# Bio-Climatic Analysis and Thermal Performance of Upper Egypt "A Case Study Kharga Region"

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ABSTRACT

As a result of the change and development of Egyptian society, Egyptian government has focused its attention of comprehensive development to various directions. One of these attentions is housing, construction and land reclamation in desert and Upper Egypt. In the recent century the most attentions of the government is the creation of new wadi parallel to Nile wadi in the west desert. Kharga Oasis is 25°26′56″North latitude and 30°32′24″East longitude. This oasis, is the largest of the oases in the westren desert of Egypt. It required the capital of the new wadi (Al Wadi Al Gadeed Government). The climate of this oasis is caricaturized by; aridity, high summer daytime temperature, large diurnal temperature variation, low relative humidity and high solar radiation. In such conditions, man losses his ability to work and to contribute effectively in the development planning due to the high thermal stress affected on him. In designing and planning in this region, it is necessary not only to understand the needs of the people but to create an indoor environment which is suitable for healthy, pleasant, and comfortable to live and work in it. So, efforts have been motivated towards the development of new concepts for building design and urban planning to moderate the rate, direction and magnitudes of heat flow. Also, reduce or if possible eliminate the energy expenditure for environmental control. In order to achieve this, attention has to be focused on building design to improve its thermal performance, which is a function of building form, orientation, location, and materials used and produce comfortable environmental conditions without increasing of energy consumed. This can be valid in three stage, the first one by using the bio-climatic analysis, the 2$^{nd}$ one by the handle and simplified calculation methods (U-value, Thermal time constant, and Degree day), and the 3$^{rd}$ one is by the simulation method. The admittance procedure is a technique for estimating cooling/heating load and temperature changes under cyclic conditions by using the thermal characteristics (Y-value, λ, φ, Sf) of the building structure. It dependent on determining the daily means value and the swing about the mean. The admittance method is used and a computer program is developed to predict the heating and cooling load as well as the environmental air temperature by the author. This study deals with the bio-climatic analysis and thermal performance of building in Kharga Oasis. The results show that, the air catcher, court and Passive cooling systems (evaporative cooling), maintained the indoor climate in the thermal human comfort zone during the hottest period under the effect of climatic conditions of Kharga. Also shading devices, and suitable orientation achieve a harmony building with environment. Using insulating materials in exposed walls and roof save energy by about 60%. The Thermal insulation thicknesses between 0.03-0.05m for exposed walls and 0.05m for exposed roofs are suitable to valid the required thermal resistance in Kharga Oasis according to the Egyptian Residential Buildings Energy Code, ECP 306-2005.

**Keywords:**
Admittance, building envelope, cooling and heating load, Kharga Oasis, thermal performance

## 1. Introduction

El-Kharga Oasis ( *Al-Kharijah)* is the southernmost of Egypt's five western Oasis. It is located in the westren Desert, about 200 km to the west of the Nile valley, it is the capital of New Valley Governorate (Al Wadi Al Gadeed). It is located 550 kilometers to the south of Cairo. Kharga Oasis is 25°26′56″north latitude and 30°32′24″east longitude. This Oasis, is the largest of the oases in the westren desert of Egypt and consists of a depression about 160km long and from 20km to 80km wide. The Kharga Oasis must be one of the most beautiful places in the world, especially at sunset; everything you see at this "green island in the middle of a yellow ocean of sand", is natural. Whether, you are sleeping under the stars, or just relaxing between the high palm-trees, you will find a feeling of integration with the environment. Kharga is the most modernized of Egypt's western oasis. The main town is a highly functional town with all modern facilities, and virtually nothing left of old architecture. There are extensive thorn palm, acacia, buffalo thorn and jujube forests in the oasis surrounding the modern town of Kharga. Although the Kharga Oasis occupies around one third of the whole lands of Egypt, it contains the least population density in the whole nation with around 20,000 inhabitants nowadays and a population density of 4 persons in each square kilometer. The reason behind this is the vast areas of the deserts surrounding the Kharga Oasis.Tourism is not considered a major activity for the people living in Kharga. Most of the people of Kharga work in normal jobs like the inhabitants of Cairo, Alexandria, and the other cities of Egypt and the other work with agriculture . Al Wadi Al Gadeed also hosts one of the largest phosphates mine in the world in the area of Abu Tartour. Kharga Oasis has many monuments and ancient sites such as; Temple of Hibis, Cemetery of Bagawat, Temple Of Ghweita, Temple of Qaser Al Zayyan, Temple of Dush in the Oasis of Paris and museum of Antiquities of Al Kharga [(1)]. Thermal comfort plays a vital and an important role for people to continue and chair in the development for their nation. Most of natural developing project lies in the desert to go out from the narrow valley which is about 5% of Egypt area. Where the climate of this region is caricaturized by; aridity, high summer daytime temperature, large diurnal temperature variation, low relative humidity and high solar radiation reaches to about 1000W/m$^2$ on horizontal surface in summer season. These extreme thermal environments reflected on people and their effort in development and sustainability due to the high thermal stress. So it is important to study and evaluate the effect of the external environment conditions on the thermal comfort for people in the open areas and in residential building in this region. Also study the effect of thermo-physical and optical properties of the building materials on saving suitable environmental condition inside building. Building envelope (walls/ roof) regards as the main construction element which has an important role in the thermal performance of unconditioned building and in saving energy in conditioned building. Where roof considered the major part of the building envelope, affected by the extreme weather, attention must be focused on roof. In Egypt different field measurements and theoretical studies were carried out to investigate the thermal performance of the traditional houses under the effect of local external climatic conditions of Cairo region (30$^o$N) [(2& 3)]. Theoretical and experimental study was carried out to investigate the thermal performance of a pre-fabricated concrete flat in 15 May city, Cairo, Egypt and the results investigate that reasonable agreement achieve between the theoretical and experimental indoor air temperature of the flat [(4)]. Saving energy consumption in hot arid region and the effect of nocturnal radiation in increasing the thermal efficiency of the building was studied theoretically under the climatic conditions of Aswan (24$^o$N) [(5)], Egypt. The requirement for building in the Waste Costal of Red See (Ghardaga) was carried out [(6)]. Evaluating the external climatic conditions of Toshky region (23.5$^o$N), Egypt and the thermal performance of some traditional building built their. This study shows that using Nobaa sandstone in wall alone is not favorable and didn’t valid thermal comfort due to the high storage, high thermal mass and thermal conductivity of it, also shows that domes or vault built from concrete without using material with special thermal characteristics is not the solution, and if dome hasn't top opening to loss the hot air, a hot heat island is found and led to discomfort [7, 8 & 9]. A developed new building material with three line defense of thermal insulation used in walls and apply the concept of domes and vault with good thermal insulation help in valid the thermal comfort in building in Toshky region, and let the indoor environmental condition of the building to be within the comfort zone in the very hot and dry period in summer [10]. The thermal performance of exposed composed roofs in very hot dry desert region in (Toshky) region, Egypt was carried out and investigate that; the construction roof systems (insulated concrete, double, planted and un-insulated concrete roofs) valid an indoor air temperature thermal damping of about 96%, 90%, 89%, and 76% respectively, the green roof gives the lower indoor air temperature, due to the evaporation process [11]. The thermal performance of building envelope in very hot dry desert region in Egypt (Toshky Region) was carried out and investigate that; the indoor air temperature of hollow clay brick and light sand block are nearest to the upper limit of thermal comfort [12]. Theoretical and experimental studies were carried out to evaluate the thermal performance of building with different building envelope in different country. The thermal performance of building and optimization the thermal insulation thickness in walls were studied [13]. The thermal performance of a vegetated cladding system on facade walls was also study [14]. Experimental approach to the contribution of plant –covered building envelops were study [15]. The effect of thermal mass walls to reduce building heating or cooling load where also studied [16]. In Mediterranean countries theoretical and experimental study was carried out to evaluate the thermal performance of building. The ventilating roofs have been widely used, the effect of roof tiles on the thermal performance of ventilated ducts were studied, and indicate that the presence of air permeable layer and elements to protect the ventilation duct eliminate any difference in performance which were due to the cross section of the ventilation duct [17& 18]. The finite element model was carried out to investigate the thermal performance of non air conditioned buildings with vaulted roof and flat roof. It clear that building with a vault roof have lower indoor air temperature compared to those with a flat roof , that is because such roof dissipate more heat by convection and thermal radiation at night due to the enlarged curved surfaces [19]. Different insulation materials (mineral wool, polyurethane, and polystyrene) were used to evaluate the thermal performance of building for decreasing the thermal demand and heating and cooling load [20]. Previously theoretical and experimental studies were carried out using different passive approach; shading, insulation, roof pond, movable shading, and evaporative cooling for roof [21-27]. Measurements and analytic work carried out under the climatic conditions of central Anatolia to provided valuable insights on the thermal performance of detached dwellings of traditional and contemporary construction [28]. With the energy crisis, efforts have been motivated towards the development of new concepts for building design and urban planning to moderate the rate, direction and magnitudes of heat flow and reduce or if possible eliminate the energy expenditure for environmental control. In order to achieve this, attention has to be focused on building design to improve its thermal performance and produce comfortable environmental conditions. This can be valid in three stage, the first one by using the bio-climatic analysis, the second one by the handle and simplified calculation methods (U-value, Thermal time constant [29], and Degree day [30]), and the third one by the simulation method. Where the simplest calculation method is not enough to give a limit of comfortable zone inside the buildings, but it may give a picture about the building energy consumed. The simulation method regarded the best method. There are many mathematical methods to solve the equations of heat transfer through the building envelope, from which the matrix method [31]. The admittance procedure using the matrix solution is used to estimating the energy transfers and temperature changes under steady cyclic conditions. It was developed by Danter and Loudon at the building Research Station [32 & 33], then used by Milbank and others to give the thermal characteristics (Y-value; Y, decrement factor; $\lambda$, time lag; φ , surface factor; Sf of multi-layer construction [34 & 35]. It determines the temperature dependent on the daily mean and swing about the mean. So a computer program was developed and prepared to calculate the heating and cooling load of a residential building in Egypt and also to predict the indoor air temperature. The program is dependent on the admittance method. This study deals with the evaluation of bio-climatic analysis of Kharga Oasis. Also investigate the effect of external climatic condition and thermo-physical characteristics and thermo-physical properties of building materials on the thermal performance of residential building to valid comfort and save energy according to Egyptian residential code[36].

## 2. Climatic Factor

The main factors affecting on studying the thermal performance of building are; the outdoor climatic condition (outdoor air temperature, relative humidity, solar intensity, and wind peed).

