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THERMAL CHARACTERISTICS OF A ROOM TOWARDS AN ENERGY CONSERVATION

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ABSTRACT

This article aims to determine the dynamic thermal performance of a room. The internal temperature as well as the thermal load for walls and rooms were determined using a modified form of the thermal time constant model. The effect of building materials, volumes, orientation, depth, ventilation modes, seasons and exposure area on both internal temperatures and thermal load are studied. A suitable design is given to verify different desired thermal conditions towards energy conservation. A simple method is introduced to get the internal wall temperature and the wall thermal load from a chart based on the wall thermal time constant. Correlation are also given to get the most suitable room depth for each building material depending on the thermal time constant, other correlation is given to get the enclosure thermal load depending on the enclosure volume and on the enclosure thermal time constant. The study showed that the increase of the thermal time constant leads to converging the thermal response.

Keywords: Optimum Thermal Design, Thermal Load, Energy Conservation, Correlation

1.INTRODUCTION

Nowadays the world suffers from energy crisis and it must search for new sources of energy. Energy conservation techniques must be more positively encouraged and intensive actions than those of the present available. Energy -saving through buildings, can be grouped into two categories, which are; methods applicable during architectural design such as : optimizing shape, size, location, orientation and the ratio of glazed to solid boundaries and simple low-cost methods

such as reduction of room temperature, draught proofing, application of thermal insulation's and installation of double glazing.

Many studies are carried out in this field such as :

Studying of the shape and size of a building[1] which were desirable from the thermal comfort point of view. it showed that he ratio of surface area over volume of 0.277 has the best thermal behavior. Studying the effect of the rates of ventilation of office building [2] with other different elements such as building materials, proportion of window area and the room volume with respect to the orientation and shading. An integration in the building envelope design process is studied[3], the study created a computerized approach to support integrated building envelopes design as a functional design and as a principal design process research project involving the development of a knowledge - based expert system is dealt[4] with the practical computer environmental presently, named HYPERCARD. The calculation of peak design load and building load profiles are identified and analyzed [5] to get important input design parameters by using DOE-2 program. Some studies in this field using the thermal time constant method in analysis of the thermal performance of buildings or in evaluating the thermal factors of walls and of buildings. These studies are such as: Studying the using of ceiling and partitions with appropriate air moving in a modular design[6] The thermal analysis of the use of windows as passive solar collector is based on the total thermal time constant method. The saving of energy are carried out [7]could be affected by increasing the air change rates with controlling of the structural heat capacity and the insulation. A simple dynamic thermal analysis program using thermal time constant method carried out[8] and concluded that a dynamic thermal index should be used in conjunction with the thermal transmittance in order to evaluate the thermal performance of a wall.An evaluation of the hourly indoor air temperature by the thermal time constant method is given[9] and another one ,is also given ,to calculate the mean indoor air temperature with ventilation[10] when the floor consists of multi-layers construction or a ground floor without insulation. They developed a thermal network analysis and obtained heat balance equations.

The present work is to find relations of passive system elements to facilitate the integration of parameters towards the energy conservation. the relation between building materials with the room dimensions is studied to find the most suitable designs.The integration between the glazing materials and the constructions is important to find the suitable ones for different purposes of energy conservation because the Thermal Time Constant Method contains the most major factor represents the thermo-physical properties of materials.

2.PHYSICAL THERMAL MODEL

The room considered is in a multistory building. The facade is partly glazed and party opaque. It is assumed that the room is surrounded , by identical rooms. There are four types are: 105 mm thickness of heavy concrete(Type I),105 mm heavy concrete + 100 mm air gap + 60 mm polystyrene and 5mm timber (Type II), 250 mm thickness of sandbrick (Type III), and 400 mm thickness of limestone (type IV). Two layers of plaster; with 20mm thickness, on both sides for four types of construction. The dimensions of the room are 2.8 m x 2.8 m x 2.8 m. Other dimensions were considered by increasing the width or the depth or both of them times original length which is 2.8 m.

3.THEORETICAL ANALYSIS

This Study using the Thermal Time Constant Method [11] and its some Modification to calculate the indoor air temprature in the case of entering the solar radiationinto the room. The periodicity -in this case- by investigating new thermal factors [12]. The thermal load for walls and glass is also given by modefing this method and with evaluating a new enclosure thermal time constant , and this will be published in details in another study[13].

4.RESULTS AND DISCUSSION

Figure (1) shows a comparison between the present theoretical results and previously published experimental results (M) [14] for external and internal surfaces temperature of the room made of sand brick in the Building Research Center. Good agreements between calculated and previously published measured results; especially at noon hours. Also, both of them, has the same decrement factor and the same periodicity of the phase shift. But, there is a difference between the calculated and measured results at early and night hours, due to unexpected effects such as the net radiation which may be, at that day, decreases than the normal. Also, there, may be, increase in the relative humidity than the usual recorded values which cause increase the latent heat. These effects could increase the wall temperature than the calculated values.

