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ASSESSMENT OF A SUSTAINABLE BUILDING USING ECO-FRIENDLY INSULATION MATERIALS

RAID AHMED MAHMOOD

Mechanical Department, College of Engineering, University of Zakho,Kurdistan Region, Iraq
School of Mechanical and Electrical Engineering, University of Southern Queensland, Australia
E-mail: raid.ahmed@uoz.edu.krd

Abstract - In air conditioning and refrigeration, insulation materials are essential in building insulation to achieve high performance and reduce energy consumption. However, nowadays, environment concerns have been increased as a result of using petrochemical insulation materials. The petrochemicals insulation materials have a direct effect on the environment as a result of using non-renewable materials, fossil energy consumption, and to the disposal stage. Eco-friendly insulation materials are the solution to decrease the environment concerns and build a sustainable building. Eco-friendly insulation materials have been used in this work to assess and compare its effectiveness in building insulations. Four eco-friendly insulation materials which excited by the nature were used in wall insulation. The overall heat transfer coefficient U was used to assess and compare the insulation efficiency. The basic wall configuration was used in comparison. The results revealed that the eco-friendly insulation material have effective insulation efficiency and can be used to reduce the energy loss through a walls by 50%.

Keywords - Eco-Friendly Insulations, Sustainable, Overall Heat Transfer Coefficient.

I. INTRODUCTION

The new vision for the safer future and cleaner environment is to build and create a sustainable building using eco-friendly insulation materials. The eco-friendly insulation materials are the ultimate friendly materials that can be used in building insulation to reduce the energy consumption and reduce the chemical emission as they have zero effect on the environment. However, reducing the energy consumption by using good insulation materials is a big challenge [1]. Therefore, much attention has been given to use the alternative insulation materials in building insulation. In the most of developed countries, buildings consume about 40% of energy and buildings are also taking the responsibly of 1/3 of greenhouse gas emissions [1]. In the last decade, the eco-friendly insulation materials were defined as materials that can be used to improve the building insulation and reduce the environment concern [2].

The eco-friendly insulation material can be recycled as it is manufactured from natural materials which do not have effects on environment [3]. Using eco-friendly isolation materials will play an important role to manage and reduce the energy demand which has been increased during the last decade. Some researchers investigated natural material to be used in thermal insulation. [4] investigated the use of wood fiber as a natural material in thermal insulation. The study assessed the wood fiber in terms of its suitability for thermal insulation, combustion resistance and thermal conductivity were considered in the study. [5] investigated the use of air gap in wall as an insulation and it effect on the temperature profile. The study revealed that the air gap is good insulator but it thickness should not exceed 4 cm. [6] investigate the use of olive seed, waste PVC, and wood chips to create an insulation materials. The results revealed that the lower unit weight and higher water absorption rate have been achieved by the samples with olive seed, waste PVC, and wood chips. [7] investigate the using of glass powder and oil palm to provide eco-friendly insulation material. The study reported that the thermal conductivity of the bricks can be reduced by using the oil palm and glass powder, so the new thermal conductivity of the prototype bricks was 0.39 W/m.K. The porosity values for developed bricks was in the range of 19 %–27 % as compared to the bulk density of (1628.02–1338.7) kg/m3. [8] considered and investigated the usage of cellulose fiber as an eco-friendly insulation material. The study reported that the cellulose fiber offers good thermal properties and has low embodied energy. [9] investigated the usage of sunflower stem in building insulation material. The physical and thermal properties were considered in the investigation. The results showed that the sunflower can be used in concrete to reach good thermal and physical properties, so the new thermal conductivity was 0.096 ± 0.003 W/m.K while the average compressive strength value at 60 days of 0.50 ± 0.1 MPa for the wall mixtures and 0.10 ± 0.01 MPa for the roof mixtures after an average 17 % strain. The existing studies show that there is a lack in the investigation and development of building insulation materials that should consider the coast, environment, and technology. This paper assesses and presents the ech-friendly insulation materials which are available in nature to reduce the dependence on non-eco-friendly insulation materials in building insulation, considering the coast, environment, and technology.

