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Article

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Evaluation of the Use of Lignocellusic Biomass in Thermal Insulation for Green Building

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Abstract. Preserving the temperature of the indoor environment within the acceptable limits during the cold weather using a minimal amount of energy consumption is an important factor in the modern housing systems and green buildings. Therefore, this study aims to provide eco-friendly insulation material (organic material). The utlised organic material in this study was Lignocellusic Biomass (it is also known as Poaceae common reed, and Phragmites australis) and straw. The insulation efficiency of this organic matter was evaluated via testing its performance under controlled conditions. The experimental work included three types of insulation, namely organic insulation (straw and reeds), industrial insulation material (fiberglass), and bricks (without insulation). The insulation level was monitored using an infrared camera. The thermal profile was created for each insulation scenario. The results showed that the efficiency of the organic insulation was similar to the fiberglass; only a 0.84% difference was noticed between the industrial and the organic insulation materials in terms of efficiency, which proves that the Lignocellusic Biomass is a potential eco-friendly alternative for the industrial insulation materials.

1. Introduction

Around the world, many countries have witnessed tremendous development and steadily in various fields, industrial, agricultural, commercial, and urban [1, 2]. Accompany this development a steady increase in the number of people, especially in the oil and trade countries. Many villages and cities have been paved to connect them with each other and to facilitate the transportation process between countries and cities [3-5]. Moreover, the cities and villages have expanded their borders significantly as a result of the steady increase in the number of population. Due to this development, the consumption of various types of goods to and from countries and continents, and it was natural for them to include many activities that directly affect the surrounding environment, and human health and safety [6-8]. In recent years, issues relating to environmental issues such as waste accumulation, water pollution [9-11], and global warming [12-14] are becoming a prominent part of modern life as a result of the overuse of non-sustainable materials [15-18]. For example, the weather temperature has dramatically increased around the world [19-21], water pollution dramatically increased [22-25], and water consumption has also increased to an alarming level [26-28]. Therefore, sustainable recycling processes became an urgent need to minimise the impact of modern life on both environment and public health. The sustainable cycles can only be attained if a greater proportion of renewable materials can be recycled or reused such as lignocellulosic materials. Various studies attempt to tackle these issues by applying novel approaches in different industrial sectors, such as in water treatment [29-31], wastewater treatment [32-36], waste management [37], and civil engineering [38-40].

One of the main concerns for the development of sustainable cities is the cement and concrete industry because the cement industry generates huge amounts of greenhouses gases [41-43], where it has been proved that the cement industry responsible for about 8% of the total amount of carbon dioxide in the atmosphere of the Earth planet [44, 45]. In addition, the concrete industry is depleting the natural resources in an alarming trend [46, 47].

Thus, the construction industry became a major concern for environmental engineers and organisations, and therefore; significant efforts were done to develop alternatives for the traditional construction materials (development of green buildings). Green buildings are an area of ongoing research, as this approach to design is believed to substantially reduce the negative effects of the construction industry on environmental emissions through the use of highly energy-efficient techniques [48]. Throughout the world, the massive development in the building industry leads to enlarging the levels of energy consumption as a result of inoccupation needs, especially in the housing sector. High energy consumption can cause many problems such as depleting the raw energy sources and environmental issues which result in the generation of huge quantities of greenhouse gases. Therefore, these problems arouse the research and the need to improve the efficiency of energy consumption of housing buildings across the globe. The use of sustainable materials and renewable energy is thus becoming a key factor in the future of building designs [48]. In this context, the thermal insulation of buildings plays a crucial role for decrease energy consumption. As well as provide a comfortable indoor environment. Keeping the residential buildings warming with acceptable limits of temperatures can be attained by using effective insulation materials. Engineers depended on many treatments that can use thermal insulation materials in built walls, floors, and roofs to prevent the excessive temperature in summer and loosen temperature in winter. In addition, use the sunshades, curtains, and aforestation for protection from excessive thermal radiation. Moreover, utilizing and renewable materials as insulators can support the sustainability concept. Use of materials that are non-toxic, ethical, and sustainable, lignocellulosic biomass is one of the oldest building materials that are employed to provide shelter and keep the human safe and away from the external risks. For instance, wood and straws are still utilized in many areas in the world. These materials can be easily combined with other types of building materials. Consideration of the environment in design, construction, and operation, therefore, study the potential methods of construction that include focusing on low-energy methods taking advantage of sustainable, natural materials. This will contribute to providing low-energy green buildings, primarily which can be applied to residential buildings. Using insulation in the building can enhance the energy efficacy of the existing or new structures. This could be considerably improved through the application of appropriate thermal insulations [1].

