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Effect of Using Local Insulation Materials on the Indoor Temperature of Residential Buildings at Iraq

Abstract- In this research, a thermal insulation between the two layers of a wall has been used for the residence buildings to reduce the heat transmitted across the walls and thus reducing the power consumption for cooling load. A MATLAB program was used to obtain the thermal response for various types of walls from the energy sources (solar radiation and ambient temperature) in summer season in Baghdad, Iraq. Local materials used in this study as thermal insulators between the two layers of walls are: local cane mat, wood sawdust and cork grains. Modeling tests were carried out on June, July and August via using Matlab program. The simulation results obtained have been compared for five different types of walls are: usual wall, thick wall, wall containing local cane mat, wall containing wood sawdust and wall containing cork grains, which helps in finding the heat flow across the wall where boundary conditions varied according to solar radiation and environment thermal load. The results showed that using the walls containing of local cane mat, wood sawdust and cork grains can reduce the heat gain by 50%, 44% and 40% respectively, compared with usual wall and thus reduce the power consumption.

Keywords- Local insulation materials, heat flow, MATLAB program.

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1. Introduction

The heat transmitted to the residential buildings across walls and ceilings in the summer represents the greatest part from the heat to be removed by air conditioning. The amount of power consumed by residential buildings in Iraq is estimated at (70%) of the total energy produced in Iraq in 2012 [1]. In the past Iraqi people used thick walls in their building to prevent extreme weather condition especially in summer where temperatures in Iraqi usually higher than (50°C) in hot zones where a hot summer is accepted. Special attention has to be paid to study the cooling load. Many research works had well established to procedure methods in calculating cooling load. It matter of energy saving, if one wants to reduce cooling load to maintain the comfort condition for humans, so extended in this field will be expected, now and in the future. The heat leak to residential buildings through the walls and ceilings consume a large amount of energy where the units of climate controllers need to a large amount of power, therefore, the heat leak studies have received a big attention in previous decades. The accurate estimates of heat leak through composite walls accompanied by low-cost practical methods for reducing heat leaks is an effective method that used for reducing power consumption. Theoretically and

experimental heat transfer investigations were carried out through the walls of building by many researchers [2]. Tong and Gerner [3] conducted a study about the effect of vertical partition on the natural convection for the air-filled rectangular enclosures using a finite difference scheme. They found that when the partition was placed midway between the vertical walls lead to a significant reduction in heat transfer. Wong et al. [4] carried out a simulation program to determine the effects of the rooftop garden on energy consumption, cooling load and roof thermal for the commercial building consisting of five-story in Singapore. The thermal resistance was estimated by using data from site measurements, and the effect of a rooftop garden with these three types of plants on the energy consumption of building were also simulated. They found that installation a garden on the rooftop of a commercial building save the energy consumption by 0.6 to 14.5%, also they found that the shrubs were more effective in reducing the energy consumption and also the increasing in soil thickness reduced the energy consumption in the building. The correlation between thermal conductivity and the thickness of selected insulation materials in the wall of building was analyzed by Mahlia et al. [5]. They found that the thermal conductivity and the optimum thickness of insulating materials have a

non-linear relationship, which is useful for estimating the optimum thickness of insulating materials to reduce the heat flow rate through the building walls. Mahlia and Iqbal [6] conducted a study to determine the effect of introducing of air gaps in the building wall which contains, in its installation, the optimum thickness of different insulation materials, potential cost savings and emission reduction. They found that using different insulation materials with air gaps of 2 cm, 4 cm and 6 cm, it reduced the energy consumption and emissions by 65-77% compared with a wall without insulation or air gaps, and thus considerable saving in costs. Al-Hadithi [7] carried out a numerical study to determine the effect of using a phase change material (PCM) on the heat transfer in the building wall. He mixed the (PCM) represented by paraffin wax by (25%) with concrete of (75%) to create a treated wall. The results showed that the possibility of using the PCM can be reduce the heat gain from outside to the inside of room and thus reduce the cooling load. Atef [8] studied experimentally the effect of using local covering materials for internal walls from different decorative materials on the cooling load. The study showed that using the medium density fiberboard materials and the hollow plastic sheets with insulator reduces the cooling load by (27%). Madhumathi and Sundararaja [9] studied experimentally the effect of phase changing materials that consist of polyethylene type with the conventional building materials in the hot regions on the cooling load and room temperature. They found that using the PCM improve thermal comfort and reduces heat entering to the room by 33.33%. The present work focuses to test the different wall thickness in order to reach the optimum thickness in addition to use insulation inside the wall in hot zone in Iraq to reduce cooling load and maintaining comfortable temperature. The aim of this research is to study the possibility of using the local natural insulation materials for residential buildings and to select a suitable thickness of the walls to reduce the heat that flowing through the walls and transmitting across the building. A local cane mat, wood sawdust and cork grains were used as local natural insulators. The tests were conducted and the results obtained from walls containing on the insulators were compared with the traditional wall and thick wall in the months of June, July and August in Baghdad city, Iraq.

