

Research Article

The Integration of Natural Fiber in Radiant Barrier Foil for Roof Thermal Insulation

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Abstract: The installation of radiant barrier foil on roof is a common practice to minimize heat transfer in building envelope, especially when heat wave occurs. As the heat wave becomes more intense these days, modification on the existing radiant barrier foil is needed in order to make significant changes in temperature difference so that it will still be relevant to use. The modification includes the additional layer of coconut fiber that is sandwiched between two sheets of regular radiant barrier. Apart from that, the modification also includes sheet of felted human hair as the additional layer that is sandwiched between two sheets of regular radiant barrier. This study emphasizes on investigation regarding the viability of using coconut fiber and felted human hair as thermal insulation for roof. A temperature difference measurement was conducted through the implementation of USB temperature data logger to determine the capability of the modified radiant barrier to minimize heat transfer. From this study, it was found that the integration of coconut fiber and felted human hair in the middle, increases the capability to reduce heat when used as insulating element in comparison with the regular radiant barrier foil and the control set, as depicted by the significant indoor temperature drop in comparison with the outdoor temperature.

Keywords: radiant barrier; heat transfer; coconut fiber; human hair; felt; thermal insulation.



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1. INTRODUCTION

In tropical climate countries such as in Malaysia, it is mandatory to keep the indoor conditions to be thermally comfortable to maintain the productivity of occupants (Zain & Ahmed, 2008). Therefore, most buildings in Malaysia utilize mechanical cooling systems which leads to high electricity consumption. In general, buildings consume about one-third of the world's energy (Klee 2007). To minimize this dependency, building insulation is often being implemented to improve energy efficiency. For instance, the utilization of radiant barrier foil on roof is proven to reduce indoor temperature which promotes thermal comfort to the occupants (Allen 2008).

Thermal insulation is the process of reduction of heat transfer between objects in thermal contact or in range of radiative influence. Examples of applications of thermal insulations involve clothing, buildings, mechanical systems, refrigeration, spacecraft, automotive etc. Common thermal insulators are wool, fiberglass, rock wool, polystyrene, polyurethane, and goose feather etc. These materials are very poor conductors of heat and are therefore good thermal insulators. (Rodriguez et al. 2011).

The focus of this project would be related to renewable fibrous thermal insulation such as coconut fiber because of the ability to regenerate itself and biodegrade easily when disposed. The justification of the materials selection for this project is derived from consideration of certain factors such as cost and availability of resource. In Malaysia, coconut plants exist abundantly, and its physical, chemical or mechanical properties have been studied extensively which provides concrete database that can cater for promising applications. A study conducted by Manohar et al. in 2006 regarding the potential of naturally occurring biodegradable fibers such as coconut fiber and sugarcane fiber to be used as building thermal insulation. It was found that Coconut fiber and sugarcane fiber have acceptable apparent thermal conductivity values for use as building thermal insulation. Other potential examples of sustainable material for thermal insulation are the human hair. The primary function of human hair is to insulate human bodies.

The existing radiant barrier foil that is usually being installed on roof is designed and constructed by incorporating double sided high reflectivity aluminium films bonded with a layer of 10 mm polyethylene bubble sheet which provides insulation against radiant heat transfer since it is an excellent heat reflector. However, there are certain limitation on the extent of the heat penetration that can be prevented with those layering, in which the insulating effect may not be effective anymore and will result in heat transfer occur at an undesirable rate. In this project, investigation will be carried out to solve the issue regarding the limitation of the existing radiant barrier foil to extend its insulating capability by incorporating coconut fiber and felted human hair in between the radiant barrier.

2. METHOD & MATERIAL

2.1 Construction of A Prototype House

A prototype house with dimensions 100 m (l) x 100 m (w) x 133.5 m (h) was constructed to mimic building envelope in order to test the effectiveness of the modified radiant barrier foil.

2.2 Felting Human Hair

Human hair was collected from local barber shop in Perak. The hair was soaked to remove impurities. The wet hair was then mixed with bar soap and felted manually to produce continuous sheet and dried under the sun.

2.3 Installation of Regular Radiant Barrier Foil and Modified Radiant Barrier Foil

In this project, the modified radiant foil barrier and regular radiant barrier foil are installed on the roof frame inside the prototype house one at a time.

