Impact of Heat Exchange on Building Envelope in the Hot Climates

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Abstract--The building envelope consists of both opaque and transparent parts of the walls and roof which in addition to the floor – are connected to the external environment. These may be single or multi layer, and represent the partition between the external and internal environment.

The functions of the envelope include structural, aesthetical, environmental and other tasks. The environmental function is the primary one that protects the inner environment of the building from the impact of external variations of climatic phenomena. The building envelope is subjected to climatic influences by its individual orientation and composition. The main function of the building envelope in hot climates is to minimise external heat stress. Indoor thermal control can only be achieved through understanding of the thermal performance of the building envelope in relation to relevant weather parameters. It is also becoming increasingly realised that much can be done to mitigate heat stress in unconditioned buildings and to reduce cooling and heating loads and the energy consumption of air conditioned buildings, through a proper choice of building envelope materials and envelope 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. Also, the building envelope directly influences the cooling peaks and air conditioning system capacity requirements. The thermal properties of the envelope are determined by the combination of wall mass, thermal resistance; insulation location, external surface colour, texture, and size. This study concentrates on the building envelope role in heat exchange and its characteristics and energy conservation in hot climates. The study also discusses the envelope’s response to climatic conditions, which is a major determinant of the amount of energy required to maintain thermal comfort of the inner environment.

Keywords-- building, envelope, Heat exchange, impact, hot climates

I. INTRODUCTION

As a thermal barrier, the building envelope plays a significant role in optimizing interior temperatures, the amount of energy required to maintain thermal comfort, affects the penetration of the natural lighting, and defines the heating and cooling needs of the building.

Comfortably built environments are also required for improving human productivity inside buildings. Satisfaction of the environment takes into consideration the conservation of energy criteria and improvement of internal thermal comfort, which can be achieved through proper thermal design of the building envelope. Absorptivity of the external surfaces, thermal capacity and thermal conductivity of the envelope of the building also have a profound effect on the internal environment, and in turn on the energy consumption inside the building. The location and area of glazing all affect energy consumption differently according to weather conditions. The design of the building envelope can also greatly affect infiltration rates. Understanding sustainable design strategy is to minimize heat gain through the envelope, by enhancing its design and choosing the appropriate building materials. These can be achieved mainly through:

1. Redesign of the envelope
2. Usage of alternative material
3. Usage of insulation material
4. Appropriate ventilation system
5. Shading & enhancing of surrounded microclimate
6. Optimum building orientation
7. Optimum window areas;

A study undertaken in Belgium by Verbeeck and Hens suggested a hierarchy of energy saving measures for retrofitted dwellings which involve roof and floor insulation as priorities followed by thermally better performing glazing and a more efficient heating system (G. Verebeek, H. Hens, 2005)

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

An appropriate design strategy could minimize the thermal impact; this can be achieved through protecting the building envelope from heat transfer via selection of materials & specified construction details. Based on this, desirable internal environmental comfort could be attained with minimum energy consumption.
Building envelopes contribute more than 50% of the embodied energy distribution in major elements in residential buildings (E. Gratia, A. Herde, 2007) and also contributes approximately 50–60% of their total heat gain (A. Uihlein, P. Eder, 2007, A. Utama, S.H. Gheewala, 2009). These contributions have significant influence on building performance. Also, studies have shown that building envelope materials have significantly influenced cooling load in high rises and contributed to their energy life cycle (A. Utama, S.H. Gheewala, 2009).

Double skin envelope systems have been applied to buildings to control the influence of tightly sealed envelopes on energy consumption and ventilation (Previous studies indicate that double skin envelopes contribute to energy savings (Y. Kim, S. Kim, S. Shin, J. Sohn, 2009; E. Gratia, A. Herde, 2007)).

To this end, in order to reduce energy used and its effects on the climate, several strategies are necessary, including energy demand reduction, adoption of passive system and increased energy efficiency (E. Lee, S. Selkowitz, V. Bazjanac, V. Inkarojrit, C. Kohler, 2002). In this context, the thermal energy performance of the building envelope and sustainability is significant to achieve optimal performance of buildings (Y. Kim, S. Kim, S. Shin, J. Sohn, 2009).