2. Experimental Wok

To achieve the objective of this research represented by reducing the heat transmitted to residence buildings across the walls, three types of local insulators were used and placed between the two layers of brick wall at (24 cm thickness) in a room constructed with dimensions (4 m x 4 m x 3 m) and the building orientation towards the east in Baghdad, Iraq. In the current work, five types of walls were tested are: usual wall, thicken wall, wall containing on local cane mat, wall containing on wood sawdust and wall containing on cork grains in the months of June, July and August, as shown in Figure 1 a, b and c.

The figure shows a schematic diagrams for the usual wall, thicken wall and wall containing on the insulation material respectively. The types and contents of each wall are shown in Table 1. Figure 2 shows a photographic of the local insulation materials proposed to be used in this work.

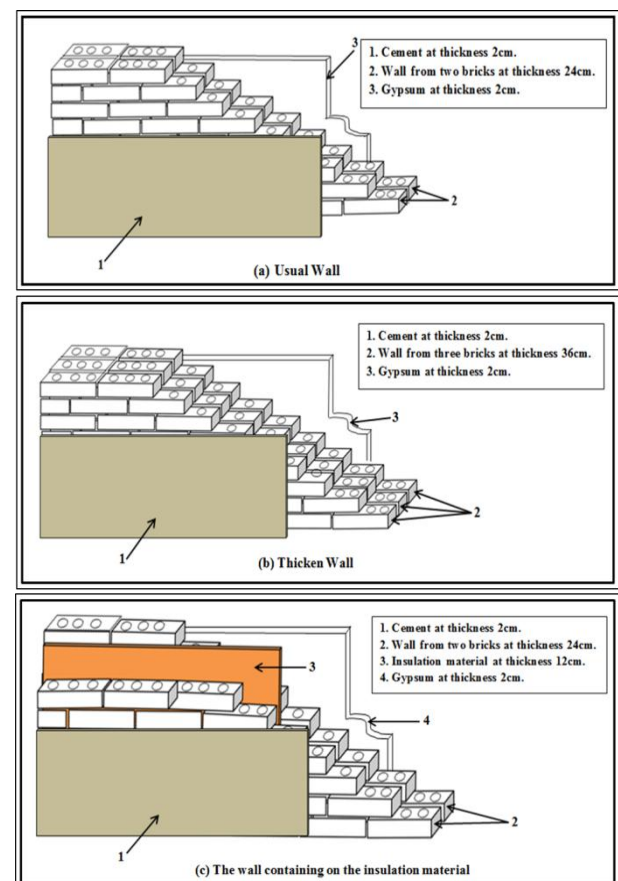


Figure 1 a, b and c: Schematic diagram of the usual wall, thicken wall and the wall containing on the insulation material respectively.

Table 1: Types and contents of each wall used

Wall Type	Sample	Content
Usual wall	1	2cm cement, 24cm brick , 2cm gypsum
Thicken wall	2	2cm cement, 36cm brick, 2cm gypsum
Insulation in wall	3	2cm cement, 12cm brick, 12cm local cane mat, 12cm brick, 2cm gypsum
Insulation in wall	4	2cm cement, 12cm brick, 12cm wood saw dust, 12cm brick. 2cm gypsum
Insulation in wall	5	2cm cement, 12cm brick, 12cm cork grains, 12cm brick, 2cm gypsum

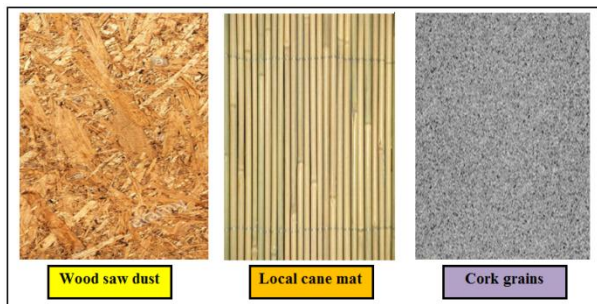


Figure 2: Photographic image for local insulation materials used

The walls used in this work were constructed according to the thermal properties shown in Table 2.

Some samples of the local insulation materials according to their thermal properties were chosen and laboratory test was conducted them in the laboratory of materials testing and heat transfer in the Materials Engineering Department - University of Technology in Baghdad. The device (Thermal constants analyzer TPS 500) Swedish origin was used in the experimental test to find the thermal conductivity of the local insulation materials as shown in the Figure 3.

Table 2: Thermal properties of the wall construction materials [13].

