https://doi.org/10.33261/jaaru.2019.26.4.005 *Association of Arab Universities Journal of Engineering Sciences (2019) 26(4): 30–40*

Association of Arab Universities Journal of Engineering Sciences
مجلة اتحاد الجامعات العربية للدراسات والبحوث الهندسية

Experimental Study of Using Thermal Insulation In Buildings Walls To Reduce Heating Load In Al - Kut City

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Published online: 31 December 2019

Abstract— Experimental study has been carried out on a small room model constructed from sandwich panel in Al-Kut city to reduce the heating load in winter season. Three types of thermal insulation were used; (Glass wool, Air gap and Sawdust). The room model dimensions were (2m length x2m width x2.4 m height). Room's south wall includes two openings of 0.3m width, 1m height. The first opening is closed by common bricks only, while the second opening is built with double walls from brick separated by thermal insulation of thickness 2cm. The results show that the maximum energy saving of heating load at night time when using thermal insulation were.69%, 58.4%, and 53.6%for glass wool, sawdust and Air gap respectively.

Keywords— Thermal Insulation, Heating Load, Glass Wool, Sawdust.

1. Introduction

Most of the buildings are built in the present, far away from the principles of power conservation because the designer not following the controls and regulations during the design process. The problems have arisen in the buildings because it does not deal intelligently with harsh climatic conditions. Current statistics estimates the number of constructed housing units had exceeded three million units in 2009[3]. This number of housing units will increase in the future. The climatic changes in the world and Iraq due to global warming and the pollution resulted from the use of human resource for the abnormal production of energy as wall as using concrete in buildings construction, all these led to a significant rise in the temperature of the buildings. [6] Studied to reduce cooling load and improve thermal insulation materials effect in Iraq buildings by using (geothermal energy storage phenomenon). This researcher indicates using a vertical plate with high thermal conductivity was extended at depth 3 m as a part of the structural composition of the south and east walls. The result of study indicates using the plate only without thermal insulation reduce the cooling load (12.7%) in the east wall and (13.2%) in the south wall. While the results of study indicate using plate with thermal insulation (Thermal conductivity 0.04W/m.K) in different arrangements of the wall. The plate reduces the cooling load (8%, 15.8% and 41.3%) in the east wall and (8%, 14.5% and 40%) in the south wall. [4] Studied experimentally using composite materials as a thermal insulation consists from (natural fibers) Jute, Egg shell, Black feather and White feather. Two rooms of (1m, 1m, and 1m) are built, the first room was the reference source of the temperatures measured and the second room was used to test the insulation effect. Results showed (jute composite material) gives good thermal insulation compared to other natural materials. [7] Studied experimentally the influence of ventilated cavity wall on cooling load in Iraqi building during August. It is found that when fresh air passed through cavity wall at 25.5 °C, equals to the temperature of the space with air velocities range of (0785, 0.157,0.282 m/s) reduces the cooling load by (65.1, 70.7, 75.7%) compared to the reference wall. The use of ventilated cavity wall reduced the inside average temperature by (1.45, 1.53, 1.71°C) also reduced the daily temperature difference of the inside surface between (0.94, 1.01 °C) compared with the conventional walls.[8] studied experimentally using insulation material for buildings walls in Iraq to reduce cooling and heating load. Two rooms of (1m length, 1m width, 1m height) are built in Al kut city at (32.5o latitude). The room is set such as each wall faced, west, east, south and north direction. The models or room are built from thermo-stone (20cm), brick (24cm) and sandwich panel (5cm). Styropor is used as another type of thermal insulation to test and compared with brick wall. The heat gain was calculated from all above insulations material compared with normal brick room. The obtained energy saving for sandwich panel was 70% (best model) while that for styropor was about 54.28%.and for thermo-stone was 33%. The main objective this work is reduce heating load in winter season for a building of 2m width , 2m length and 2.4m height in Al Kut city by using different thermal insulation materials such (Glass wool, Sawdust and Air gap) between two brick walls. The time interval used was 10 min for (24) hr.

2. Room Model

The model included one room of (2m length, 2m width and 2.4m height) with roof and all walls built from sandwich panel of (0.034W/m.k) thermal conductivity and thickness of 5cm in order to prevent heat loss from indoor to outside or versa. Two openings were made in the south oriented wall of 1m height and 0.3m width, as shown in Fig.1

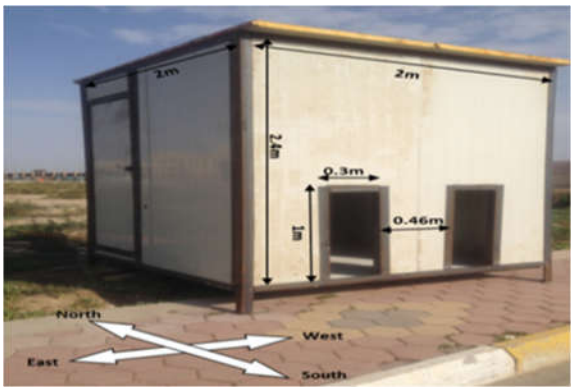

Figure 1: Room Model

3. Measurement Device

3.1 *Data logger (Lab jack)*

Lab jack data logger (U3-LV) model was used to measure the wall room and ambient temperatures with as shown in Fig.2. This device consists of sixteen channels which is connected by sensor wire (LM35) and installed from inside and outside of the walls. The error percentage for this device was (0.146%). Fig.3 shows lab jack extension used to record the temperatures.