### TABLE 1

<table>
<thead>
<tr>
<th>Orientation of the wall</th>
<th>Most insulation economy materials thickness (cm)</th>
<th>Accepted thickness range economically (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>11</td>
<td>9-13</td>
</tr>
<tr>
<td>Northern</td>
<td>10</td>
<td>8-13</td>
</tr>
<tr>
<td>North-East</td>
<td>10</td>
<td>8-13</td>
</tr>
<tr>
<td>Eastern</td>
<td>10</td>
<td>8-12</td>
</tr>
<tr>
<td>South-East</td>
<td>9</td>
<td>8-11</td>
</tr>
<tr>
<td>Southern</td>
<td>7</td>
<td>7-10</td>
</tr>
<tr>
<td>South-West</td>
<td>10</td>
<td>8-13</td>
</tr>
<tr>
<td>Western</td>
<td>10</td>
<td>8-13</td>
</tr>
<tr>
<td>North-West</td>
<td>10</td>
<td>8-13</td>
</tr>
</tbody>
</table>

Source: Hussain; 1984

### II. AN OVERVIEW OF ENVIRONMENTAL IMPACT ON BUILDING ENVELOPE

The envelope represents the exterior surface of a building including all external additions e.g. chimneys, bay windows, etc.; it 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 internal comfort level by managing temperature and relative humidity as well reducing heating and air conditioning costs.

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 (M.T. Bomberg & W.C. 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. However, more accurate results were obtained with numerical and analytical methods considering the transient thermal behaviour of the building envelope, while some authors used a dynamic time dependent method based on the finite volume implicit procedure to compute the yearly transmission loads through the wall under steady periodic conditions (S.A. Al-Sanea, M.F. Zedan, S.A. Al-Ajljan,2005; S.A. Al-Sanea, M.F. Zedan,2002; M. Ozel,2008) ; M. Ozel,2011; S.A. Al-Sanea, M.F. Zedan, S.A. Al-Ajljan,2003, the others used an analytical method based on Complex Finite Fourier Transform N. Daouas,2011; N.Daouas, Z. Hassen, H.B. Aissia, 2010).

The thermal properties of the envelope are determined by the combination of wall mass, thermal resistance, insulation location, external surface features, and the area and location of the envelope’s transparent parts.

All of these affect energy consumption differently according to weather conditions, which greatly affects infiltration rates.

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 manage the heat flow through the envelope and enhance its thermal properties.

Building material with proper physical and constructional architectural properties with respect to radiation will contribute to controlling heat transmission through the building envelope taking in consideration avoidance of thermal bridges: “Thermal bridges are parts of the building envelope where the otherwise uniform thermal resistance are significantly changed”, e.g. at structural joints with roofs, floors, ceilings, and other walls, or other building envelope details such as corners, window or door openings (Goldberg, M. (2007)

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 and also seasonal fluctuations “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).

Besides, it is necessary to know the building envelope’s optimal sustainable performance through the incorporation of thermal energy performance indicators with other indicators such as environmental, material efficiency, economic, etc.

Moreover, studies to date have tended to focus on state level policy implications (A. Uihlein, P. Eder,2007 ; B. Tonn, J.H. Peretz,2007).

III. OPTIMISING BUILDING ENVELOPE COMPONENTS,

THERMAL COMFORT & ENERGY

The components of the envelope, which include walls, windows, doors, roofs, etc., have different effects on heat exchange, whereby heat gain through unshaded windows and roofs, represent the largest proportion of the total amount of heat gain of the building. Different types and thicknesses of walls is might improving the thermal resistance of the building envelope beside the lower U value a shorter heating period is obtained (Kalmár, 2004) fig.3. Consideration of sustainable design criteria for is also needed for a building that suitable environment in such a way that it becomes part of nature; in view of the concept of a sustainable envelope which strives to make judicious use of the surrounding resources in order to create a harmonious environment and excellent living space for the dwellers, while minimizing the environmental impacts, ecological foot-prints and reducing energy consumption in the building. The environmental function represents the main function that protects the inner environment of the building from the impact of external variations of climate. It may depend on mechanical and electrical systems—as additional elements—to reach the comfort zone when the envelope is unable to protect the inner environment from climate variations, and to achieve a thermal balance inside the building.
Buildings that stay thermally comfortable with small energy consumption are considered “low-energy buildings.” The energy consumption for space heating pr.sqm floor area has been reduced by 50% in some countries over the last 20 years. During this period the building codes have gradually become more stringent.