Material	Thermal conductivity K (W/m.k)	Density ρ (kg/m ³)	Specific heat capacity C _P (kJ/kg.k)
Gypsum	0.8	1500	1
Brick	0.40	1900	0.85
Cement	1	2500	0.9



Figure 3: Device used in samples test

Table 3 shows the results of laboratory test for the thermal properties of the insulation materials. The temperatures were measured by using thermocouples placed inside and outside the room and at distances spaced between them.

Table 3: Thermal properties of the local insulation materials.

Material	Thermal conductivity K (W/m.k)	Density ρ (kg/m ³)	Specific heat capacity C _P (kJ/kg.k)
Local cane mat	0.11	400	0.52
Wood sawdust	0.15	750	1.7
Cork grains	0.13	26	0.77

3. Theory

A computer program has been prepared in the language of (Matlab) for the purpose of calculating the heat transferred across the walls before and after placing the insulating materials which were used between the two layers of wall. The maximum and minimum temperatures on the months of (June, July and August) were measured as shown in Table 4 to determine the cooling load of the walls within the specifications of the American Association of air conditioning, cooling and ventilation engineers Ashrae [10] in order to estimate the thermal loads.

Table 4: Average summer environment condition in Baghdad – Iraq.

Month	Max. temp (°C)	Min .temp (°C).	Relative humidity %	
			P.M	A.M
June	42	30	13	34
July	48	33	13	32
August	47	32	13	33

The quantity of heat flow through wall (Q_{wall}) is calculated by: [10]

$$Q_{wall} = U_w \cdot A_w \cdot CLTD_w \quad (1)$$

Where:

U_w = Overall heat transfer coefficient ($W/m^2.k$).

A_w = Wall surface area (m^2).

$CLTD_w$ = The temperatures difference of the cooling load for the walls which determine according to the direction and the temperature of external design and the difference of daily change for the external temperatures (k).

The total thermal resistance (R_T) for the walls is given by [10]:

$$R_T = \frac{1}{f_i} + \frac{x_a}{k_a} + \frac{x_b}{k_b} + \dots + \frac{x_n}{k_n} \quad (2)$$

Where:

R_T = Total thermal resistance ($m^2.k / W$).

k_a, k_b, k_n = The thermal conductivity values for the compositions of structural materials for walls ($W/m.k$).

x_a, x_b, x_n = The layers thickness of the walls components (m).

f_i = The inside film resistance for components of internal wall ($W/m^2.k$).

f_o = The outside film resistance for components of external wall ($W/m^2.k$).

The overall heat transfer coefficient (U) can be calculated as follows [10] :

$$U_w = \frac{1}{R_T} \quad (3)$$

All data were stored in the program. Thermal conductivity, specific heat capacity, thermal diffusivity and thermal effusivity were calculated theoretically for each wall through the following equations Holman [11], Oyekan and Kamiyo [12]:

Thermal conductivity (k) in ($W/m.k$) [11] :

$$k = Q \cdot \Delta x / A \cdot \Delta T \quad (4)$$

Where:

Q = the quantity of heat flow (W).

Δx = the distance between the wall ends (m).

A = the wall surface area (m^2).

ΔT = the temperature difference between the wall ends (k).

Specific heat capacity (C) in ($J/kg.k$) [11] :

$$C = q / m \cdot \Delta T \quad (5)$$

Where:

q = the heat energy (J).

m = the mass of the material (kg).

ΔT = the difference in temperature (k).

Thermal diffusivity (α) in (m^2/sec) [12]

$$\alpha = k / \rho \cdot C \quad (6)$$

Thermal diffusivity (β) in ($W / m^2 .k .sec^{0.5}$) [12]

$$\beta = k \cdot \rho \cdot C \quad (7)$$

The previous equations were included in the following flow chart:

