REDUCTION OF HEAT TRANSFER THROUGH WALLS IN BUILDING BY USING LOCAL NATURAL INSULATION IN IRAQ

Haqi Ismael Qatta
Department of Electro- Mechanical Engineering , University of Technology - Baghdad

ABSTRACT

The energy saving is very important in the practical application engineering . This research studies on this subject in the field of air conditioning. A numerical program has been developed to obtain the thermal response of different walls to energy sources (solar and ambient temperature) in summer of Iraq. Anew local natural insulation is used to reduce heat gain to air-conditioned space. This work proposed to used local natural insulation from palm fiber , local cane mat and local plastic mat to save energy required to condition a space . A finite element solution for heat flow through wall is used with suitable iteration solution where boundary conditions are varying due to solar radiation and environment thermal load. The result- in saving of about 50% of energy that may pass through walls when used mat cane local compared to the mat plastic local and palm fiber.

Key word: local natural insulations , heat flow, finite element method

تقليل انتقا ل الحرارة خلا ل جدران البنا ية با ستعما ل عوا زل طبيعية محلية في العر ا ق

الخلاصة :-

ان توفير الطا قة جدا مهم فى التطبقا ت العملية الهند سية. البحث يدرس مو ضو ع تكييف الهو اء فى البنا يا ت . تم استعما ل بر نا مج عد دى للحصول عاى الاستجا بة الحرارية لانواع متعددة من الجد ران لمصا در الطا قة (الشمسية و درجة حرارة المحيط) فى فصل الصيف فى العراق . عوازل طبيعية محلية ا ستعملت فى البحث لتقليل الحرارة المتزايدة و للحصو ل عاى جو مكييف ، هذا العمل منا سب لا ستعما ل العوازل الطبيعية المحلية (ليف النخيل ، حصيرة القصب المحلى و حصيرة البلاستك المحلى) لتو فير الطا قة المطلوبة للحيز المكييف. الحل بطريقة العناصر المحددة لجريان الحرارة خلا ل الجدران مناسب للعمل التكرارى فى ظروف محددة وتتغير نتيجة الاشعاع الشمسى والحمل الحرارى المحيطي .اوضحت النتائج بان توفير 50% من الطا قة خلا ل الجدران عندما نستعمل حصيرة القصب المحلى مقا رنة مع العوازل الاخرى المستعملة فى البحث وتوفير 20% من الطا قة خلال الجدران عند ما نستعمل جدار ذو سمك40 سم فقط من الطا بوق بدون العوازل.

NOMENCLATURE

A. Apparent solar radiation at air mass (w/m2)

B. Atmospheric extinction coefficient
C. Diffused coefficient

C_p-specific heat (j/kg.k)
q- heat flux (w/m2)
h- coefficient of heat transfer by convection(w/ m2.k)
k- thermal conductivity (w/m.k)
I-solar flux (w/m2)
N_i-shape function (dimensionless)
t-time (hr)
T-temperature (℃)
[C] ,[K] ,[F]- Matrices

Greek

ρ ---density (kg/m3)
α ---absorptivity
ε ---emissivity
β ---solar altitude with horizontal
γ ---solar surface angle (from south)
θ ---angle of incidence
ϑ ---reflectivity
σ ---stefan Boltzmann constant = 5.669×10^{-8} w/m2 .k^4
Ω ---region
Γ ---surface
λ ---tilt angle

Subscript

d- diffused
DN-direct normal
Co- convection at outside
ci-inside convection
e-effective
H-horizontal
Ws-wall surface
dp- dew point
r-radiation
inf-ambient
in-inside conditions
e- element
ref-reflected
rerad- reradiation
G-ground
Low- low temperature radiation
o- outside condition
v- vertical

INTRODUCTION

Old Iraqi people used to build thick walls in their building to prevent extreme weather conditions especially in summer where temperatures in Iraq is usually higher than 45℃ . In hot zones where a hot summer is excepted , special attention has to be paid to study cooling load .Many references had well established to procedure of calculating cooling load. It is matter of energy saving if one wants to reduce cooling load to maintain the comfort condition for humans ,so extended studies in this field will be expected , now and in the future.

Heat leak through building walls and ceilings consume a substantial amount of energy .Since climate control units require a significant amount of electric energy ,studies of heat leak has received considerable attention in the past decades. An accurate estimate of the heat leak through the composite , multi- layered walls accompanied with practical low cost methods for reducing the heat leaks was an effective way of reducing energy consumption. This work will focus on the factors that reduce the fabric heat gain by testing the appropriate thickness of poplar-used wall type and proposed a suitable thickness and usage of insulation inside the wall in hot region ,such as in Iraq, to reduce cooling load required to maintain a space at comfortable temperature(20℃).Investigations of the heat transfer through the building walls have been treated both experimentally and theoretically by several researchers.[ASHRAE1997,Spilter1997,Faye2000]

Ho and Yih[1987] . Analyzed conjugate natural convection and conduction in amulti-layer wall. They considered isothermal left and right sides of the wall and adiabatic boundary condition in both top and bottom surfaces . Tong[1986] and Gerner , analyzed natural convection in partitioned air-filled rectangular enclosures and reported that placing a partition midway between the vertical walls results in the greatest reduction in heat transfer. Kangni [1991] , investigated natural convection in partitioned walls for various aspect ratios and for a wide range of wall thicknesses.Turkoglu and Yucel[1996] , investigated numerically natural convection heat transfer in enclosures with conducting multiple partitions and side walls, However, in their analysis the side walls were assumed to be isothermal, thus eliminating the temperature gradient in the y-direction within the solid. They also kept the top and bottom surfaces perfectly insulated. They reported that Nusselt number decreases as the number of partitions is increased up to 4. They also reported that the cavity aspect ratio had an insignificant effect on their calculations.

J. Hirunlabh[1998] .Studied heat and habitation by using a consists of a glass cover, air gap, black metallic plate an found that the MSW with 14.5 cm air gap and 2 m^2 of mass flow rate of about 0.01-0.02 kg /s . Room ensuring human comfort resulting from the ventilation simulated and experimental results showed a good accuracy can be used to evaluate the long-term reduction of heat.

Antar and Thomas[2001] . " The approximate simple one dimensional analysis for the problem under investigation has two alternative thermal circuits, an upper bound thermal circuit and a lower bound one. Calculation show that the percentage difference in estimating the upper bound and lower bound heat transfer rate reaches 39%. This indicates significant two dimensional effects.. A block of cavities in the heat flow direction was considered with the objective of increasing the thermal resistance. The previous literature search considered the number of cavities as a major factor reducing the heat leak.

N.H Wong,[2002] .Simulated program was used to determination of energy consumption ,cooling load and roof thermal the commercial building in Singapore. The thermal resistance estimated using data from site measurements,and the rooftop garden with these three types of plants were on the building roof were also simulated. The results five-story commercial building can result in asaving of shrubs was found to be most effective in reducing building that the increase of soil thickness would further reduce content of soil can affect the outcome quite substantially.