“It is economically feasibly to save an estimated 40-50% of the energy in new buildings (new envelope) and 15-25% in existing buildings.” (Kannan, 1999).”The kind and thickness of the external envelope of a building influences the amount of heat transmitted to inner space during summer time and its transmission to the outside during wintertime. That happens through conduction method and convection as well as radiation method. Building operation time also to be considered “Approximately 2/3 of total energy is spent when building is in use (Fanger; 1999). “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).

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 attached to the external surface of the envelope. This thin layer of insulation must be attached to its inner surface in case of vapor condensation appearing, to prevent moisture condensation and concentration inside the envelope section and its later appearance on the inner surface.

The employment of thermal insulation is one of the most effective ways of building energy conservation for cooling and heating. Therefore, the selection of a proper insulation material and determination of optimum insulation thickness is particularly vital (J. Yu, C. Yang, L. Tian, D. Liao, 2009). In literature, there are also a few studies on the environmental impact of thermal insulation. Çomakli and Yüksel;2004 investigated the environmental impact of heat insulation used for the reduction of heat loss in buildings.

The thermal capacity of the envelope in a hot climate helps reduce the thermal temperature instability of the inner environment and delays the heat from reaching peak level. In addition, since external thermal temperature during night time drops, it is also necessary to protect the inner environment from external variations of temperature.

According Evans (1990), the time lag of the envelope walls in hot climate must be within the range of 8-18hrs, because a larger time lag period will not enhance the inner thermal environment.

On the other hand, the heat gain through the roof of more than 20-30 hrs time lag will reach the inner environment at the same time as the ventilation heat gain, which increases heat gain. 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 it becomes long wave. The transmitted solar radiation across window glass is able to increase the air thermal temperature of the inner environment to high values and to even more than external air temperature, through what is called the “Green House Effect”, while the normal transmission range through glass is 70% of descending solar radiation (Al-Rawi; 1988: 47).

Thus, it is necessary to limit solar heat gain by the inner environment through the following recommendations:
- Use heat filter glass (high performance tinted glass) for windows.
- Adjust the building to optimum orientation to get lowest window exposure to solar radiation.
- Use shading devices (louvers), vertical, horizontal and compound types according to need for each orientation.

For cold climates the internal heat gain is welcomed as it contributes to the heating of the building. Whereas for warm climates the internal heat gain must be minimized since an additional heating of the building is undesirable. The benefit of decreasing the internal heat gain in warm climates is therefore twofold:
1. The electricity cost for the appliances is reduced.
2. The electricity cost for removed of internal heat gain is reduced. (Reimann; 2000).

![Baghdad Temperatures](Source: www.golden gate weather services)
3.1 Aim of the Study

Generally, the hot climate is characterized by a large diurnal air temperature range coupled with a high intensity of incident solar radiation. 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 in such climates should consider three main parameters:

- First, the form, size & orientation of the building.
- Second, the fenestration, & exposure & size 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 & the thermal capacity and conductance of the elements.

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 and the exterior environment varies with the features of the design of the specific building’s function.

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

3.2 Strategy of Choosing Variables

Increasing the Time Lag for the building envelope will be achieved through implementation of the following alternatives (variables):

1. Providing insulation material, like foam boards or polystyrene as an additional layer to the envelope.
2. Changing the gross area and locations of windows while taking into consideration the minimum optimum size in each direction.
3. Choosing the optimum color and texture for exterior surfaces.
4. Adding more variables (more alternatives) for walls and the roof, and testing the impact of each with the assistance of computer simulation.

This research considered the following proposals to facilitate the steps of the calculation without imposing big effects on the final output:

1. 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:
   \[ K = \frac{K}{dx} \text{ (W/m°C)} \]
   \( d = \text{density (kg/m}^3\) and that has an impact on the time lag (Gross, 1995: 80)
2. Assuming the heat flow in the perpendicular direction to the section (the envelope surface).
3. Assuming that complete air ventilation rate for the house building happens once per hour.
4. Assuming that the doors have the same specifications for heat flow as the windows and the same U-value (thermal transmittance).
5. Assuming that the average number of people praying at each prayer time is 30 persons, for average stay of 30 minutes. This is acquirable to 15 persons per hour. The metabolic rate for each person is considered.
6. Using shading Devices (louvers) of selected types according to the building orientation. It is concluded that a south oriented 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 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 (Al-Azawi, 1984:183).

