IN);
    END;
    TEMPORARY ROOFS:
      akeel roof
        = (C12 - 2 IN HW CONCRETE,
           CONCRETE - SAND AND GRAVEL 4 IN,
           B4 - 3 IN INSULATION,
           B4 - 3 IN INSULATION,
           SDNG - ASPHALT INS 1 / 2 IN,
           C13 - 6 IN HW CONCRETE);
    END;
    PROJECT="mosque
                                          (HBLC)  667  359 ";
    LOCATION=bag 21minus                                  ;
    DESIGN DAYS=A-JUN-BAGHDAD                                ;
    GROUND TEMPERATURES=(10.00,12.00,16.00,22.00,28.00,33.00,34.00,
        34.00,30.00,24.00,17.00,11.00);
  BEGIN BUILDING DESCRIPTION;
    BUILDING="Building #1";
      NORTH AXIS=190.00;
      SOLAR DISTRIBUTION=0;
      ZONE 1 "Zone 1":
        ORIGIN:(23.10,13.11,0.00);
        NORTH AXIS =0.00;
        EXTERIOR WALLS:
          STARTING AT(0.00,0.00,0.00)
          FACING(180.00)
          TILTED(90.00)
          akeel 12(22.00 BY 6.00)
            WITH WINDOWS OF TYPE
            SINGLE PANE HW WINDOW(2.00 BY 0.70)
              REVEAL(0.00)
```

```
    AT (17.00,2.10)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(2.20 BY 0.70)
    REVEAL(0.00)
    AT (2.00,2.10)
  WITH DOORS OF TYPE
  HOLLOW WOOD DOOR(2.00 BY 2.00)
    REVEAL(0.00)
    AT (17.00,0.10)
  WITH DOORS OF TYPE
  HOLLOW WOOD DOOR(2.00 BY 2.00)
    REVEAL(0.00)
    AT (9.50,0.10)
  WITH DOORS OF TYPE
  HOLLOW WOOD DOOR(2.20 BY 2.00)
    REVEAL(0.00)
    AT (2.00,0.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(0.70 BY 1.00)
    REVEAL(0.00)
    AT (9.50,2.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(0.70 BY 1.10)
    REVEAL(0.00)
    AT (10.80,2.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 3.90)
    REVEAL(0.00)
    AT (7.50,0.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 3.90)
    REVEAL(0.00)
    AT (7.50,0.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (12.20,0.00),
STARTING AT(22.00,0.00,0.00)
FACING(90.00)
TILTED(90.00)
akeel 12(11.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (4.00,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (6.30,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(0.70 BY 1.00)
    REVEAL(0.00)
    AT (5.40,4.50)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
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```
        REVEAL(0.00)
        AT (6.30,4.90)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 0.60)
        REVEAL(0.00)
        AT (4.10,4.90)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 0.60)
        REVEAL(0.00)
        AT (6.30,4.90),
    STARTING AT(22.00,11.10,0.00)
    FACING(0.00)
    TILTED(90.00)
    akeel 12(10.10 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 0.60)
        REVEAL(0.00)
        AT (4.40,4.80)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (4.40,0.70),
    STARTING AT(11.90,11.10,0.00)
    FACING(90.00)
    TILTED(90.00)
    akeel 12(1.50 BY 6.50),
    STARTING AT(11.90,12.60,0.00)
    FACING(0.00)
    TILTED(90.00)
    akeel 12(1.80 BY 6.50),
    STARTING AT(10.10,12.60,0.00)
    FACING(270.00)
    TILTED(90.00)
    akeel 12(1.50 BY 6.50),
    STARTING AT(10.10,11.10,0.00)
    FACING(0.00)
    TILTED(90.00)
    akeel 12(10.10 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.10)
        REVEAL(0.00)
        AT (4.70,0.60)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.20 BY 0.60)
        REVEAL(0.00)
        AT (4.70,4.90),
    STARTING AT(0.00,11.10,0.00)
    FACING(270.00)
    TILTED(90.00)
    akeel 12(11.10 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (3.30,0.40)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (6.40,0.40)
      WITH WINDOWS OF TYPE
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```
        SINGLE PANE HW WINDOW(1.10 BY 0.60)
          REVEAL(0.00)
          AT (3.40,4.80)
        WITH WINDOWS OF TYPE
        SINGLE PANE HW WINDOW(1.10 BY 0.60)
          REVEAL(0.00)
          AT (6.40,4.80)
        WITH WINDOWS OF TYPE