P.T Tsilingiris[2004]. Wall time varing conduction heat transfer investigation and cooling loads in air conditioning practice and absolute .The walls store heat , absorb and dissipate a fraction at a later time , which depends on the wall thermal developed numerical model , which was validated succeed and allows the prediction of transient and quasi- steady design groups of a growing thermal inertia .The model a heat flux for a wide range of progressively heavier meteorological conditions , something which allows the drastic reduction of the daily fluctuation of the quasi-steady drastic reduction of the daily fluctuation of the quasi- steady broad range of heavier walls.

Dr. Mohammad[2004] S.Al-Homoud . Buildings are large consumers of energy in all count substantial share of energy goes to heat and cool build reduced through many means; notable among them envelope and its components. The proper use of thermal insulation in buildings does conditioning system size but also in reducing the annual periods of thermal comfort without reliance on mechanical periods .

T .M.I[2006] . Mahlia , B.N Taufiq , Ismail . Correlation between thermal conductivity and the building wall has been analyzed . It was found thermal conductivity and optimum thickness of insulation material and practical use to estimate the optimum thickness of through building wall by knowing its thermal conductivity .

Joseph Virgone [2007] , Jean Noel. In construction, the use of phase change materials solar radiation and / or internal loads. The application of wood house makes it possible to improve thermal conductivity composed of a new PCM material is investigated in lightweight internal partition wall .

T. M.I[2010]. Mahlia ,A . Igbal . The demand for electricity in the Maldives continues to mainly due to the growing number of high-rise air -condition appliances in the residential and commercial sector, emission reduction achieved by installing different buildings wallsAlso investigates the effect optimum insulation thickness is based on the cost bene study found that by introduction optimum thickness of different 2 cm , 4 cm and 6cm, energy consumption and emission wall without insulation or air gaps.

The aim of this research is to minimize the heat that could be flow through the walls by selecting a suitable thickness of the walls or adding some suitable local natural insulation to minimize the heat that could be transmitted through the building.

MATHEMATICAL AND NUMERICAL MODEL

1. Boundary conditions

The governing differential equation that cover this case is Fourier equation while the possible boundary conditions ,Figs (1,2 and 3) shows the specification of the walls .

D. Solar heat gain

Solar radiant heat gian is the net solar radiation absorbed by the wall . It is assumed that all solar radiation incident on the wall surface becomes heat gain except for the portion reflected at the surface. The absorptive of the wall is taken (0.8) for gray color . To determine the reflected and absorbed portion of solar energy for gray color an available data for absorptive for solar radiation and for low temperature radiation can be obtained[John2004].The induced energy to wall surface is.[Faye 2000]

$$I_i = \alpha \left(I_{DN} \cos\theta + I_{dv} + I_G \right) \tag{1}$$

$$\cos\theta = \cos\beta \cdot \cos\gamma \tag{2}$$

$$I_{DN} = A\, e^{-\beta \div \sin\beta} \tag{3}$$

$$I_d = I_{DN}\, C = I_{dH} \tag{4}$$

$$I_G = (I_H + I_d)\, \vartheta / 2 \tag{5}$$

$$I_H = I_{DN} \sin\beta \tag{6}$$

$$I_{dv} / I_{dH} = 0.55 + 0.437 \cos\theta + 0.313 \cos^2\theta \tag{7}$$

For $\cos\theta > -0.2$

$$I_{dv} / I_{dH} = \tag{8}$$

For $\cos\theta < -0.2$

A,B and C can be found in [ashrae1999] .Many references establish the criteria of calculating azimuth angle (γ) and angle of sun(β) . A computer program has be written in (VB-6) language developed to calculate this angles at each hours of a day from May to August in order to obtained the part of solar energy induced to wall surface at each quarter of hour of a day ,the calculation will determined the solar energy that strike the surface for the four direction north ,south ,east ,west at latitudes of 32.2 ,this can be introduced by correct the direction with respect to the south which can be determined by Azimuth angle. The diffuse solar energy that reflected as it strike earth surface will be closed to 0.3 of the total , which is again must halved for vertical surface[Faye2000].

E. Thermal radiant heat transfer

A well defined linezed radiation coefficient is [chiasson2000]

$$H_r = 4\, F_{s\text{-}sky}\, \varepsilon_{low}\, \sigma\, (T_{ws} + T_{sky} / 2)^3 + 4\, F_{s\text{-}G}\, \varepsilon_{low}\, \sigma\, (T_{ws} + T_G /2)^3 \qquad (9)$$

Where

$F_{s\text{-}sky} = F_{s\text{-}G} = 0.5$ for vertical wall

$\varepsilon = 0.9$

And without a detailed model of the surrounding ground , it is usually assumed to have the same temperature as the air .

The value of (T_{sky}) can be obtained from [ASHRAE1999] , where the average weather condition is shown in Table- 1.

$$T_{sky} = T_{air} [\, 0.71 + 0.0056\, T_{db} + 7.3 * 10^{-5}\, T^2_{db} + 0.013 \cos(2\pi t / 24)\,]^{.025} \qquad (10)$$

And for simplicity a reliable value of sky temperature as used by the blast program . Which is that it equals environment dry bulb temperature (-6^o k).

Instantaneous sky temperature is used to determine thermal radiant heat transfer ,the effective sky temperature that seems to affect amount of reradiating energy and a well known method to obtain effective sky temperature is [TM1997]

$$T_{sky\text{-}e} = T_{sky} \cos(\lambda/2) + [\, 1 - \cos(\lambda/2)\,]\, T_{inf} \qquad (11)$$

λ – is the tilt angle of the surface from horizontal, then for vertical surface.

$$T_{sky\text{-}e} = 0.5\, T_{sky} - 0.5\, T_{inf}$$

$$q_{rerad} = h_r\, (T_{sky\text{-}e} - T_{ws}) \qquad (12)$$

F. Outside convection heat transfer.

Convection to outside surface is defined by many references[ASHRAE1997]. A correlation recently developed seems to have reasonable balance between accuracy and ease of use.

$$h_o = \{ [\, C_t (\Delta T)^{1/3}]^2 + [a V_o^{\,b}]^2 \}^{1/2} \qquad (13)$$

It is worth to mention that the common wind direction in summer in Iraq is north-west wind with velocity of (4 m /sec). So all walls will treated as leeward walls and have a value of the heat transfer coefficient of leeward direction. Then the heat transfer by convection to or from the wall can be defined as [TM1997]

$$q_{co} = h_o \left(T_{inf} - T_{ws} \right) \quad (14)$$

Daily temperature variation program is published by Parton[parton1981], and is used in this work but it need some special assumption depend on the location ,it needs the hour after the noon of the sun to reach the maximum temperature which is measured in Baghdad to be (3 hours) also this program need the time in hours after sun raise to reach the minimum temperature which is chosen to be zero.