IV. DISCUSSION
4.1 Alternate construction Details and Materials of the Building Envelope

The building simulation program is employed in the assessment of the “Model House” to show the environmental impact on its inner environment. The BLAST program provides the engineering and architectural community with a tool for estimating the behaviour of the model house envelope with different variables of construction materials, specifications and design under climatic fluctuations in the Baghdad region. Computer simulation was applied for different alternatives for walls & roofs. The most common building material in the Baghdad region is fired brick. Roofs and floors are generally constructed with 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) was a common roofing method during the first half of the 20th century.

The materials used in Iraq (Baghdad is its capital) before that, and by so many civilizations in the Mesopotamian area, were fired bricks with the dimensions of (0.30 x 0.30 x 0.05 m), also used in Babylon, give good practical examples of thermally optimum materials. Moreover, we can benefit from using cavity walls for the two layers of the walls that 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 air flow should be more than 40% of the cavity section. “This method performs as a compact shading structure” (Homm, 1984:43).

In addition, thermal isolation inside the walls (near the outer surface, where there is 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), Nora (local lime mortar) have good thermal specifications and have been found through experience to be the optimum materials used in the traditional buildings in Baghdad.

Outdoor air temperatures vary considerably and the temperatures at night often cool down from 45°C during the day to 18°C at night. This means that the solar heat of the day must be stored for the night. This can be done by choosing a construction design with massive building components that have a heat storing effect due to their mass, which reminds us of the treatment of massive walls in traditional Baghdad houses.

The envelope components of the house must be heat insulating and heat storing. The external walls should have K-values of about 0.5 to 1.0 w/m.k:

"The use of insulating double-glazing would be advisable if insulating glazing could be manufactured economically. In the roof zone the K-value to be obtained should be about 0.5 w/mk.

The necessary heat storing capacity must be ensured by internal massive components (concrete components and internal masonry walls). In case of multi-layer external components the insulating layer should be located outside while the storing layer inside” (Gertis, 1981:127).

Flat (horizontal) roofs and pitched roofs convey high thermal energy to the inner space. It is interesting to note that using traditional brick roofs (Jack Arching System) instead of reinforced concrete roofs makes hardly any change in energy consumption. This is likely due to the thermal bridges through (I-Beam) used in the first type of roof.

4.2 Thermal Behavior Analysis due to Building Envelope Modification

Many basic correction alternatives can be applied to the building of the new typical “Model house” in Baghdad to assess their influence on the general thermal balance of the inner environment of house building. They are as follows:

i. Thermal testing for the window orientation in the following directions:
   1. West
   2. South
   3. South-west

   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 optimize a suitable heat supply during the wintertime; and the prevention of solar radiation and reflected heat from the surroundings entering the house during the summertime, through the window openings, which is more serious in hot climates. 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.
4. The height of each window related to the ground level.
5. The determination of the shading devices.

ii. Thermal testing for the walls and roof of the house building after implementation of the following alternatives;
1. Increasing the thickness of the walls, using cavity type and insulation.
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. Changing the color of the external surfaces of the house building from dark colors to light colors to increase their reflectivity and minimize the absorption of solar energy (heat), which has an effect on building envelope role in heat exchange.

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 house 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.

The typical Middle Class House building in Baghdad has been simulated for the four different roof structures and five different walls as shown in the graphs fig.(3).

Weather data for the Baghdad region is obtained from the Iraqi Meteorological station. Baghdad’s location is on Longitude 44°, Latitude 33°; Since Baghdad city has become hotter during the past 10 years, the general increase in temperature is denoted as the "Random urbanization & war effects" and it occurs when the natural environment is transformed into that of the city.

V. 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). One of the BLAST preprocessors, 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: The result of simulations can be displayed in a multitude of fashions numerically as well as graphically, as shown in attached graphs. The areas have been in focus for the simulations of this research are:

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 graph (see the attached figs.3, 4 and 5). Blast and Energy-Plus program, both use the heat balance in passive designed buildings, which is the best available thermal assessment simulation tool available. Energy Plus currently has no user interface. BLAST is a more mature program with an interface.