II. ECO-FRIENDLY INSULATION MATERIAL

Eco friendly insulation materials are the ultimate natural material that can be recycled and reused. Most

of the eco-friendly are available and easy to obtain such as Sunflower stem, Cotton stalks, Durian, Rice, and Sheep wool [10]. These natural materials have zero effect on the environment and human health during the building lifecycle. Therefore, a sustainable building can be easily generated by using the eco-friendly insulation materials in building insulation [11]. The eco-friendly insulation materials present an efficient thermal insulation and provide safer environment. There are many different types of eco-friendly insulation materials. However, some of these materials have been assessed and investigated in the current study.

2.1 Cotton stalks.

Cotton is a natural material and available in nature, it can be classified as eco-friendly insulation material [12]. During the last decade, the cotton was widespread and used as an insulation in commercial and domestic sectors. The thermal conductivity of the cotton is between 0.058 and 0.081 W/m.K.

2.2 Sheep wool.

Sheep wool is one of the effective eco-friendly material that has a low thermal conductivity. The thermal conductivity is about 0.035 w/m.K and its density is 31 kg/m^3. The wool fibers trap air and provide a thermal barrier. Sheep wool works well to regulate humidity [13]. It doesn't itch or doesn't burn easily, when exposed to heat or fire. The sheep wool also can help to absorb harmful substances in the atmosphere.

2.3 Rice straw.

Rice has been officially reported as a natural thermal material in 2013 to be used in building insulation. It can be used to manufacture panels to cover walls, roofs and partitions [14]. It does not have a disposal concern and/or toxicity. The rice has low thermal conductivity which is between 0.046 and 0.056 W/m.K and its density is about 154 kg/m3.

2.4 Durian

The Durian is one of the most tropical fruit that recently was used to make insulation materials using its fibers [15]. It is very popular fruit in Thailand and South East of Asia. The durian has low thermal conductivity which is about 0.064 W/m.K and its density is 428 kg/m3. Figure 1 shows the Durian plant (left) and fruit (right).

Figure 1 The Durian plant (left) and Durian fruit (right) ADDIN EN.CITE

III. HEAT TRANSFER AND THERMAL CONDUCTIVITY

Heat is an energy and it usually flows into or out of a building through a combination of conduction, convection, and radiation [16]. However, it is important to distinguish the component parts and define the units of flow such as thermal conductivity. In the conduction heat transfer mode, the thermal conductivity is a parameter that measures material's ability to conduct the heat and it is an important part to estimate the thermal resistance [17]. Each and every material has its own thermal conductivity which represents the material thermal property.

A thermal resistance is a parameter that can be drived from the thermal conductivity and thickness for the conduction heat transfer mode, as shown in equation 1 [18].

$$R = \frac{L}{k} \qquad (1)$$

Where the L is the wall thickness in (m) and k is the thermal conductivity in (W/m.K).

In order to obtain a good wall insulation and wall thermal design, Overall transmission coefficient (U) must be considered. The overall transmission coefficient is a parameter that meaures heat that passes through a wall in steady state, it expressed W/m2.K. The overall transmission coefficient can be calculated as the the inverse of the total thermal resistance (RT) of the wall, as shown in equation 2 [18].

$$U = \frac{1}{RT} \qquad (2)$$

For a multi layers wall as shown in Figure 1, electrical resistance technique can be used for the complex wall problems for both parallel and series layers arrangements. As can be seen from Figure 2 (b), the electrical resistance represents the multi a wall with layers. Using the definition of the conduction thermal resistance which is the ratio between the wall thickness and wall thermal conductivity, RA, RB, RC will be calculated. Then, U will be the inverse of RT, as shown in equation 3.