2.4 Assessment of Thermal Insulating Effect Through the Measurement of Outdoor and Indoor Temperature Difference

The insulating effect of coconut fiber incorporated radiant barrier foil and felted hair incorporated radiant barrier foil was assessed through the measurement of outdoor and indoor temperature differences by using two units of Elitech USB Temperature data logger. One data logger

was placed inside the prototype house and another one was placed outside the prototype house for one hour. After one hour, the data will be collected and analyzed on a computer. To compare the effectiveness of the modification another two sets of condition were analyzed which includes the installation of two layers of regular radiant barrier foil and the other one is without any installation of radiant barrier foil that served as a control set.

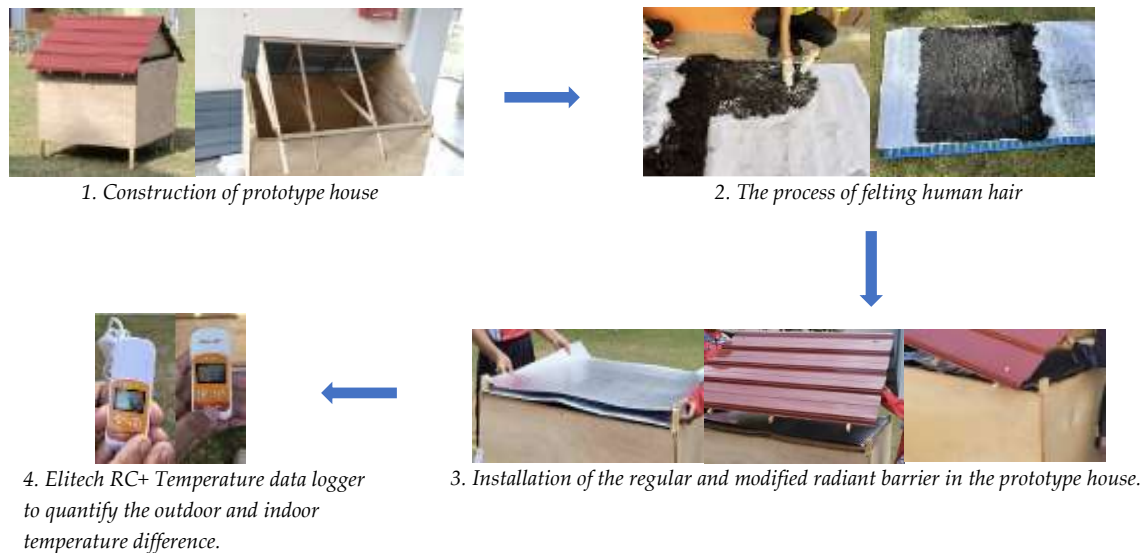


Figure 1. Summary of preparation and efficiency analysis of modified radiant barrier foil.

3. RESULTS

The efficiency of the modified radiant barrier in terms of thermal insulating capabilities was assessed by using USB temperature data logger. Data analysis was carried out through Elitech software.