3.2 *Heating Unit*

The room temperature is set at 24oC by using heating unit (Split Aux) types. The split capacity is 3500W for heating.

3.3 *Solar Power Meter*

The solar power type (TES-1333R) shown in Fig.4. Is used to read the solar radiation (Ir).

Figure 2: Lab jack model U3-LV

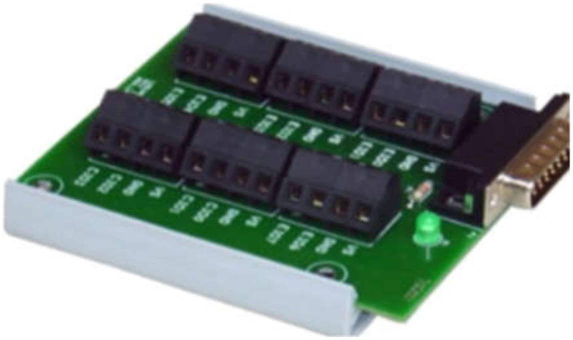

Figure 3: Lab jack extension

Figure 4: Solar Power Meter

4. Types of Walls and Experimental Test

One wall made from common brick was built to close the first opening with cement mortar used to fix the brick. The wall dimensions were (1m high, 0.3m width and 0.24 m thickness) as shown in Fig.5. The thermal conductivity of brick is (0.54W/m.K).The second opening is closed by two brick walls of 0.12m thickness each with air gap of 2cm between them as shown in Fig.5. The thermal insulation material of 2cm thickness is placed in the air gap. The thermal conductivity of insulation materials and overall heat transfer coefficient of the walls are given in Table.1 Thermistor sensor types (LM35) is used to measure the temperatures. Three LM wires are uniformly distributed at each wall face (exterior and interior) as shows in Fig.5. Three LM wires are installed in room middle space to read the average room temperature (Tr) as shows in Fig .5. One wire is used to record the ambient temperature.

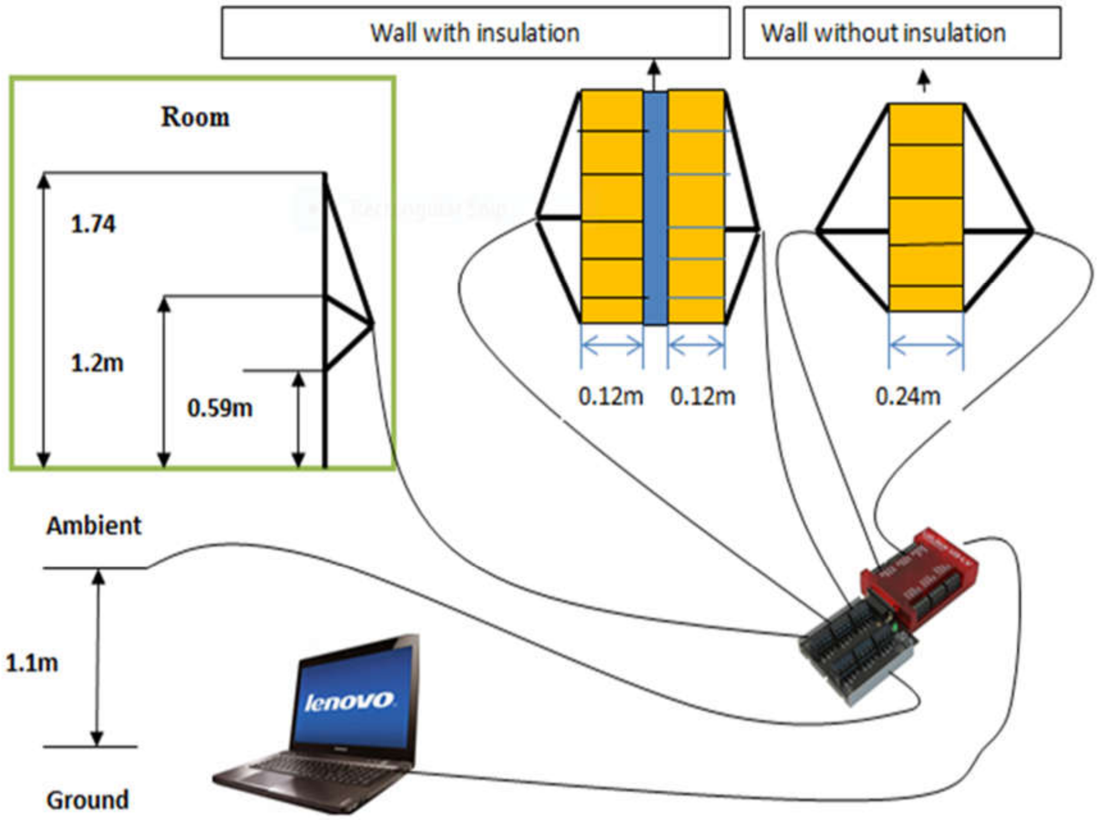

Figure 5: Layout of temperatures measurement equipment

5. Data Processing

5.1 *Overall Heat Transfer Coefficient of wall.*

This coefficient is evaluated such as .[5]

$$U = 1/R\_T \qquad (1)$$

$$R\_T = 1/h\_i + \sum x/k + 1/h\_o \qquad (2)$$

Where:-

R_T: Total resistance, m^2 K/W.