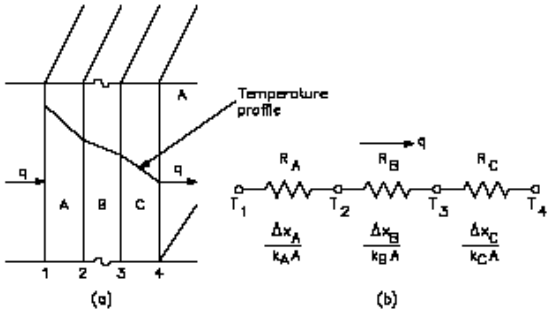

Fig. 2 Multi layers wall, (a) layers arrangement, (b) thermal resistance technique.

$$U = \frac{1}{\frac{\Delta Xa}{K_A} + \frac{\Delta Xb}{K_B} + \frac{\Delta Xc}{K_C}} \qquad (3)$$

Then, the heat that passes through the multi layers wall can be estimated from equation 4.

$$q = A\,U\,\Delta T \qquad (4)$$

Where the A is the surface area of the wall and ΔT is the temperature difference between the inside and outside wall sides.

IV. WALL STRUCTURE

In the building insulation, the structure of walls play an important role to achieve high performance of insulation performance, consequently; the energy consumption will be reduced.

In order to understand the difference between the insulated and non-insulated walls, this section presents an assessment of using eco-friendly insulation materials in a proposed wall and then compare the results with non-isolated wall.

4.1 proposed wall without insulation.

Usually, some building do not use insulation material in its wall, ceiling and partition. So it is usually consisted from three layers namely: the inner layer, the middle layer and the outer layer. In order to assess the eco-friendly insulation material a proposed wall used to estimate the overall transmission coefficient (U). So, three lyres were used inner (white gypsum), middle (bricks), and outer (cement) with thicknesses (5cm, 25cm, 5cm) respectively. The thermal conductivity of each layer was obtained in order (0.17 W/m.K, 0.7 W/m. K, 1.4 W/m. K). Table 1 presents the layers and its thickness and thermal conductivity.

Material	K (W/m.K)	Thickness
A	0.17	50 mm
B	0.7	250 mm
C	1.4	50 mm

Table 1 layers and its thickness and thermal conductivity.

Figure 3 presents the structure of the proposed wall without insulation.

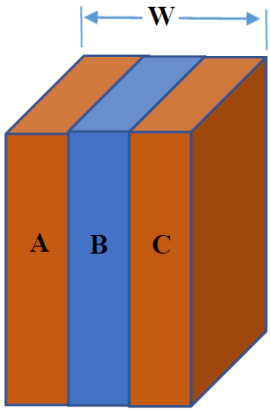

Fig. 3 Wall construction without insulation.

4.2 Proposed wall structure with insulation.

An eco-friendly insulation material was used in the proposed wall with insulation. The overall thickness of the proposed wall with insulation is same as that wall without insulation which is 35 cm. The configuration of proposed wall with insulation consists of five layers, the first layer is white gypsum, the second layer is bricks, the third layer is sheep's wool isolation, the fourth layer is bricks and the last layer is cement. The thicknesses of each layer is 5cm, 10cm, 5cm, 10cm, and 5cm, respectively. Thermal conductivities of the layers are 0.17 W/m.K, 0.7 W/m. K, 0.035 W/m. K, 0.7 W/m. K, and 1.4 W/m. K, respectively. Table 2 presents the thickness and thermal conductivity for each layer.

Material	K (W/m.K)	Thickness
A	0.17	50 mm
B	0.7	100 mm
IM	0.035	50 mm
B	0.7	100 mm
C	1.4	50 mm

Table 2 layers and its thickness and thermal conductivity.

Figure 4 presents the structure of the proposed wall with insulations.

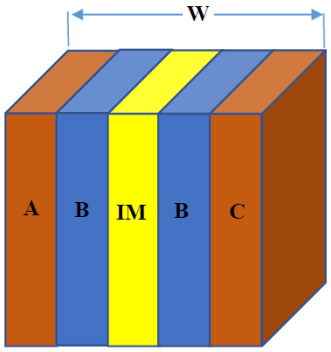

Fig. 4 Wall structure with insulation.

