Journal of Engineering and Development, Vol. 14, No. 3, September (2010) ISSN 1813-7822

Experimental and Theoretical Investigation Of Composit Materials As Thermal Insulation For Resident Building

Prof. Dr. Qasim S. Mehdi
Al - Mustansiriya Unv.
College of Engineering
Mechanical Dept.

Dr. Fadhel A. Abdulla
Al - Mustansiriya Unv.
College of Engineering
Mechanical Dept.

Ahmed A. Abdul Shaheed
Al - Mustansiriya Unv.
College of Engineering
Mechanical Dept.

Abstract

This work involves a theoretical and experimental investigation of three types of composite laminated materials as thermal insulations for roofs. The composite consist of three types fiberglass with polyester resin. The first is of; random fiberglass type-1, (density of 659.3 kg/m^3).The second is random fiberglass type-2, (density of 731.8 kg/m^3) and the last is matt fiberglass,(density 1010.5 kg/m^3). The theoretical investigation involved a study of the solar radiation received by the walls and roof, heat gain reduction of roof for the three types of composite materials at different variables; these involved the (insulation thickness, number of layers of composite insulation, volume fraction, and the air gap between roof and the insulation. The experimental investigation is divided into two parts: the first part included measurement of thermal conductivity of composite materials using Lee's disc method with different volume fraction. The second part included manufacturing of two rigs (reference rig and test rig) with dimension (1m x 1m x 1m height). Theoretical results proovs that the heat gain for the roof is more than that of the walls. Also the heat gain is decreased with different percentages depending on the type of insulation. Obviously the heat gain is decreased with using air gap. The thermal conductivity is increased with volume fraction theoretically and experimentally. Experimental result proofs that using random fiberglass type-1 is best in the present work. Also the air gap increases the efficiency of thermal insulation.

Key wards: - composite material, thermal conductivity, insulation

---

الخلاصـــــــة

تمت دراسة نظرية وعملية لاختبار ثلاثة انواع من المواد الركبة كعوازل حرارية للسقوف. تتكون هذه المواد من الالياف الزجاجية وراتنج البولستر. انواع الالياف المستخدمة هي الياف زجاجية عشوائية نوع-1 وتبلغ كثافتها 659.3kg/m^3, الياف زجاجية عشوائية نوع-2 وتبلغ كثافتها 731.8 kg/m^3, والياف زجاجية (حصيرة) ذات كثافة 1010.5 kg/m^3.تضمن الجزء النظري حساب كمية الاشعاع الشمسي المستلم عبر الجدران والسقف , وتحديد نسبة تخفيض الكسب الحراري للسقف عند استخدام العوازل الثلاثة لعدة متغيرات هي (سمك العازل,عدد طبقات الالياف في العازل, الكسر الحجمي, وجود فجوة هوائية بين العازل والسقف). يتضمن الجزء العملي قسمين: يتضمن القسم الاول قياس الموصلية الحرارية للمواد المركبة لعدة كسور حجمية باستخدام تقنية (اقراص – لي). في القسم الثاني تم بناء هيكلين ابعاد كل منهما (1مx1مx1م) , الهيكل الاول يعتبر مصدر اساس لدرجات الحرارة المقاسة اما الهيكل الثاني فيستخدم لاختبار العوازل الحرارية. اثبتت النتائج النظرية ان الحرارة المكتسبة عبر السقف مقارنة بالجدران هي الاكبر. كما ان الكسب الحراري عند استخدام العوازل الحرارية الثلاثة يقل بنسب متفاوتة وحسب نوع العازل. كما يقل الكسب الحراري بشكل ملحوض عند استخدام فجوه هوائية بين العازل والسقف. لوحظ ان الموصلية الحرارية للمواد المركبة تزداد بزيادة الكسر الحجمي لهذه المواد نظريا وعمليا. برهنت النتائج العملية ان استخدام الالياف الزجاجية العشوائية- نوع 1 , هو افضل العوازل الحرارية المستخدمة في البحث الحالي من خلال تقليل كمية الحرارة المكتسبة عبر السقف, بينما اظهر استخدام الفجوة الهوائية تحسن كفاءة العزل الحراري.

Nomenclature

Letter	Description	Unit
AEC	Atmospheric Extinction Coefficient	-------
ASR	Apparent Solar Radiation (at air mass=0)	W/m^2
f_i	Inside air film resistance	$W/m^2.K$
f_o	Outside air film resistance	$W/m^2.K$
DFR	The diffuse radiation factor	-------
I_b	Hourly beam radiation on a horizontal surface	W/m^2
I_d	Hourly diffuse solar radiation	W/m^2
I_{dn}	Hourly beam radiation on as plane normal to the beam direction	W/m^2
I_r	Hourly incident radiation	W/m^2
I_t	Total solar radiation incident on the surface	W/m^2
IV	Rate of energy supply to the heater	W
k1, k2,…,kn	Thermal conductivity of each layer of roof assembly	W/m.K
k	Thermal conductivity of composite	W/m.K
k_f	Thermal conductivity of fiber	W/m.K
k_m	Thermal conductivity of matrix	W/m.K
L_{loc}	Longitude of the location in question in degrees west	Degree
L_{st}	Standard meridian for the local time zone	Degree
n	The day of the year $1 \le n \le 365$	-------
r	Radius of disc	m
T_A, T_B, and T_C	Temperature of disc A, B, and C in lee's disc technique	C°
t_i	Inside air temperature	C°
t_o	Daily average outdoor temperature	C°
V_f	Volume fraction of fiber	-------
x1,x2,..,xn	Thickness of each layer of roof assembly	m
α	Absorptance of the surface of solar radiation	-------
ω	Hour angle	degree
δ	Declination angle	degree
ϕ	Latitude angle	Degree

Introduction

Most of the energy is spent for heating and cooling purposes. World has still got enough resource in order to use for heat insulation purposes or heat insulating materials. In Iraq the major source of heat gain in building is solar radiation. It is characterized by its variability. Roof surfaces are most exposed to solar radiation. The temperature in summer season reaches up to 50 C^o in most sunny days in Baghdad [33^o N]. This needs the use of air-conditioning equipment to cool the space in order to reach the suitable conditions for humans. The solar radiation absorbed by roofs is transmitted down to the inside living space. Most energy through the ceiling (35%), windows and floors (12%) each, walls (11%), doors (5%), and (25%) through infiltration **[ASHRAE-, a, 1997]** [1].