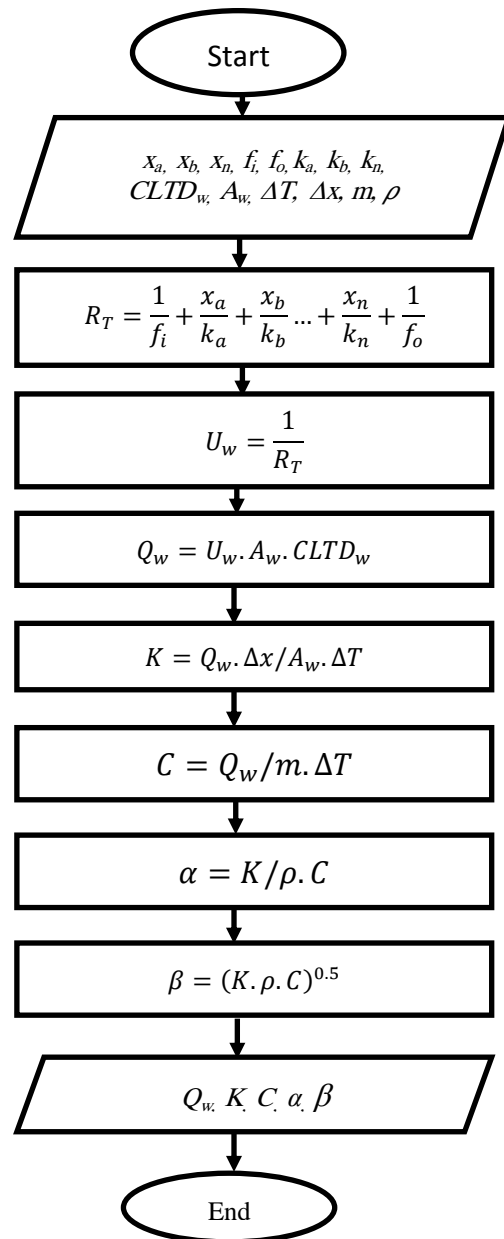


Figure 4: Flow chart

4. Results and Discussion

The temperature difference values for the walls were determined by calculating the value of the daily range, which represents the difference between the maximum and the minimum temperature as shown in the Figure 5.

The figure shows the temperature rates for the summer months (June, July and August) in the Baghdad city. It was found that the highest difference in the daily range occurs in July. After calculating the daily change, the value of the amount of heat transferred across the walls used in this study (usual wall, thickened wall and wall containing the insulator) has been found. Solar energy contains the energy diffused directly on the ground. At sunrise, the east wall will begin to receive the large quantities of solar energy in the morning, the solar energy which strikes the wall will vanish, either in the opposite direction of the east wall (the west wall), the solar energy in the afternoon will increase significantly and will vanish at sunset.

Figure 6 shows the variation of heat gains during day hours for the usual wall on the months of June, July and August, respectively. From the figure, it was observed that the maximum heat gain was in July month, this is because of the effect of the highest solar radiation and ambient temperature compared with the months of June and August. The delay in the maximum heat gain is resulting from the heat capacity of the materials from which usual walls are made (brick, gypsum and cement). The maximum heat gain for the usual wall was (45, 49 and 47 W/m²) on the months of June, July and August, respectively.

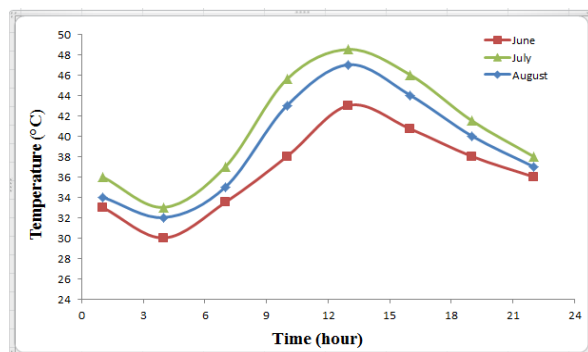


Figure 5: Temperature rates for the summer months June, July and August in Baghdad