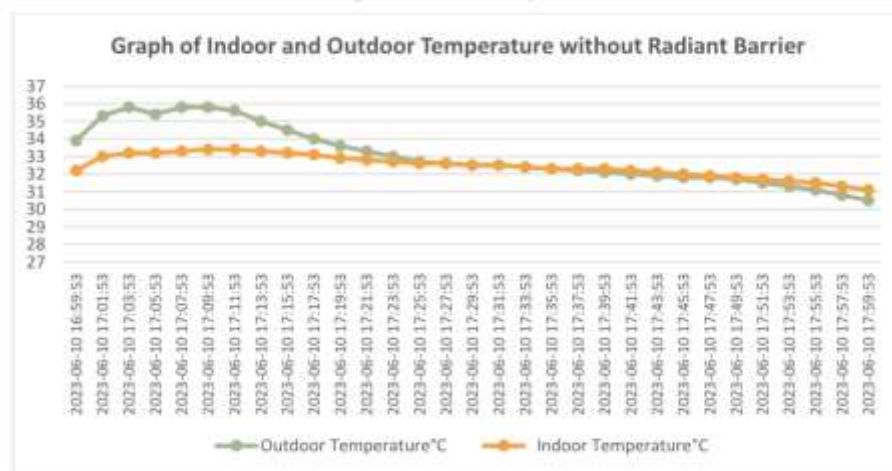


Figure 2. Graph of Indoor and Outdoor Temperature Without Radiant Barrier

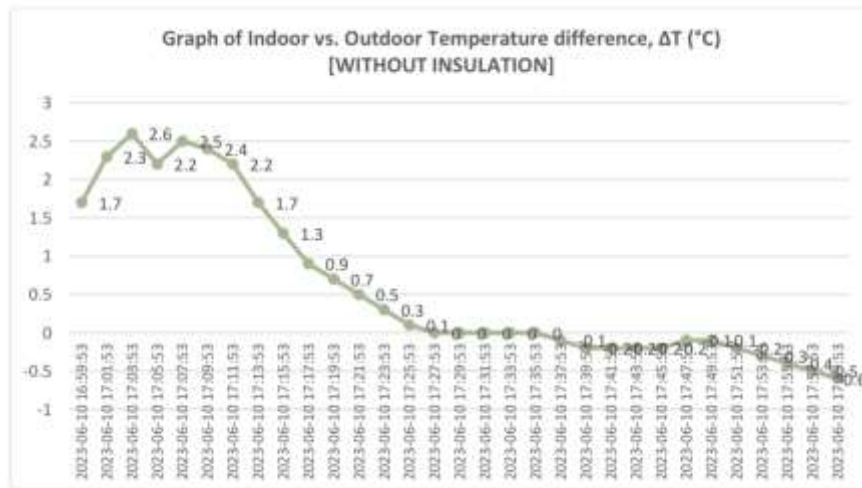


Figure 3. Graph of Indoor vs. Outdoor Temperature difference without Radiant Barrier

From the graph shown in Figure 2 and Figure 3, it can be seen that most of the time, the temperature of indoor and outdoor do not vary significantly since the rooftop is not being insulated.

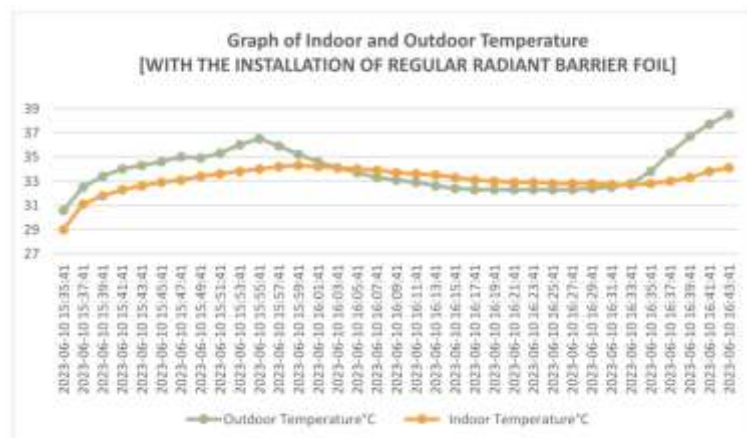


Figure 4. Graph of Indoor and Outdoor Temperature with the installation of regular Radiant Barrier

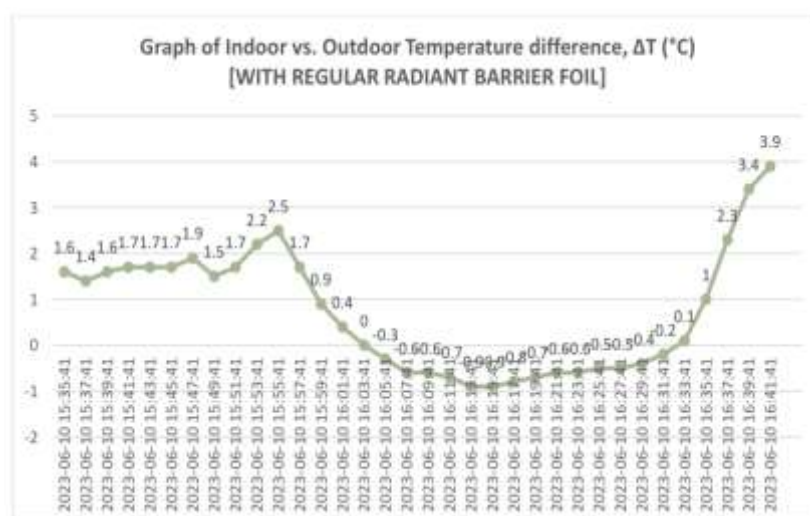


Figure 5. Graph of Indoor vs. Outdoor Temperature difference with the installation of regular Radiant Barrier

Figure 4 and Figure 5 show that the indoor and outdoor temperature readings are fairly significant especially in 4.45 pm onwards since it is very hot at that time and the efficiency of radiant barrier foil in reflecting the heat is prominent.