h_i: Convection heat transfer coefficient for membrane layer inner wall equal (9.26W/m^2°C).

h_o: Convection heat transfer coefficient for membrane layer outer wall equal (34.1W/m^2°C).

x: The thickness of layers, m.

k : The thermal conductivity of the layers.

5.2 *Sol-Air Temperature*

Sol-air temperature is the outdoor air temperature that, in the absence of all radiation changes gives the same rate of heat entry into the surface, as would the combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with outdoor air.[1]

$$T\_e = T\_a + \propto/h\_o * I\_t - (\varepsilon\, \Delta R)/h\_o \qquad (3)$$

T_e : Sol-Air Temperature.°C

T_a: Ambient temperature.°C

α: Absorption of surface for solar radiation

I_t: Total solar radiation incident on surface, W/m^2

ε: Hemispherical remittance of surface .

ΔR: Difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature, W/m^2, for vertical surface ΔR = 0.

5.3 *Heat Loss by using Radiant Time Series (RTS) Method*

The radiant time series is a new simplified method for performing design heat load calculations that is derived from the heat balance[2]

Conductive heat loss of using Conduction Time Series

$$Q\_(i,\theta-n) = UA(T\_(e,\theta-n) - T\_(r,\theta-n)) \quad (4)$$

Where

Q_(i,θ-n): Conductive heat input for the surface n hours ago, W.

U: Overall heat transfer coefficient for the surface, W/(m^2K) .

A: Surface area, m^2 .

T_ (e,θ-n): Sol-air temperature n hour's ago, °C .

T_ (r,θ-n): Presumed room air temperature n hour's ago, °C.

Conductive heat loss through the walls can be calculated by using conductive heat inputs for the current hours and past 23 h and conduction time series.

$$Q\_\theta = C\_0\, Q\_(i,\theta) + C\_1\, Q\_(i,\theta-1) + C\_2\, Q\_(i,\theta-2) + C\_3\, Q\_(i,\theta-3)\; C\_23\, Q\_(i,\theta-23) \quad (5)$$

Q_θ: Hourly conductive heat loss for the surface, W.

Q_(i,θ): Heat input for the current hour, W .

Q_(i,θ-n): Heat input n hours ago, W.

C_0, C_1, etc. : Conduction time factors.

Conduction time factors for the wall [2] are given in Table.2

5.4 *Energy Saving*

It is calculated such that;

$$S.E = (Q\_b - Q\_p)/Q\_b \quad (6)$$

Where-:

Q_b: Heat loss for brick wall, W/m^2.

Q_p: Heat loss for insulation wall, W/m^2.

6. Results and Discussion

6.1 *Temperature Distribution*

6.1.1 Effect of using air gap

Fig.6 and Fig.7 indicate a comparison thermal behavior of two walls (brick wall and two walls from brick with air gap) at same time in winter season at (8-Jan-2018). It can be noted that room temperature (Tr) is nearly constant between (23°C to 26.5°C) since the controller of heating unit was setted at 24°C, and the solar radiation (Ir) is increased from (100W/m2) at 8a.m to maximum value at 1p.m about (695 W/m 2). Then decreased to minimum value zero at 6 p.m while the ambient temperature (Ta) is increased from 3.5°C at 7a.m to maximum value 15°C at 1 p.m, and then decreases with the decrease in solar radiation to sunset to minimum value at the end of night time Fig.6 shows that temperatures on the inner and outer surface of brick wall, (Tbi and Tbo) are increased during day time to the value more than ambient temperature (Ta) and more than room temperature (Tr). While during night time these temperatures decreases to lower than room temperature which means that heat is lost to outside through wall. Hence the insulation must be used to reduce the heating load .The minimum reported (Tbi and Tbo) was at 7a.m (11°C and 7°C) respectively. Fig.7 shows that the same rate of temperature variation on the inner and outer surface of insulated wall (Tini and Tino) except that the minimum temperature of inside insulated wall is higher. The difference between inside and outside wall surface temperatures was increased due to air gap effect. The minimum (Tini and Tino) was at 7a.m (13°C and 6°C) respectively. Fig.8 Illustrates a comparison between the temperature difference of brick wall and two brick walls with air gap. The maximum value during night time was (7.5°C) at 6a.m for insulated wall while that for brick wall was (4.4°C) at 6a.m. So the maximum energy saving was 41.3% for heating load. Due to air gap thermal insulation.