Figure (2) shows a comparison of the calculated peak environmental temperature for a room by the admittance method [15] and the present thermal time constant method. The room made of concrete material, and it is S&W corner room of 2.8m H(height) . The room dimension is assumed W (west), S (south) is from 2.8 m to 4.4 m. Both south and west glass area is 1.6 m^2. The figure shows good agreements between the results obtained by the two calculated method. This figure also illustrated that the room dimension of 4.4m x 4.4 m is more suitable than other dimension - while the increase of internal air temperature is due to use the west exposure in summer which is affected by high thermal insolation-, this is will be more clearified in discussion of Fig. (7).

Table (1) shows the comparison between two cooling load calculation methods, the CLTD ASHRAE's method [16] and the present t_c thermal time constant method , for the peak cooling load values in Cairo on Latitude 30 8 at south, north, east and west orientations, for concrete wall material of 6.6 m^2 area. The Table illustrated a good agreement between the results of the two calculated methods.

Figure (3) shows the relation between t_c and $T_{wi,max}$ for concrete (t_c=15 hr) sandbrick (t_c=23 hr) limestone (t_c=69 hr) and con+ a.g.+ins (t_c=91 hour). The figure illustrated that as the t_c increases the $T_{wi,max}$ decreases. By knowing t_c, one can investigate the $T_{wi,max}$ from Figure (3) for the same place and time.

Figure (4) shows the effect of the total wall thermal time constant t_{cw} on the peak wall thermal load/m^2, $Q_{L,max}/m^2$. This figure shows that the peak wall thermal load /m^2 decreases as the t_{cw} increases, that is for both heating and cooling loads. It is also shown that the thermal load is slowly decreases, for large t_{cw} values. There is another decrease of the thermal load; above t_{cw} of 33 hr, other slower decrease is found above 58 hr and the slowest decrease is happened at values of t_{cw} ;above 101 hr. So, from this figure , one can define the required materials , which could save the desired amount of energy by choosing the suitable material's t_c value.

Figures (5,6) show the effect of increase of the width and depth by the same ratio on the mean thermal load/m^2 i.e. the effect of the ratio W/2.8 of rooms made of concrete and of sand brick on the mean thermal load at west in summer and at south in winter, respectively. The glass area and the height of room for the two cases are 15% and 2.8 m, respectively. From these two figures, one can found that the most suitable ratio of W/2.8; to reduce the room load is between 1.5-2 in summer and between 1-1.5 in winter.

Figures (7,8) show the effect of orientations (one or more) on the maximum indoor environmental temperature $T_{ei,max}$, and the daily mean thermal load $Q_{L,mean}$ in summer and winter conditions ; for rooms made of concrete. The rooms dimensions are 4.2 m x 4.2 m, x 2.8 m and the glass area is 15% of the exposures. From these two figures, one can say that both $T_{ei,max}$ and $Q_{L,mean}$ decreases for orientations N(north), E(east), S(south)&N,N&R(roof),but N&W(west) is slightly higher , the favorite orientations for three exposed enclosure is N&E&S . The maximum values of $T_{ei,max}$, $Q_{L,mean}$ are increased for some directions which have two and more orientations; especially for directions which have exposed roofs. That is, at closed conditions, but at ventilated conditions as shown in Figure (9). The decrease of temperature is significant for rooms of two and three orientations. It is also illustrated that the air temperature with ventilation is decreased at three orientations than at one and two orientations, and that is contrast to the closed condition which is discussed in Fig. (7).

Figures (10) shows the result of the optimized design of W=D=1.5 H, G=20% of the exposures for two rooms made of concrete and con+a.g.+ins, respectively at closed and ventilated condition of ACH=4 . The rooms are corner rooms at S & E orientations to get useful of the -mostly -wind direction in Cairo . It is shown from this figure that the ventilation at those orientations has a large effect on reducing indoor air temperature along the day, but the light material (concrete) is affected largely than the heavy materials (con+a.g.+ins).

So, the modefied total thermal time constant method (t_c)[12],[13] is clearly shows the small finite differences values between various conditions at closed and ventilated conditions and on entering the solar radiation into the room which reached from one and more orientations, that is due to the handling the actual thermal mass and by specifing effective parameters through dealing with the mthod in its modefied form.

Corrections For Suitable Depth And Thermal Load

The relation between suitable depth, incident solar energy radiation and total enclosure thermal time constant numerically carried out and is given by:

$$D/D_{ss,ref}=1.00086(I_{wo,mean}/I_{ss,mean,ref})^{0.98}(t_{ce,ref}/t_{ce})^{0.994} \quad (1)$$

The maximum error is 0.07

where ref. is the reference material which is concrete + air gap +insulation con+a.g.+ins) .$D_{ss,ref}$ is taken 2.8 m which is the most suitable depth for the reference material at south in summer.

$I_{ss,mean,ref}$ is the mean incident solar radiation at south in summer.

$t_{ce,ref}$ is the total enclosure thermal time constant for reference materials.

This relation illustrates that the most suitable depth is directly proportional to the incident solar radiation and inversely proportional to the total enclosure thermal time constant.