### 2.1. The Outdoor Air Temperature and Relative Humidity.

Figure (1.a) shows the monthly mean maximum / minimum of the outdoor air temperature of Kharga Oasis. The figure shows that the monthly mean maximum / minimum temperature increase gradually from January till reaches it's maximum value of about 40° C in May, June, July, and August and then began to decrease. The figure also shows the neutrality temperature and the upper/lower limit temperature of comfort in Kharga Oasis Eq.(1) and table (1). Figure (1.b) shows the monthly mean maximum / minimum relative humidity in kharga Oasis, it seems to be decreased gradually from January to reach minimum value in May and June then began to increase slowly. The minimum value in the monthly mean maximum relative humidity is about 15%. It is clear from the figure that through summer season in Kharga Oasis that the low value of relative humidity with the high value of dry temperature led to the importance of using evaporative cooling in Kharga Oasis in general and in building in special case to secure the thermal comfort for people[37].

### 2.2. The Solar Intensity Incident on Horizontal and Different Orientations

Figure (2) shows the variation of the computed solar intensity fallen on the horizontal surface and walls of different orientations on Kharga Oasis, during summer season (July, 21) according to Shaltout[38] and ASHREA, 1981[30]. The figure shows that the south orientation is the best orientations received minimum values of solar intensity during summer season and this help in making it easy to control the solar radiation falling on that orientation. The horizontal surface receives the greatest amount of solar intensity and its maximum value reaches 1071 $W/m^2$. Also the east/west direction receives high solar intensity with respect to the other orientations where their maximum values reaches 780 $W/m^2$. The figure clear the amount of solar intensity fallen on the north direction in the morning and afternoon where its maximum value reaches 210 $W/m^2$ at 7 a.m. and 17 p.m. which is the less amount with respect to the other orientations. Figure (3) shows the sun path diagram for Kharga Oasis through the year for the different direction. The figure shows that the months from march to September need the importance of shading to protect people from solar radiation, also the shading must be from 8 a.m. to 15p.m. The west orientation receives higher intensity than the east orientation due to the albedo effect[39].

### 2.3. Wind speed and direction

Figure (4) shows the average annual wind direction and speed in Kharga Oasis. It is clear that the wind direction is north to north west with velocity range between 5.4 to 12 m/s in summer season and between 4 to 10 m/s in winter season. This value of wind is enough to use wind mill in this area as one of the renewable energy [39].

## 3. Different Methods of Evaluating the Thermal Performance of Building Envelope

There are many methods to evaluate the thermal performance of buildings. The first approach is the Bio-climatic method, which has been proposed for buildings that take more passive approach for heating and cooling in areas where acceptable humidity can be maintained. The second method is the experimental methods; there are two types of experimental techniques, which are used to determine the thermal performance and energy efficiency of building under the different external climatic conditions of different seasons.

### 3.1. Bio-Climatic Method

The thermal comfort of human being is governed by many physiological mechanisms of the body and these vary from person to person. In any particular thermal environment it is difficult to get more than 50% of the people affected to agree that the conditions are comfortable. Personal (activity, clothing, age and sex) and physical environmental variables (air temperature, radiant temperature, relative humidity and air speed) are the principle factors affecting the human thermal comfort. There are many different Bio-climatic methods used to evaluate the thermal performance of building envelope; Mahony tables (40), Olgyay chart (41), Givoni chart,(42), . .etc is simplest methods. These methods are dependent on the external climatic conditions of the location and the approach to thermal comfort. They are not accurate but they give a good idea about design requirements. The Bio-climatic methods are a guide to the various approaches to passive heating and cooling in different climates. They do not give a complete configuration about the thermal performance of the building and its thermal load. On the other hand a formula determined the “indoor Comfort” temperature, $T_n$ relative to an exponentially weighted running average outdoor temperature, $T_o$ and applicable to free running building without mechanically narrowly controlled indoor temperature was developed as follows (43).

$$T_n = 17.6 + 0.31*T_o \quad (1)$$

within the limitation that $17.8\ ^oC < T_n < 29.5\ ^oC$ .
Where,

$T_n$ = neutrality temperature
$T_o$ = Monthly mean outdoor temperature

Table (1) shows the upper/lower limit temperature ($T_n \pm 2$) of the comfort zone in Kharga Oasis. It is clear from the table that in Kharga Osais the upper limit of comfort in summer season reach to 29.7 and the lower limit of comfort in winter season reach to 19.9; these help individuals to be bear with the high temperature in this region. Givoni’s and ASHREA psychometric charts based on the linear relationship between the temperature amplitude and vapour pressure of the outdoor air in various regions. It can be used at the pre-design analysis stage for assessing the climate, establishing the thermal control task and selecting the appropriate passive control techniques. Figure (5) shows the design strategies on psychometric (according to ASHRE 55-2005 ) chart with the designed comfort of Kharga Oasis and the extended zone for using ventilation, thermal mass, evaporative cooling, passive heating and mechanical heating and air conditioning . The figure shows that in winter season the climate of Kharga Oasis is near to the comfort zone and using the passive heating system tasks make the building to be in the comfort region. In summer season the figure shows that this region need extensive cooling, and using shading, green area and evaporative cooling help the climate of the building to reach the comfort zone. The figure shows that the mechanical cooling need to reach 780 hours per year (8.9%). Sun shading of windows need to reaches 2437 hours (27.8) %, comfort need to reaches 1924 hours (22 %). Direct evaporative cooling need to reaches

2230 hours (25.5%), passive solar gain reaches to 1227hours (14%) and other needs shown in the figure [39].

Table 1: The upper / lower limit temperature of the comfort zone during the summer season in Kharga Oasis.

| Months | Jan | Feb | Mar | Apr | May | Jun. | Jul. | Aug | Sep. | Oct. | Nov | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max. Temp. | 22.0 | 27.0 | 29.6 | 35.7 | 39.6 | 40.2 | 39.8 | 38.7 | 36.5 | 35.4 | 28.1 | 23.8 |
| Min. Temp. | 5.2 | 9.1 | 12.5 | 17.9 | 22.1 | 24.8 | 4.7 | 24.5 | 23.3 | 20.5 | 14.5 | 7.4 |
| Avg. Temp. | 13.9 | 18.1 | 21.1 | 26.8 | 30.9 | 32.5 | 32.3 | 31.6 | 29.9 | 28 | 21.3 | 15.6 |
| Tn Temp. | 21.9 | 23.2 | 24.1 | 25.9 | 27.2 | 27.7 | 27.6 | 27.4 | 26.9 | 26.3 | 24.2 | 22.4 |
| Tuc Temp. | 23.9 | 25.9 | 26.1 | 27.9 | 29.2 | 29.7 | 29.6 | 29.4 | 28.9 | 28.3 | 26.2 | 24.2 |
| Tlc Temp. | 19.9 | 21.2 | 22.1 | 23.9 | 25.2 | 25.7 | 25.6 | 25.4 | 24.9 | 24.3 | 22.2 | 20.4 |

Tn =neutrality (comfort) temperature, Tuc = Upper limit of comfort, Tlc = Lower limit of comfort

### 3.2. Experimental Technique

There are two types of experimental techniques, which are used to determine the thermal performance and energy efficiency of building under the different external climatic conditions of different seasons. The first one is the temperatures distribution through the envelope elements, indoor air, mean radiant temperatures, and internal surfaces temperatures are measured and recorded for at least three days. Internal and external relative humidity, solar radiation, and wind speed are measured and recorded. Damping factor, decrement factors, and time lag of the building envelope were determined. Also the human degree of sensitivity to the indoor climate is measured and determined by using the indoor weather stations. In which the human degree of sensitivity is given by the Predicted Mean Vote (PMV) value which lies between –3& 3 table (2). It is a set of environmental variables, which satisfies Funger comfort equation [44]. The second one is that used for evaluating energy consumption in the building. It is a technique for measuring the energy consumed, for cooling/heating loads, lighting, equipment's…etc by using voltmeter analysis stations. These measurements are contributing in the field of electrical planning of any countries, and also to know how energy efficiency can be improved. This method of measurement is adequate in the case of commercial building rather than in the case of residential buildings. The third approach is the simulation method, which is carried out by energy software programs.

Table 2: Predicted Mean Vote (PMV) according Funger Equation

| **Case** | **Very cold** | **Cooled** | **Cool** | **Comfort** | **Warm** | **Hot** | **Very hot** |
|---|---|---|---|---|---|---|---|
| **PMV** | -3 | -2 | -1 | 0 | 1 | 2 | 3 |

### 3.3. The Mathematical Model for Thermal Evaluation of Building Envelope

#### 3.3.1. Analytical Study

The thermal response of building is defined as the reaction of the building envelope to some form of heat input (heat gain from external/ internal building envelope, fenestration, and ventilation/ infiltration) and the amount of internal loads (people, light and equipments). It depends mainly on orientation, size, windows to wall ratio, on the thermo physical and optical properties of the building materials, and on the external environmental conditions. All these forms of heat are either sensible or latent heat and transform inside the building to conductive, convective and radiant heat gain which in turn transfer to cooling load. Heat transfer in building takes place by three simultaneous modes; conduction, convection and radiation. Heat is also transfer by ventilation and stored in the building fabric. The general equation governing the heat flow through a homogeneous layer in one dimension is written as; [31].

$$k\,(\partial^2 T / \partial x^2) = \rho\, C_p\, (\partial T / \partial t) \quad (2)$$

Where; T is the temperature ($^oC$), x is the space dimension (m), t is the time (sec), k is the thermal conductivity (W/m $^oC$), $\rho$ is the density (kg/m$^3$) and $C_p$ is the specific heat; (J/kg $^oC$).