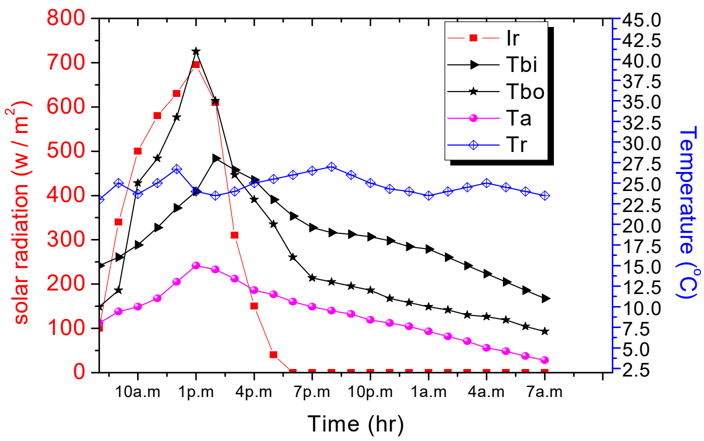

Figure 6: Temperature and solar radiation history for brick wall (8-Jan-2018)

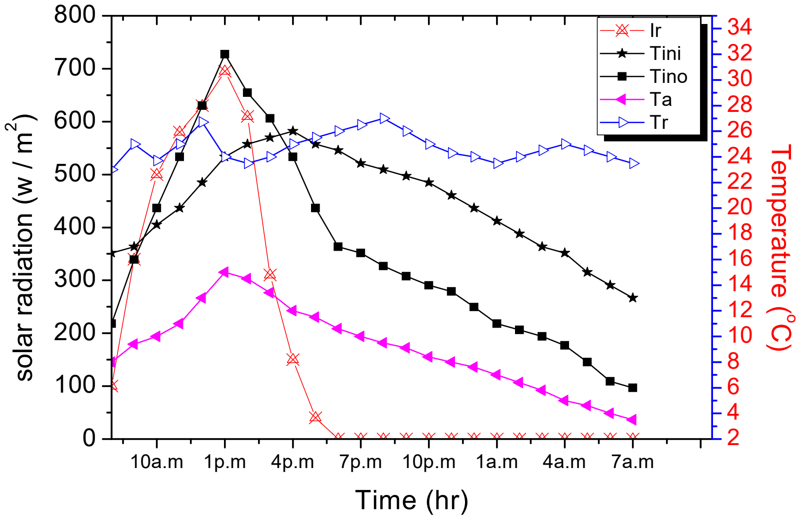

Figure 7: Temperature and solar radiation history for two brick walls with 2cm air gap (8-Jan-2018)

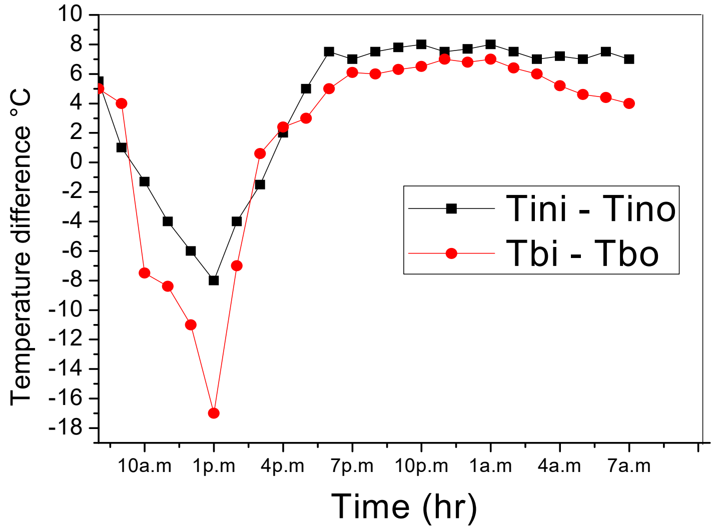

Figure 8: Comparison between hourly temperature difference for brick wall and two brick walls with 2cm air gap (8-Jan-2018)

6.1.2 Effect of using glass wool

Fig.9 and Fig.10 show a comparison of thermal behavior of the two investigated wall (brick wall and two brick walls with glass wool). It can be noted that room temperature (Tr) is nearly constant between (23.5°C to 26°C) since the controller of heating unit was setted at 24°C, and the solar radiation (Ir) is increased from (120W/m2) at 8a.m to maximum value at 1p.m (709 W/m 2). While the ambient temperature (Ta) is increased from 5.3°C at 7a.m to maximum value of 20°C at 3p.m and then decreases with decrease in solar radiation to sunset to minimum value at the end of night time Fig.9 indicates that (Tbi and Tbo) are increased during day to the value more than ambient temperature (Ta) and more than room temperature (Tr). While during night time these temperatures decreases to lower than room temperature which means that heat is lost to outside through wall. Hence, the insulation must be used to reduce the heating load. The minimum reported (Tbi and Tbo) was (14°C at 6a.m and 6.3 at 7a.m°C) respectively. Fig.10 indicates same rate of temperature variation on the inner (Tini) and outer surface (Tino) of insulated wall is obtained except that the minimum temperature of inside insulated wall was higher. The difference between inside and outside wall surface temperatures was increased due to glass wool effect. Minimum values of (Tini and Tino) are at 7a.m (16°C and 6.3°C) respectively. Fig.11 Illustrates a comparison between the temperature difference of brick wall and two brick walls with glass wool. The maximum value during night time was (11°C) at 6a.m for insulated wall while that for brick wall was

(7°C) at 6a.m. So the maximum energy saving was 36.3% for heating load due to glass wool insulation.