For thermal load, one can divide the materials into light material which have $t_c<33$ hr and heavy material which have $t_c>33$ hr. The correlation of the wall thermal load for light materials is

$$Q_{Load}/Q_{Load,ref}=0.0199x(vol./vol_{,ref})^{1.85}(t_{ce}/t_{ce,ref})^{0.98} \quad (2)$$

The maximum error is 0.086 and the reference material is concrete which have t_{ce}=21.2 hr. It is applied at south and west orientations and for sand brick room of t_{ce} = 26.1 hr with very small difference. This relation indicates that the enclosure thermal load is directly proportional to the volume as shown in Fig. (6).

The correlation of the enclosure thermal load for heavy material is:

$$Q_{Load}/Q_{Load\ ,ref}=18.156(vol/vol_{,ref})^{1.399}(t_{ce}/t_{ce,ref})^{.9376} \quad (3)$$

The maximum error is 0.005 and the reference material is (con+a.g.+in) which have t_c = 91 hours. This equation indicates that load of the heavy materials is directly proportional with the volume and on the enclosure thermal time constant.

5.CONCLUSION

The study shows the dependence of thermal response values on the thermal time constant. The most suitable design is getting more easier by this method than any other methods. The suitable design for a room can be chosen as follows: The exposed wall's material is of large thermal time constant greater than 33 hr or 58 hr. The width and depth is favorite to be 1.5 times of the height. The most suitable orientation are north & west or south & east or north south with 15% glass area at each exposure. A converge of thermal factor values are found for large thermal time constant materials. The thermal time constant method helps in the analysis of the thermal response factors for both walls and rooms and gives a direct indication of them by using their thermal time constant. The method, also, helps in finding relations between some designed elements, and some thermal factors such as: depth , thermal load, internal wall temperature and the incident solar radiation ; depends on the total wall and total enclosure thermal time constants and finding the integration between all passive system elements towards energy conservation.

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Table (I): Comparison of peak Load Caiculation by CLTD, ASHREA methed and the present t_c method for a concrete wall $U = 3\ W/m^2\ ^oC$, area $6.6\ m^2$

Time	South		West		North		East	
	CLTD	t_c	CLTD	t_c	CLTD	t_c	CLTD	t_c
14	176	180	249	263	136	148	330	340
15	201	211	266	288	144	156	342	353
16	227	231	272	301	150	161	351	362
17	240	239	290	326	157	168	345	353
18	227	226	304	350	165	172	332	341
19	201	208	349	362	171	176	311	322
20	172	169	349	362	162	165	289	296

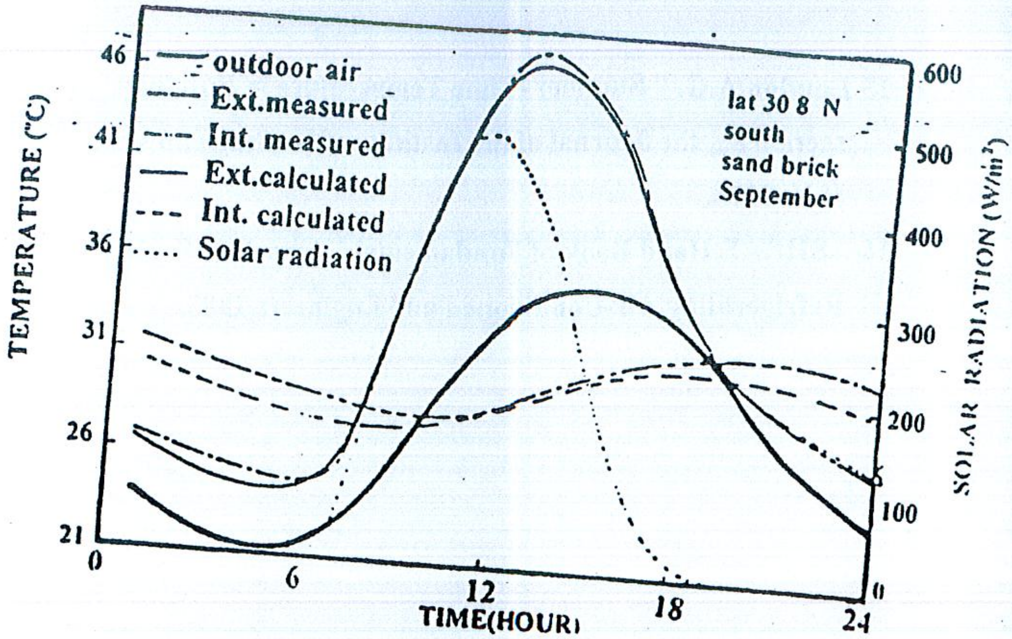

Fig.(1): Comparison between measured(M) and the present calculated(C) temperature for external (ext.) and internal (int.) of a room made of sand brick walls.