G. Inside convection heat transfer.

As with the previous step, many references detailed the inside average heat transfer coefficient which is taken to be (8.29 $w/m^2 .C^o$), assume the heat transfer to the air-conditioned room of (26 C^o) which is the most poplar and comfortable during summer, than the heat transferred by convection is

$$q_{ci} = h_{in} \left(T_{ws} - T_{in} \right) \quad (15)$$

2. Outside surface boundary condition formulation.

The outside surface equation of heat transfer can be summarized as

$$q_{ws} = I_i + q_{co} - q_{rerad} \quad (16)$$

3. Walls type and Materials properties.

Five types of wall is tested as shown in Table-2, the properties of material in Table-3 and the properties of local natural insulation in Table -4.

4. Finite element Formulation

The space wise discretization of Fourier equation subject to the above boundary condition can be accomplished using Galerkin method. The region of interest (Ω) is divided into a number of elements (Ω^e) , with usual shape function (N_i) associated with each node, the unknown function (T) is approximated through the solution domain at any time by .[R.W.Lewis 1996]

$$T = \sum N_i \, (x,t) \; T_i \, (t) \quad (17)$$

Where $T_i(t)$ are the nodal parameters substitution of the above equation into Fourier equation and the application of Galerkin method results in a system of ordinary differential equations of the form [Lewis1996].

$$[\,C\,]\,\ddot{T} + [\,K\,]\,\dot{T} + [\,F\,] = 0 \quad (18)$$

$$\ddot{T} = \partial T_1 / \partial t \quad , \quad \partial T_2 / \partial t \; \ldots\ldots\ldots \quad \partial T_P / \partial t$$

$$\dot{T} = T_1 \quad , T_2 \; \ldots . \; T_P$$

$$F = F_1 , F_2 \; \ldots . \; F_P$$

Where p is the total no. of node and the typical matrix elements are

$$K_{ij} = \sum \int_{\Omega} k_w \left(\frac{\partial N_i}{\partial x} \cdot \frac{\partial N_j}{\partial x} \right) d\Omega \qquad (19)$$

$$C_{ij} = \sum \int_{\Omega} \rho_w \; C_{pw} \; N_i \; N_j \; d\Omega \qquad (20)$$

$$F_i = - \sum \int_{\Gamma} q_{ws} \; d\Gamma \qquad (21)$$

In the above, the summation are taken over the contribution of each element (Ω), in the element region and (Γ) refers only to the element with external boundary on which surface condition is applied , using liner shape function which normalize to time interval (Δt) , the result is in standard linear shape function, then the application of weighted residual theory to equation with linear shape function then the result is in matrix form of

$$\left(\frac{[C]}{\Delta t} + \emptyset [k] \right) \dot{T}_{n+1} + \left(\frac{-[C]}{\Delta t} + (1- \emptyset [k] \; \dot{T}_n + F = 0 \qquad (22)$$

Where $F = F_{n+1} \; \emptyset + F_n \; (1- \emptyset)$

And ($\emptyset$) can have different value. In this solution a forward difference has been chosen due to its simplicity (i.e . $\emptyset = 0$) an iteration solution has been used at each time step to insure an accurate results. Atime step of (¼) hour is chosen and a starting time at first of (May) with initial condition wall temperature of (26 ℃) , and it will be stopped at (22 August) .It has be written in (VB-6) language, the way of solving a problem in one direction and the accuracy of this solution to be about ± 2.

RESULT AND DISCUSSION

The daily variation of dry bulb temperature in August is shown in Fig-4. It is assumed that the maximum temperature occurs (3 hours) after the noon of the sun and minimum temperature occurs at sunrise . The energy strikes the wall surfaces facing (north- N , south - S,west - W and east- E) is shown in Fig-5 for 21 July, the solar energy contains direct , diffused and ground- reflected energy. East wall will start to receive high amount of solar energy as the sun raises which will be reduced significantly at noon because the direct solar energy (which strike the wall) will vanished at that time similarly the case for the west wall but in the other direction where the energy will increased significantly after the noon of the sun where the direct solar energy will vanished at sun set. The heat convicted to the air- conditioned space of 26 ℃ , assume constant heat transfer coefficient of (8.29 w/m2 .℃).

1. Fig (6,7 and 8) is shown the typical wall construction in Iraq at (21 June, 21 July and 21 August) , assume total wall thickness of (28 cm composite of 2 cm gypsum , 24 cm brick , 2 cm cement) . The maximum heat flow to air- conditioned space is at (21 July) , due to the combined effect of solar radiation and ambient temperature will dominate at this month. The delay in maximum heat gain is due

to heat capacity of the materials from which walls are made (i.e brick , gypsum , cement) . Not all the heat energy entered the wall will be gained by air-conditioned space but some energy will be stored in the wall causes an increasing in its temperature and some may reradiate to the environment and some may convective from the wall surface.

2. Fig (9,10 and 11) indicates the heat gain through that walls at 21 June, 21 July and 21 August respectively .The reduction in heat gained to space in all direction for new proposed wall thickness is about (20%) . This proposed wall thickness can be active in south , east and west wall since the north wall alresdy received less heat . This proposed increasing in wall thickness take into account for the cost of the additional wall thickness . A damping in the variation of heat gained is observed between usual wall thickness and thick-wall , this is because of increasing of insulation capacity for the thick-walls.

3. Fig(12,13,14,15,16,17,18,19 and 20) indicates the load required to maintain comfortable at conditioned space for 21 June , 21 July , 21 August respectively using the fore mentioned insulation . More saving in energy is obtained, reaching (50%) from that of the usual wall thickness , this reduction is obtained by adding all the induced energy to the space having four direction walls of same type during one day. The advantage of the new wall composition is to minimize load required to maintain recommended temperature inside the conditioned space , also its advantages is to more delay than that of thick wall for the maximum peak load for a time where the load on electricity net is not in the peak . More damping than that of thick-wall is observed because of high insulation capacity of the walls having insulation through them, and the best local natural insulation is the local cane mat than palm fiber and local plastic mat .A comparison is made between results of this work and experimental measurement for temperature through west wall having usual thickness during August in a room kept at (26c) .Three probs of a thermocouple is placed at surfaces and at the middle of the wall. Very good near –by results are obtained for the usual wall thickness which give the required confidence to the whole results of this work as shown in Fig21.

CONCLUSIONS

The energy transfer to condition a space in hot summer in Iraq has obtained numerically using finite element method with a varying boundary condition including solar energy and ambient thermal load. The influence of increasing wall thickness and adding local natural insulations material has studied separately ,which seems to reduce heat transferred to air-conditioned space and also to delay the hour of maximum heat gain other than the hours of peak load in electric net.

1. Energy saving of (20%) is achieved by thickened walls.
2. Energy saving of (50%) from that of usual thickness by using local natural insulations (cane mat) through walls

Table1. Average summer environment conditions in Bagdad- Iraq.