[Cummings 1991] [2] investigated the effect of ceramic coatings on top of an asphalt shingle roof of a Florida residence to observe the reduction in attic temperature and house cooling. Roof absorptivity decreased from 0.78 to 0.27 when the coating was applied. **[Ron & mark 2001]**[3] applied a ceramic paint coating to the roof of a finisher barn room at the Arkell Swine Research Station. Results clearly indicate that the ceramic coating resulted in virtually zero heat gain during day light time periods. **[Philip 2003]**[4] studied the effect of radiant barrier system in Florida house attic. Since the attic airspace separates the hot roof surface from the ceiling, no heat will be moved down by conduction. In fact the heat will not convert down from the hot roof to the ceiling due to heated air rises. **[Karen & Bas 2003]**[5] had an experiment with a green roof to improve the thermal performance of a roofing system through shading, insulation, and thermal mass, thus, reducing a building's energy demand for space conditioning. **[Yucel et. al 2003]**[6] made experimental tests for the expanded polystyrene as insulating and construction materials which are (or close) to homogenous. **[John & Camille 2007]**[7] were carried out extensive experiments on shielded and un- shielded roofs. The results indicate that a highly reflective solar barrier can reduce the rate of heat transfer into buildings. **[Fujino & Handa, 2002]**[8] described the features of PWFA (Plastic Waste / Fly Ash) composite. A small amount of glass fiber as reinforcement and a fire retardant was added in the ingredient of the composite. The thermal conductivity for the specimen 100×100 mm2 decreased with increasing the specimen temperature.

It is clear that there is a lack off information in using composite materials as thermal insulation. In the present work an experimental and theoretical investigation is carried out to study the behavior of composite material as a thermal insulation.

The Physical Model:-

Solar radiation has an important effect on the heat gain transferred to the space through the roof. This depends on the location of the sun and the clearness of the atmosphere as well as on the nature and orientation of the building. Solar radiation is varies both hourly and from day to day through the year.

The total solar radiation (I_t) of a terrestrial surface of any orientation and tilt with an incident angle (θ) is the sum of three variables as follows; see fig. (1)

$$I_t = I_b + I_d + I_r \tag{1}$$

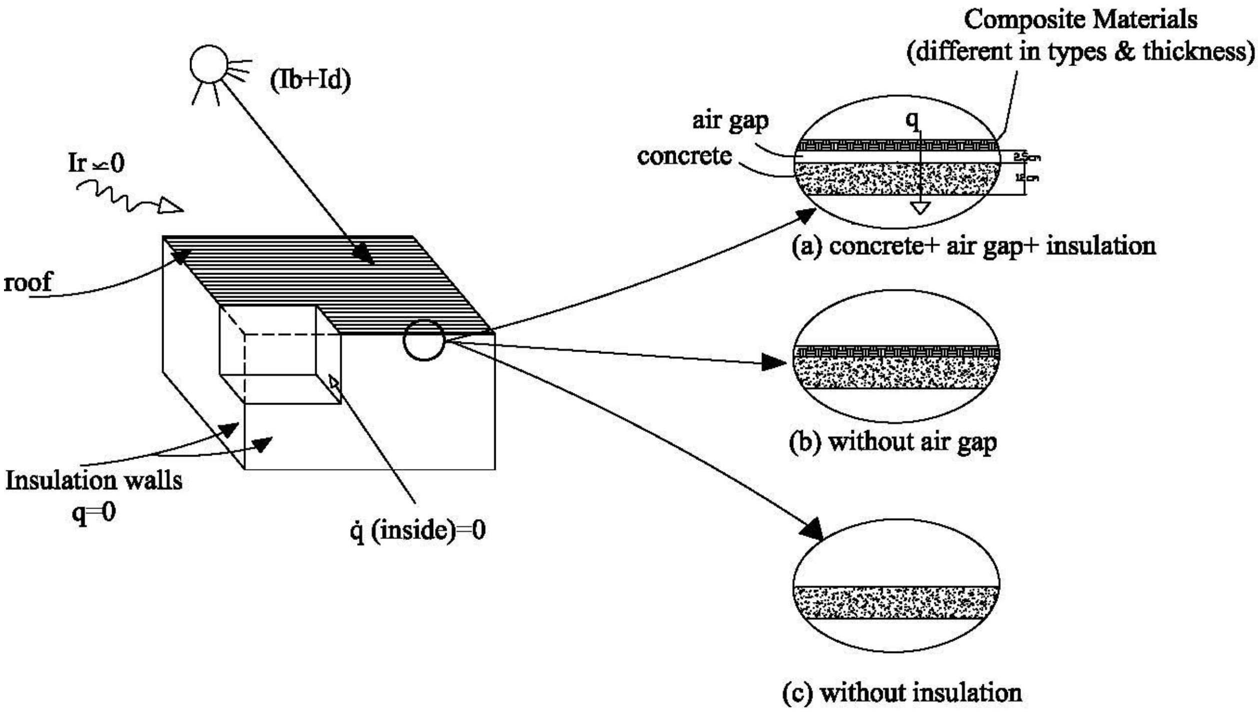


Fig (1) The Physical Model

Solar Radiation on a Horizontal Surface:-

Beam and diffuse radiation is calculated referring to experimental results for Baghdad city. Direct radiation (I_{dn}) is depends on the altitude of the sun only **[ASHRAE b, 1997]**[9].

$$I_{dn} = \frac{ASR}{\exp(AEC / \sin \alpha)} \tag{2}$$

Table (1), shows the values of ASR & AEC.

Table (1) Solar radiation calculation constants for the twenty first day of each month[ASHRAE b, 1997][9].

Month	**ASR** W/m^2	**AEC** Dimensionless	**DRF** Ratio
Jan.	1230	0.142	0.058
Feb.	1214	0.144	0.060
Mar.	1185	0.156	0.071
Apr.	1135	0.180	0.097
May.	1103	0.196	0.121
June.	1088	0.205	0.134
July.	1085	0.207	0.136
Aug.	1107	0.201	0.122
Sept.	1151	0.177	0.092
Oct.	1192	0.160	0.073
Nov.	1220	0.149	0.063
Dec.	1233	0.142	0.057

Altitude angle of the sin (α) can be estimated from **[John, 1980][10]**,

$$\sin\alpha = \cos\phi_z = \cos\delta.\cos\phi.\cos\omega + \sin\delta.\sin\phi \tag{3}$$

The declination angle of the sun (δ) can be calculated from the equation **[Peter, 1980][11]**

$$\delta = 23.45.\left[\sin\left(360\left(\frac{284+n}{365}\right)\right)\right] \tag{4}$$

Hour angle (ω), can be estimated from,

$$\omega = (12 - \text{solartime}) * 15 \tag{5}$$

$$\text{Solar time} = \text{standard time} + 4(L_{st} - L_{loc}) + E \tag{6}$$

E is the term of time given as :

$$E=9.87\sin 2B-7.53\cos B-1.5\sin B \qquad (7)$$

Where

$$B=\frac{360(n-80)}{365} \qquad 1\le n\le 365 \qquad (8)$$

$$\therefore I_b=I_{dn}\sin\alpha \qquad (9)$$

The diffused radiation for a clear sky is computed by **[ASHRAE b, 1997][9]**

$$I_d=DRF\ \ I_{dn} \qquad (10)$$

Where DRF is given in table (1)