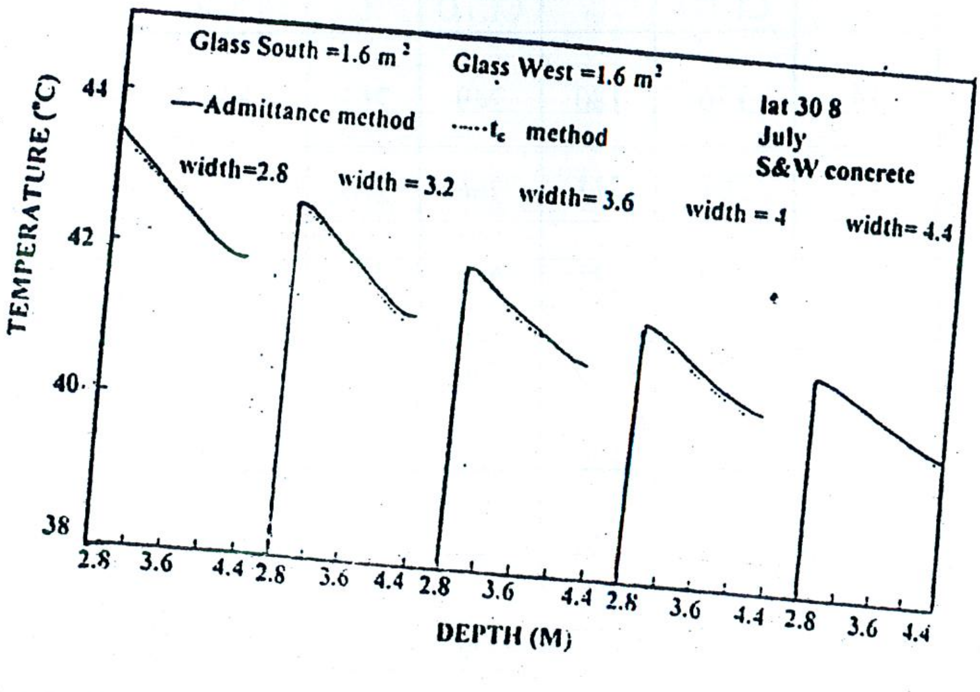

Fig.(2):Comparison of the peak environmental temperature for corner room of S&W orientation by the Admittance and present t_c method.

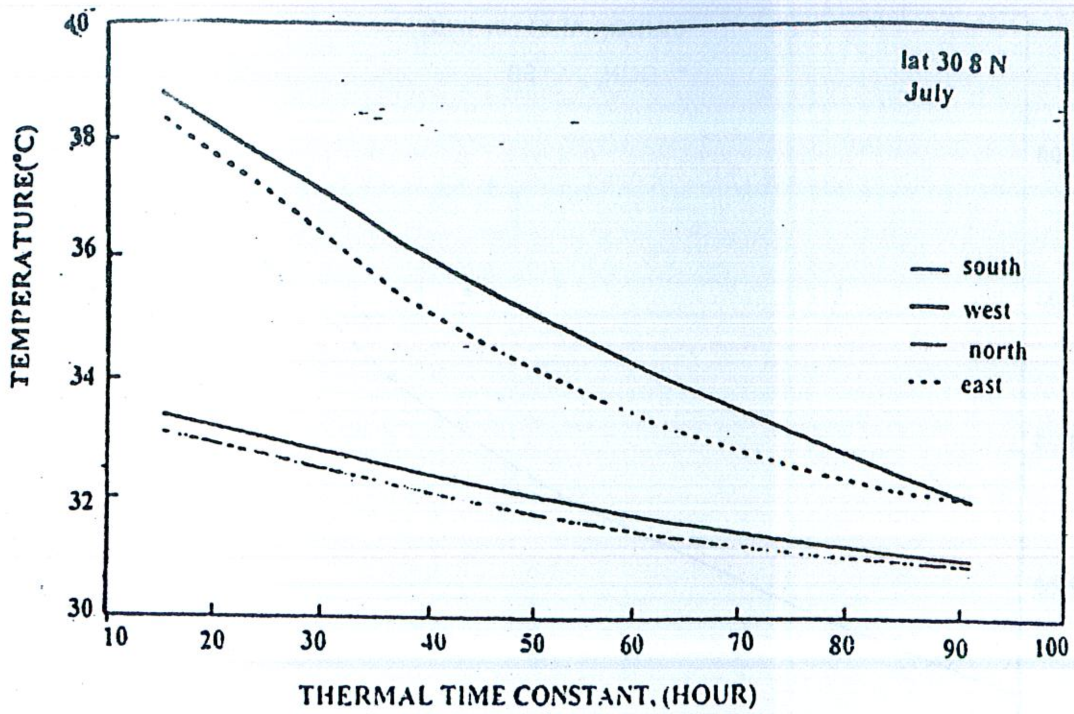

Fig.(3): Variation of the peak internal wall temperature with the thermal time constant t_c for four original orientations on July.