This work aimed to investigate a sustainable construction method by a simulation cavity wall together with a renewable insulating component using organic materials such as lignocellulosic biomass and specifically straw that compacted by a simple reed in the process of insolation.

2. Material and methods

2.1 Experimental procedure

In this research, the primary material used for insulation is straw, which is mostly used as bale-shaped insulation, but this technique consumes a wide amount of floor space. The goal of this study is therefore to create efficient use of insulating materials enabling a reduced land consumption factor. The straw

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was spread in a compact layer for the study, supported by means of a basic reed frame. On the one side of the cavity wall was an electronic heat source applied (side:A), the temperatures of the other side of the cavity wall (side:B) have been monitored using an infrared camera. Different cavity wall systems, such as the rat-trap bricks bonds have been shown to minimize the consumption of material when used in building construction. The combination of a similar cavity wall structure with a low-impact, renewable material of insulation can preserve precious natural resources to improve future building projects' overall energy efficiency. It should be noted that the above approach is rather simplistic; considerations such as the exact density of the material and the quality of the moisture are not taken into account. This research technique is only in order to demonstrate the feasibility of using recycled insulation materials for potential building projects. The adopted technique to test the efficiency of straw and reed as thermal insulation materials was a simplistic approach. As discussed previously, uses of cavity walls have the capability to insert the insulation material inside them (such as the Rat-Trap Bond) [49]. In this procedure, a simulation part of the cavity wall was employed. The traditional clay bricks and cement mortar was used to build the cavity wall, which can be observed in the left part of Figure 1.

Figure 1. The simulations of the cavity wall section including the combination of the organic materials.

The organic insulation parts included compacting straw in a sheet, around 40 mm thick, reinforced back by reeds which serve as vertical supporters. To facilitate the construction and transportation of the specimens, the straw layer was covered by a thin layer of cardboard (which had a negligible impact on thermal performance) as can be seen in the right part of Figure 1. The changes in temperature were observed over time using a thermal imaging camera after providing an electronic heat source. This source of heat was mounted behind the cavity wall facing the brick portion. The test with no insulation was completed at the beginning to provide a basis for testing the effect of the insulation once used. By the same token, the standard fiberglass insulation layer was provided and then utilised in the cavity wall and then examined to identify the effectiveness of this type of insulation. The measurement of temperature degrees was carried out at the same location on the walls (marked on the wall), which was straightly located in line with the heating source. This procedure for the measurement of the temperatures at the same location minimized the temperature difference due to external influence in the laboratory during the performance of the experiments. Moreover, the section of the simulation cavity wall was supplied by a thermocouple placed on both sides of the cavity wall for accurate measurement of the temperature difference between the two sides of the cavity wall. Figure 2 offers visual assistance in the arrangement of the thermocouples positions (A, and B) in relation to the source of heat. A was in direct contact with the source of the heat side; meanwhile, B was on the opposite side.

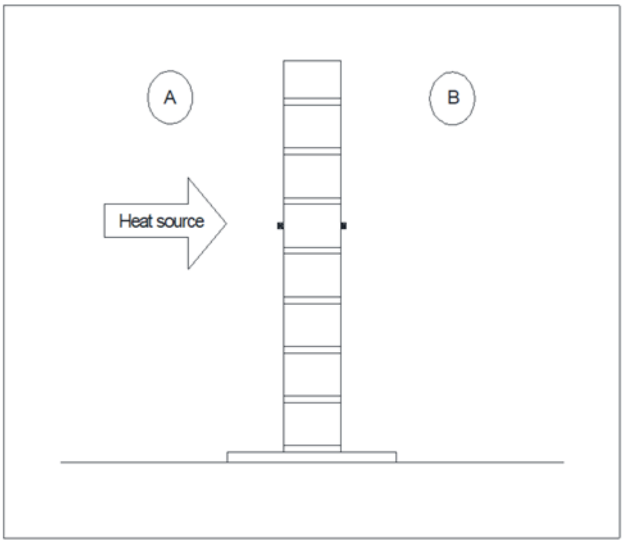

Figure 2. Simulation of the cavity wall section.