The boundary conditions assumed to solve this equation at the outside/inside surfaces are;

$$k\,(\partial T / \partial x)_{x=0} = h_{so}\,(T_{so} - T_{si}) \quad (3)$$

$$k\,(\partial T / \partial x)_{x=l} = h_{si}\,(T_{si} - T_{ai}) \quad (4)$$

Where; $T_{so}$ and $T_{si}$ are the outside / inside surface temperature ($^oC$), $T_{ao}$ and $T_{ai}$ are the outdoor / indoor air temperature ($^oC$), $h_{so}$ and $h_{si}$ are the heat transfer coefficient of the outside/inside surface including the radiation and convection components (W/m$^2$ $^oC$). The temperatures and heat flow at both the internal and external surfaces as a resulting solution of Eq. (2) are given as linear equations as follows; [45 & 46]

$$\begin{vmatrix} T(o,t) \\ q(o,t) \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} T(L,t) \\ q(L,t) \end{vmatrix} \quad (5)$$

Where;

$A = \mathrm{COSH}\,(1 + i)\,\varphi$ $\qquad$ $B = [\,R / (1 + i)\varphi\,]\ \mathrm{SINH}\,(1 + i)\varphi$

$C = [\,(1 + i)\varphi / R]\ \mathrm{SINH}\,(1 + i)\,\varphi$ $\qquad$ $D = A$

and, R is the thermal resistance of slab; (L/k) (m$^2$ $^oC$ /W)

L is the total thickness of homogeneous layer; (m)

$\varphi$ is the $(\omega L^2 / 2\alpha)^{1/2}$

$\omega$ is the frequency of temperature oscillation; $2\pi f$

$\alpha$ is the Thermal diffusivity; $k/\rho\, C_p$ (m$^2$/s)

For composite construction of n's layers, and expanding the overall transmission matrix to include the boundary layers of combined convective / radiative resistance, Eq. (2) becomes;

$$\begin{vmatrix} T(o,t) \\ q(o,t) \end{vmatrix} = \begin{vmatrix} 1 & R_{so} \\ 0 & 1 \end{vmatrix} \begin{Vmatrix} A_i & B_i \\ C_i & D_i \end{Vmatrix} \begin{vmatrix} 1 & R_{si} \\ 0 & 1 \end{vmatrix} \begin{vmatrix} T(L,t) \\ q(L,t) \end{vmatrix} \quad (6)$$

Then, the heat fluxes at the innermost and outermost boundaries can be given where; $R_{so}$ /$R_{si}$ are the external/internal surface resistance (m$^2$ $^oC$ /W). The solution of Eqs. (3& 4) due to the heat gain / loss through the building envelopes and the stored in the construction are given as;

$$\alpha_s I = h_{so}\,(T_{so} - T_{ao}) - k\,(\partial T / \partial x)_{x=o} + q_s \quad (7)$$

$$- k\,(\partial T / \partial x)_{x=l} = h_{si}\,(T_{si} - T_{ai}) + \Sigma\ h_r\,(T_{si} - T_i) + q_s \quad (8)$$

Where; $\alpha_S$ is the absorptive of the surface to the shortwave solar radiation (non), I is the total solar radiation affecting the surface (W/m$^2$), $q_s$ is the storage heat through the structure (W/m$^2$), and $T_i$ is the other surface temperature (°C). Also the heat balance equation at the indoor air assuming the casual and internal heat gain equal zero is written as; [47]

$$C_V (T_{ao} - T_{ai}) + \Sigma A_i h_i (T_i - T_{ai}) = o \quad (9)$$

Where; $C_V$ is ventilation conductance (W/°C), the convective term includes the walls, the ceiling and the floor. The convective and radiation parts of heat transfer; ($q_c$, $q_r$) in Watt are calculated in the developed program as follows;

$$q_c = A\ h_c\ (T_i - T_{ai}) \quad (10)$$

$$q_r = A\ h_r\ (T_{si} - T_i) \quad (11)$$

Where; A is the surface area ($m^2$), $h_c$ is the convection heat transfer coefficient ($W/m^2$ °C). For internal building surface, $h_c$= 3 for walls, 4.3 for upward flow to ceiling, and 1.5 for downward flow to floors. For external building surface, $h_c$= 5.8 + 4.1 v, where v is the wind speed in m/s and $h_r$ is the radiative heat transfer coefficient ($W/m^2$ °C) [47].

### 3.3.2. Numerical Method for Calculation

The admittance procedure is a technique for estimating cooling/heating load and temperature changes under cyclic conditions by using the thermal characteristic (y-value, $\lambda$ ,$\varphi$ , Sf) of the building structure. It is dependent on determining the daily mean value and the swing about this mean. A computer program using this method to calculate the heating / cooling load and the environmental air temperature were calculated. The "sol-air temperature"; $T_{eo}$ is written in a mathematical form as follow [48].

$$T_{eo,t} = T_{ao,t} + R_{so} ( \alpha_s\ I_t - \ \varepsilon\Delta R) \quad (12)$$

The actual rate of heat transfer into the room at any time t ($Q_t$ )is given as the sum of both the mean and swing value about the mean, and can be written in a final form [46]

$$Q_t = A\ U\ \ \{(T_{eo} - T_{ei}) + \lambda\ (T_{eo,t-\varphi} - T_{eo})\} \quad (13)$$

Where; $T_{ei}$ is the constant indoor environmental temperature (°C), and U is the heat transfer coefficient. Heat transferred through partition, ceiling and floor between the conditioned space and the adjacent space due to the temperature difference between them is given as;

$$Q_{ad,t} = AU\ (T_{ad,t} - T_{ei}) \quad (14)$$

Where; $T_{ad}$ is the adjacent space temperature at time t (°C).

The total instantaneous rate of heat gain through a glazing material (TIHG) is balanced by conduction heat gain/loss due to air temperature difference between outdoor and indoor, and the solar heat gain due to transmitted and absorbed solar energy [48].

$$TIHG_t = U_g\ (T_{ao,\ t} - T_{ei}) + (\tau + \alpha\ U_g/\ h_o\ )\ I \quad (15)$$

Where; $U_g$ is the coefficient of heat flow of the glass ($1/ (R_{so} + R_{si})$); ($W/m^2$ °C).

The term ($\tau$ +$\alpha$ $U_g$/ $h_o$) is called the "Solar Heat Gain Coefficient". For reference glazing material for the ASHRAE procedure (DSA), it is equal 0.87 [48] According to Loudon, [33]. ($\tau$ + $\alpha$ $U_g$/ $h_o$ ) is called the "Solar Gain Factor". This instantaneous heat gain value is converted to cooling load after made a modification for the cyclic transmitted part by means of the surface factor (46). The admittance method gives the environmental temperature where, it is a convenient temperature of calculating rates of heat flow for both the steady state and diurnal temperature swings. . It need the magnitudes of the various load fluctuations at each point in time for each harmonic considered and about the mean condition are determined and modified by the decrement and surface factors appropriate to their type and frequency. This gives the energy fluctuation imposed on the enclosure at each frequency and experienced at some time after the initial excitation, a delay which depends on the time lag related to the factor used. The total fluctuating load at each point in time and at each frequency is obtained by summing the individual load fluctuation released at each time. In final form it is given as;

$$T_{ei,t} = T_{ei}\,(\text{mean}) + T_{ei,t}\,(\text{swing}) \quad (16)$$

Where; $T_{ei}$ (mean) / $T_{ei,t}$ (swing) is the mean / swing internal environmental temperature; ($^{o}C$), they were developed from the daily mean and swing in the energy gain.

The mean total energy gain from walls, roof, windows, people, and lighting (with neglecting here the presence of people and lighting) is given as;

$$Q_{tm} = \{\Sigma(AU)_{si} + \Sigma\,(AU)_{gj} + C_v)\,(T_{ei} - T_{ao}) \quad (17)$$

Where; $\Sigma(AU)$ is the sum product of exposed surface / glass areas and the appropriate U-value; (W/ $^{o}C$).

$$C_v = 0.33\ N\ V \qquad \text{(low rate of ventilation),}$$

$$1/C_v = 1/0.33\ NV + 1/4.8\ \Sigma\ A \qquad \text{(higher rate of ventilation),}$$

N is the rate of air interchange; ($h^{-1}$), V is the room volume; ($m^3$), and $\Sigma A$ is the total areas of surfaces bounding the enclosure, weather internal or external. The swing total energy gain from walls, roof, windows, ventilation, people, and lighting given as;

$$Q_{ts} = (\ \Sigma A_j\ Y_j + C_{v,t})\ T_{ei,t} \quad (18)$$

Where; $\Sigma A_j Y_j$ is the area-weighted admittance of room; (W/ $^{o}C$), it is equal to the sum of product of areas (solid and glass weather external or internal) and the appropriate Y-value of each surface. Table (3) summarized the equation for heating and cooling.

### 3.3.3. Algorithms of the Computer Program

A computer program is developed and prepared in order to simulate and analyses the dynamic building thermal behavior using the Basic language. The heat transfer problem under dynamic conditions is solved by means of the admittance method. This program is developed to calculate the heating and cooling load of a residential building in Egypt and also to predict the environmental temperature in three step;

- Firstly, calculate the hourly heat gains deriving by each building component (walls, windows, doors, etc.)under the hypothesis that the environmental temperature is constant.
- Secondly, calculate the heating and cooling load of a building where, the room heat

Table 3: Summarized the equation for heating and cooling loads

| Load Source | Equation | Description |
|---|---|---|
| External Roof or Walls | $\bar{Q}_{cond} = U * A * (\bar{T}_{eo} - T_{ci})$<br>$\tilde{Q}_{cond} = U*A*DF*(T_{eo}(\theta-\phi) - \bar{T}_{eo})$ | The cooling / heating load composed of two parts the mean part ($\bar{Q}_{cond}$) and the swing part about the mean ($\tilde{Q}_{cond}$)<br>→ Environmental indoor air temp.<br>→ Mean sol - air temp.<br>→ Sol - air temp. at time $(\theta - \phi)$ }<br>→ Decrement factor }<br>→ Surface area }<br>→ Design heat transfer coefficients<br>These two parts depend on inside and outside design dry bulb temps., the colour of external surface, the latitude, orientation, time of calculation and the thermophysical properties of the construction. |
| Partiton, Ceiling & Floor | $Q_{part} = U * A * \Delta T$ | → Design heat transfer coefficient. }<br>→ Surface area. }<br>→ Design temperature difference. } |
| Glass Conduction | $Q_{gcond} = U_g * A_g * \Delta T$ | → Design heat transfer coefficient according to the glass type & internal / externel shading.<br>→ Net glass area.<br>→ Design temperature difference |
| Glass Solar | $\bar{Q}S_{gm} = S * A_g * I_m$<br>$\tilde{Q}S_{gs} = S_a * A_g * (I(\theta) - I_m)$ | → Solar gain factor<br>→ Mean solor intensity.<br>→ Mean glass load.<br>→ Swing of solar intensity about daily mean.<br>→ Alternating solar gain Factor.<br>→ Swing glass load |
| Internal Light | $\bar{q}_{Lt} = No.*LHG*A_f * DRT/24$<br>$\tilde{q}_{Lt} = No.*LHG(\theta)*A_f - \bar{q}_{Lt}$<br>$Q_{Lt\ tot}(t)$ | → Light number.<br>→ Heat gain of each lamp<br>→ Floor area<br>→ Duration time of lighting.<br>→ Mean light heat gian<br>→ Swing light heat gain<br>→ The total load fron light |
| People | $\bar{q}_{occ} = No. * PHG * DRT/24$<br>$\tilde{q}_{occ} = PHG(t) - \bar{q}_{occ}$<br>$Q_{occ}(t)$ | → Number of occupants in space.<br>→ Heat gain from occupants.<br>Mean occupants heat gain.<br>→ Swing occupants heat gain<br>→ Total load from occupants. |
| Ventilation and Infilraion | $q_{sen} = 1.232 * ACH * \Delta T$<br>$q_{lat} = 3012 * ACH * \Delta W$<br>$Q_{tot} = 4.334 * ACH * \Delta h$ | Sensible heat gain → Design temp. diff.<br>Laten heat gain → Humidity ratio diff<br>Total heat gain, $(q_{tot}) = (q_{sen} + q_{lat})$<br>→ Enthalpy diff.<br>→ Air change per hour<br>→ Constant according to each part<br>This heat gain depend on the ACH and the inside and outsid dry bulb temp. and on the humidity ratio. |

load is the heat quantity that has to be given or subtracted from the room in order to maintain the air temperature equal to a constant value.