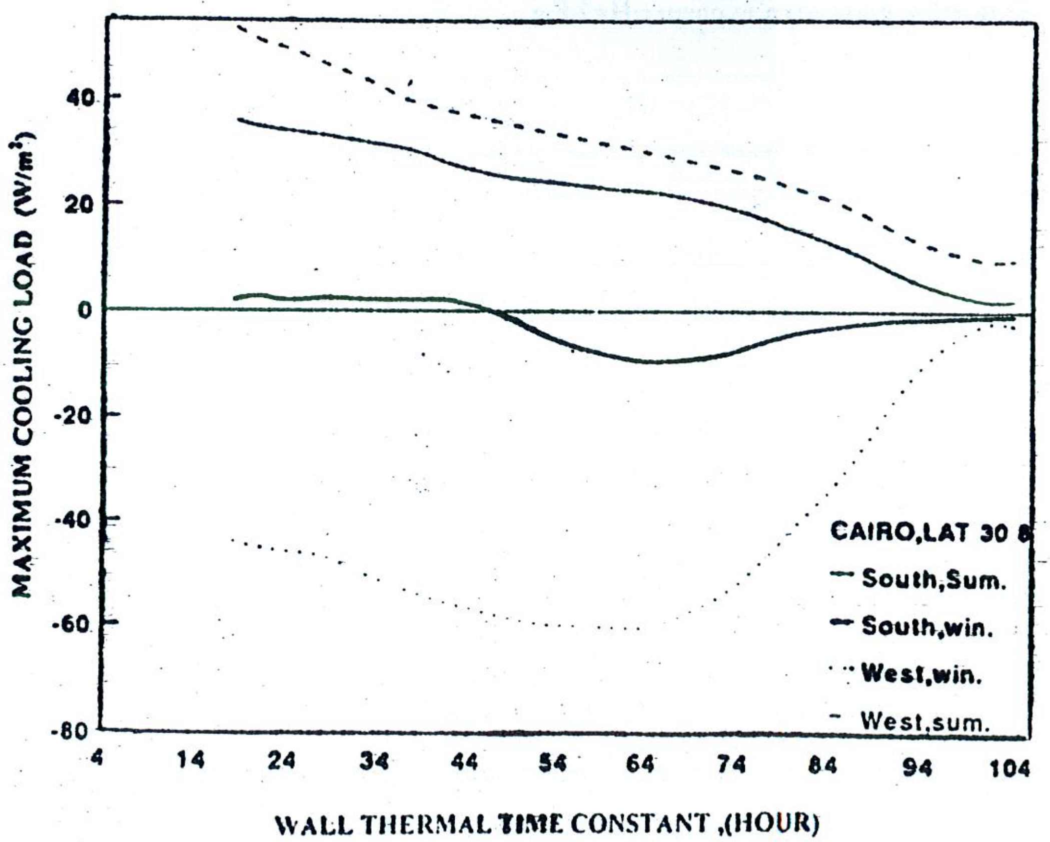

Fig.(4): Effect of total wall thermal time constant on the maximum thermal load per meter square for summer and winter conditions at south and west orientations.

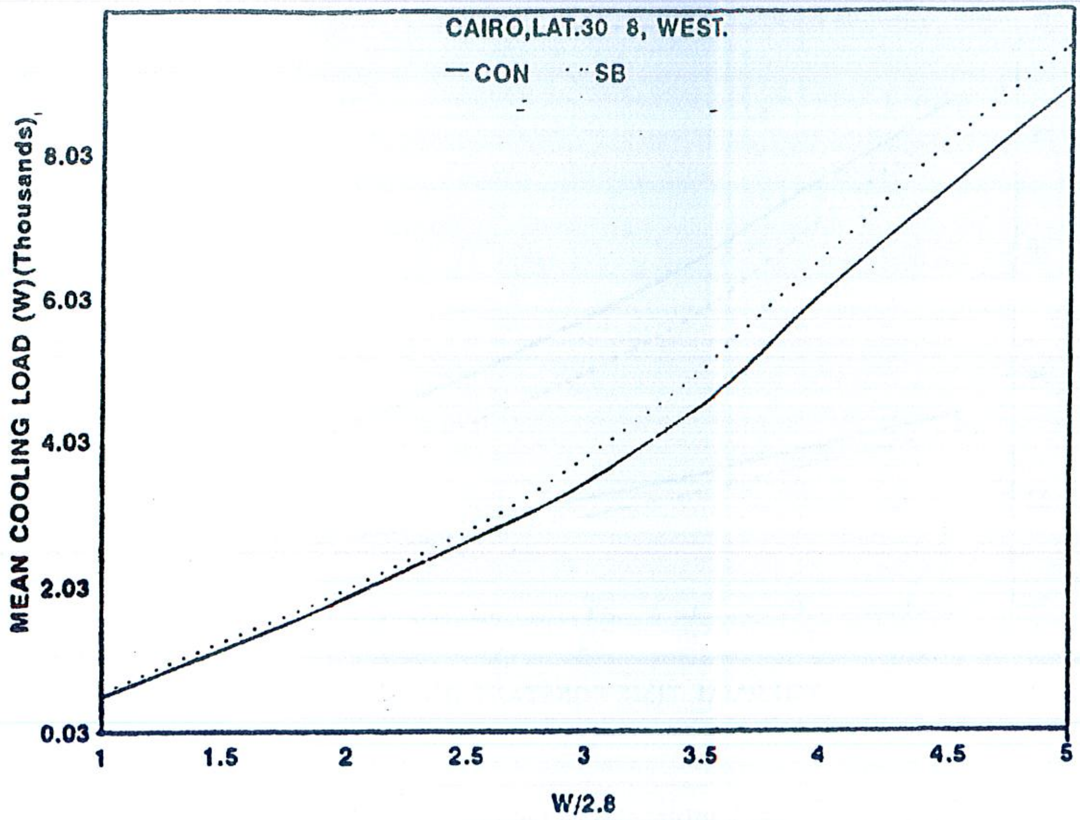

Fig.(5):Effect the ratio of W/2.8 of a room made of concrete or sand brick on the daily mean thermal load in summer condition and at west orientation with 15% glass area exposure,H=2.8m.