        SINGLE PANE HW WINDOW(0.70 BY 1.00)
          REVEAL(0.00)
          AT (5.10,4.40);
    SLAB ON GRADE FLOORS:
      STARTING AT(0.00,0.00,0.00)
        FACING(90.00)
        TILTED(180.00)
        SLAB FLOOR(15.70 BY 15.70);
    ROOFS:
      STARTING AT(0.00,0.00,10.00)
        FACING(180.00)
        TILTED(0.00)
        akeel roof(15.70 BY 15.70);
    RELATIVE VELOCITY= 0.137 ,Constant,
      FROM 01JAN THRU 31DEC;
    RELATIVE HUMIDITY= 0.5 ,Constant,
      FROM 01JAN THRU 31DEC;
    METABOLIC RATE= 1 ,Constant,
      FROM 01JAN THRU 31DEC;
    WORK EFFICIENCY= 0 ,Constant,
      FROM 01JAN THRU 31DEC;
    CLOTHING INSULATION= 1 ,Constant,
      FROM 01JAN THRU 31DEC;
  END ZONE;
 END BUILDING DESCRIPTION;
END INPUT;



BEGIN INPUT;
  RUN CONTROL:
    NEW ZONES,
    NEW AIR SYSTEMS,
    PLANT,
    REPORTS(FANGER,ANNUAL COMFORT REPORT,96),
    UNITS(IN = METRIC, OUT = METRIC);
    TEMPORARY LOCATION:
      BAG 21MINUS
        = (LAT=33.00,LONG=-44.00,TZ=21);
    END;
    TEMPORARY DESIGN DAYS:
      A-JUN-BAGHDAD
        = (HIGH=38.00,LOW=21.00,WB=20.00,DATE=21jun,PRES=99351.00,
           WS=3.50,DIR=315.00,CLEARNESS=1.10,WEEKDAY        );
    END;
    TEMPORARY WALLS:
      AKEEL 48
        = (PLASTER - CEMENT SA 3 / 4 IN,
           BRICK - COMMON 8 IN,
           BRICK - COMMON 8 IN,
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        PLASTER - GYPSUM SA 1 / 2 IN,
        PLASTER - GYPSUM SA 1 / 2 IN);
  END;
  TEMPORARY ROOFS:
    akeel roof
      = (C12 - 2 IN HW CONCRETE,
        CONCRETE - SAND AND GRAVEL 4 IN,
        B4 - 3 IN INSULATION,
        B4 - 3 IN INSULATION,
        SDNG - ASPHALT INS 1 / 2 IN,
        C13 - 6 IN HW CONCRETE);
  END;
  PROJECT="mosque
                                  (HBLC)  667  359 ";
  LOCATION=bag 21minus                             ;
  DESIGN DAYS=A-JUN-BAGHDAD                           ;
  GROUND TEMPERATURES=(10.00,12.00,16.00,22.00,28.00,33.00,34.00,
      34.00,30.00,24.00,17.00,11.00);
BEGIN BUILDING DESCRIPTION;
  BUILDING="Building #1";
    NORTH AXIS=190.00;
    SOLAR DISTRIBUTION=0;
    ZONE 1 "Zone 1":
      ORIGIN:(23.10,13.11,0.00);
      NORTH AXIS =0.00;
      EXTERIOR WALLS:
        STARTING AT(0.00,0.00,0.00)
        FACING(180.00)
        TILTED(90.00)
        AKEEL 48(22.00 BY 6.00)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(2.00 BY 0.70)
            REVEAL(0.00)
            AT (17.00,2.10)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(2.20 BY 0.70)
            REVEAL(0.00)
            AT (2.00,2.10)
          WITH DOORS OF TYPE
          HOLLOW WOOD DOOR(2.00 BY 2.00)
            REVEAL(0.00)
            AT (17.00,0.10)
          WITH DOORS OF TYPE
          HOLLOW WOOD DOOR(2.00 BY 2.00)
            REVEAL(0.00)
            AT (9.50,0.10)
          WITH DOORS OF TYPE
          HOLLOW WOOD DOOR(2.20 BY 2.00)
            REVEAL(0.00)
            AT (2.00,0.00)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(0.70 BY 1.00)
            REVEAL(0.00)
            AT (9.50,2.90)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(0.70 BY 1.10)
            REVEAL(0.00)
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    AT (10.80,2.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 3.90)
    REVEAL(0.00)
    AT (7.50,0.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 3.90)
    REVEAL(0.00)
    AT (7.50,0.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (12.20,0.00),
STARTING AT(22.00,0.00,0.00)
FACING(90.00)
TILTED(90.00)
AKEEL 48(11.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (4.00,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (6.30,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(0.70 BY 1.00)
    REVEAL(0.00)
    AT (5.40,4.50)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (6.30,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (6.30,4.90),
STARTING AT(22.00,11.10,0.00)
FACING(0.00)
TILTED(90.00)