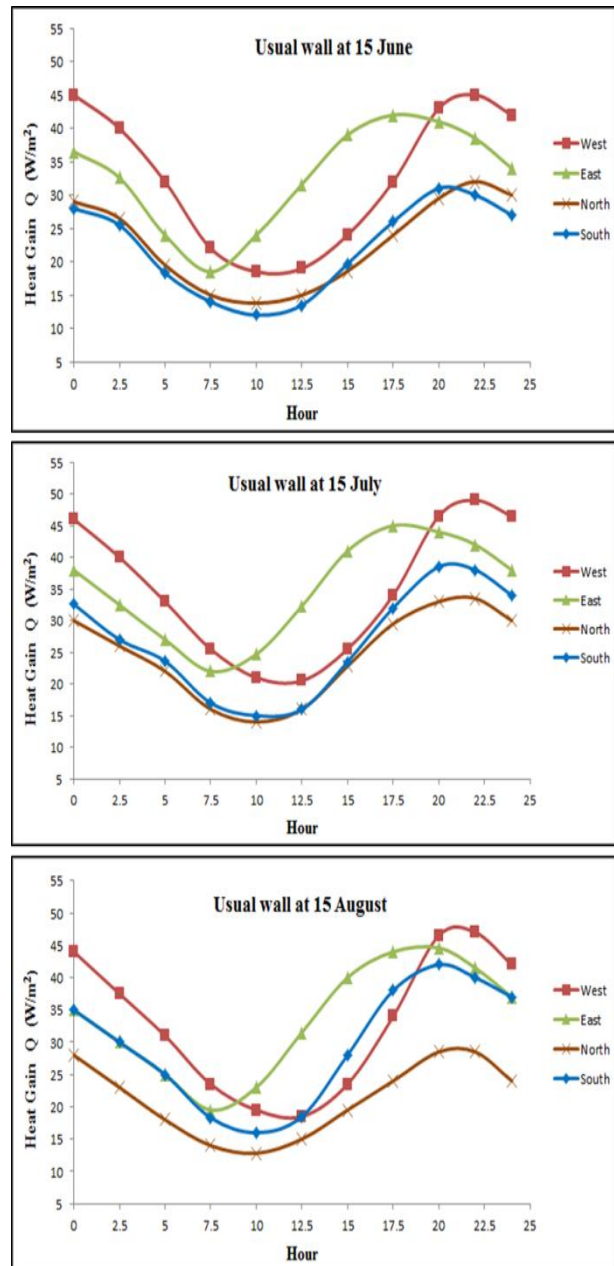


Figure 6: Heat gains through usual walls at 15 June, 15 July and 15 August respectively

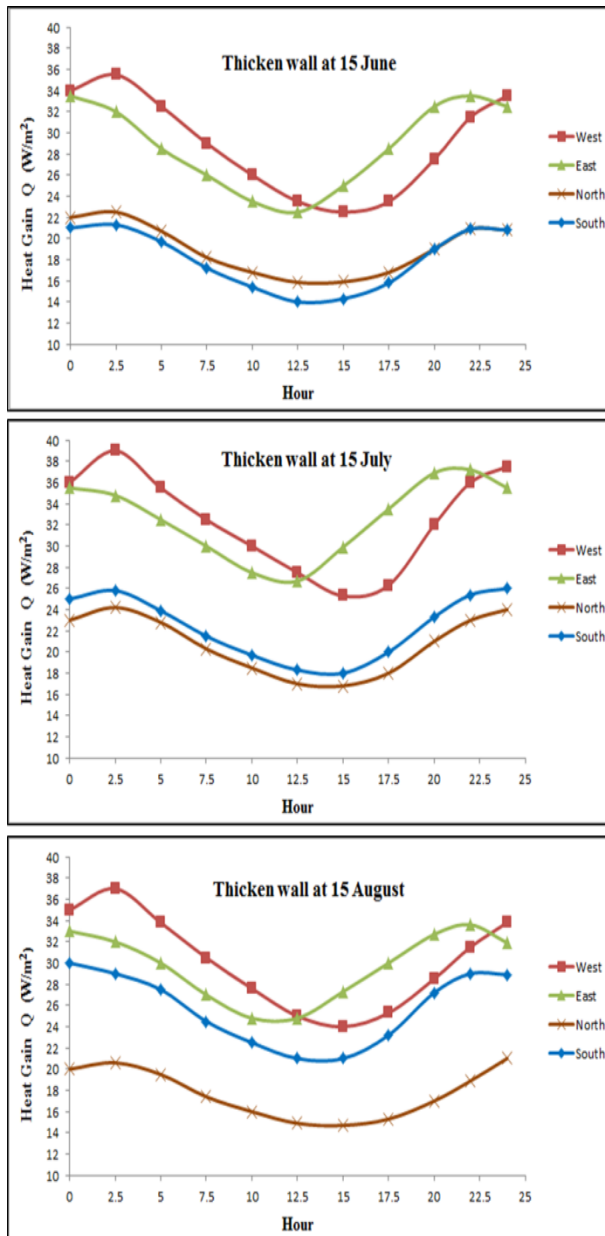


Figure 7: Heat gains through thicken walls at 15 June, 15 July and 15 August respectively

Figure 7 shows the variation of heat gains during the day hours for the thickened wall on the months of June, July and August, respectively. Increase the thickness of the wall will help to increasing the thermal resistance for the wall components and thus reducing the thermal conductivity of the energy (the solar radiation and ambient temperature). The figure shows that maximum heat gain was (36, 39 and 37.5 W/m^2) on the months of June, July and August, respectively. Therefore, the maximum heat gain in the thickened wall will reduce by (20%) compared with the usual wall, this is due to the increase in the wall thickness which led to the reduction in the heat gain.

Figures 8 - 10 show the variation of heat gains through the day hours for the walls containing the insulators (local cane mat, wood sawdust and cork grains) on the months of June, July and August, respectively. The heat transfer process through the walls depends on the heat capacity for the wall components and this capacity depends on the (thermal conductivity, specific heat, density). Therefore, the use of insulators between the two layers of the wall will help to get more energy saving, this saving will help to reduce the consumption of electrical energy.