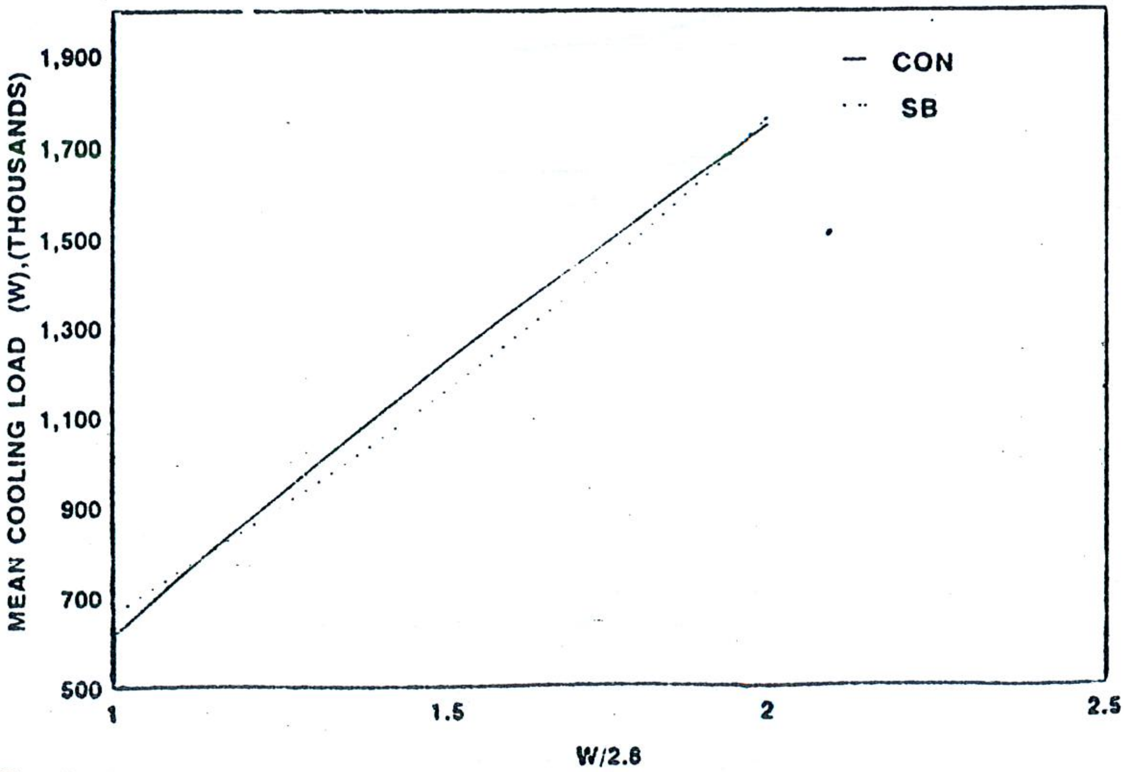

Fig.(6): Effect the ratio of W/2.8 of a room made of concrete or sand brick on the daily mean thermal load in winter condition and at south orientation with 15% glass area exposure, H=2.8 m.