Month	Max. temp	Min. temp	Relative humidity% P.M	A.M
June	46	30	13	34
July	48	33	13	32
August	48	34	13	33

Table2 .Types of walls

type	Sample	Content
Usual wall	Sample-1	2cm cement, 24cm brick,2 cm gypsum
Thicken wall	Sample-2	2cm cement,36cm brick, 2cm gypsum
Insulation in wall	Sample-3	2cm cement,12cm brick,12cm local cane mat, 12cm brick, 2cm gypsum
Insulation in wall	Sample-4	2cm cement, 12cm brick, 12cm palm fiber, 12cm brick , 2cm gypsum
Insulation in wall	Sample-5	2cm cement, 12 cm brick, 12cm local plastic mat, 12cm brick , 2cm gypsum

Table 3.The properties of material

Material	Thermal conductivity	density	Specific heat capacity
	K (w/m.k)	ρ(kg/m^3)	j/kg.k
Gypsum	0.43	1200	1080
Brick	0.70	1600	840
cement	8.65	1885	796

Table 4. The properties of local natural insulation

Insulation	Thermal conductivity	Specific heat capacity
	K (w/m.k)	j/kg.k
Local cane mat	0.03	7100
Palm fiber	0.09	6600
Local plastic mat	0.21	6100

	o o	o o	
	o o	o o	
	o o	o o	
	o o	o o	
1	o2 o	o 2 o	3

No.	Dimension	Material
1	2cm	Cement
2	24cm	Brick
3	2cm	gypsum

Fig 1.Usuall wall

	o o	o o	o o	
	o o	o o	o o	
	o o	o o	o o	
	o o	o o	o o	
1	2	2	2	3

No.	Dimension	Material
1	2 cm	Cement
2	36 cm	Brick
3	2 cm	Gypsum

Fig2.Thickenwall

No.	Dimension	Material
1	2 cm	Cement
2	24 cm	Brick
3	12 cm	Insulation
4	2cm	Gypsum