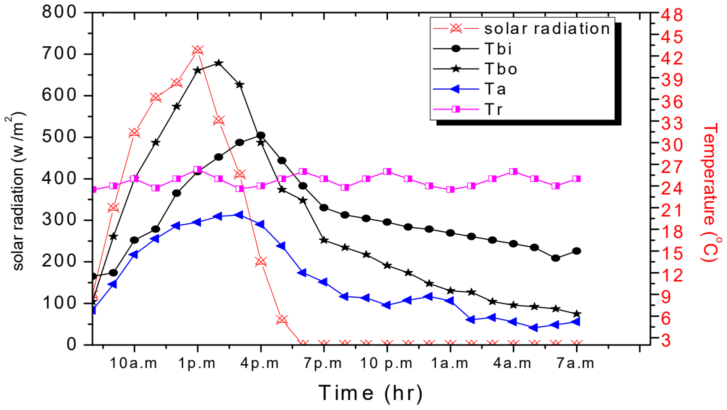

Figure 9: Temperature and solar radiation history for brick wall (10-Jan-2018)

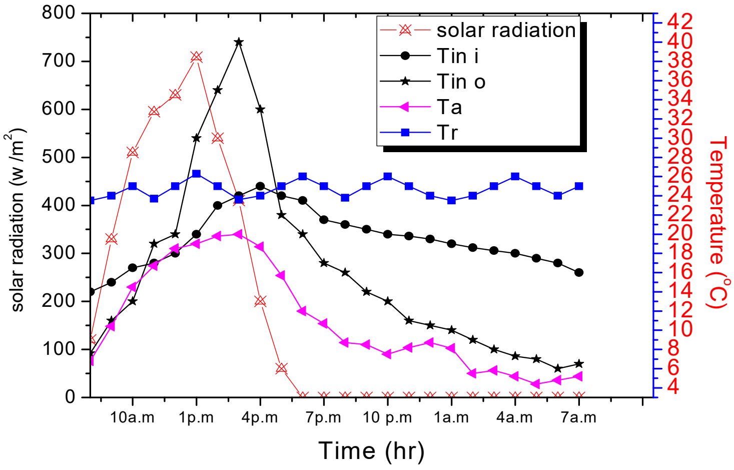

Figure 10: Temperature and solar radiation history for two brick walls with 2cm glass wool (10-Jan-2018).

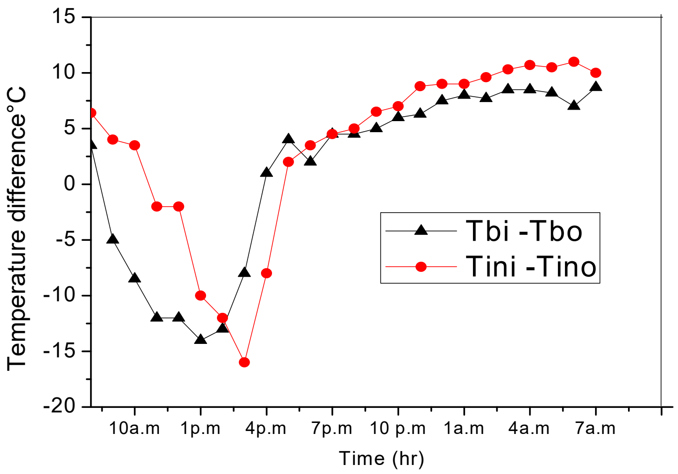

Figure 11: Comparison between hourly temperature difference for brick wall and for two brick walls with glass wool (10-Jan-2018).

6.1.3 Effect of using sawdust

Fig.12 and Fig.13 indicate that room temperature (Tr) is nearly constant between (23°C to 26.5°C) since the controller of heating unit was setted at 24°C, and the solar radiation (Ir) is increased from (160W/m2) at 8a.m to maximum value at 1p.m about (719 W/m 2). While the ambient temperature (Ta) is increased from 3.5°C at 7a.m to maximum value of 14°C at 3p.m and then decreases with the decrease in solar radiation to minimum value at the end of night time. Fig.12 indicates that temperatures on the inner and outer surface of brick wall, (Tbi and Tbo) are increased during day time to the value more than ambient temperature and more than room temperature. While during night time these temperatures decreases to lower than room temperature which means that heat is lost to outside through wall. Hence, the insulation must be used to reduce the heating load. The minimum reported (Tbi and Tbo) at 7a.m were (14.2°C and 7°C) respectively. Fig.13 shows the same rate of temperature variation on the inner and outer surface of the insulated wall (Tini and Tino) except that the minimum temperature of inside insulated wall was higher. The difference between inside and outside wall surface temperatures was increased due to sawdust effect. The minimum (Tini and Tino) at 6a.m were (15°C and 4°C) respectively. Fig.14 Illustrates a comparison between the temperature difference for brick wall and for two brick walls with sawdust. The maximum value during night time (11°C) at 6a.m for insulated wall while that for brick wall was (7.3°C) at 6a.m. So the maximum energy saving was 33.6% for heating load due to sawdust insulation.