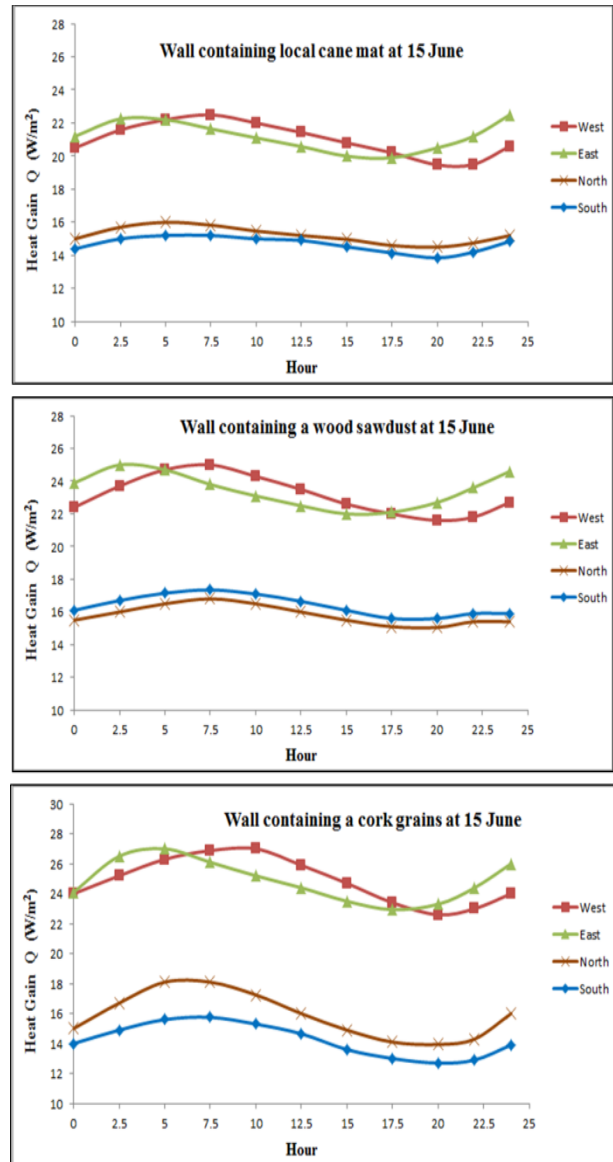


Figure 8: Heat gains through walls having insulator of: local cane mat, wood saw dust and cork grains respectively, at 15 June.

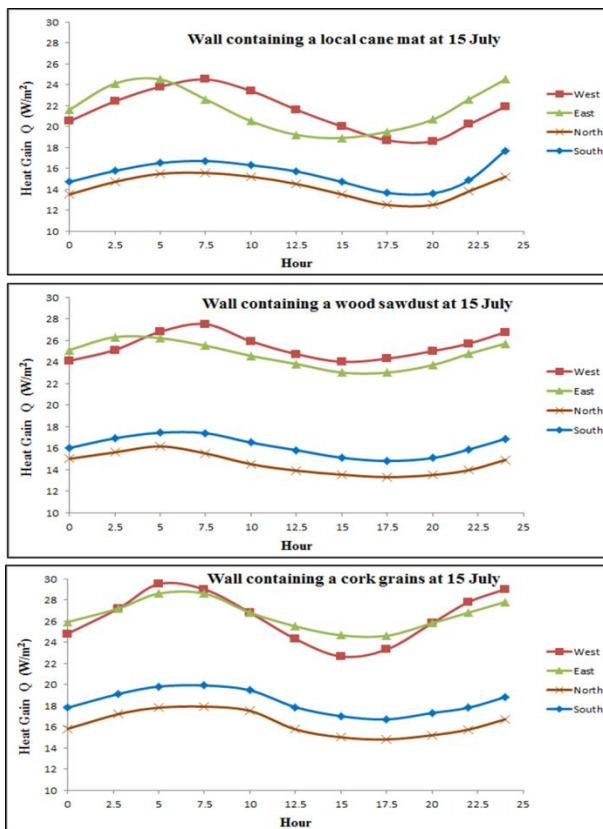


Figure 9: Heat gains through walls having insulator of: local cane mat, wood saw dust and cork grains respectively, at 15 July