	o o	o o	……	
	o o	o o	……	
	o o	o o	……	
	o o	o o	……	
1	2	2	3	4

Fig3.Insulation in wall

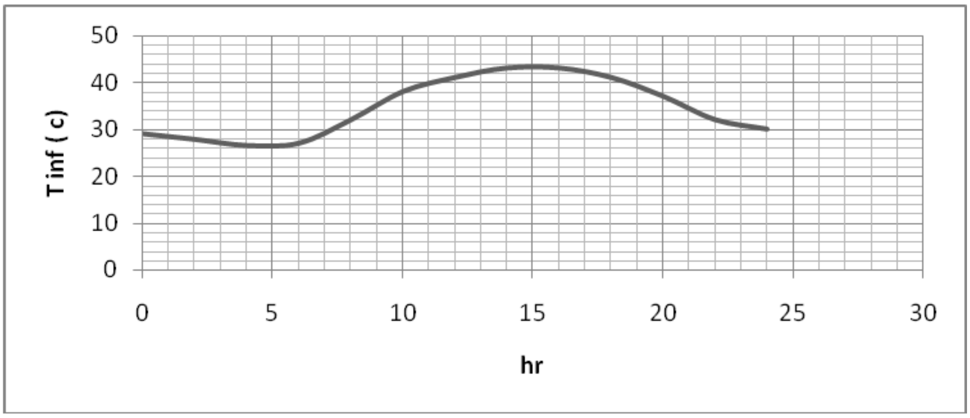

Fig 4.Daily variation of environment dry-bulb temperature at July

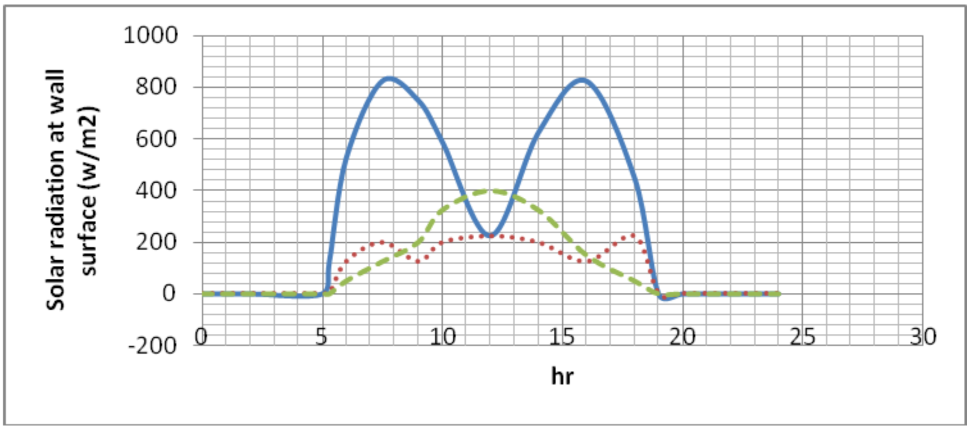

Fig5.Solar radiation at walls (normal to wall+ diffused + reflected) at 21 July

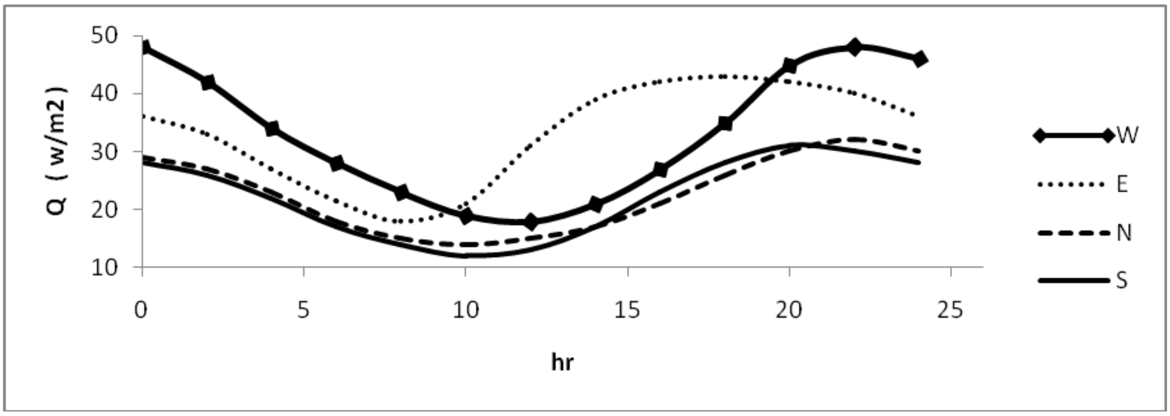

Fig-6. Heat gain through walls of usual thickness at 21 June

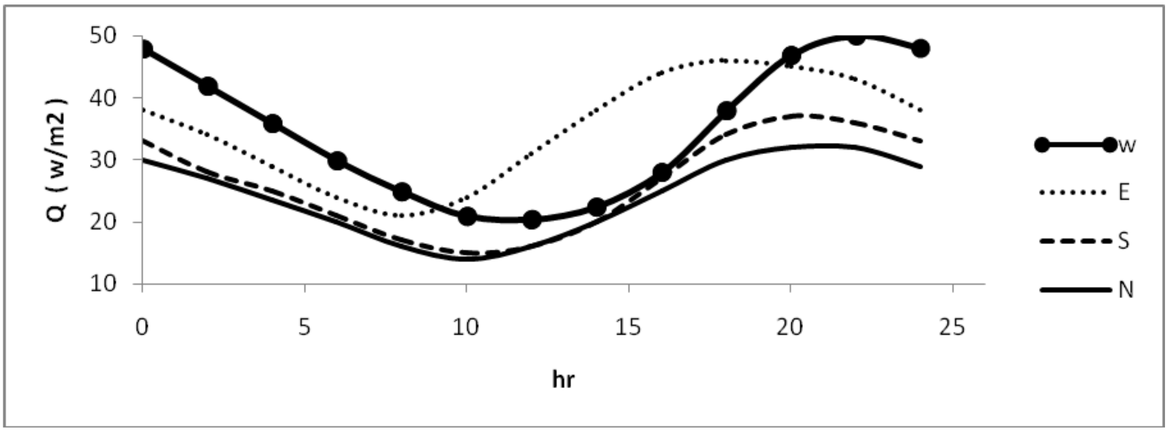

Fig-7. Heat gain through walls of usual thickness at 21 July

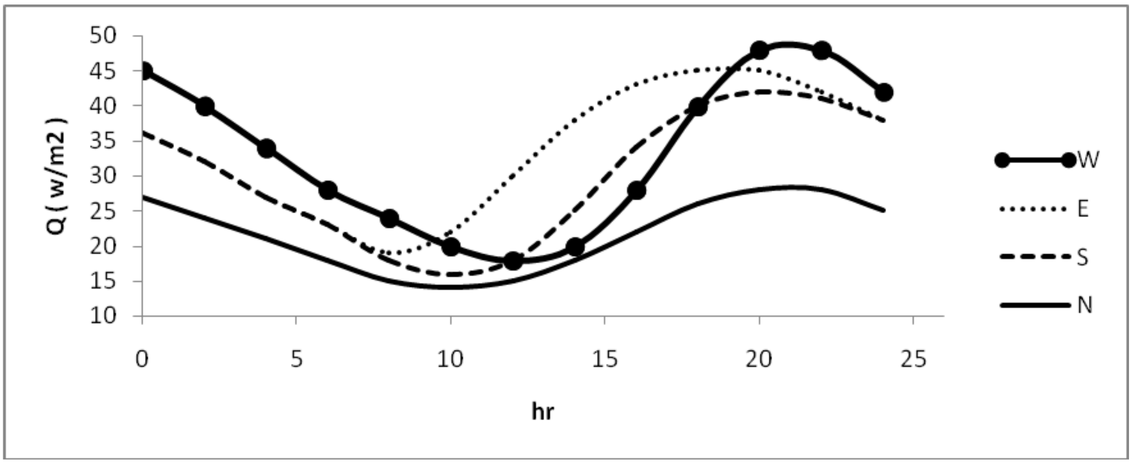

Fig-8. Heat gain through walls of usual thickness at 21 August

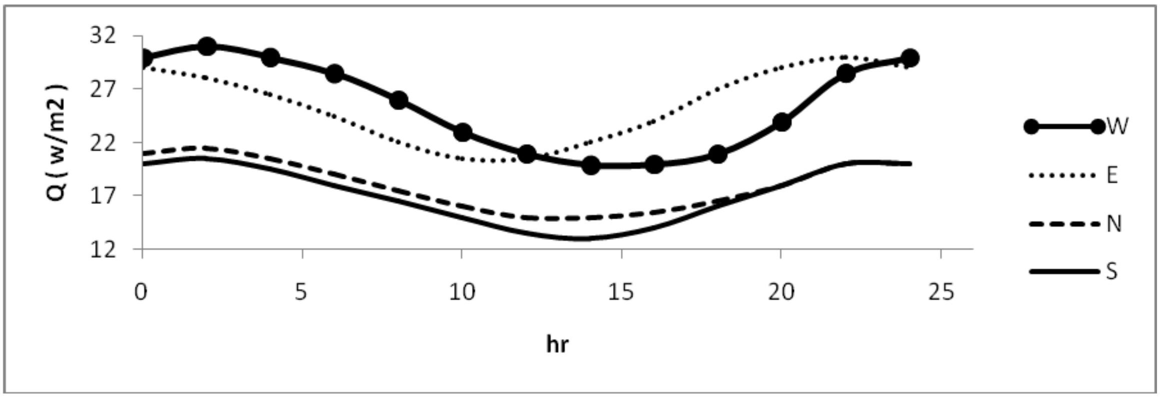

Fig-9. Heat gain through thickwalls at 21 June

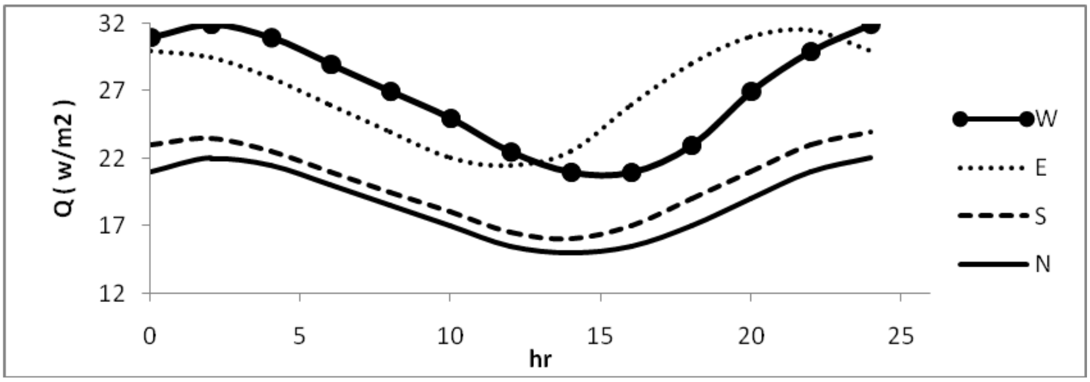

Fig-10. Heat gain through thickwalls at 21 July

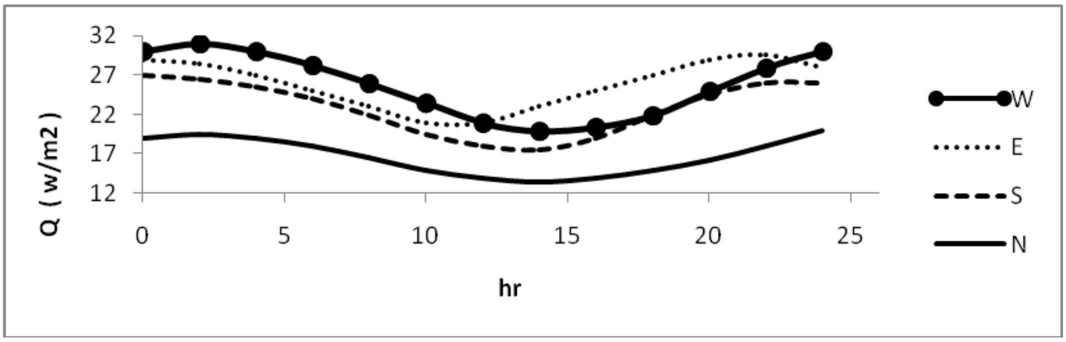

Fig-11. Heat gain through thickwalls at 21 A ugust

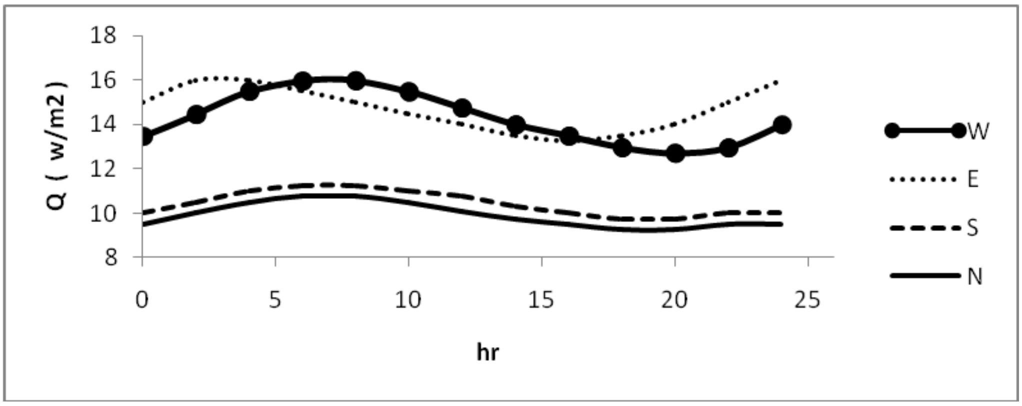

Fig-12. Heat gain through walls having insulator (cane mat)at 21 June

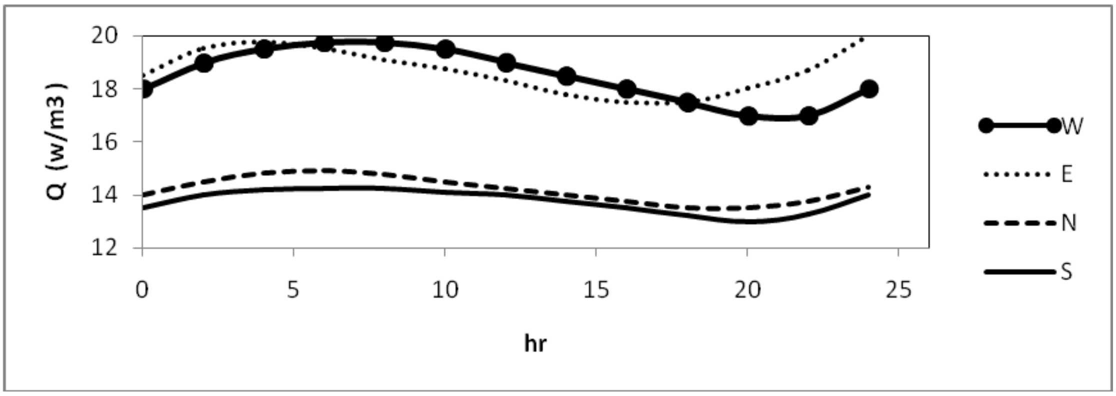

Fig-13. Heat gain through walls having insulator (palm fiber) at 21 June

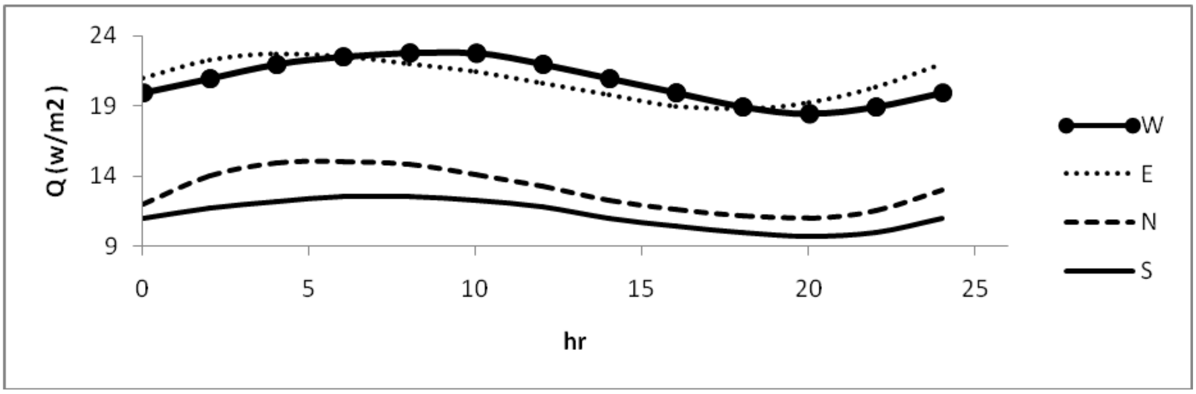

Fig-14. H eat gain through walls having insulator (plastic mat) at 21 June

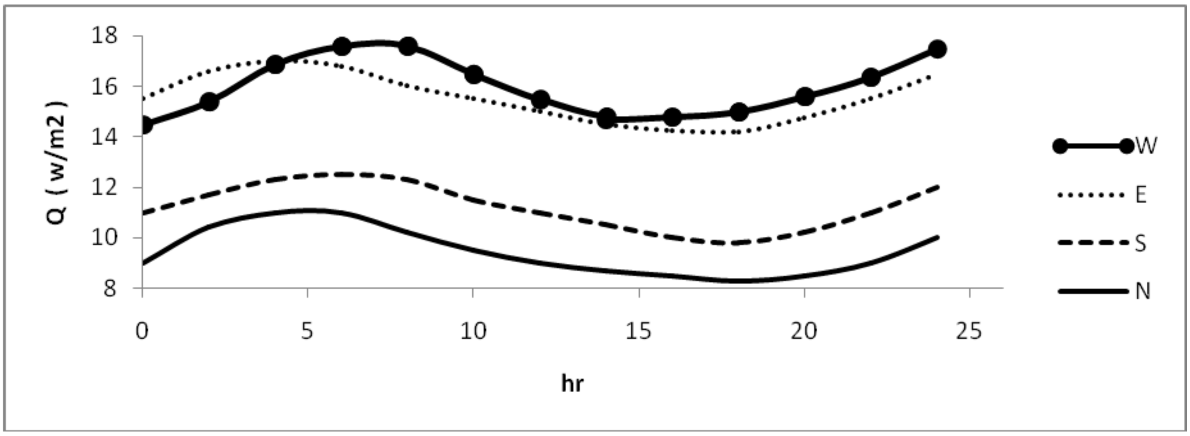