Subs. equ. (9) & (10) in equation (1)

$$\therefore I_t=I_{dn}\sin\alpha+DRF\,I_{dn} \qquad (11)$$

Transmission Heat Gain:-

The transmission heat gain through the roof is caused by the difference between the interior with the exterior temperatures, in addition to the effect of solar radiation. The rate of heat transfer can be expressed in terms of sol – air temperature. Sol – air temperature is meaning the equivalent temperature to air temperature included the effect of solar radiation.

$$Q=UA\,\Delta T_{eq} \qquad (12)$$

$$\Delta T_{eq}=t_{ed}+\left[(t_o-t_i)-15\right]+\left[\frac{20-D.R.}{2}\right] \qquad (13)$$

The overall thermal transmittance coefficient can be calculated as follows:

$$UA=\frac{1}{R_{roof}} \qquad (14)$$

Where,

$$R_{roof}=\left[\frac{1}{f_o}+\frac{x_1}{k_1}+\frac{x_2}{k_2}+........+\frac{x_n}{k_n}+\frac{1}{f_i}\right] \qquad (15)$$

Thermal conductivity coefficient of specimen was measured experimentally by using Lee's disk method principle, see fig. (2) **[Duncan, 2000][12]**

$$k=\left(\frac{Q\,t_s}{T_B-T_A}\right)\left[T_A+\frac{2T_A}{r}\left(t_A+\frac{t_s}{4}\right)+\frac{t_sT_B}{2r}\right] \qquad (16)$$

(Q), can be obtained in terms of (IV), since the total heat supplied must be equal to

$$Q=\frac{IV}{\pi r^2(T_C+T_A)+2\pi r[t_A T_A+\frac{t_s}{2}(T_A+T_B)+t_B T_B+t_C T_C]} \quad (17)$$

Theoretically, Maxwell model is used to estimate the thermal conductivity of the types of composite materials which are used in the present work.

Maxwell model is used for two phase mixtures;

$$K=\frac{km[k_f+2k_m-2v_f(k_m-k_f)]}{k_f+2k_m+v_f(k_m-k_f)} \quad (18)$$

Theoretical thermal conductivity values were compared with experimental values, and good agreement was obtained.

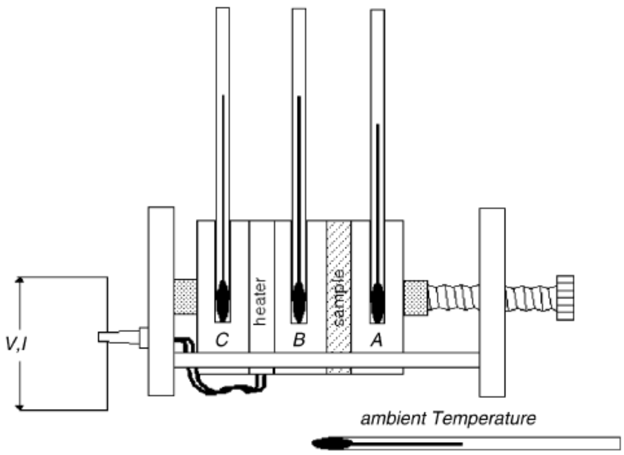


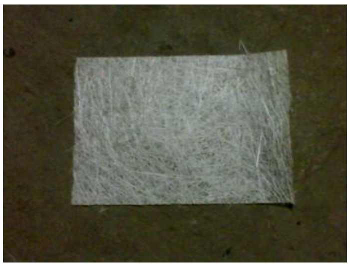
Fig. (2) Lee's disc schematic.

Composite Material (thermal Insulation) Manufacturing:-

Insulation is a material which has high thermal resistance that can be installed in the building envelope to minimize heat gain to the living space. Most insulations are heterogeneous materials made of low thermal conductivity, and involve air pockets.

Three types of fiberglass were used to make the insulation layers which are used in the present work.

The first type of fiberglass is called (Matt Fiberglass) which has a density (1010.5 kg/m3), the second type which is called (Random fiberglass) and this type has divided into two types (type1) and (type2) according to the density, density of (type 2) is (731.8 kg/m3) and for (type 1) is (659.3 kg/m3). All types are shown in fig (3)


Matt fiberglass ***Random fiberglass type 1.*** ***Random fiberglass type 2.***

Fig (3) Types of fiberglass

These materials where used to make the insulation mixed with polyester resin which is first mix with a hardener (2%), without adding the hardener the polyester will stay liquid and it will never solidify. The amount of hardener added is constant through out all the experiments that made in the present work, adding more hardener will cause faster solidification of polyester. In this work different volume fractions and different thicknesses of insulation were studied to investigate the best construction for composite thermal insulation.

At first the effect of volume fraction is studied for four different volume fractions of fiberglass. After determining the best volume fraction of fiberglass in composite insulation, a study was accomplished to find the effect of the thickness of insulation and the number of layers.

The hand lay – up technique was used in this work to represent the specimens of composite insulation. The hand lay-up process may be divided into four basic steps:

- Mold preparation molds can be made of wood, plastics, composites or metals. The mold design depends on the shape of the product, size, reinforcing materials, type of resin, and additives.

- Gel coating consists of applying a resin layer called as gel coat on the mold surface. The coating is polyester, mineral-filled, pigmented, nonreinforced layer

- Lay-up in which the chopped strand mat, fabric in the form of reinforcement is applied to the gel coat surface.

-finishing is time desired machining and assembly work is carried out on the cured composite part

The Experimental Rig Model:-

Two models were build to study the effect of composite materials when it is used as a thermal insulation in roof. The first model is used as a reference model (with out insulation), but the second model is used as a test model (with different types of insulation).

Their dimensions are (1* 1*1m height) as shown in fig. (4). the roof is made of concrete layers with 12cm thickness.

Walls is made of 6cm polystyrene, in order to neglect the heat gain through it as shown in fig.(4). The ground model was covered with 4cm polystyrene. Thermocouples, (type-T) were used to measure the temperatures in different location at models as shown in fig (5).

The thermal insulation is fixed upon the concrete layer of the roof in two arrangements. The first one in a direct contact with concrete, but the 2^{nd} one there is an air gap between the concrete layer& the insulation layer.

Small two opened windows in the walls were made to make air ventilation inside the model.