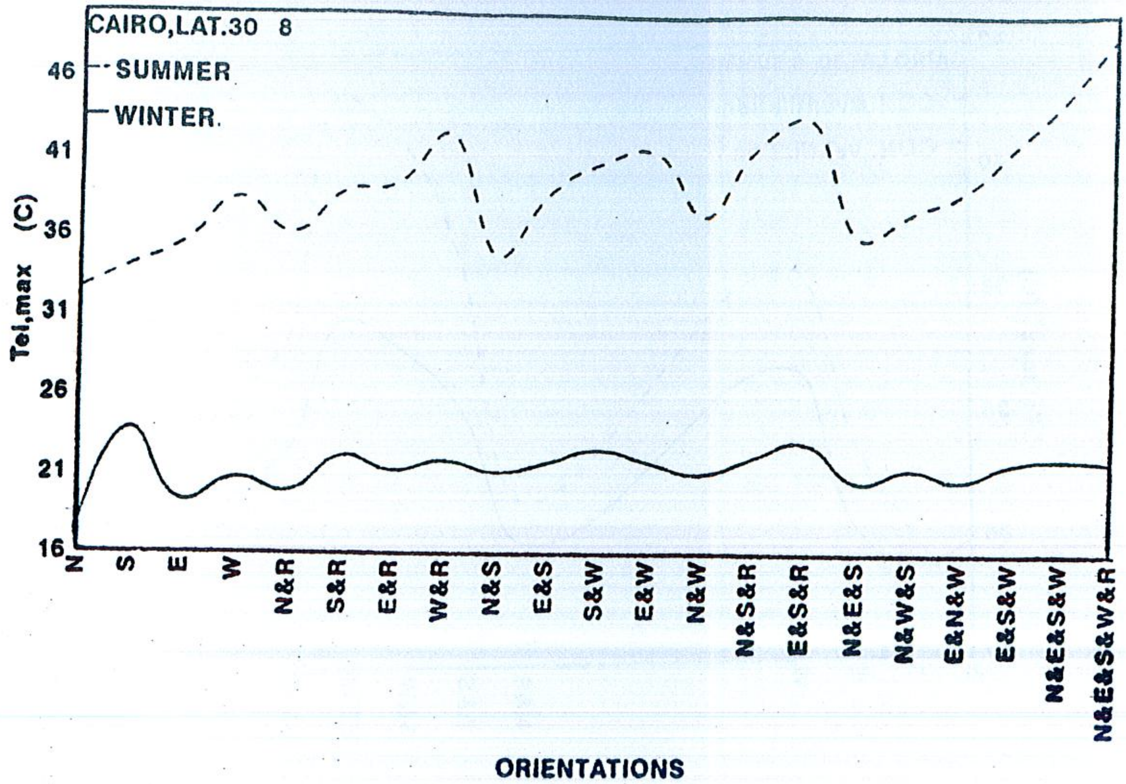

Fig.(7): Effect of different orientations, one and more on the peak environmental temperature in summer and winter conditions for rooms made of concrete with optimized dimensions 4.2m x 4.2m x 2.8m with glass area 15% of every exposure.

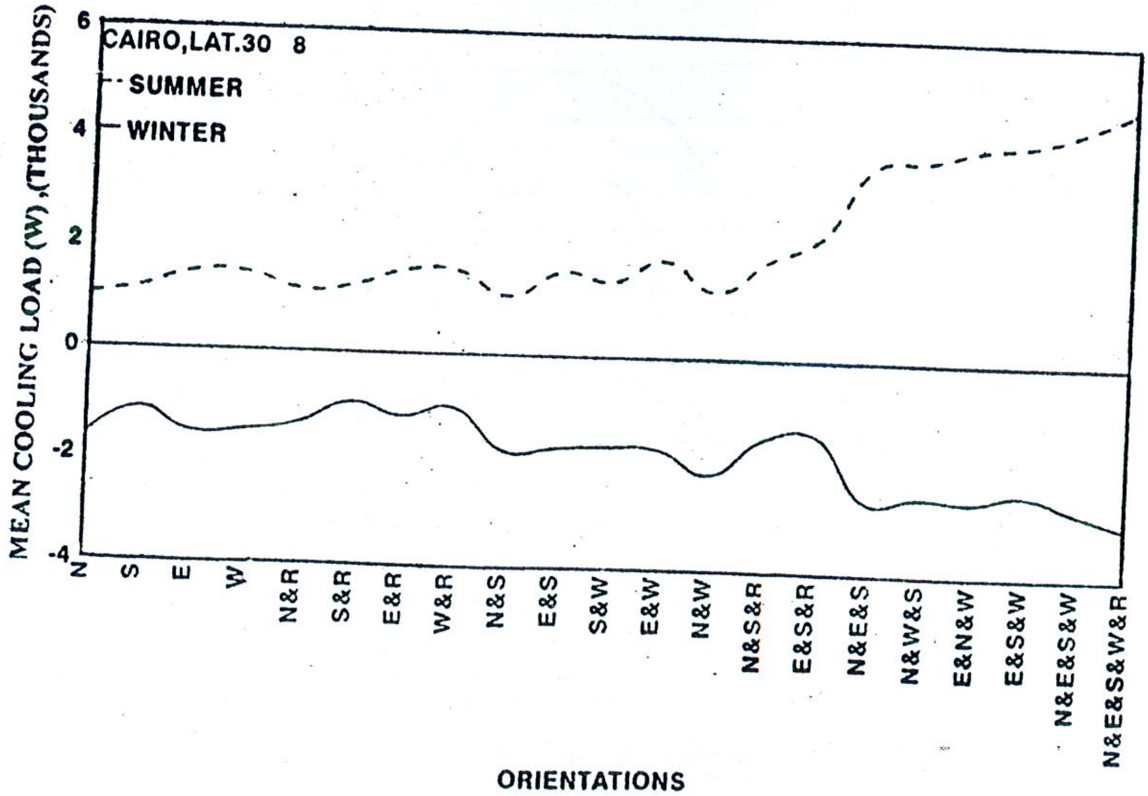

Fig.(8): Effect of different orientations, one and more on the daily mean thermal load in summer and winter conditions for rooms made of concrete with optimized dimensions 4.2m x 4.2m x 2.8m with glass area 15% of every exposure.