Fig-15. Heat gain through walls having insulator (cane mat) at 21 Jul

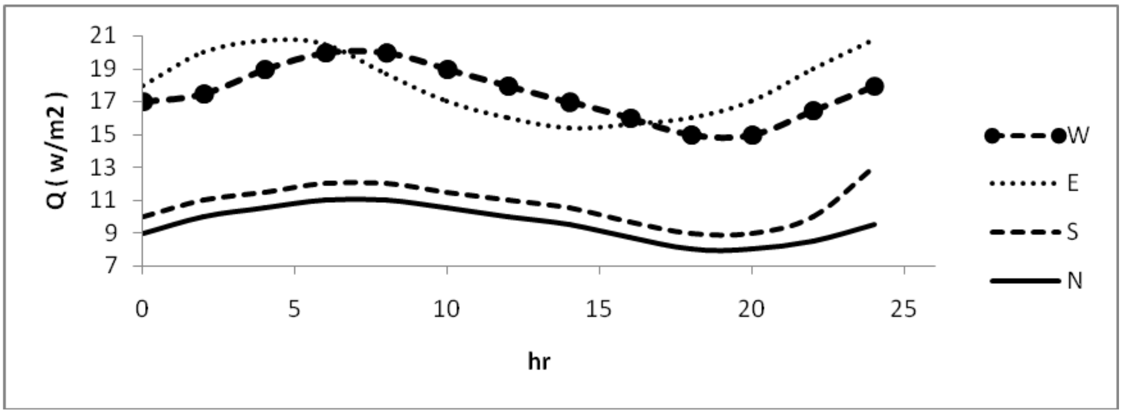

Fig-16. Heat gain through walls having insulator (palm fiber) at 21 July

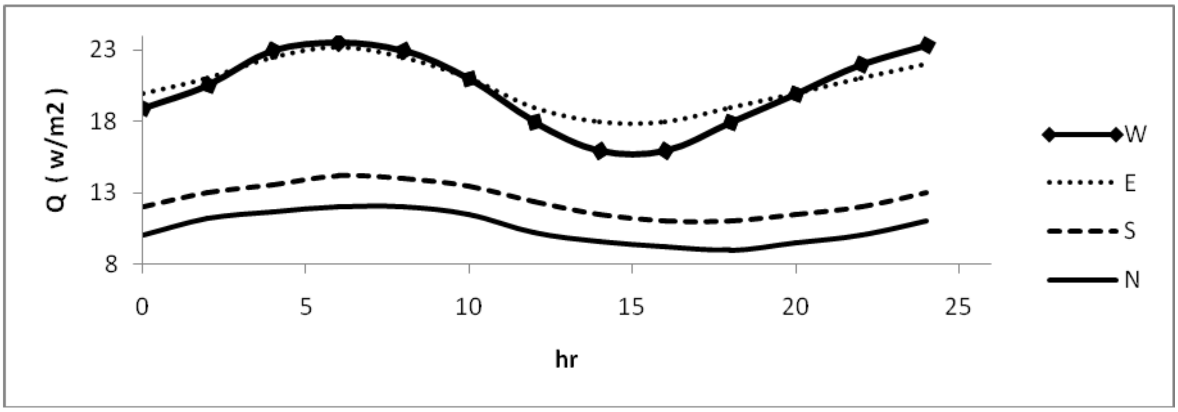

Fig-17.Heat gain through walls having insulator (plastic mat) at 21 July

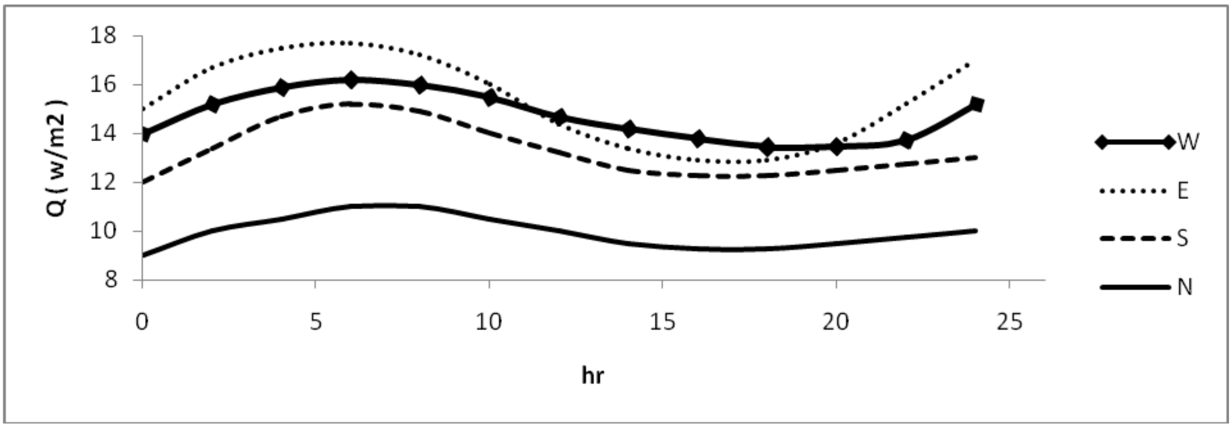

Fig-18. Heat gain through walls having insulator (cane mat) at 21 August

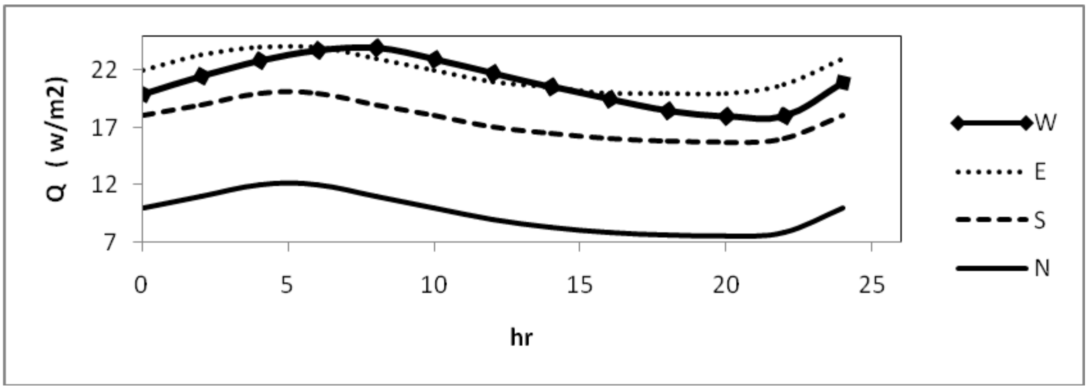

Fig-19. Heat gain through walls having insulator (palm fiber) at 21 August

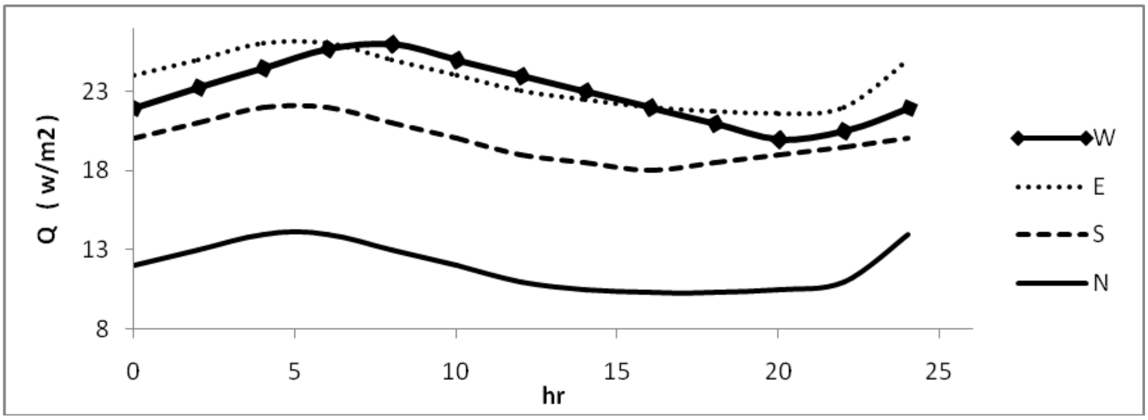

Fig-20. Heat gain through walls having insulator (plastic mat) at 21 August

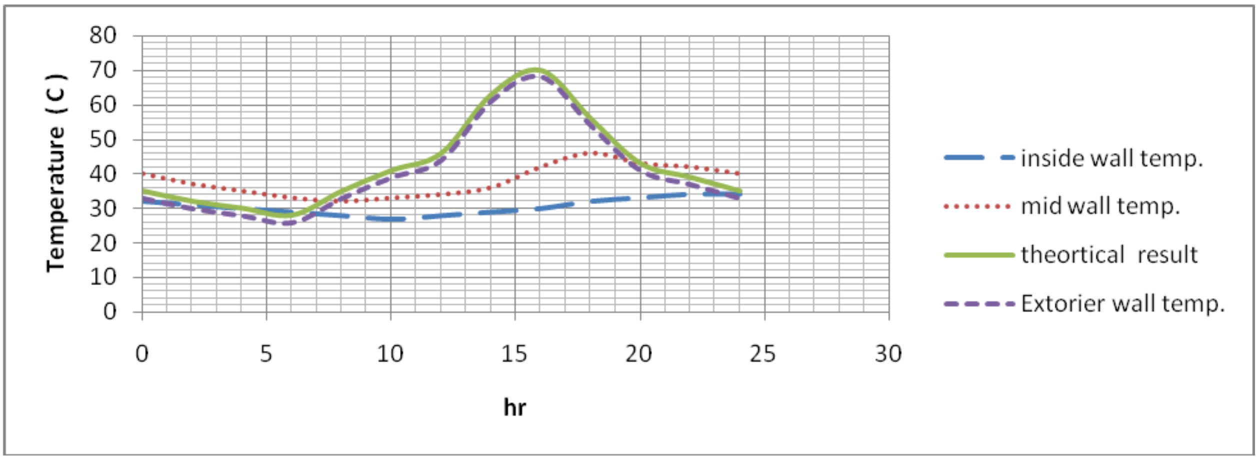

Fig21 .Comparison between experimental and theoretical temperature of west wall at 21 August at different location through wall

REFERENCES

ASHRAE (1997), ASHRAE Hand book-Cd (1997)

Antar, M. A . and Thomas, L .C. " Heat transfer through a composite wall with Enclosed spaces ; A practical two- dimensional analysis approach , ASHRAE Transaction 106(2001) pp 318-324.

ASHRAE Hand book - CD –HVAC application (1999).

Chiasson , A.D , J .D . Spitler, S.J .Rees, M.D .S mith. "Amodel for simulating The performance of a shallow pond as a supplemental heat rejecter with close-Loop ground- source heat pump systems ASHRAE Transaction.106(2) .2000