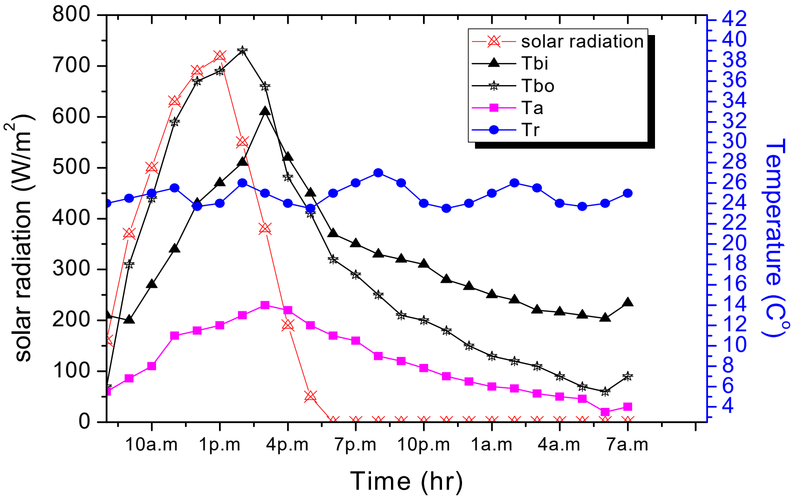

Figure 12: Temperature and solar radiation history for brick wall (12-Jan-2018).

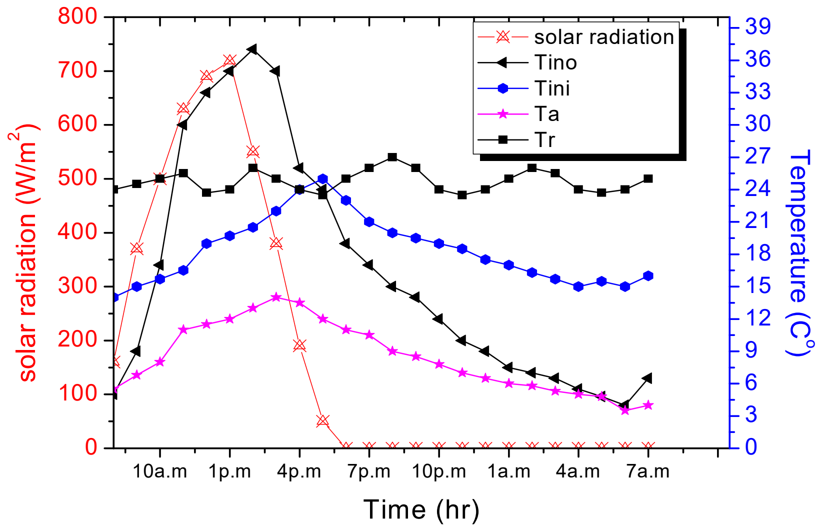

Figure 13: Temperature and solar radiation history of two brick walls with 2cm sawdust (12-Jan-2018).

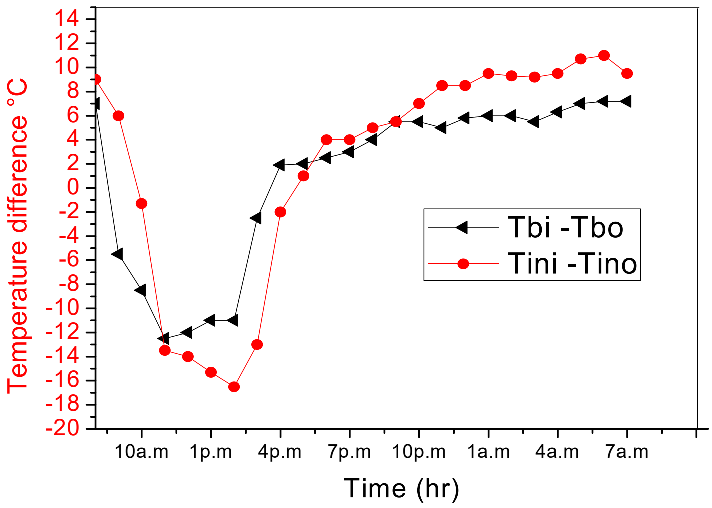

Figure 14: Comparison between hourly temperature difference for brick wall and for two brick walls with sawdust (12-Jan-2018).

6.2 *Heat Loss from the Wall*

6.2.1 Effect of using air gap

A comparison of heat loss from brick wall and two walls with air gap is shown in Figure15. The maximum heat loss in the brick wall was (-49.6W/m2) at 8a.m while the maximum heat loss of brick wall with air gap was (-23W/m2) at same time. So the insulation saves energy by 53.6%. Then heat loss started to decrease at daytime and reach to a minimum value of (-14.3W/m2) at 6p.m for brick wall and (-6W/m2) at 6p.m for wall with insulation air gap. Heat loss increases at night time because the ambient temperature decreases. Highest heat loss for brick wall is reported because it have low thermal resistance (0.57m2.°C /W) while the wall with air gap indicated less heat loss since it has higher thermal resistance due to using air gap (0.72m2.°C /W).