- The third, by means of the energy balance of the room is rebuilt in order to calculate the actual internal air temperature.

A master program is prepared. Through it, the hourly cooling/heating load due to each source (walls, windows, doors, infiltration/ventilation, occupants and light) is calculated, and the environmental temperature is estimated. This program included within it four subroutine. The first one to calculate the outdoor air temperature using the maximum and diurnal range

temperature of the given site with the percentage value [48]. The second subroutine program is developed to calculate the direct, diffuse and global solar radiation intensity on horizontal surface and obtained in hourly values. The input data file for this subroutine includes; the day, month, latitude, the cloud cover, and the annual relative humidity. Figure (6) shows a flow chart subroutine of solar radiation intensity (Solar subroutine) on horizontal surface. These input data can be taken from a file called the weather data file. The third subroutine program is concerned with the characteristics of the construction of the walls such as the conductance (U-value), the admittance (Y-value), the decrement factor (λ), time lag (φ) and the surface factor (Sf). The input data file for this subroutine includes the inside / outside surface resistance ($R_{si}$ & $R_{so}$), the air gap resistance ($R_{ag}$), and the thermo-physical properties of the layers of the construction (thermal conductivity, k, density; ρ, and specific heat; $C_p$) and their thicknesses. Figure (7) shows a flow chart of thermo-physical and characteristics properties subroutine (Admit subroutine). These input data taken from a file called the construction data file. This data file contains 5 different walls in which each wall can be composed of 5 layers (may contain air gap in between). The fourth subroutine program is developed to simulate the direct and diffuse solar intensity on vertical surfaces according to their orientations. It is also concerned with the heat gain due to transmission and absorption for both the direct and diffuse solar intensity through the window (shaded or un-shaded). Figure (8) shows a flow chart subroutine of solar radiation intensity on vertical (Opaque/ window) surfaces area. To simulate the master program a building data file is developed to include the geometry of the building, its volume, inside constant environmental temperature and humidity ratio at which the calculation done, the number of walls, its absorpetivity, whether it is external or internal, its length and width, and the azimuth of each wall. Also the temperature of the neighbor zone (whether it is equal to the outdoor air or constant value or has different temperature) for this wall. Also shows if this wall has windows, door or hasn't any opening. For each window the characteristics of it (U-value and y- value) and its dimensions and whether this window shaded or not. If the window shaded, the data include the width of the shade device and the distance between it and the window. For each door the area and U-value are found. The output data of this program starting with the city name and its altitude, the day and month of calculation, the hourly values of the weather data, the mean environmental conditions, the characteristic of each construction (U-value, Y-value, λ , φ ,Sf), its area and its wall azimuth angle, the average values of the cooling/heating load of each component and also the total of the zone and the hourly values of the heating and cooling load of each component and the indoor environmental temperature. These output values printed or stored in a file.
The program has been applied to a prefabricated apartment in the new city of 15 May of Egypt. A validation of the program including a comparison between the measured and estimated indoor air temperature as shown in Figure (9)[4].

## 4. Case Study

To study the thermal performance of building in Kharga Oasis, a test model of 10*10*3 m is chosen and oriented to north direction. The simulation is carried out on the building by using different alternative walls and roofs to reach to the favorite building materials used in this region. Tables (4& 5) describe the thermo-physical properties and thermo-physical characteristics of these walls and roof used. In this study July 21 was chosen for the cooling load calculation as an indication for the hottest period and Jun. 21 was chosen for the heating load calculation as an indication for the coldest period.

Table 4: Walls description of different building materials with / without thermal insulation and their thermo-physical properties and characteristics

| No | Wall Description | Thermo-physical Properties | | | | Thermo-physical characteristics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | L | k | D | Cp | U | R | TL | DF | Y |
| | | m | W/m°C | Kg/m³ | J/Kg°C | W/m²°C | m²°C/W | | non | W/m²°C |
| 1 | Inside plaster* | 0.025 | 0.727 | 1602 | 840 | 2.351 | 0.425 | 8 | .33 | 4.993 |
| | Cement brick | 0.25 | 1.4 | 2000 | 880 | | | | | |
| | Outside plaster* | 0.025 | 1.4 | 2000 | 880 | | | | | |
| 2 | Heavy sand brick | 0.25 | 1.4 | 2000 | 880 | 2.475 | 0.404 | 7 | .4 | 4.965 |
| 3 | Sand stone | 0.25 | 0.97 | 2260 | 840 | 1.982 | 0.505 | 9.4 | .26 | 4.829 |
| 4 | Lim stone | 0.25 | 0.73 | 2380 | 840 | 1.697 | 0.589 | 10.8 | .21 | 4.699 |
| 5 | Clay brick | 0.25 | 0.42 | 1470 | 840 | 1.188 | 0.842 | 10.6 | .27 | 4.14 |
| 6 | Light sand brick | 0.25 | 0.29 | 483 | 850 | 0.902 | 1.109 | 9.3 | .38 | 3.666 |
| 7 | Cement brick | 0.25 | 1.4 | 2000 | 880 | 0.877 | 1.14 | 10.8 | .17 | 5.32 |
| | Polystyrean layer | 0.025 | 0.035 | 16 | 1400 | | | | | |
| | Cement brick | 0.25 | 1.4 | 2000 | 880 | | | | | |
| 8 | Cement brick | 0.25 | 1.4 | 2000 | 880 | 0.539 | 1.855 | 11.1 | .15 | 5.369 |
| | Polystyrean layer | 0.05 | 0.035 | 16 | 1400 | | | | | |
| | Cement brick | 0.25 | 1.4 | 2000 | 880 | | | | | |
| 9 | Cement brick | 0.25 | 1.4 | 2000 | 880 | 0.389 | 2.571 | 11.3 | .14 | 5.386 |
| | Polystyrean layer | 0.075 | 0.035 | 16 | 1400 | | | | | |
| | Cement brick | 0.25 | 1.4 | 2000 | 880 | | | | | |
| 10 | Cement brick | 0.25 | 1.4 | 2000 | 880 | 0.305 | 3.279 | 11.5 | .14 | 5.394 |
| | Polystyrean layer | 0.1 | 0.035 | 16 | 1400 | | | | | |
| | Cement brick | 0.25 | 1.4 | 2000 | 880 | | | | | |

Rso = 0.055 Rsi = 0.123

* for each wall material inside / outside plaster layer with its properties were repeated

## 5. RESULTS AND DISCUSSION

### 5.1 The thermal response of walls

The quantitative effect of building envelop (walls/ roof) depend on their thicknesses and thermo-physical properties, i.e the type of the materials affect the temperature of both the indoor air and surfaces and thus have a very pronounced effect on the occupants' comfort in natural conditions. While in air conditioned space, the thermo-physical properties of the materials used determined the amount of heating /cooling load which is provided and also the temperature of the internal surfaces. To investigate the effect of building materials on heating /cooling load of building in Kharga Oasis, different building materials of different masses and U-value are used in the wall construction of the case study. Each wall composed of 0.25 m brick/ stone and 0.025m internal/ external plaster. Table (4) illustrates the building materials used with their thermo-physical properties and characteristics. The roof of this case is commen reinforced concrete of 0.1m and the absorpetivity of the wall is chosen as light color with value equal 0.3. Figure (10) illustrate the hourly variation of the cooling load of south wall with different building materials summer season. The figure also shows the outdoor air temperature which reach it's maximum value of about 40° C and it's minimum value of about 24°C with a diurnal range of about 15°C and still over 30°C for 12 hours. The figure demonstrate that walls have U-value approximately ≥ 2 W/m²°C (cement brick, sand brick and sand stone) give a higher and large fluctuation of cooling load. The figure also shows that walls have U-value < 2 W/m²°C (clay brick, light brick and lime stone) have a nearly steady fluctuation and approximately equal load. Minimum load found between 9.0 am and 13.0 pm, while the maximum load found between 20.0 pm and 24.0 mind night with different time lag

Table 5: Roof description with different construction type / different insulation thickness And their thermo-physical Properties and thermo-physical characteristics

| No | Roof Description | Thermo-physical Properties | | | | Thermo-physical characteristics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | L | k | D | Cp | U | R | TL | DF | Y |
| | | m | W/m°C | Kg/m³ | J/Kg°C | W/m²°C | m²°C/W | | non | W/m²°C |
| 1 | Inside plaster* | 0.025 | 0.727 | 1602 | 840 | | | | | |
| | Heavy concrete layer | 0.15 | 1.4 | 2700 | 900 | 2.043 | 0.489 | 9 | .25 | 5.221 |
| | Sand layer* | 0.05 | 0.39 | 1598 | 880 | | | | | |
| | Cement tiles and mortar* | 0.05 | 1.2 | 2200 | 1000 | | | | | |
| 2 | Lika concrete layer | 0.15 | 0.28 | 1290 | 1000 | 1.089 | 0.918 | 11 | .27 | 3.944 |
| 3 | Normal concrete layer | 0.15 | 1.4 | 2700 | 900 | 2.043 | Shaded | 9 | .25 | 5.221 |
| 4 | Heavy concrete layer | 0.10 | 1.4 | 2700 | 900 | 2.204 | 0.454 | 7.7 | .36 | 5.269 |
| 5 | Heavy concrete layer | 0.1 | 1.4 | 2700 | 900 | | | | | |
| | Polystyrean layer | 0.05 | 0.025 | 16 | 1400 | 0.531 | 1.883 | 10.1 | .21 | 5.526 |
| 6 | Heavy concrete layer | 0.10 | 1.4 | 2700 | 900 | | | | | |
| | Polystyrean layer | 0.075 | 0.025 | 16 | 1400 | 0.385 | 2.597 | 10.3 | .20 | 5.54 |
| 7 | Heavy concrete layer | 0.10 | 1.4 | 2700 | 900 | | | | | |
| | Polystyrean layer | 0.1 | 0.025 | 16 | 1400 | 0.302 | 3.311 | 10.5 | .19 | 5.547 |
| 8 | Heavy concrete layer | 0.10 | 1.4 | 2700 | 900 | | | | | |
| | Polystyrean layer | 0.125 | 0.025 | 16 | 1400 | 0.248 | 4.032 | 10.7 | .19 | 5.551 |
| 9 | Heavy concrete layer | 0.10 | 1.4 | 2700 | 900 | | | | | |
| | Polystyrean layer | 0.15 | 0.025 | 16 | 1400 | 0.211 | 4.739 | 10.9 | .19 | 5.554 |

Rso = 0.055 Rsi = 0.123

For each roof inside plaster, Sand layer, cement tiles and mortar were repeated.

between them according to their heat capacity. Table (6) illustrate the total cooling / heating load of 9 different walls construction versis the U-value under the external climatic conditions of summer/ winter seasons in Kharga Oasis. The figure shows that as the U-value increase the cooling/ heating load increase. Walls with U-value approximately ≥ 2 W/m²°C give the higher load. Related to table (4) the U-value varies between 0.902 and 2,475 W/m²°C, with a thermal resistance varies between 0.425 and 1.109 m²°C/W. while the Egyptian energy code require R-value varies between 0.8 and 1.3 m²°C/W for desert region from Egypt.