Frederic kuznik . "Optimization of a phase change material " Applied Thermal Engineering ,volume 28 ,Issues 11-12 , August 2007.

Faye .C. Mcquistion (et.al) " Heating ,Ventilating , and Air conditioning " 5th field rectangular cavity, international communication in Heat and Mass Transfer, 14 (1987) pp 91-100.

Hand book of air conditioning system design , carrier air conditioning company (1965).

HO ,C.J and YIH ,Y .L .' Conjugate natural convection heat transfer in an air -

J.Hirunlabh , W.Kongduang ," Study of natural ventilation of houses by tropical climate " Renewable Energy , volume 18, Issue 1-2 September(1998) .

John Lienhard IV & V" Aheat transfer Hand book " 3rd 2004.

Kangni, A. Yedder .B and Bilgen , E " Natural convection and conduction in enclosures with multiple vertical partitions ; Int .J . Heat and Mass .Transfer 34 (1991) pp2819-2825.

Mohammad S. AL-Homoud " Performance characteristics and practical building thermal insulation materials " Building and Environment , volume 40 , Issue 3, March 2004.

N. H Wong . D.K.W Cheong , H Tan ." The effects of rooftop garden on energy building in Singapore' volume 35 , Issue 4 , May 2002.

P.T Tsilingiris " Thermal flywheel effects on the time varying through structural walls"volume 35, Issue 10 , November 2003.