Fig (4-a) experimental models

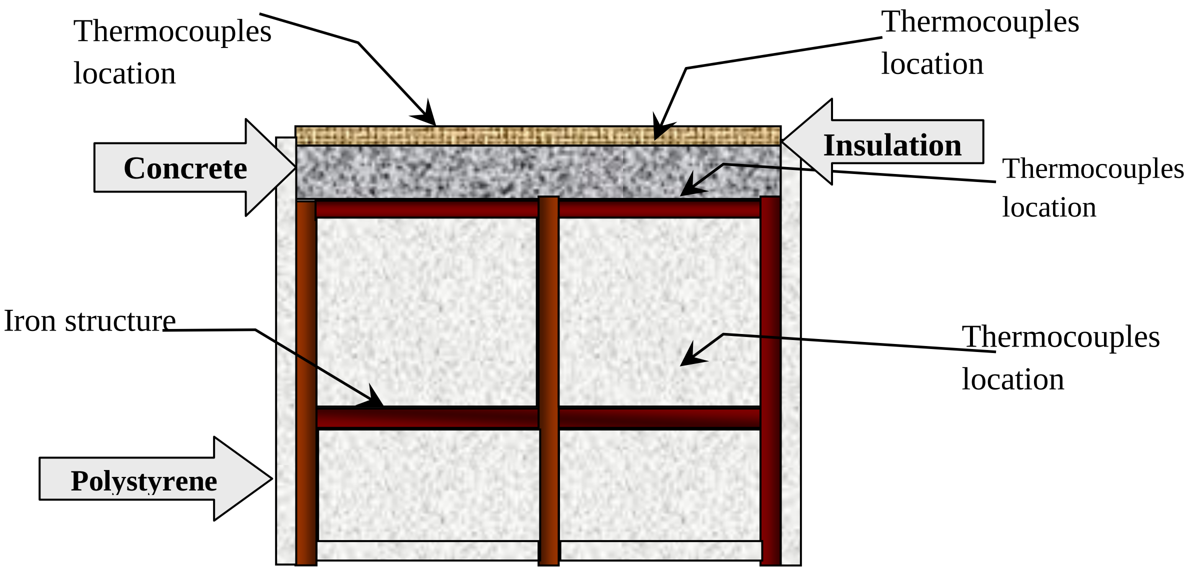


Fig. (4-b) Structure of the model (side section)

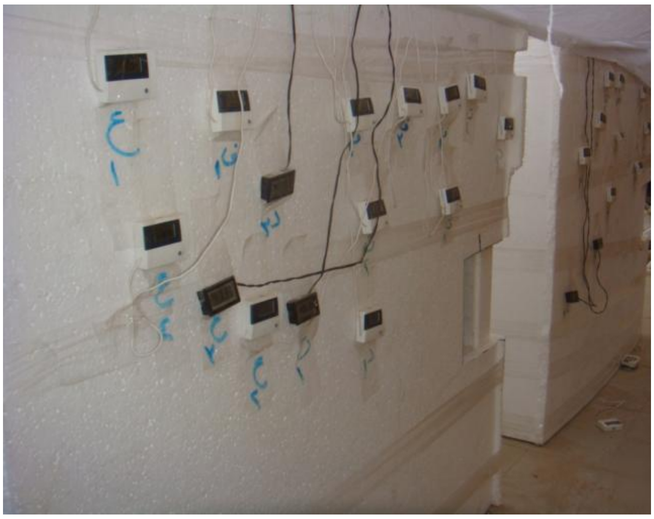


Fig (5) Arrangement of thermocouples

Results and Discussion:-

Results is divided into two categories, the first is theoretical results. It is included the calculated incident solar radiation upon the walls and roof of building in Baghdad (Lat 33°N) on (21August, 2008). As shown in Fig. (6), it can be seen that the roof is received larger amount of incident solar radiation than the walls. Fig. (7) shows a comparison between the calculated solar radiation incident on the roof and the measured on (21 August 2008) **(Iraqi meteorological Organization)[13]**. The percentage of error between the two values is acceptable. Fig (8) shows the relation between the percentages in heat gain reduction with insulation thickness without air gap for three types of fiberglass. Heat gain reduction is calculated according to the following equation

$$Q\% = \frac{Q_a - Q_b}{Q_a} \qquad (19)$$

Where :

Q% : heat gain reduction percentage.

Q_a % : heat gain through reference model (without insulation layer).

Q_b % : heat gain through test model(with insulation layer).

It is so clear from Fig. (8) that as the thickness of insulation layer increases, the heat gain reduction will also increases. Figure shows that the random type (1) fiber is the best than the other two types when the thickness of insulation layer is fixed.

Fig.(9) shows the effect of air gap layer addition between the composite insulation layer and the concrete layer on the heat gain reduction percentage. The enhancement in the heat gain reduction percentage is clear and maximum especially at the insulation thickness equal to (2cm). The range of enhancement for the type one of insulation is about (10% - 32%).

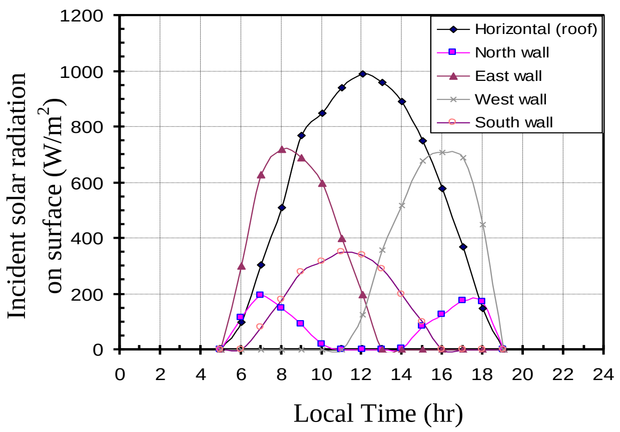


Figure (6) The incident solar radiation on walls and roof, (21 August 2008)

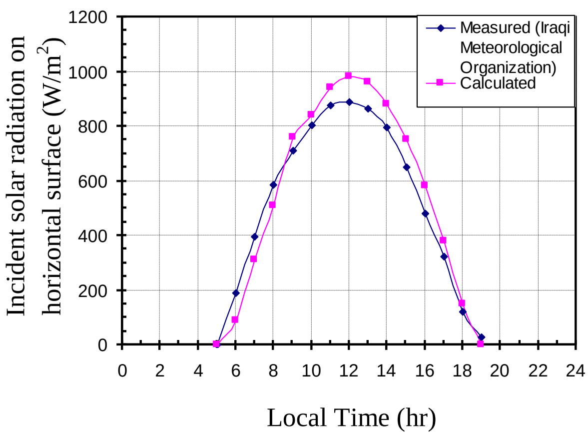


Figure (7) The incident solar radiation on horizontal surface, (21 August 2008).

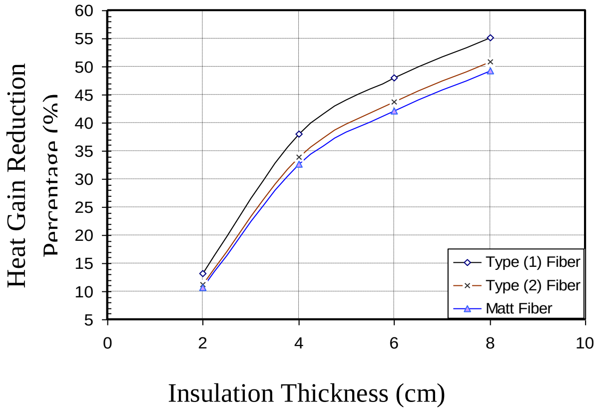


Figure (8) Heat gain reduction percent for different thicknesses of composite insulation without air gap.