Table 6: The wall construction with their U-value, R-value, and the total cooling / heating load .

| Walls Construction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| U-value (W/m²°C) | 0.902 | 0.926 | 1.188 | 1.246 | 1.697 | 1.906 | 1.982 | 2.351 | 2.475 |
| R-Value (m²°C/W) | 1.109 | 1.08 | 0.842 | 0.803 | 0.589 | 0.525 | 0.505 | 0.425 | 0.404 |
| Cooling load (KW) | 24.6 | 25.3 | 32.4 | 34.0 | 46.3 | 52.0 | 54.1 | 64.1 | 67.5 |
| Heating load (KW) | -18.1 | -18.6 | -23.9 | -25.1 | -34.1 | -38.3 | -39.8 | -47.2 | -49.7 |

Figure (11) illustrate the hourly variation of the cooling load of the different wall orientation for the building case study during summer season under the external climatic condition of Kharga Oasis. In this case clay brick of 0.25 m with 0.025 m inside / outside plaster layer was used. The roof of this case is common reinforced concrete of 0.1m. the apsorbetivity of the wall is chosen as medium color with value equal 0.6. The figure demonstrate that all the walls of different directions have the same thermal behavior between 7 a.m. and 15 p.m. and by difference in their values .Due to the difference of the amount of solar radiation fallen on each the maximum cooling load of east/ west directions accrue at 20 p.m. hour and 3a.m. hour the west cooling load is high than the east wall by about 17.7% due to the exposed of the west direction to the high ambient temperature of the after noon and the albido phenomena. The north cooling load is near to the south cooling load and increases about it in the early morning and late afternoon by about 3.4%. It is also clear from the figure that the east / west direction are higher than the north/ south direction. Finally it is clear from the figure the importance of using north/ south direction as favor faces for the building and the importance of reducing the cooling load of both east and west direction. From figure (10) and table (6) it is clear that the required R- Value of walls can be achieved by using traditional building materials with different thickness but using thermal insulation can verify the R-Value required without increase the wall thickness. Figure (12) shows the hourly variation of the cooling load of west wall with and without thermal insulation. In this case cement brick of 0.25 m with 0.025 m inside / outside plaster layer was used. The roof of this case is common reinforced concrete of 0.1m. The apsorbetivity of the wall is chosen as medium color with value equal 0.6. The figure shows the effect of thermal insulation in reducing the cooling load, and the effect of increasing the insulation thickness in reducing the cooling load. Figure (12) shows the high fluctuation of wall without insulation with respect to the approximately nearly stable of the wall with insulation of different thickness. The figure also shows that minimum insulation thickness valid a reduction in the cooling load to about 63%. Table (7) shows the total walls cooling load and the reduction per cent in cooling load of all walls when using the thermal insulation of different thicknesses.

Table 7: The total walls cooling load and the reduction per cent in cooling load R-Value of all walls when using the thermal insulation of different thicknesses.

| Walls with Different Insulation Thickness | | | | | |
|---|---|---|---|---|---|
| Thicness (cm) | 0 | 2.5 | 5.0 | 7.5 | 10.0 |
| R-Value ($m^2K/W$) | 0.425 | 1.14 | 1.855 | 2.571 | 3.279 |
| Cooling load (W) | 78856 | 29432 | 18092 | 13060 | 10218 |
| Reduction (%) | 0 | 63 | 77 | 83 | 87 |

This table illustrate that for wall with low thermal resistance in Kharga Oasis in Egypt thermal insulation material must used in all exposed walls to save thermal comfort inside building spaces during long summer season, and conserve energy. Also it is clear that thermal insulation of thickness between 0.03 and 0.05cm is enough to valid the thermal resistance according to the Egyptian Energy Code.

### 5.2 The thermal response of Roof

The external surface of the roof is often subjected to the largest temperature fluctuations, and the high intensity of solar radiation. So in hot countries it is believed that the roof is the main heating element of a building in summer. Simulation were carried out on the case study regarding the walls is clay brick of 0.25 m and with 0.025 m inside/ outside plaster layer was used. Different roof constructions were used and the apsorbetivity of the wall and roof is chosen as medium color with value equal 0.6. Figure (13) illustrate the hourly variation of the outdoor air temperature and the cooling load of roof constructed from different building materials during summer season. The figure shows that all the roof have the same behavior with different in the maximum and minimum cooling load values and shifting in the peak time. The figure shows that roof of U-value approximately grater than 1.5 W/m$^{2o}$C (Heavy concrete, light concrete, Roof with sand layer and roof with air gap) give the higher and large fluctuation load through the day . The difference in the load values of these roofs during the afternoon period is clear where the peak value of roof with air gap /sand layer are less than the heavy concrete by about 25%, and 16% , while these difference are not clear through the night time and early hours of the day. Roof with U-value less than 1.5 W/m$^{2o}$C give low load than the other roofs through the day. These roofs give nearly load through the night and early hours of the day while in the after noon they behave approximately the same with one hour late. The figure also shows that roof with minimum U-value and maximum R-Value give the minimum load with maximum time lag. From these results we can notes that air gap layer or sand layer may be used to minimize the cooling load of heavy concrete roof. Table (8) shows the roof construction with their U-value, R-value, the maximum and the total cooling load.

Table 8: The roof construction with their U-value, R-value, the maximum and the total cooling load .

| U-value (W/m$^2$K) | Roof Construction | | | | | | |
|---|---|---|---|---|---|---|---|
| | Heavy concrete | Light concrete | Sand Layer | Air gap | Clay Roof | Lika roof | Shaded Roof |
| | 2.043 | 1.879 | 1.719 | 1.652 | 1.352 | 1.089 | 2.043 |
| R-Value (m$^2$K/W) | 0.489 | 0.532 | 0.582 | 0.605 | 0.74 | 0.918 | 0.489 |
| Max. Load (W) | 4634 | 4316 | 3910 | 3488 | 3355 | 2526 | 1221 |
| Cooling load (W) | 75258 | 69199 | 63296 | 60830 | 49813 | 40123 | 18806 |

From figure (13) and table (8) it is clear that the required R- Value of residential building according to the Egyptian Energy Code in Kharga Oasis (3 m$^{2o}$C/W) is not valid. Different insulation materials (Vermiculite, pearlite, sand, and polystyrene layer) added to the concrete roof can increase the thermal resistance of the roof. Figure (14) shows the hourly variation of the cooling load of roof with and without polystyrene layer. The figure shows the effect of thermal insulation in reducing the cooling load, and the effect of increasing the insulation thickness in reducing the cooling load. Table (9) shows the total roof cooling load with / without polystyrene layer, and the reduction per cent in cooling load as thermal insulation with different thickness used. The figure shows the reduction in cooling load increase as the insulation layer thickness increase. Roof with thermal insulation layer of different thickness give loads approximately the same and far away from the roof without insulation

Table 9: The total roof cooling load and the reduction per cent in cooling load when using the thermal insulation of different thicknesses.

| Roofs with different Insulation Thickness | | | | | | |
|---|---|---|---|---|---|---|
| Thickness (cm) | 0 | 5 | 7.5 | 10 | 12.5 | 15 |
| R-Value (m$^2$K/W) | 0.454 | 1.883 | 2.597 | 3.311 | 4.032 | 4.739 |
| Cooling load (W) | 81183 | 19567 | 14185 | 11124 | 9150 | 7771 |
| Reduction (%) | 0 | 76 | 82.5 | 86 | 89 | 90 |

### 5.3 The Thermal Response of Windows on the Cooling Load

to clarify the effect of window ratio on the cooling load of residential building in Kharga Oasis, we simulate the case study with window of differ ratio start from 0 % to 100% of the south direction. Figure (15) shows the cooling load of south wall and window with different glass to wall ratio due to the solar heat gain and conduction. The figure shows that the total cooling load of the south wall without any opening reach to 7200 W. the figure illustrate that as the window ratio increasers the cooling load from the solar heat gain and due to conduction through the window are increased rapidly. The total cooling load of the south wall is approximately equal to the cooling load from solar heat gain of window with ratio of 20%. This figure shows that how much the glass is week to gain heat by conduction and solar. From the figure we conclude that in hot region like Kharga Oasis; it is perfable to make the opening very small, but smart glass can be used for large opening in this area without increasing the load on the building.

## 6. CONCLUSIONS

The results of this study show that energy efficiency of building envelope system is generally expensive and are cost-effective especially for residential buildings. The results of this study concluded that.

1. Bio-climatic methods are important to verify the first idea of design for non-conditioning buildings. Analysis by Mahoney tables investigates that, the planning of city must be compact and the opening must be less than 20%. The walls and roof must have high heat storage and building design must be compact.
2. Digital computer solutions for the problems of periodic heat flow through building sections play a major role in enhancing energy code for residential buildings.
3. Simulation methods and the parametric analysis are required in helping engineer and physics' to evaluate the energy consumption of the buildings and the environmental air temperature before constructed.
4. The advantages of the matrix method over other exact mathematical methods, in solving the Fourier heat conduction equation, especially in the case of multi-layered sections, have been will established.
5. The matrix method is one of the calculation techniques which give realistic answers to the problem of cyclic temperature predictions in buildings.
6. The main advantage of the admittance procedure is that acceptable temperature and energy predictions are given by a reasonable digital computer solution.
7. The three parameters Y, $\lambda$, Sf give designers a qualitative indication of the likely behavior of buildings.
8. The thermo-physical properties and characteristics of most common building materials in Egypt are listed in tables
9. Tradition building material with thermal resistance R-value varies between 0.8 and 1.3 - $m^{2o}C/W$ is suitable for exposed walls in Kharga Oasis ( desert region) according to the Egyptian Residential Buildings Energy Code, ECP 306-2005
10. For exposed roofs in Kharga Oasis and the required thermal resistance has a minimum R-value =3 m K/W.
11. To verify Egyptian Residential Buildings Energy Code, ECP 306-2005, the Thermal insulation thicknesses between 0.03-0.05m for exposed walls and 0.05m for exposed roofs are suitable to valid the required thermal resistance in Kharga Oasis
12. Light color and shading help in decrease the direct share of solar radiation on heat gain through walls.