2.2 Data collection

There were three tests conducted, one for each insulation type: organic, fiberglass, and without insulation. The temperature was settling at the baseline (the baseline reading of approximately 19 °C) and to ensure the consistency of the findings, each type of individual insulation was examined three times. Negligible differences were noticed among the recorded final temperatures, thus; the margin of errors was acceptable. The initial surface wall temperature record was roughly similar to the ambient room temperature (19˚C). The electric heat source was set to maximum temperature and placed at 300 mm behind the cavity wall. 1000 mm in front of the front face of the wall, the thermal imaging camera was placed. The thermocouples were installed on each side of the wall, enabling measurement of the difference in temperature between the two wall faces to ensure the accuracy and validity of the collected data. Once ready to start the procedure, trigger the heat source simultaneously start timing the procedure. The temperature readings were recorded by the infrared camera (readings are transmitted to the laptop using relevant software). The final surface temperature record was carried out after 25 minutes from the initial record.

3. Results and Discussion

The following findings were obtained from an infrared camera; the wall's surface temperature was tracked during the experiment's duration. The wall's surface temperature was observed and reported after 25 minutes. For each insulation scenario, a thermal profile has been developed, the unique key given with each thermal profile allows an understanding of the estimated temperature across the wall portion. Figure 3 shows the recorded temperature changes for each insulation scenario. First, as can be seen in Figure 3a that illustrates the thermal profile of the detected surface temperature after passing 25 minutes when there was no insulation case. The findings showed that the highest temperature which was founded on the wall section equal to 21.4˚C, meanwhile the lowest temperature was 19.8˚C. Second, when organic or 'green' insulation was applied, Figure 3 b shows the thermal profile of the measured temperature on the wall surface after 25 minutes. The highest recorded temperature on the wall section was 20.5˚C compared to the lowest recorded temperature was 18.6 ˚C. Lastly, Figure 3c depicts the thermal profile of the measured surface temperature of the wall section after 25 minutes during industrial (fiberglass) insulation. The highest and lowest recorded temperatures were 20.3˚C, and 18.9 ºC, respectively. As an interpretation of the aforementioned results, it is probable that no insulation case will easily pass the heat through the cavity wall section causing the highest temperature readings. This means that the best of all three test scenarios is both the maximum measured temperature and the lowest observed temperatures. The use of no isolation for the first test provided a foundation for testing the other two insulation materials. It has been found that fiberglass insulation has the lowest temperature reading of the wall surface (20.3˚C), to the degree predicted; it seems fair that a homogeneous industry criterion should have the higher performance under the test conditions. Therefore, fiberglass can be considered as the most effective insulation in terms of thermal insulation quality. Also, the organic materials showed a high insulation performance, which makes them have the potential for future application, as the highest measured temperature for the fiberglass was 20.5 ºC, this is just 0.2 ºC higher than the maximum detected temperature.

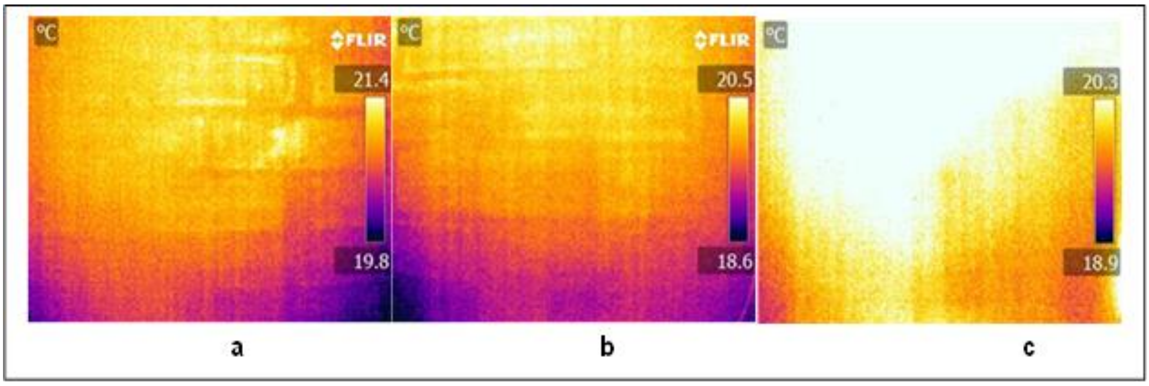

Figure 3. Thermal profile of the three insulation scenarios

Reviewing Figure 4, it can be found that the difference of temperature between both sides of the cavity wall faces A and B was the lowest of all insolation scenarios when no insulation was used (65.51˚C). This result was anticipated and indicates that more heat was transmitted through the system than was the case when using insolation materials. In the case of adding fiberglass insulation to the wall, the detected temperature change between the wall sides was 83.63 °C, this was the highest temperature difference observed; demonstrating that the fiberglass stops most heat loss through the structure of the wall. By the same token, the addition of the organic insulation to the wall showed a temperature difference of 79.54 ºC between both sides of the wall. Compared to the base case which is not included an insulator material, using the organic combination material can lead to a valuable improvement in the thermal insulation properties of the wall structure. It is interesting to note that differences between the detected temperatures difference approximately near to that one which can be seen when industry-standard fiberglass was employed.