5.1 Computer Simulations

The analytic study by computer simulations as shown in the graphs reflects the thermal behaviors of the "Model House" envelope and other modifications of the envelopes after applying "alternatives" in terms of the employment of different materials 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 inner environment thermally by increasing wall thickness to more than 0.36 m or even using cavity walls with the same specifications of the "Model House" in terms of wide openings and other features. Therefore, in light of the findings, we can conclude that for a climatically balanced structure in a hot dry climate region, the most proper external wall envelope elements should be 0.36m thick.
In addition, it is recommended that the occurrence of the inner maximum environmental temperature be delayed to the period 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 until 12.30 (22°C), but starts again warming continually from 5.00pm to 8.30 pm (19.5°C-20.5°C) respectively. This is an acceptable comfortable temperature in winter and needs low energy consumption.

The computer simulation shows that this could be achieved by using a half glass and a 0.36m envelope (all apertures and doors shown in the plan at fig.3, height are 2.0m). The computer simulation also indicates that the traditional RC flat roof is still the best thermally in terms of cost, labor skill, and heat exchange after applying additional insulation materials (6 inch insulation) see table 1).

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 house’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. Using variables (Material Alternatives) aimed at obtaining a comparison evaluation, helps give the optimum solution regarding the thermal problems of the envelope. It is useful to know the thermal behavior of the envelope under different conditions, as is mentioned in the analytical study through computer simulation as shown in the figures.

This reflects the thermal behavior of the envelope regarding the employment of different materials and energy consumption.

The appreciation of the massive structure of the traditional houses 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". Computer simulations have shown that here is no additional advantage in increasing wall thickness to more than 0.36m or using cavity walls in terms of cost, or even the enhancement of the inner thermal environment. The time lag is mainly caused by the thermal capacity of the opaque external elements, but the heat transfer through ventilation and windows, on the other hand, tends to shorten the lag. The actual time of occurrence of the maximum therefore, depends on the relative dominance of one over the other. 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 maximum solar isolation and 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 heat that has already been transferred to the inner environment, resulting in an increase in the maximum indoor temperature. Therefore, in light of the findings, it is concluded that, for a climatically balanced structure in this region, the external wall envelope elements should be 36cm thick. In addition, 1.7Wm⁻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 in winter to be 25°C at 10am. Thus, the envelope keeps the inner environment warm until 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 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, and that is what was stated about the bad envelope behaviour in terms of the mannerisms of a "Thermos flask". In this case, there is overlapping heat gain occurrence.

“Well 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 polystyrene generally compares very favorably with insulating plaster board, fiberboard or insulating screeds.” (Seeley Y.Ivory H. 1981)

“Fig. 5 Envelope behavior using different types of roof, Baghdad

Fig. 6 Green roof layers (Source: WWW.GSky.com)

Fig. 7 Section showing the American, Wick Drain Corp details of the Green Walls

source-WWW.GSky.com

5.2 Recommended Future Test

Additional future research is recommended for further computer simulations synthesis tests particularly on “eco and green architecture” requirements. Crystallizing guidelines for “Green Envelope”, Roof garden or “Green Roof” and walls, will contribute increasing roof and walls thermal mass that reduces uncontrolled heat transmittance in hot climate regions. As such, the amount of heat flow will be proportioned to the specified “green” treatments for an envelope, as shown in some examples in Figs. (6, 7, 8&9)
VI. CONCLUSION

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. The climatic stress on human inhabitants has been studied in accordance with comfort limits. The hot climate regions are severe; it has large daily and annual cycles. It has about two or three comfortable months, four cold months and six hot months. The building has to satisfy two contrasting functions: keeping the heat out in summer, and keeping the heat inside in winter. Consideration of the following criteria for controlling inner environment is quite necessary;

1. Selecting materials and a construction system on the basis of low thermal transmittance (low \( U \)-value) and high thermal storage capacity 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, or foaming a Portland cement mixture with a foaming agent such as aluminium dust to make insulated concrete roof slab can be done.

2. Using the most common economical thermal isolation materials (11 cm) thick for the roof; (7 cm) thick for south-facing walls; (8 cm) for south-east 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.

3. Designing well shaded walls and windows, selecting suitable window glass and size for each orientation. These areas should be minimal on the east and west elevations.

4. Using double roof, and walls skin, and the early ideas on "Filter" Architecture” to get high thermal protection.

5. Designing the building 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.

![Figure 8&9: Green Envelope Concept](Source: Study on Thermal Performance of Green Roofs: A Case Study in a Tropical Region by Caroline Santana de Moraíz & Maurício Roriz); PLEA2003, conference on passive and low energy architecture, Santiago, CHILE9-12Nov.2003, http://www.ijmra.us

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