13. For non-conditioned building orientation, shape, size, shading devices and control opening areas in the envelope has the first priority.
14. Bio-climatic by ASHREA chart indicate that the mechanical cooling need reach to 9.0 %per year, Sun shading of windows 27.8 %, Direct evaporative cooling 25.5.
15. New smart building materials can be used to improve the thermal performance of the building and save energy of commercial and government buildings in Kharga.
16. Smart glass with good optical properties can be used to improve the thermal performance of the building and save energy of commercial and government buildings in Kharga and enable architecture to made opining with large area.
17. In summer season where the average outdoor temperature is up to 30 $^{o}$C, the traditional building is high sensitive to external climatic conditions. In this case some additional passive or low energy cooling system, air catcher, court and evaporative cooling, is needed to ensure indoor comfort.
18. According to the low relative humidity of the region, evaporative cooling considered a good passive system to improve the indoor air climate.
19. Although people living in hot regions are acclimatization to the prevailing thermal environment , they prefer higher temperature and would suffer less in hot environment. And the upper limit of comfort reach to 30$^{o}$C
20 Wind velocity range between 5.4 to 12 m/s in summer season and between 4 to 10 m/s in winter season is enough to use wind mail in this area. Also solar water collector must be used in this area as types of the renewable energy needed

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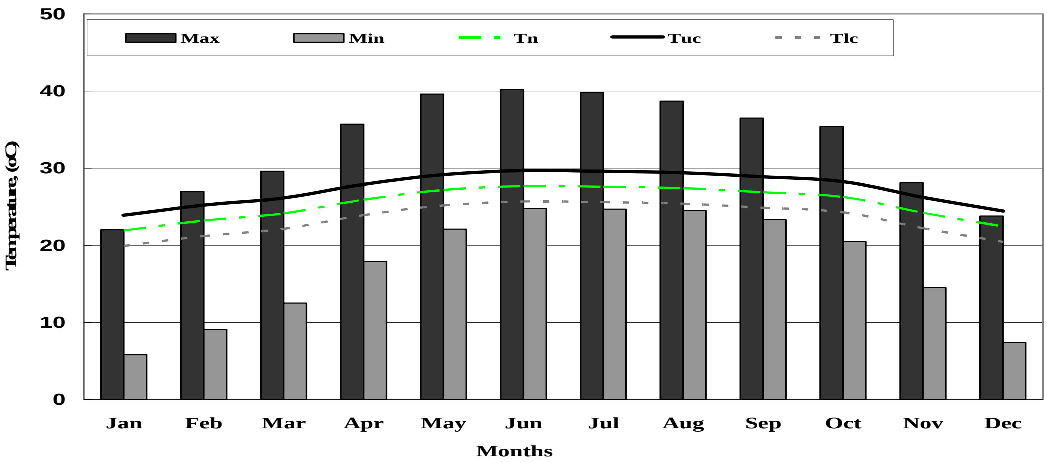



Fig. 1a. The monthly mean maximum / minimum of the outdoor air temperature, the neutrality temperature and the upper/lower limit temperature of comfort in Kharga Oasis.

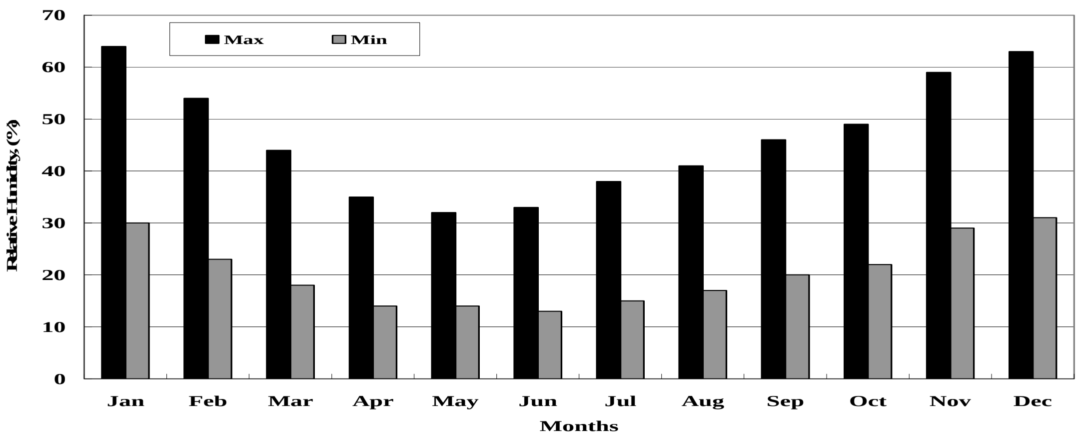



Fig. 1b. The monthly mean maximum / minimum relative humidity in kharga Oasis.

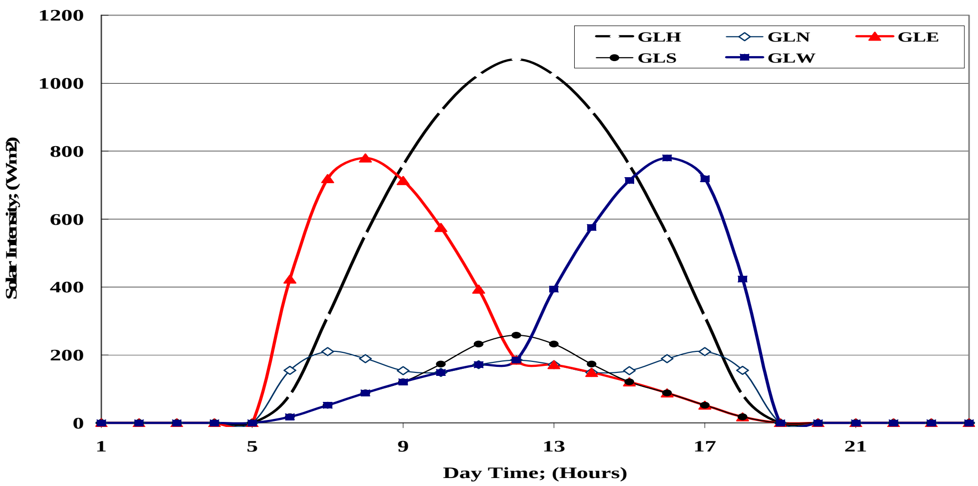



Fig. 2. The variation of the computed solar intensity on the horizontal surface and walls of different orientations on Kharga Oasis, during summer season (July, 21).

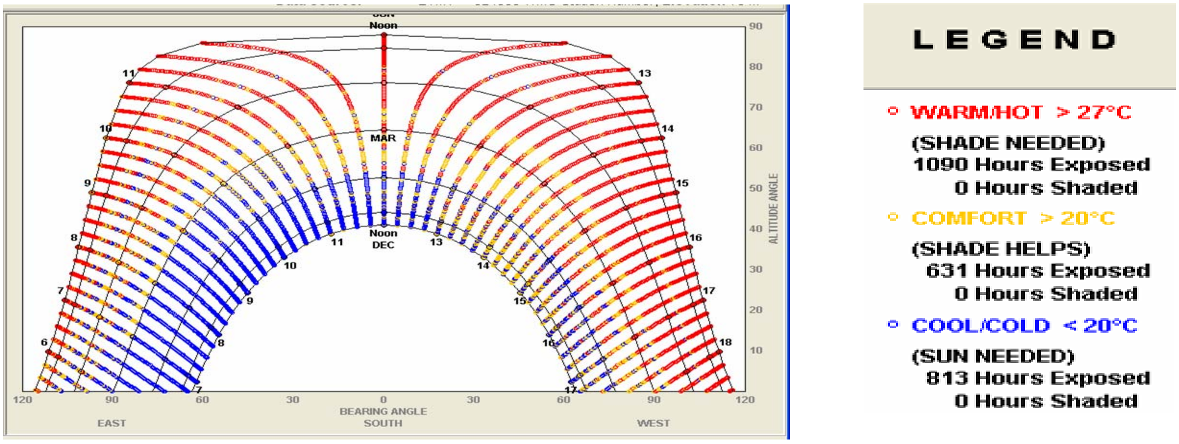



Fig. 3.The sun path diagram for Kharga Oasis through the year for the different direction.

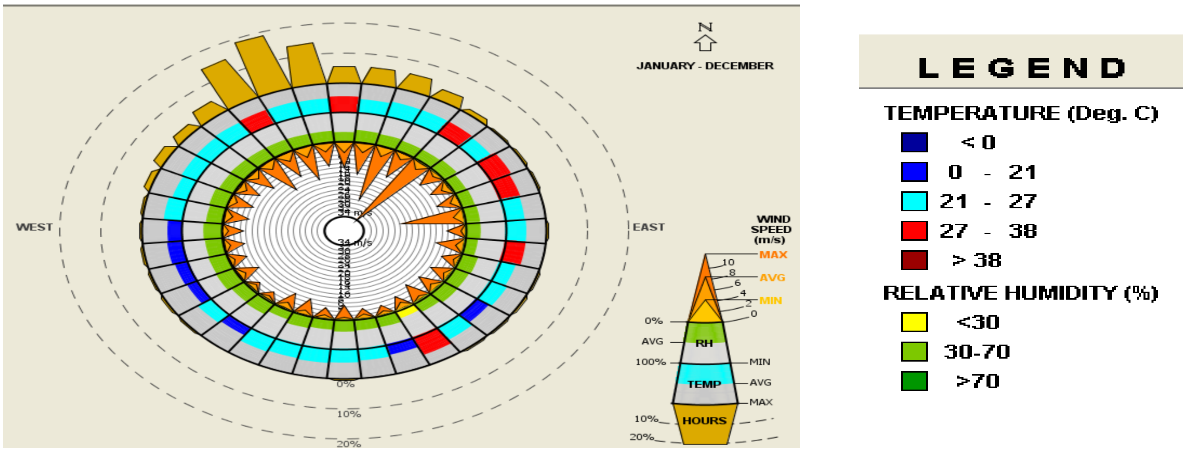



Fig. 4. The average annual wind direction and speed in Kharga Oasis.