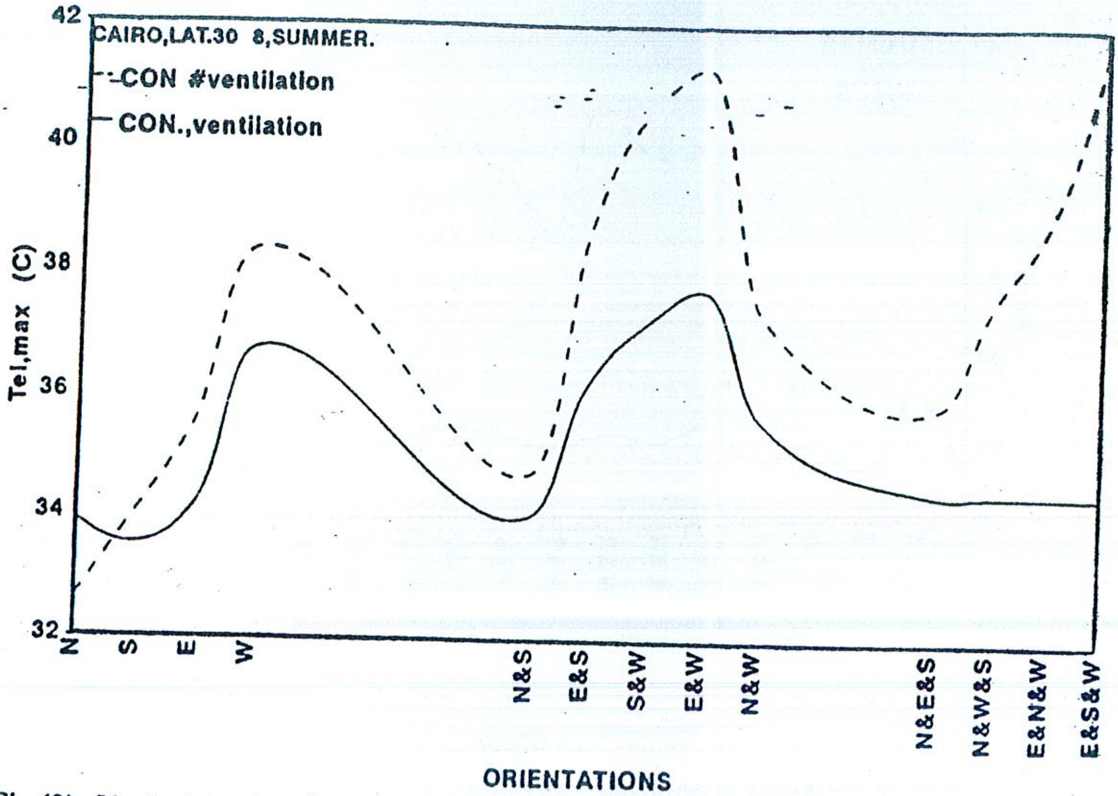

Fig.(9): Variation of peak environmental temperature with different orientations with ventilation of ACH=2 for every exposure and for closed condition for rooms made of concrete having optimized dimensions and in summer conditions.

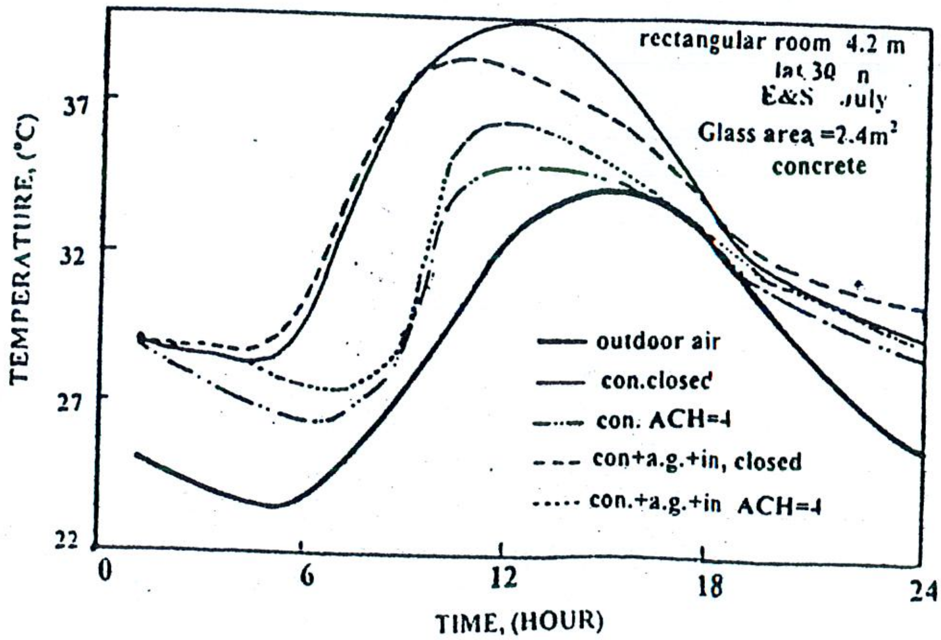

Fig.(10): Variation of air temperature for optimized rooms dimensions of con. and con. +a.g.+ in. with and without ventilation.