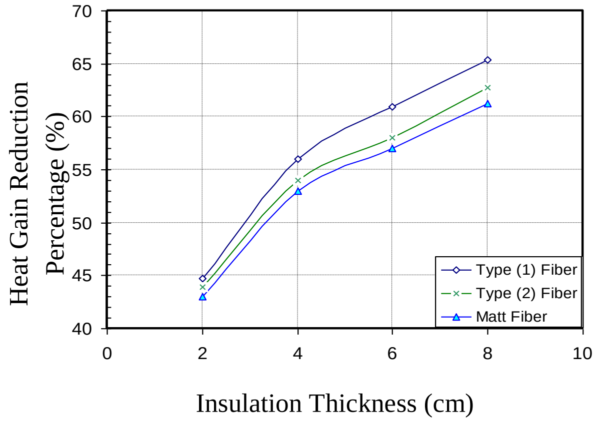


Figure (9) Heat gain reduction percent for different thicknesses of composite insulation with 2cm air gap.

Fig.(10) illustrates the effect of the numbers of layers of fiberglass in composite insulation layer for three types of fiberglass (i.e. the thickness of composite insulation constant, equal to 4 cm). It is clear that increasing the number of layers of fiberglass causes decreasing in heat gain reduction percentage. This is due to thermal conductivity of fiber glass which is higher than that of polyester resin. So for high performance of composite insulation, a minimum number of layers of fiberglass must be used. It is clear again that for the same number of layers of fiberglass in composite insulation, the random type (1) fiberglass shows the best than the other two types of fiberglass.

Fig. (11) shows the effect of air gap layer addition on the heat gain reduction percentage. It can be shown that using air gap will enhance the efficiency of composite insulation for all types and for all number of layers due to low thermal conductivity of air gap. It can be concluded that the random type (1) fiberglass has optimum percentage reduction in heat gain when comparing to other types for the same numbers of layers.

Fig. (12). shows the position of present composite insulation compared with two different types of insulation. The polystyrene insulation gives the highest rate of heat gain reduction when comparing with random fiberglass type (1) insulation and wood.

Fig. (13) show the relation between the heat gain through roof and daily time (local time) for Random fiberglass type (1) of composite insulation with fixed thickness (6cm).As it can be seen from fig., the heat gain increases as the time goes forward until it gets its maximum value at(2P.M.). It is also clear that using air gap will decreases heat gain through roof more than using insulation alone.

The second category of results is the experimental results. Three types of fiberglass were used in present work.

Journal of Engineering and Development, Vol. 14, No. 3, September (2010) **ISSN 1813-7822**

The first type is called Matt fiberglass ($\rho = 1010.5 kg/m^3$), while the second type is called random fiberglass which is divided into two types according to the density , type(1) which has a density of ($659.3 kg/m^3$) and the density of type (2) is ($731.8 kg/m^3$).

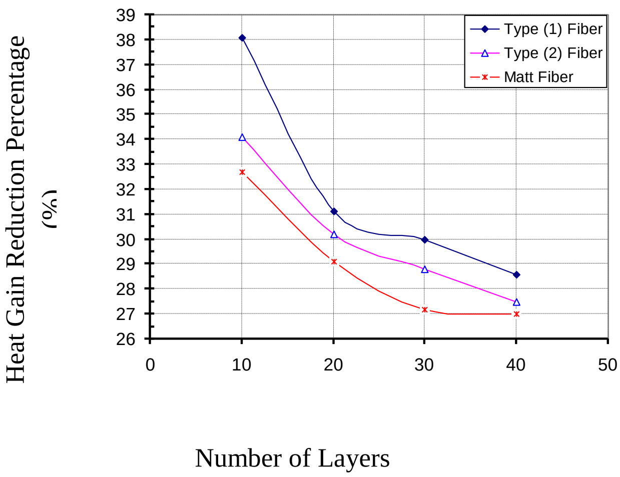


Figure (10) Heat gain reduction for different types of fiberglass for different number of layers without air gap, thickness= 4 cm

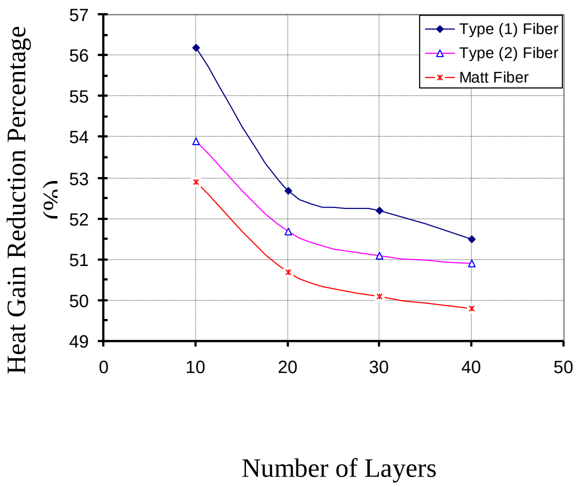


Figure (11) Heat gain reduction for different types of fiberglass for different number of layers with 2cm air gap, thickness= 4 cm

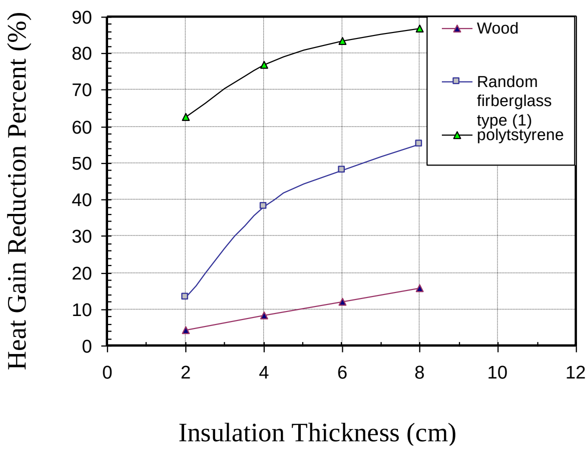


Figure (12) comparison between two types of thermal insulation with composite insulation having Random fiberglass type (1).

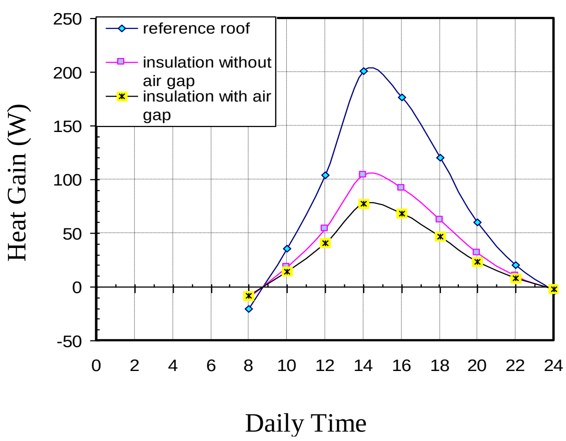


Figure (13) Relation between heat gain and daily time for 6cm thickness insulation for Random fiberglass type (1).