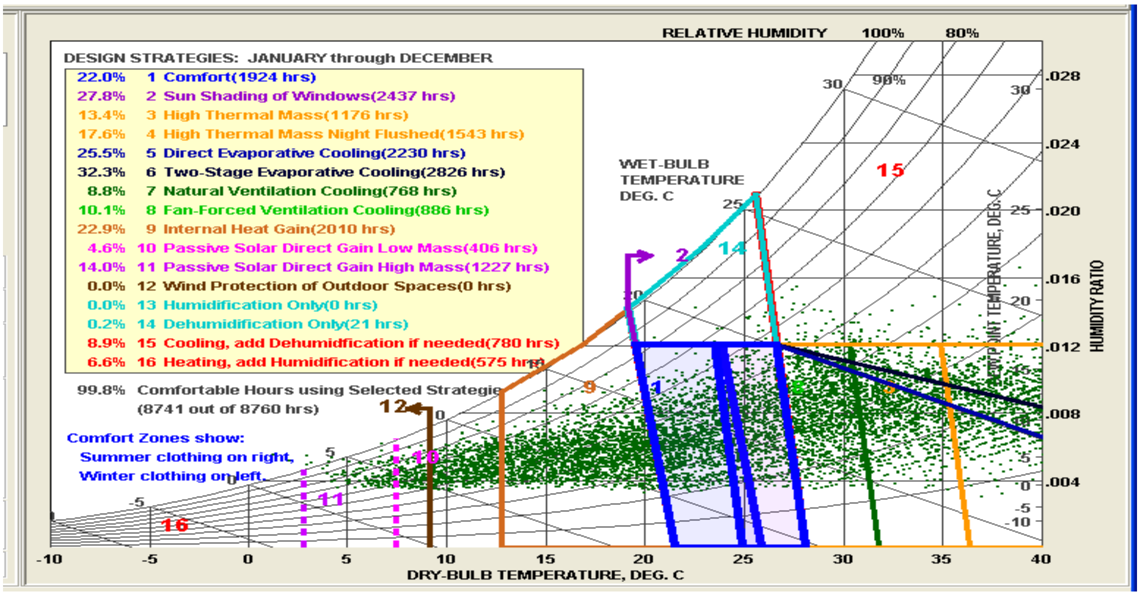



Fig.5. The design strategies on psychometric chart (according to ASHRE 55-2005) with the designed comfort of Kharga Oasis and the extended zone.

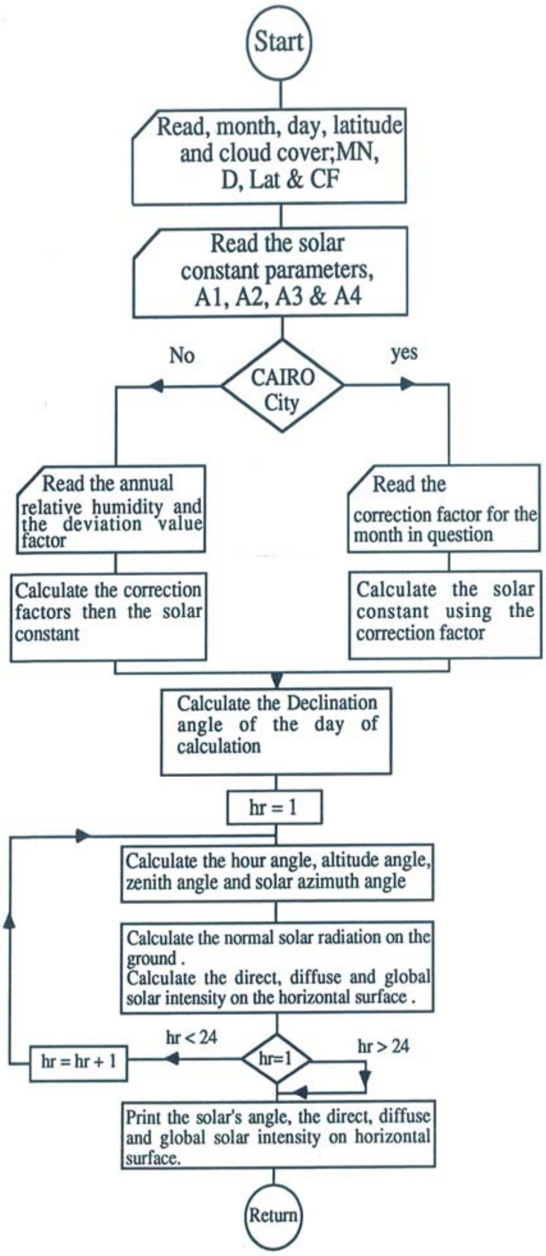



Fig. 6. Flow chart of solar radiation intensity subroutine on horizontal surface (SOLAR Subroutine.

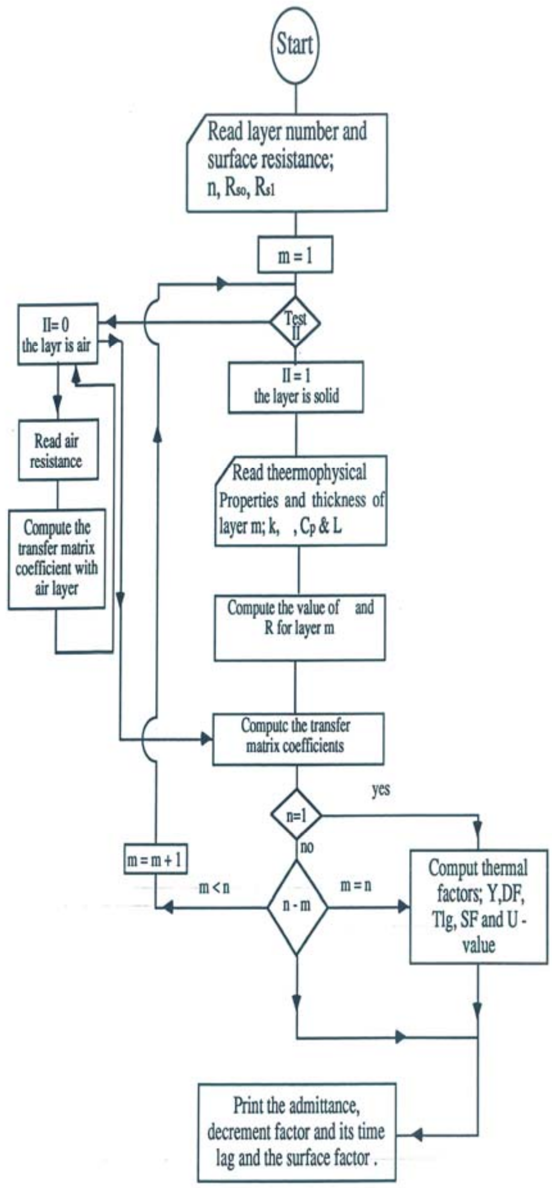



Fig. 7. Flow chart of thermo-physical and characteristics properties subroutine (ADMIT Subroutine).

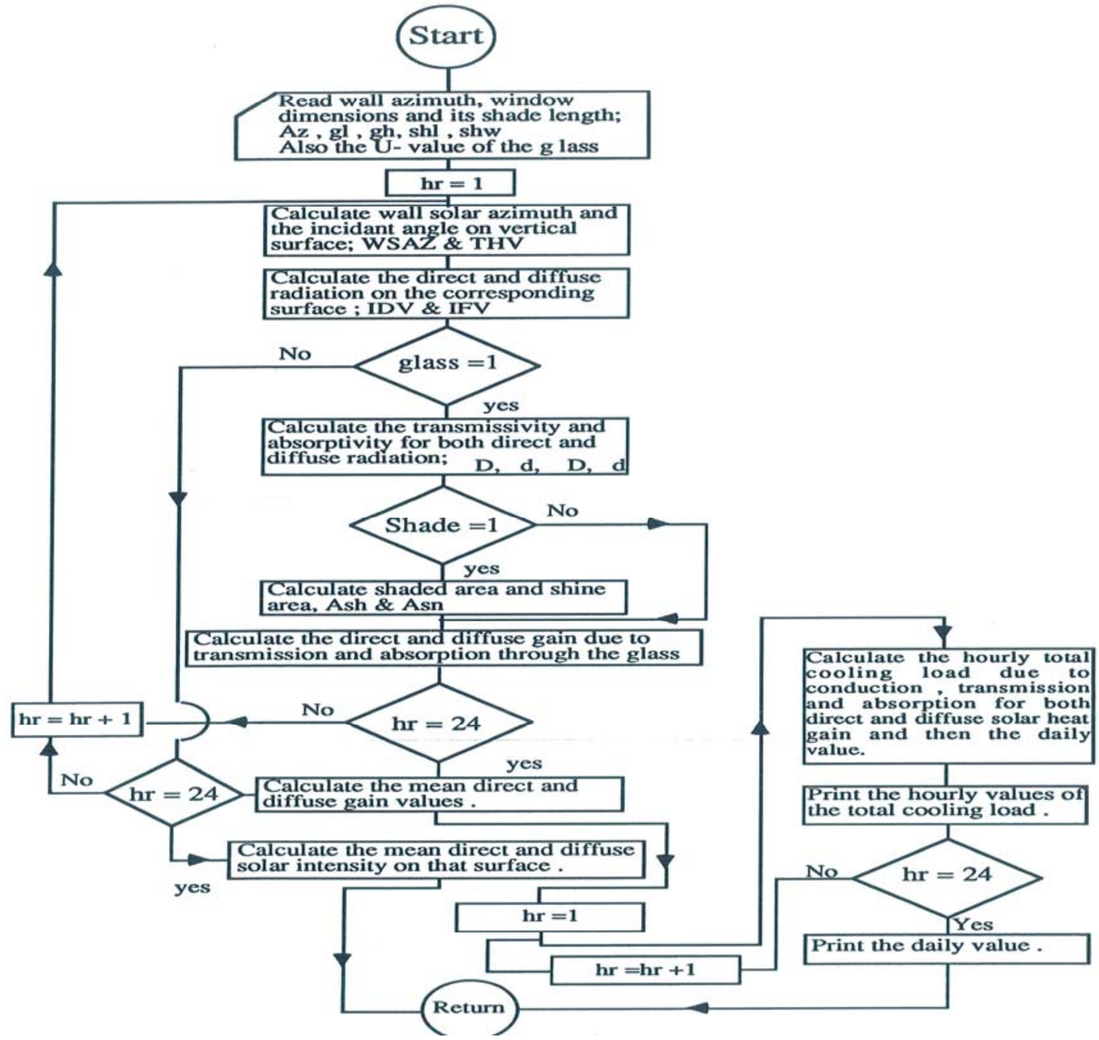



Fig. 8. Flow chart of solar radiation intensity subroutine on horizontal surface.