AKEEL 48(10.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.40,4.80)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (4.40,0.70),
STARTING AT(11.90,11.10,0.00)
FACING(90.00)
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```
      TILTED(90.00)
      AKEEL 48(1.50 BY 6.50),
      STARTING AT(11.90,12.60,0.00)
      FACING(0.00)
      TILTED(90.00)
      AKEEL 48(1.80 BY 6.50),
      STARTING AT(10.10,12.60,0.00)
      FACING(270.00)
      TILTED(90.00)
      AKEEL 48(1.50 BY 6.50),
      STARTING AT(10.10,11.10,0.00)
      FACING(0.00)
      TILTED(90.00)
      AKEEL 48(10.10 BY 6.00)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(1.10 BY 4.10)
         REVEAL(0.00)
         AT (4.70,0.60)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(1.20 BY 0.60)
         REVEAL(0.00)
         AT (4.70,4.90),
      STARTING AT(0.00,11.10,0.00)
      FACING(270.00)
      TILTED(90.00)
      AKEEL 48(11.10 BY 6.00)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(1.10 BY 4.00)
         REVEAL(0.00)
         AT (3.30,0.40)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(1.10 BY 4.00)
         REVEAL(0.00)
         AT (6.40,0.40)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(1.10 BY 0.60)
         REVEAL(0.00)
         AT (3.40,4.80)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(1.10 BY 0.60)
         REVEAL(0.00)
         AT (6.40,4.80)
       WITH WINDOWS OF TYPE
       SINGLE PANE HW WINDOW(0.70 BY 1.00)
         REVEAL(0.00)
         AT (5.10,4.40);
     SLAB ON GRADE FLOORS:
      STARTING AT(0.00,0.00,0.00)
      FACING(90.00)
      TILTED(180.00)
      SLAB FLOOR(15.70 BY 15.70);
     ROOFS:
      STARTING AT(0.00,0.00,10.00)
      FACING(180.00)
      TILTED(0.00)
      akeel roof(15.70 BY 15.70);
     RELATIVE VELOCITY= 0.137 ,Constant,
      FROM 01JAN THRU 31DEC;
     RELATIVE HUMIDITY= 0.5 ,Constant,
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          FROM 01JAN THRU 31DEC;
        METABOLIC RATE= 1 ,Constant,
          FROM 01JAN THRU 31DEC;
        WORK EFFICIENCY= 0 ,Constant,
          FROM 01JAN THRU 31DEC;
        CLOTHING INSULATION= 1 ,Constant,
          FROM 01JAN THRU 31DEC;
      END ZONE;
   END BUILDING DESCRIPTION;
 END INPUT;



BEGIN INPUT;
   RUN CONTROL:
     NEW ZONES,
     NEW AIR SYSTEMS,
     PLANT,
     REPORTS(FANGER,ANNUAL COMFORT REPORT,96),
     UNITS(IN = METRIC, OUT = METRIC);
     TEMPORARY LOCATION:
       BAG 21MINUS
         = (LAT=33.00,LONG=-44.00,TZ=21);
     END;
     TEMPORARY DESIGN DAYS:
       A-JUN-BAGHDAD
        = (HIGH=38.00,LOW=21.00,WB=20.00,DATE=21jun,PRES=99351.00,
           WS=3.50,DIR=315.00,CLEARNESS=1.10,WEEKDAY        );
     END;
     TEMPORARY WALLS:
       AAKEEL CAVITY 4-8
         = (PLASTER - CEMENT SA 3 / 4 IN,
            BRICK - COMMON 4 IN,
            B1 - AIRSPACE RESISTANCE,
            BRICK - COMMON 8 IN,
            PLASTER - GYPSUM LWA 1 / 2 IN,
            PLASTER - GYPSUM LWA 1 / 2 IN);
     END;
     TEMPORARY ROOFS:
       akeel roof
         = (C12 - 2 IN HW CONCRETE,
            CONCRETE - SAND AND GRAVEL 4 IN,
            B4 - 3 IN INSULATION,
            B4 - 3 IN INSULATION,
            SDNG - ASPHALT INS 1 / 2 IN,
            C13 - 6 IN HW CONCRETE);
     END;
     PROJECT="mosque



                                 (HBLC)  667  359 ";
     LOCATION=bag 21minus                         ;
     DESIGN DAYS=A-JUN-BAGHDAD                       ;
     GROUND TEMPERATURES=(10.00,12.00,16.00,22.00,28.00,33.00,34.00,
         34.00,30.00,24.00,17.00,11.00);
   BEGIN BUILDING DESCRIPTION;
     BUILDING="Building #1";
       NORTH AXIS=190.00;
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SOLAR DISTRIBUTION=0;
ZONE 1 "Zone 1":
  ORIGIN:(23.10,13.11,0.00);
  NORTH AXIS =0.00;
  EXTERIOR WALLS:
    STARTING AT(0.00,0.00,0.00)
    FACING(180.00)
    TILTED(90.00)
    AAKEEL CAVITY 4-8(22.00 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(2.00 BY 0.70)
        REVEAL(0.00)