Figs (14,15, and16) shows a comparison between experimental and theoretical results of thermal conductivity varying with volume fraction .For three types of composite insulation, it is clear that the thermal conductivity increases with increasing of volume fraction due to increasing the volume of fiberglass in composite sample which has higher thermal conductivity than polyester resin.

Figs. (17, 18, and 19) represent the relation between temperature reduction percent for the upper roof surface and local day time for 4cm thickness with (10, 20, and 30) layers of each type of fiberglass. Temperature reduction percent is calculated from equation:

$$T\% = \frac{T_a - T_b}{Ta} \tag{20}$$

Where : T_a :- Temperature of roof without insulation (reference model)

T_b :- temperature of roof covered with insulation (test model).

Figures show that random fiberglass type (1) is better than the other types, this due to its low volume fraction. Figs. (20, 21, and 22) shows temperature reduction percent for the lower roof surface for the same variable mentioned above. Random fiberglass type (1) is dominant in temperature reduction especially at peak time of solar radiation (12A.M to 2 P.M.) in comparing with the other two types of fiberglass. Figs. (23, 24, and 25) represent the temperature reduction percent with local day time for the upper roof surface with and without air gap. The thickness of composite insulation is 4cm and containing (10 layers) of fiberglass. It can be shown that the arrangement applied with air gap has more temperature reduction than the arrangement without air gap. This is because of low thermal conductivity of air which plays a vital role for extra insulation roof. Air gap increase the thermal resistance of the roof, therefore the insulation efficiency is improved.

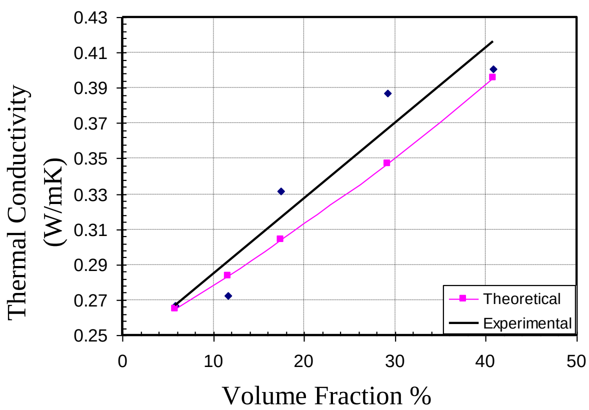


Figure (14) Comparison between theoretical and experimental results of thermal conductivity, Random fiberglass type (1).

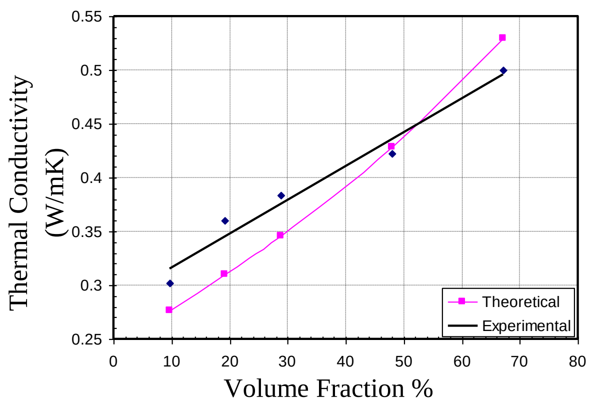


Figure (15) Comparison between theoretical and experimental results of thermal conductivity, Random fiberglass type (2).

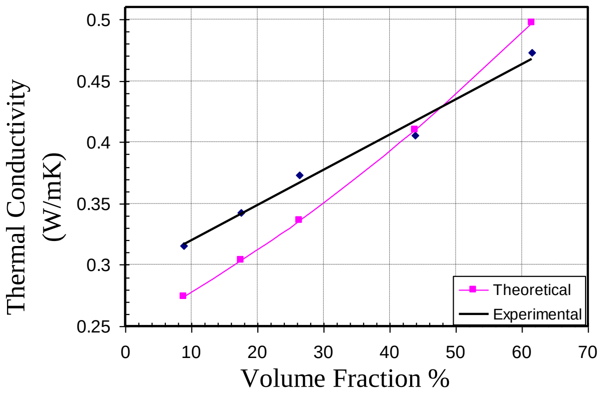


Figure (16) Comparison between theoretical and experimental results of thermal conductivity, Matt fiberglass

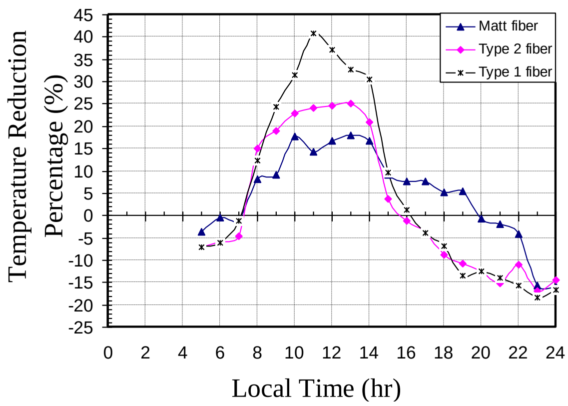


Figure (17) Temperature reduction for the upper side of roof with 4cm thickness insulation, without air gap (10 layers).

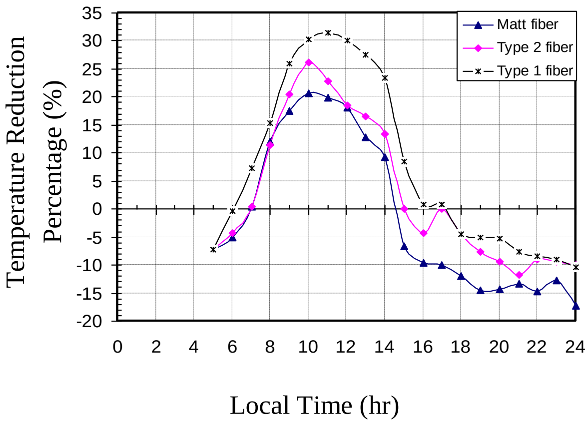


Figure (18) Temperature reduction for the upper side of roof with 4cm thickness insulation, without air gap (20 layers).