V. BOUNDARY CONDITION

Virtual boundary conditions have been designed and used to assess the proposed walls. The boundary conditions covered a range of the outdoor temperature from 30 ^{o}C to 50 ^{o}C , while the indoor temperature was designed at standard comfortable temperature which is around 25 ^{o}C [19]. The assessment considered the overall transmission coefficient U to present the effectiveness of the eco-friendly insulation materials. Therefore, lower value of U will give an effective insulated wall.

VI. RESULTS

Figure 5 presents the effect of thermal conductivity on the overall transmission coefficient (U). The figure shows that the overall all transmission coefficient is directly affected by thermal conductivity.Therefore, the eco-friendly insulation material with low value of thermal conductivity will provide an efficient value

of overall transmission coefficient. Indeed, to design good insulated building, insulation material with low thermal conductivity should be considered and used.

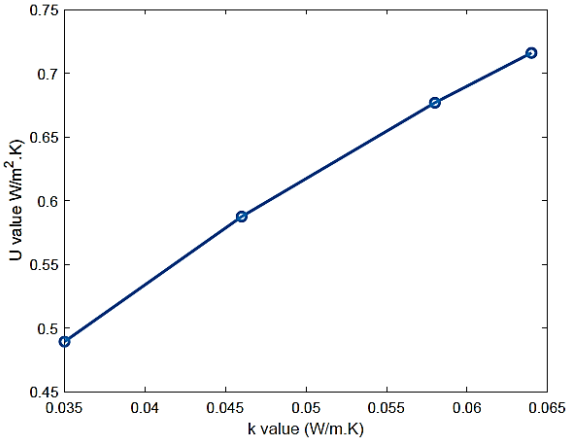

Fig. 5Effect of thermal conductivity on the overall transmission coefficient.

Figure 6 presents the comparison between the proposed wall without insulation and the proposed wall with insulation. Four eco-friendly were used to compare its insulation efficiency. As can be seen the proposed wall without insulation is affected with the outside temperature and there is a high value of heat loss when the outside temperature is over 40 ^{o}C. The figure 6 also presents the difference between the eco-friendly insulation materials and its performance at high outside temperature. The lowest heat loss was achieved by using sheep wool as insulation material. The sheep wool improved the insulation and reduced the heat loss that passes through the wall to about 50% at the high outsides temperature. While the rice straw reduced the heat loss that passes through the wall to about 36% at the high outside temperature. The cotton stalks reduced the heat loss to about 20% at the heist outside temperature. The durian gave the lowest value of the insulation improvement and the heat loss was reduced to about 12%.

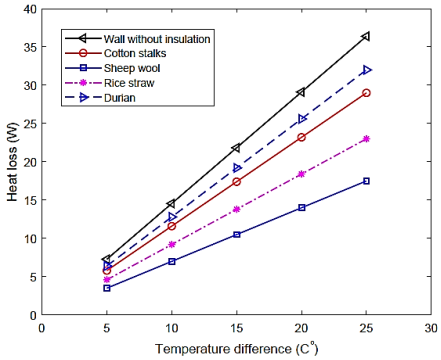

Fig. 6Comparison between the insulated wall and the wall without insulation.

VII. FUTURE VISION

For the future sustainable building and to provide a safer environment, the eco-friendly should be considered in building design and insulation. This study presents proposed eco-friendly insulation materials. The sheep wool achieved highest value of the energy reduction. However, the rice straw achieved accepted value of the insulation performance to reduce the heat loss. Therefore, these two insulation materials can be used to build effective insulation system.

VIII. CONCLUSION

Four of eco-friendly insulation materials have been assessed and considered in this study to investigate its performance to build a sustainable building. The conclusion can be listed as following,

1. The overall transmission coefficient was affected with the thermal conductivity, so the lower value of the thermal conductivity will provided a good high thermal resistance.
2. Sheep wool has achieved the highest percentage of the heat reduction compared with that wall without insulation at the high outside temperature range which is from 30 to 50 ^{o}C.
3. Rice straw can be used as an eco-friendly insulation material, it achieved an accepted percentage of the heat reduction compared with that wall without insulation.
4. Eco-friendly insulation material with low thermal conductivity can be used to build sustainable effective buildings.

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