        AT (17.00,2.10)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(2.20 BY 0.70)
        REVEAL(0.00)
        AT (2.00,2.10)
      WITH DOORS OF TYPE
      HOLLOW WOOD DOOR(2.00 BY 2.00)
        REVEAL(0.00)
        AT (17.00,0.10)
      WITH DOORS OF TYPE
      HOLLOW WOOD DOOR(2.00 BY 2.00)
        REVEAL(0.00)
        AT (9.50,0.10)
      WITH DOORS OF TYPE
      HOLLOW WOOD DOOR(2.20 BY 2.00)
        REVEAL(0.00)
        AT (2.00,0.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(0.70 BY 1.00)
        REVEAL(0.00)
        AT (9.50,2.90)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(0.70 BY 1.10)
        REVEAL(0.00)
        AT (10.80,2.90)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 3.90)
        REVEAL(0.00)
        AT (7.50,0.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 3.90)
        REVEAL(0.00)
        AT (7.50,0.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (12.20,0.00),
    STARTING AT(22.00,0.00,0.00)
    FACING(90.00)
    TILTED(90.00)
    AAKEEL CAVITY 4-8(11.10 BY 6.00)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
        REVEAL(0.00)
        AT (4.00,0.40)
      WITH WINDOWS OF TYPE
      SINGLE PANE HW WINDOW(1.10 BY 4.00)
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```
    REVEAL(0.00)
    AT (6.30,0.40)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(0.70 BY 1.00)
    REVEAL(0.00)
    AT (5.40,4.50)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (6.30,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.10,4.90)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (6.30,4.90),
STARTING AT(22.00,11.10,0.00)
FACING(0.00)
TILTED(90.00)
AAKEEL CAVITY 4-8(10.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 0.60)
    REVEAL(0.00)
    AT (4.40,4.80)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.00)
    REVEAL(0.00)
    AT (4.40,0.70),
STARTING AT(11.90,11.10,0.00)
FACING(90.00)
TILTED(90.00)
AAKEEL CAVITY 4-8(1.50 BY 6.50),
STARTING AT(11.90,12.60,0.00)
FACING(0.00)
TILTED(90.00)
AAKEEL CAVITY 4-8(1.80 BY 6.50),
STARTING AT(10.10,12.60,0.00)
FACING(270.00)
TILTED(90.00)
AAKEEL CAVITY 4-8(1.50 BY 6.50),
STARTING AT(10.10,11.10,0.00)
FACING(0.00)
TILTED(90.00)
AAKEEL CAVITY 4-8(10.10 BY 6.00)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.10 BY 4.10)
    REVEAL(0.00)
    AT (4.70,0.60)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW(1.20 BY 0.60)
    REVEAL(0.00)
    AT (4.70,4.90),
STARTING AT(0.00,11.10,0.00)
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```
        FACING(270.00)
        TILTED(90.00)
        AAKEEL CAVITY 4-8(11.10 BY 6.00)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(1.10 BY 4.00)
            REVEAL(0.00)
            AT (3.30,0.40)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(1.10 BY 4.00)
            REVEAL(0.00)
            AT (6.40,0.40)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(1.10 BY 0.60)
            REVEAL(0.00)
            AT (3.40,4.80)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(1.10 BY 0.60)
            REVEAL(0.00)
            AT (6.40,4.80)
          WITH WINDOWS OF TYPE
          SINGLE PANE HW WINDOW(0.70 BY 1.00)
            REVEAL(0.00)
            AT (5.10,4.40);
      SLAB ON GRADE FLOORS:
        STARTING AT(0.00,0.00,0.00)
        FACING(90.00)
        TILTED(180.00)
        SLAB FLOOR(15.70 BY 15.70);
      ROOFS:
        STARTING AT(0.00,0.00,10.00)
        FACING(180.00)
        TILTED(0.00)
        akeel roof(15.70 BY 15.70);
      RELATIVE VELOCITY= 0.137 ,Constant,
        FROM 01JAN THRU 31DEC;
      RELATIVE HUMIDITY= 0.5 ,Constant,
        FROM 01JAN THRU 31DEC;
      METABOLIC RATE= 1 ,Constant,
        FROM 01JAN THRU 31DEC;
      WORK EFFICIENCY= 0 ,Constant,
        FROM 01JAN THRU 31DEC;
      CLOTHING INSULATION= 1 ,Constant,
        FROM 01JAN THRU 31DEC;
    END ZONE;
  END BUILDING DESCRIPTION;
END INPUT;
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