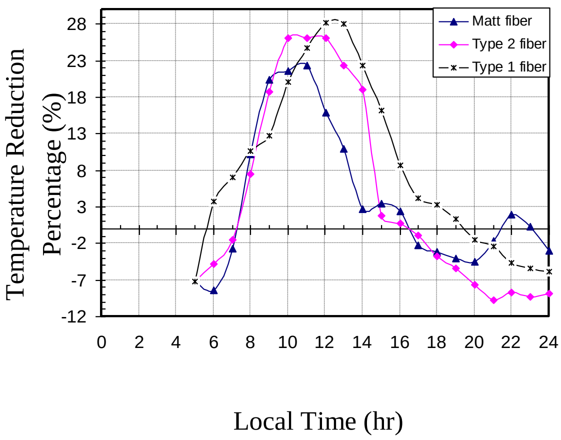


Figure (19) Temperature reduction for the upper side of roof with 4cm thickness insulation, without air gap

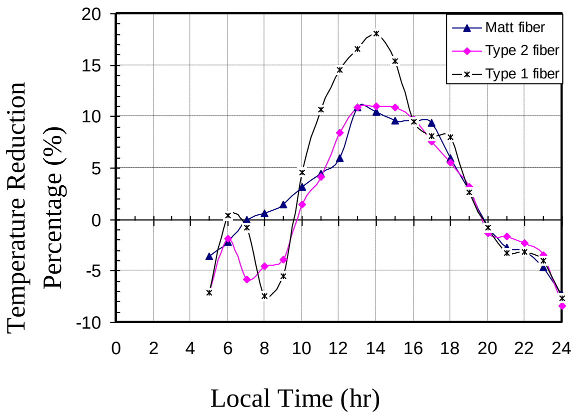


Figure (20) Temperature reduction for the lower side of roof with 4cm thickness insulation without air gap, (10 layers).

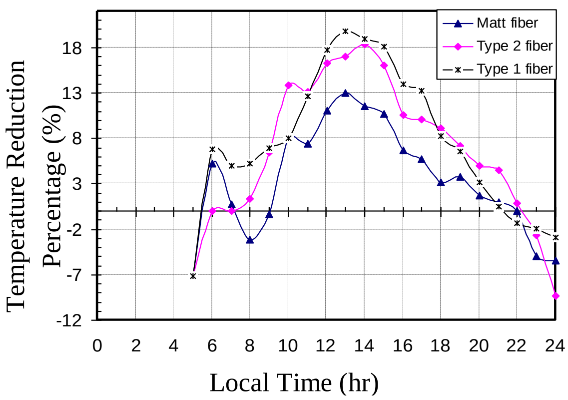


Figure (21) Temperature reduction for the lower side of roof with 4cm thickness insulation without air gap, (20 layers).

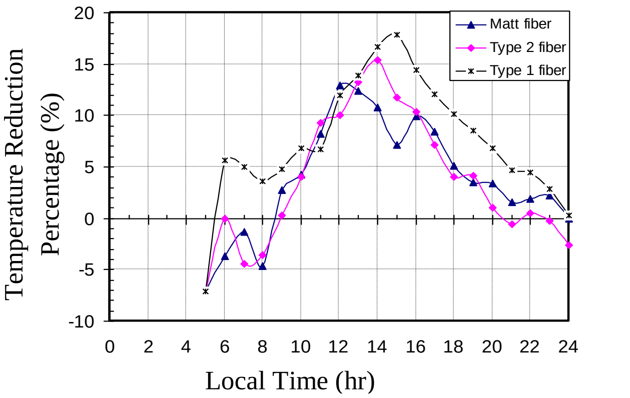


Figure (22) Temperature reduction for the lower side of roof with 4cm thickness insulation without air gap, (30 layers).

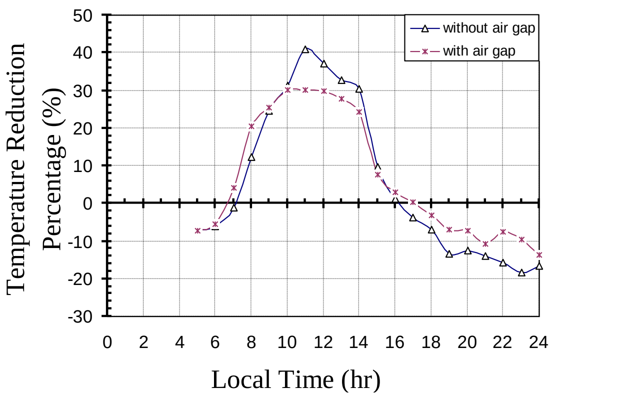


Figure (23) Temperature reduction comparison between insulation with (2cm) air gap and without air gap for roof upper surface, 4cm thickness, Random fiberglass type(1) (10 layers).

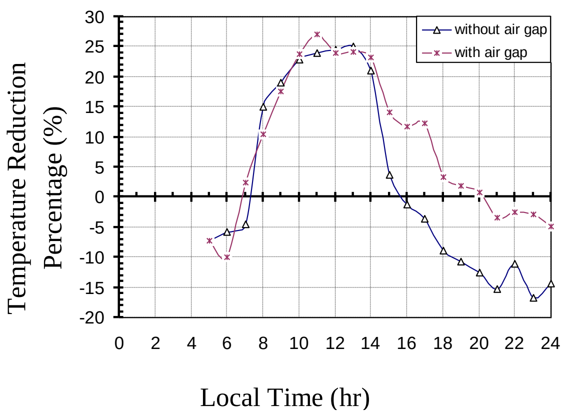


Figure (24) Temperature reduction comparison between insulation with (2cm) air gap and without air gap for roof upper surface, 4cm thickness, Random fiberglass type(2) (10 layers).

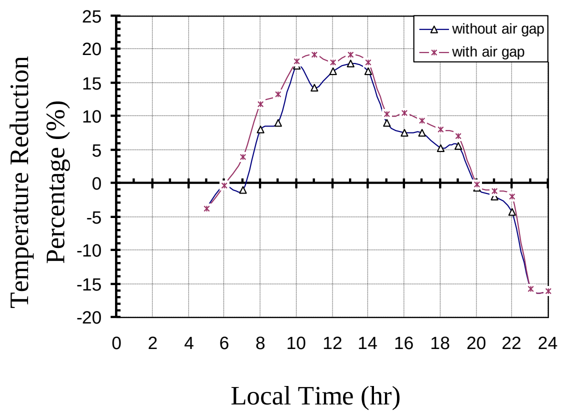


Figure (25) Temperature reduction comparison between insulation with (2cm) air gap and without air gap for roof upper surface, 4cm thickness, matt fiberglass (10 layers).

Figure (26) shows temperature reduction percent with local day time for the upper roof surface for Random fiberglass type (1) insulation without air gap. Thus, the effect of thermal insulation thickness can be studied. It can be seen that for the first three thicknesses (2cm), (4cm) and (6cm), the temperature reduction increases with the thickness however, when the thickness increases above (6cm), it clear in (8cm) thickness case, it shows a different result, where the temperature reduction begin to decrease. Also from figures (27) and (28) which give the same results for insulation but for Random fiberglass type (2) and Matt fiberglass respectively, it is so clear that the (8cm) thickness shows different and unconditioned response in temperature reduction. This is especially in early day time where it acts in reverse by keeping the roof temperature higher than that of the air temperature, increasing the negative amount of temperature reduction. Figure (29) shows the effect of thickness of Random fiberglass type (1) insulation on roof lower surface. As before, the (8cm) thickness case shows alternative response in temperature reduction in comparison with other cases. It can be concluded that increasing insulation thickness is an effective parameter in increasing temperature reduction for roof, but it has limitation. As it can be seen that the (6cm) represent the critical value which is the best thickness of insulation in present work and for all types of fiberglass. Any thickness larger than that will acts reversely by trapping heat preventing the roof from losing heat to air when the air temperature is lower than roof temperature.