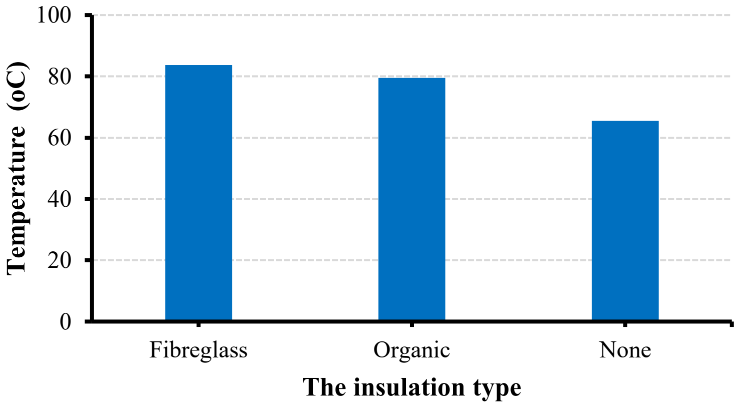

Figure 4. Thermocouple temperature differences

In terms of insulation quality, the observed temperature readings obtained from the thermocouples are given in Figure 5. The same general pattern as indicated in Figure. 4 The quality similarity of fiberglass and organic insulation can be observed, however, it is helpful to identify. In terms of percentage efficiency, only a 0.84% difference was detected between the two insolation materials. Both materials greatly improved the structure's insulation performance, shown by the lower efficiency shown when no isolation was used.

A review of the obtained readings revealed that the insulation of fiberglass was the active thermal insulation to be applied in the structure of the cavity wall. These findings were expected because the high criteria of the manufacturing process of the fiberglass insulation that is attained during this process as a thermal insulator are already in wide-scale use. The insulation of organic material was of a very simple and cheap nature, but in terms of thermal insulation, it was comparable with the alternatives of the industry standards. This result was highly promising as it indicates a major potential for the future widespread use of green insulation materials. First, it was shown that the green materials (breeds) used for organic insulation are good thermal insulators. As discussed above, straw bales are not uncommon to be applied as a green alternative insulation matter. Nevertheless, they are inefficient in terms of area and land use. Applying a composite material using straw and reeds insulation as proposed in this paper suggests a solution to make traditional green insulating materials more effective because they show strong insulating properties. Thus, the laboratory work makes suggestions for an energy-efficient building system where composite green insulation materials are employed in combination with cavity walls. International building code (IBC) stated that maintaining a minimum indoor temperature of 20°C

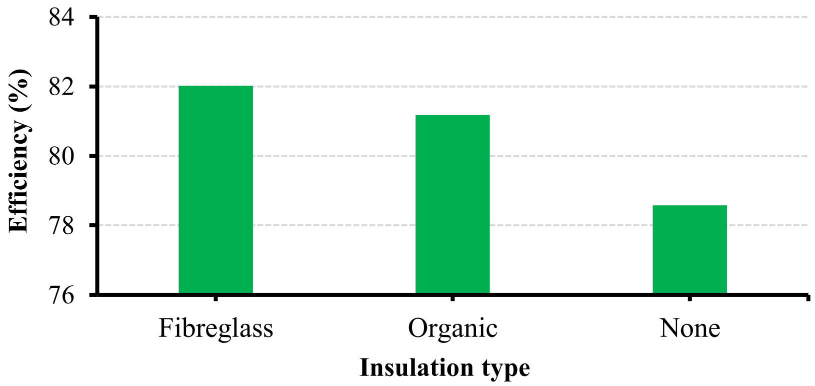

Figure 5. Insulation efficiency.

for the interior spaces that intended for human occupancy. This temperature shall be provided with active or passive space-heating systems.

4. Conclusion

The successful implementation of a number of green building strategies was done utilising the combination of straw and read as an organic insulation material with cavity wall structures in the manner as a rat-trap brick on the cavity wall. The obtained data from the experiments showed that the organic insulation has promising findings as a thermal insulator compared to the industrial insulator (fiberglass). These findings allow for the potential usage of these organic materials as a renewable material that supports the intention of moving to a green building. However, further studies are required to apply in a wide range of possible building approaches to make it applicable and scale-up in the green building industry and healthy residential environment.

For further researches, sensing systems could be used to monitor and/or control the thermal efficiency and development of temperature inside the insulation layers.

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