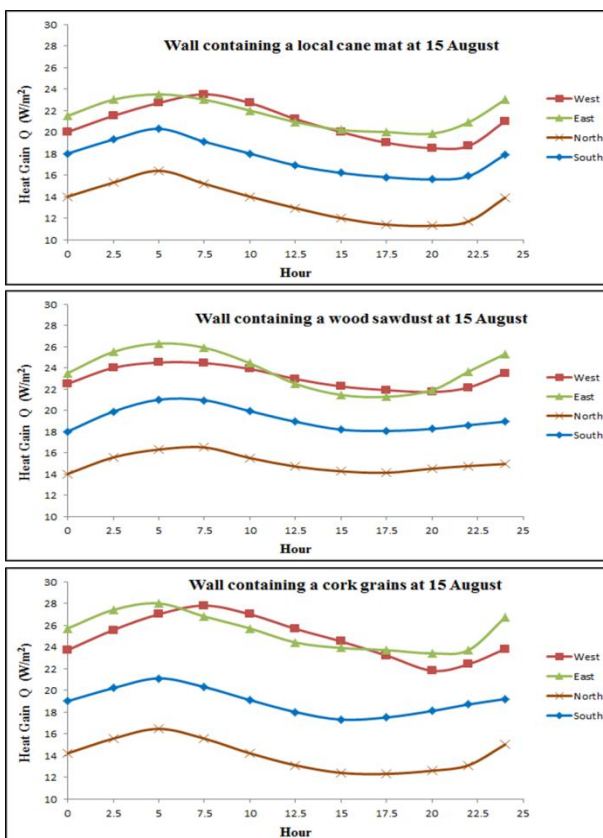


Figure 10: Heat gains through walls having insulator of: local cane mat, wood saw dust and cork grains respectively, at 15 August.

Figures 8-10, show that the maximum heat gain on the months (June, July and August) for the wall containing the insulating material from local cane mat was (22.5, 24.5 and 23.5 W/m²), respectively. So, the maximum heat gain in the wall containing the insulating material from local cane mat is less by (50%) compared with the usual wall. As for the wall containing the insulating material from wood sawdust, it was found that the maximum heat gain was (25, 27.5 and 26.3 W/m²) on the months June, July and August, respectively. Also, found that the maximum heat gain for the wall containing the insulating material from wood sawdust was decreased by (44%) compared with the usual wall. Finally, the maximum heat gain for the wall containing the insulating material from cork grains for the months (June, July and August) was (27, 29.5 and 28 W/m²), respectively. Therefore, the maximum heat gain for the wall containing the insulating material from cork grains will be reduced by (40%) compared with the usual wall. From the above results, it was found that the use of local cane mat as an insulation material between the two layers of the wall is the better one than the other two types (wood sawdust and cork grains).

Figures 11 - 14, show a comparison of the thermal performance for the proposed walls materials for each wall orientations (West, East, North and South) respectively, at 15 August. From these figures, it was found that the heat gain through the walls in the case of use a local cane mat material offers better thermal performance.

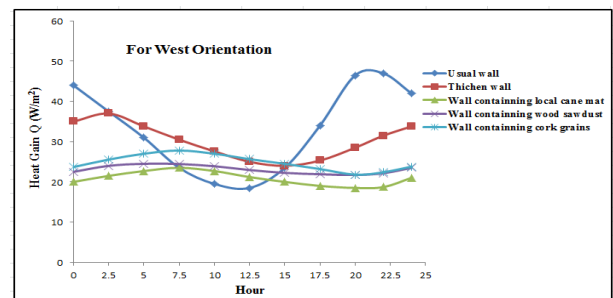


Figure 11: Comparison of thermal performance for proposed walls materials (West Orientation), at 15 August

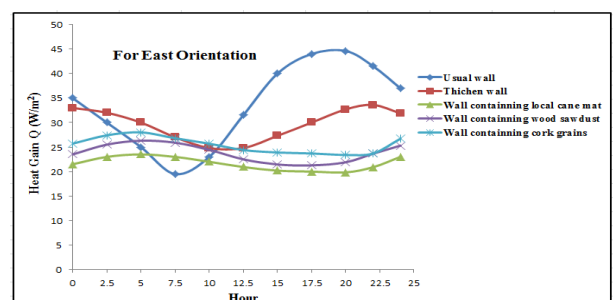


Figure 12: Comparison of thermal performance for proposed walls materials (East Orientation), at 15 August

proposed walls materials (East Orientation), at 15 August

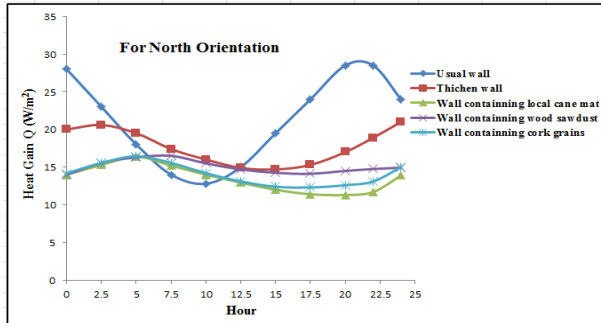


Figure 13: Comparison of thermal performance for proposed walls materials (North Orientation), at 15 August

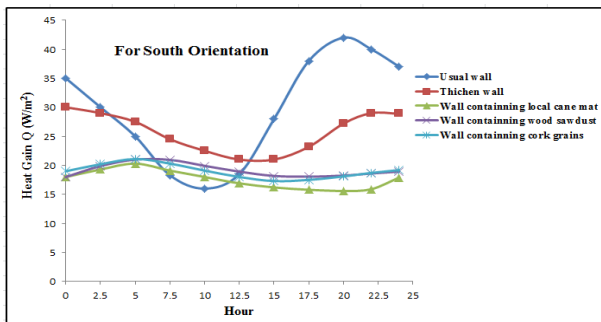


Figure 14: Comparison of thermal performance for proposed walls materials (South Orientation), at 15 August