6.2.2 Effect of using glass wool

A comparison of heat loss from brick wall and two walls with glass wool is shown in Figure 16. The maximum heat loss in the brick wall was (-48.5W/m2) at 8a.m. While the maximum heat loss of brick wall with glass wool was (-15W/m2) at the same time. So the insulation saves energy by 69%. After that heat loss started to decrease at daytime and reach to a minimum value of (-12W/m2) at 6p.m for brick wall and (-0.3W/m2) at 6p.m for wall with glass wool. Heat loss increases at night time because the ambient temperature decreases. Highest heat loss for brick wall is reported because it have low thermal resistance (0.57m2.°C /W) while the wall with glass wool have indicated less heat loss since it has higher thermal resistance due to using glass wool (1.1m2.°C /W).

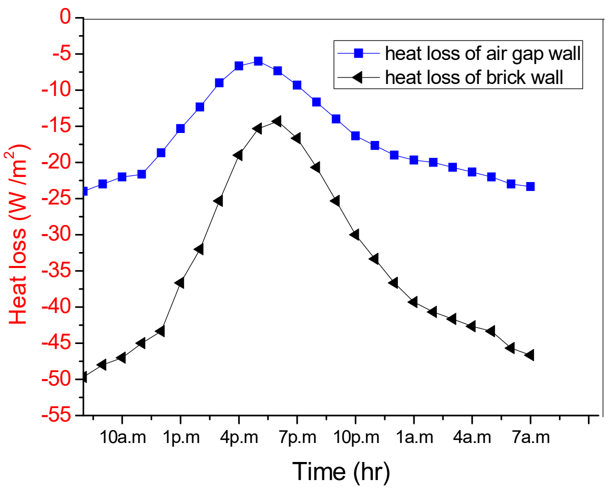

Figure 15: Comparison of heat loss from brick wall and two brick walls with air gap (8-Jan-2018)

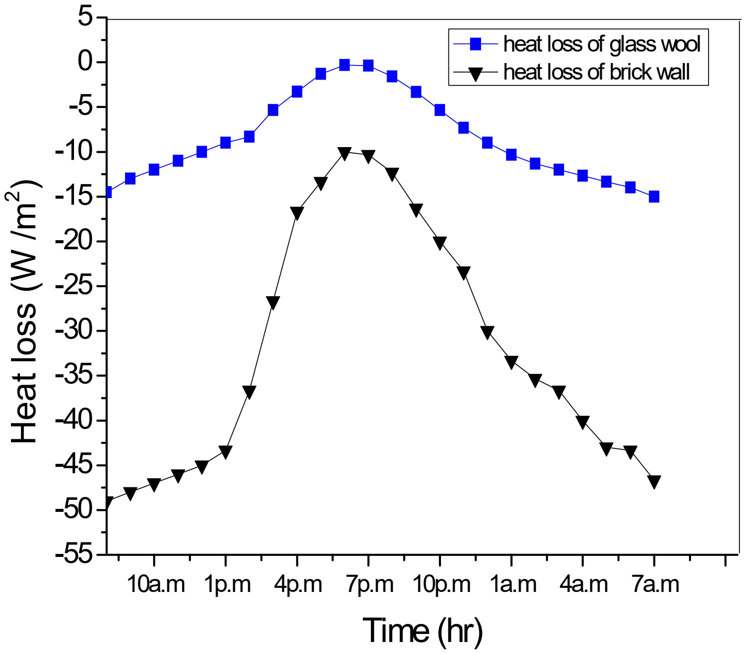

Figure 16: Comparison of heat loss from brick wall and two brick walls with glass wool (10-Jan-2018)

6.2.3 Effect of using sawdust

A comparison of heat loss from brick wall and two walls with sawdust is shown in Figure17. The maximum heat loss in the brick wall was (-53W/m2) at 8a.m while the maximum heat loss of brick wall with sawdust was (-22W/m2) at the same time. So the insulation saves energy by 58.4%. Heat loss started to decrease during daytime period and reach to a minimum value of (-10W/m2) at 6p.m for brick wall and (-25W/m2) at 6p.m for wall with sawdust. Heat loss increases at night time since the ambient temperature decreases. Highest heat loss for brick wall is reported because it have low thermal resistance (0.57m2. °C /W) while less heat loss is indicated for insulated wall since it has higher thermal resistance due to using sawdust (0.82m2.°C/W).