Parton W .J and J.A Logan. " A Model for diurnal variation in soil and air temperature

R.W . Lewis . " The finite element method in heat transfer .Mc-GrawHill company 1st edition (1996).

Spilter .J. D ,D.E . Fisher ,C.O .Pedersen. “ The radiant time series cooling load calculation procedure , ASHRAE Transactions. 103 (2) 503-515 (1997).

T.M M cClellan “ Investigation of outside heat balance models for use in a heat balance cooling load calculation procedure ASHRAE Transactions ,vol -13 No-2 (1997).

Tong, T.W and Gerner, F.M. “ Natural convection in partitioned air -filled rectangular enclosures ; International communication in heat and mass Transfer13 (1989)pp 99-108.

Torkoglu, H and Yucel,N. “Natural convection heat transferin enclosures with conducting multipartitions and side walls” Heat and Mass Transfer2(1996)pp 1-8.

T.M.I Mahlia ,B.N Taufig , Ismail, H.h.” Correlation between thermal conductivity insulation materials for building wall” energy and buildings , vol- 39 Issue 2, February 2006.

T.M.I Mahlia ,A .Igbal “ Cost benefits analysis and emission reduction of optimum air gaps for selected insulation material” vol-35 Issue 5 ,May 2010.

W.J Minkowycz “ Hand book of Numerical Heat Transfer 1st edition (1988).