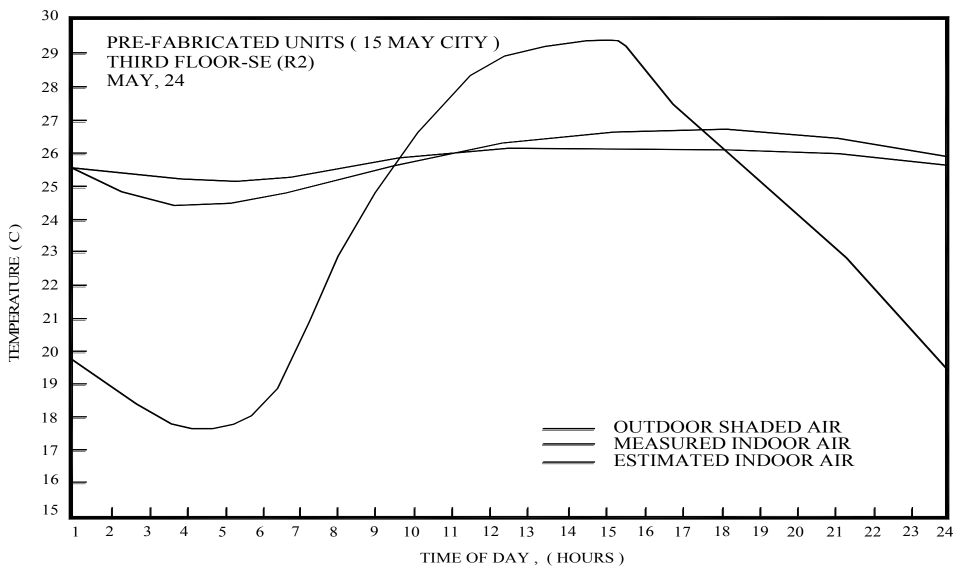



Fig. 9. Comparison between measured and estimated indoor air temperature of rooms 2 in the 3rd floor of pre-fabricated concrete building in 15-May city during summer season.

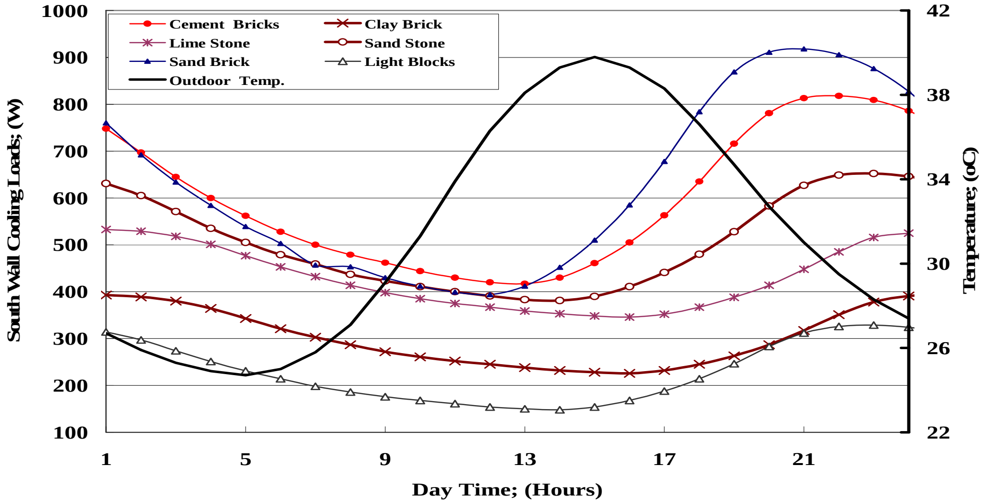



Fig. 10. The hourly variation of south wall cooling load for different building materials.

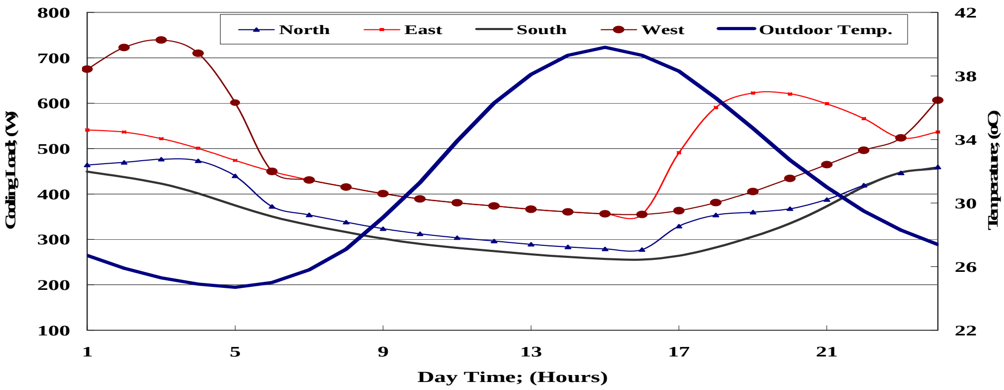



Fig. 11. The hourly variation of the cooling load of different orientation

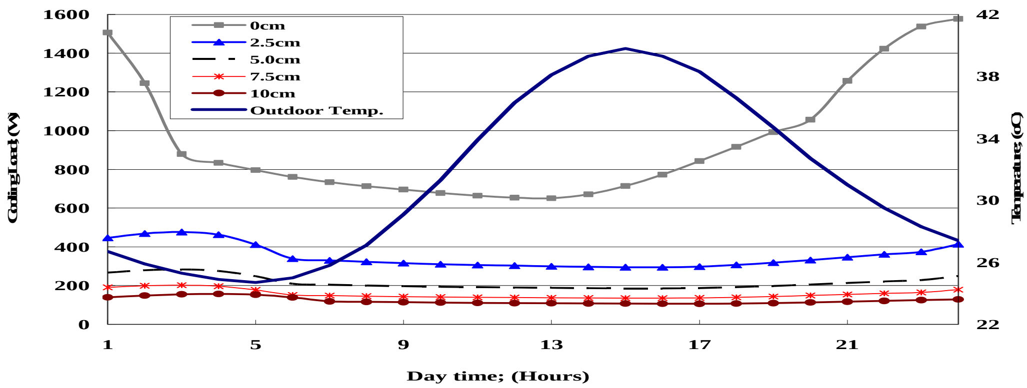



Fig. 12. The hourly variation of the cooling load of west wall with and without thermal insulation.

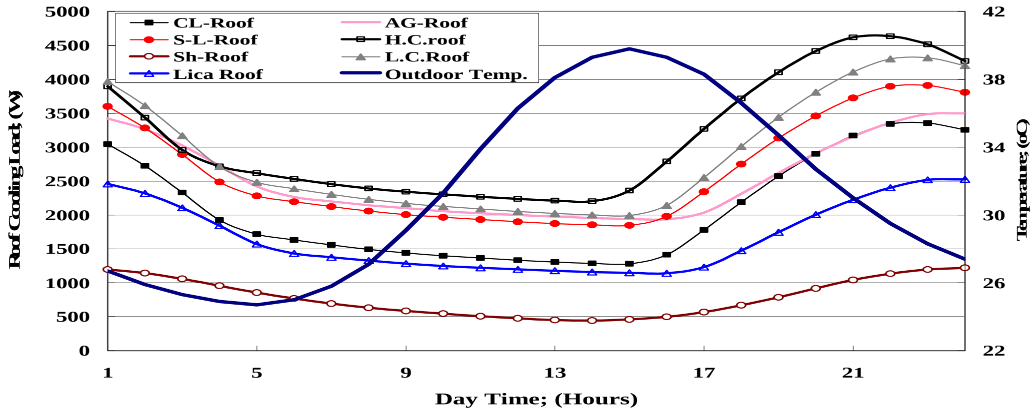



Fig. 13. The hourly variation for roof cooling loads constructed from different building materials.

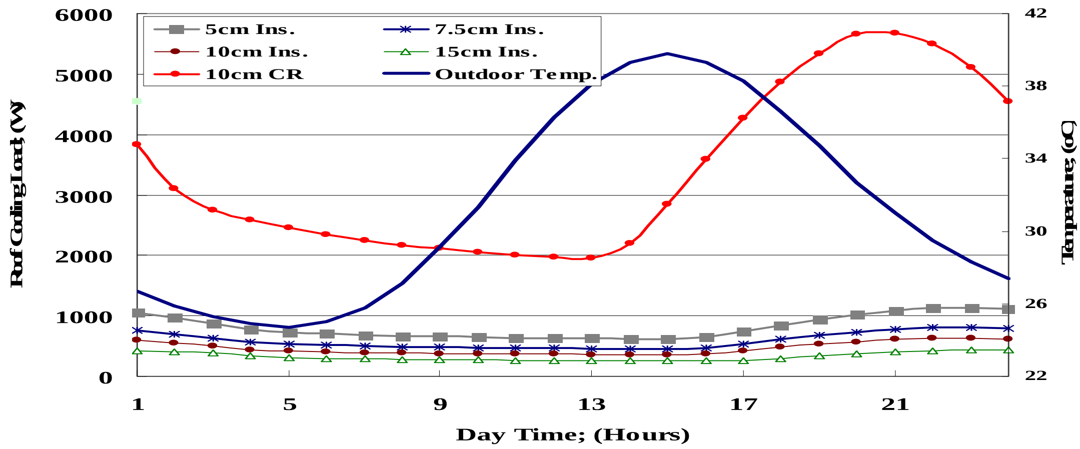
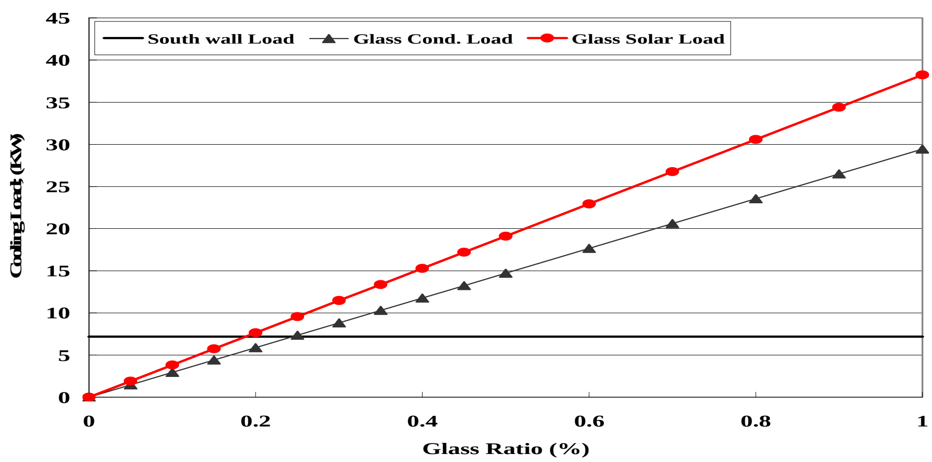



Fig. 14. The hourly variation of the roof cooling loads with and without polystirean layer




. Fig. 15. The cooling load of south wall and window with different glass to wall ratio due to the solar heat gain and conduction