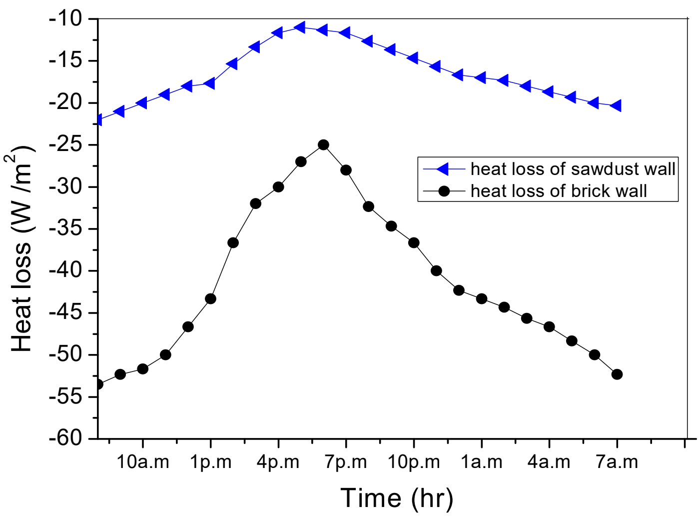

Figure 17: Comparison of heat loss from brick wall and two brick walls with sawdust (12-Jan-2018)

Table 1: Thermal conductivity of insulation materials and overall heat transfer coefficient for two brick walls with gap.

Materials	Thermal Conductivity (W/m.K)	Overall Heat transfer Coefficient(W/m^2.K)
Glass Wool	**0.038**	**0.90**
Sawdust	**0.08**	**1.21**
Air Gap	**0.026**	**1.38**

Table 2: conduction time factors

Number	CTS	Number	CTS	Number	CTS
C_0	0	C_8	0.05	C_{16}	0.01
C_1	0.05	C_9	0.04	C_{17}	0.01
C_2	0.14	C_{10}	0.03	C_{18}	0
C_3	0.17	C_{11}	0.02	C_{19}	0
C_4	0.15	C_{12}	0.02	C_{20}	0
C_5	0.12	C_{13}	0.01	C_{21}	0
C_6	0.09	C_{14}	0.01	C_{22}	0
C_7	0.07	C_{15}	0.01	C_{23}	0

7. Conclusions

Based on the obtained results the following conclusion can be extracted:

1. Using thermal insulation material in the buildings lead to reduce the drop in the inside temperature of the wall in winter season during night time, so heating load will be decreased.
2. Using thermal insulation (Glass Wool) gave better results than other thermal insulation material.
3. The maximum saving of heating load in winter is when using insulation in south oriented wall about: 69% for glass wool, 58.4% for sawdust and 53.6% for air gap.

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Nomenclature

A Surface area m^2

C_0, C_1, etc. Conduction time factors %

h_i Convection heat transfer coefficient for membrane layer inner wall W/m^2 K

H_o Convection heat transfer coefficient for membrane layer outer wall W/m^2 K

I_r Total solar radiation incident on surface W/m^2

K Thermal conductivity W/mK

Q_ (i, θ-n) Conductive heat input for the surface n hours ago W

Q_θ Hourly conductive heat loss for the surface W

Q_ (i, θ) Heat input for the current hour W

Q_b Heat Loss for brick wall W/m^2

Q_p Heat Loss form insulation wall W/m^2

R_T Total resistance m^2 K/W

ΔR Difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature W/m^2

T_a Ambient temperature °C

T_r Room air temperature °C

T_e Sol-air temperature °C

T_{bi} Temperature on the inner surface of a brick wall °C

T_{bo} Temperature on the outer surface of a brick wall °C

T_{ini} wall Temperature on the inner surface of an Insulation °C

T_{ino} wall Temperature on the outer surface of an Insulation °C

$T_{(e, \theta-n)}$ Sol-air temperature n hours ago °C

$T_{(r, \theta-n)}$ Presumed room air temperature n hours ago °C

$\Delta T (b_{(i-o)})$ Temperature difference inner and outer surface of the brick wall °C

$\Delta T_{(in (i-o))}$ Temperature difference inner and outer surface of the Insulation wall °C

U Overall Heat Transfer Coefficient W/m^2 K

x Thickness of the layer m

Letter Greek letter description Units

α Absorption of surface for solar radiation

ε Hemispherical remittance of surface

Letter Abbreviations Units

S.E Save energy %

RTS Radiant time series

دراسة تجريبية لاستخدام العزل الحراري في جدران المباني لتقليل حمل التدفئة في مدينة الكوت

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نشر في: 31 كانون الأول 2019

الخلاصة – أجريت دراسة تجريبه على نموذج غرفة صغيرة تم بناؤها من السندويج بنل في مدينة الكوت لتقليل حمل التدفئة في فصل الشتاء باستخدام ثلاث أنواع من العوازل الحرارية هي (الصوف الزجاجي، الفجوة الهوائية ونشارة الخشب). كانت أبعاد النموذج (2م طول * 2م عرض * 2.4 م ارتفاع). تم صنع فتحتين في الجدار الجنوبي ابعادها (1م ارتفاع* 0.3 م عرض). الفتحة الأولى اغلقت، بجدار من الطابوق فقط وفي الفتحة الثانية بني جدارين من الطابوق مع العازل الحراري. العازل الحراري يوضع بين الجدارين بسمك (2سم). أظهرت النتائج أن أقصى حفظ طاقة لحمل التدفئة في الليل عند استخدام العزل الحراري كانت 69٪، 58.4٪ و53.6٪ للصوف الزجاجي، نشارة الخشب والفجوة الهوائية على التوالي.

الكلمات الرئيسية – العزل الحراري، الحمل الحراري، الصوف الزجاجي، نشارة خشب.