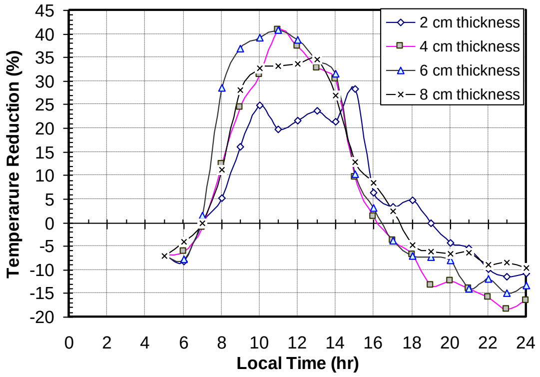


Figure (26) Effect of insulation thickness in temperature reduction on roof upper surface for Random fiberglass type (1), without air gap.

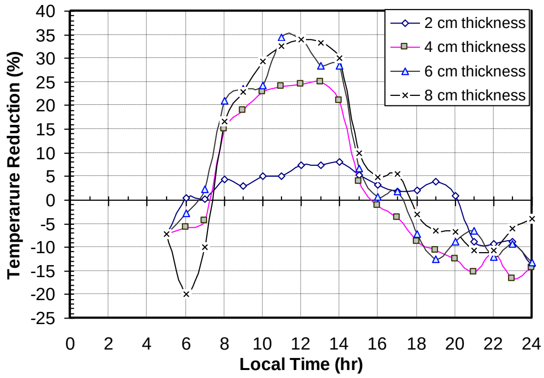


Figure (27) Effect of insulation thickness in temperature reduction on roof upper surface for Random fiberglass type (2), without air gap.

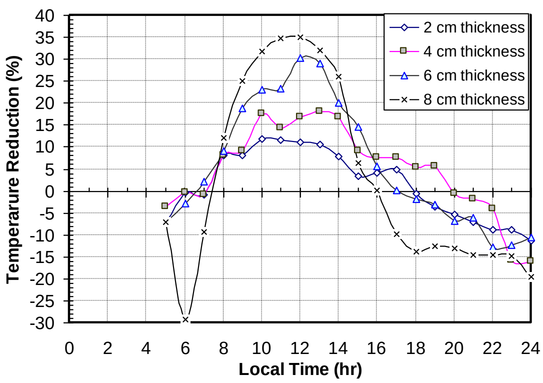


Figure (28) Effect of insulation thickness in temperature reduction on roof upper surface for matt fiberglass, without air gap.

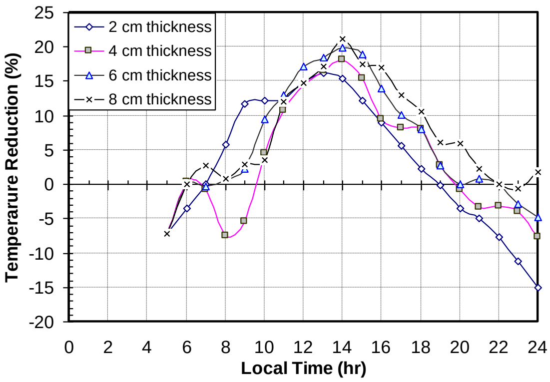


Figure (29) Effect of insulation thickness in temperature reduction on roof lower surface for Random fiberglass type (1), without air gap.

Conclusion

Many conclusions can be drawn from the present work which can be summarized as follows:

1. The results show that the three types of composite materials consisting of polyester resin and three types of fiberglass; Random fiberglass type (1), Random fiberglass type (2) and Matt fiberglass are all effective for roofs thermal insulation. The advantages of this insulation are easy to perform, and have a high stiffness, fire & water resistance, and which are available in Iraq.
2. Lee's Disc approach which utilized to determine the thermal conductivity of the composite materials insulation. This method is proved to be accurate, easy to perform, and not expensive.
3. The results show that thermal conductivity of the insulation increases with the increase of the volume fraction (which represents the volume of fiberglass in insulation layer).
4. The first type of composite material insulation (Random Fiberglass type (1)) has the optimum value of heat gain reduction in the model. It has (38.1%) heat gain reduction when compared with the other two types. These give, (34.1%) heat gain reduction for random fiberglass type (2) and (32.7%) for matt fiberglass.
5. Using air gap with (2cm) thickness between the model roof and composite insulation will enhance the insulation efficiency for all types of fiberglass. It will also increase heat gain reduction through the roof for Random type (1) from (38.1%) to (56.2 %) and for Random fiberglass type (2) from (34.1%) to (53.9%) and for Matt fiberglass from (32.7%) to (52.9%).
6. Experimental results show the optimum thickness of the first type of thermal insulation (random fiber glass type (1)) is (6cm). This represents the critical thickness for insulation type.

References

1. ASHRAE fundamentals, -a, "Thermal and Moisture Control in Insulated Assemblies" Atlanta, New York. 1997.

2. Cummings, J.B. "Evaluation of Temperature and Energy Impacts of Insulating Coatings Corporation Astec # 100 White Roof Systems", Insulating Coatings Corporation, 1991.

3. Ron D. MacDonald, Mark Armstrong; "Reducing Solar Heat Gain with Ceramic Coatings" University of Guelph, Guelph, , Canada, 2001.

4. Philip Fairy "Radiant Energy Transfer and Radiant Barrier Systems in Buildings" University of Florida 2003.

5. Karen Liu, Bas, B., " Thermal Performance of Green Roofs through Field Evaluation" the First North American Green Roof Infrastructure Conference, Chicago, IL, May 29-30, 2003.

6. Yucel K. T., C. Basyigit, C. Ozel; "Thermal Insulation Properties of Expanded Polystyrene as Construction and Insulating Materials", Suleyman Demirel University, Faculty of Architectural & Engineering, Isparta / Turkey, 2003.

7. John A., Camille G.; "Full-Building Radiation Shielding for Climate Control" University of St. Thomas, Minnesota, 2007.

8. Fujino J., T. Honda; " Experimental Investigation on the Thermal Conductivity Measurement of the Fly Ash Dispersed Plastic Composite Using Guarded Hot Plate Apparatus" Department of Mechanical Engineering, Fukuoka University, Nanakuma, Jonan-ku, Fukuoka, Japan, 2002.

9. ASHRAE fundamentals -b, "Solar Energy Use" New York. 1997.

10. John A. Duffie and William A. Beckman, "Solar Engineering of Thermal Processes" John Wiley & sons, Inc, 1980.

11. Peter J. Lunde; "Solar Thermal Engineering-Space Heating and Hot Water System" John Wiley & Sons, Inc. 1980.

12. Duncan M. Price, Mark Jarrat, "Thermal Conductivity of PTFE and PTFE Composites", Thermochimica Acta 392-393 (2002).

13. Iraq Meteorological Organization "Climatic ATLS of Iraq 2008".