5. Conclusions

The heat transfer process across the wall into the inside space was obtained by using the MATLAB program by entering a different boundary conditions including solar radiation and ambient temperature. The effect of wall thickness and adding insulation materials between the two layers of wall were separately studied. Therefore, through the results of the research work, some conclusions can be extracted as follows:

1. Increasing the wall thickness leads to reduce the heat gain by 20% compared with the usual wall, and thus reduction in the power consumption.
2. Using local insulation materials between two layers of wall leads to saving in energy by a large proportion.
3. When using a local cane mat, wood sawdust and cork grains as local insulators causes in reduction the heat gain by 50%, 44% and 40% respectively, compared with the usual wall.
4. Finally, using the local cane mat between two layers of the wall is considered as the better insulator compared with the other two types (wood sawdust and cork grains). This will help in reducing the heat gain by (50%) compared with the usual wall.

6. References

[1] A.H. Atef, "Available ways for energy conservation in Iraqi residence sector," *Journal of Al Rafidain University College for Science*, Vol. 29, p.p. 32-50, 2012.

[2] A. Ashrae, "Handbook Fundamentals, and Data Book," American Society of Heating Refrigeration and Air Conditioning Engineers, 1997.

[3] T.W. Tong and F. M. Gerner, "Natural convection in partitioned air-filled rectangular enclosures," *International communications in heat and mass transfer*, Vol. 13, No. 1, p.p. 99-108, 1986.

[4] N.H. Wong, D.W. Cheong, H. Yan, J. Soh, C.L. Ong, and A. Sia, "The effects of rooftop garden on energy consumption of a commercial building in Singapore," *Energy and buildings*, Vol. 35, No. 4, p.p.353-364, 2003.

[5] T.M.I. Mahlia, B.N. Taufiq and H.H. Masjuki, "Correlation between thermal conductivity and the thickness of selected insulation materials for building wall," *Energy and Buildings*, Vol. 39, No. 2, p.p. 182-187, 2007.

[6] T.M.I. Mahlia and A. Iqbal, "Cost benefits analysis and emission reductions of optimum thickness and air gaps for selected insulation materials for building walls in Maldives," *Energy*, Vol. 35, No. 5, p.p. 2242-2250, 2010.

[7] M.B. Al-Hadithi, "Use of phase change material in residential walls to reduce cooling load," *Anbar Journal for Engineering Sciences*, Vol. 4, No. 1, p.p. 72, 2011.

[8] A.H. Atef, "The Environmental Effect Reduction On Internal Space Temperature By Internal Walls Covering," *Journal of Kerbala University*, Vol. 10, No. 2, p.p. 35-48, 2012.

[9] A.A. Madhumathi and B.M.C. Sundararaja, "Experimental study of passive cooling of building facade using phase change materials to increase thermal comfort in buildings in hot humid areas," *International Journal of Energy and Environment*, Vol. 3, No. 5, p.p. 739-748, 2012.

[10] A. Ashrae, "Hand Book of Fundamentals," American Society of Heating Refrigeration and Air Conditioning Engineers, 2005.

[11] J.P. Holman, "Heat transfer," Mc Gran-Hill. Inc. 2004.

[12] G.L. Oyekan and O.M. Kamiyo, "A study on the engineering properties of sandcrete blocks produced with rice husk ash blended cement," *Journal of Engineering and Technology Research*, Vol. 3, No. 3, p.p. 88-98, 2011.

[13] W.M.S. Tawfeeq, "Insulation Materials," Bachelor Project, Department of Engineering of Materials, Al-Mustansiriyah University, 2016.

NOMENCLATURE

A: Surface area of the wall (m²).

C :	Specific heat capacity (J/kg.k).
$CLTD$:	Cooling load temperature difference (k).
f_i :	Inside film resistance for components of internal wall ($W/m^2.k$).
f_o :	Outside film resistance for components of external wall ($W/m^2.k$).
k :	Thermal conductivity (W/m.k).
m :	Mass of material (kg).
Q_{wall} :	Quantity of heat flow through wall (W).
q :	Heat energy (J).
R_T :	Total thermal resistance ($m^2.k/W$).
U :	Overall heat transfer coefficient ($W/m^2.k$).
x :	Layer thickness (m).
ΔT :	Temperature difference between the wall ends (k).
Δx :	Distance between the wall ends (m).
α :	Thermal diffusivity (m^2/sec).
β :	Thermal effusivity ($W/ m^2 .k. sec^{0.5}$).
ρ :	Density (kg/m^3).