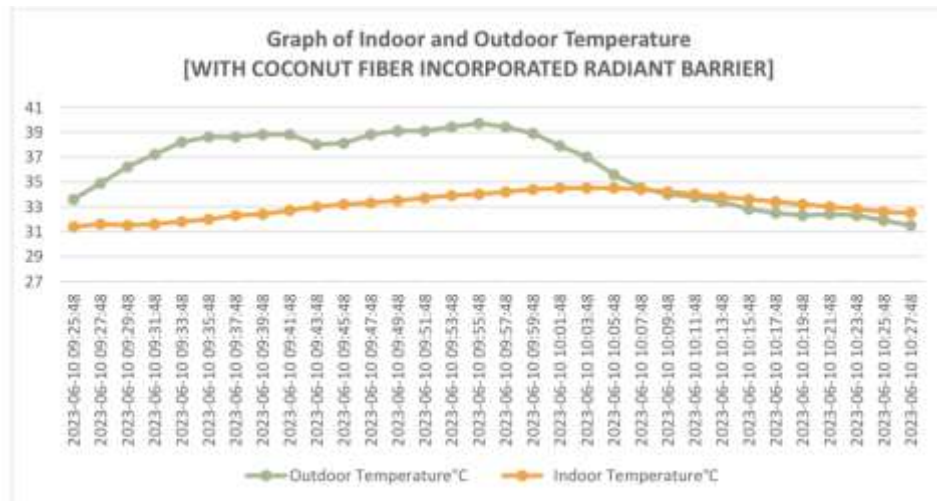


Figure 6. Graph of Indoor and Outdoor Temperature with the installation of Coconut Fiber incorporated Radiant Barrier

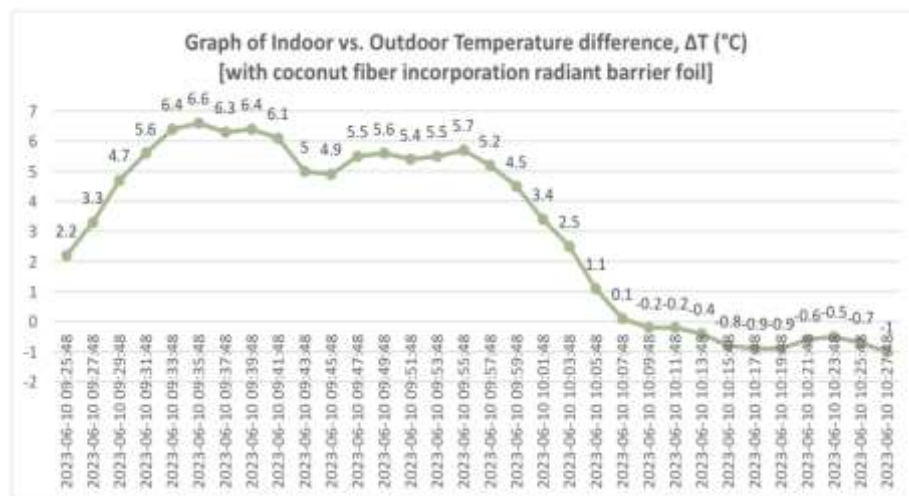


Figure 7. Graph of Indoor vs. Outdoor Temperature difference with the installation of Coconut Fiber incorporated Radiant Barrier

Based on Figure 6 and Figure 7, the difference in temperature for indoor and outdoor is the most prominent when coconut fiber incorporated radiant fiber is installed. Some of the readings in those graphs show negative temperature difference reading which indicated that the indoor temperature is more than the outdoor temperature. This is because during that range of time, the weather is cloudy while inside the prototype house still contains the trapped heat which caused the increase in temperature since there are no windows.

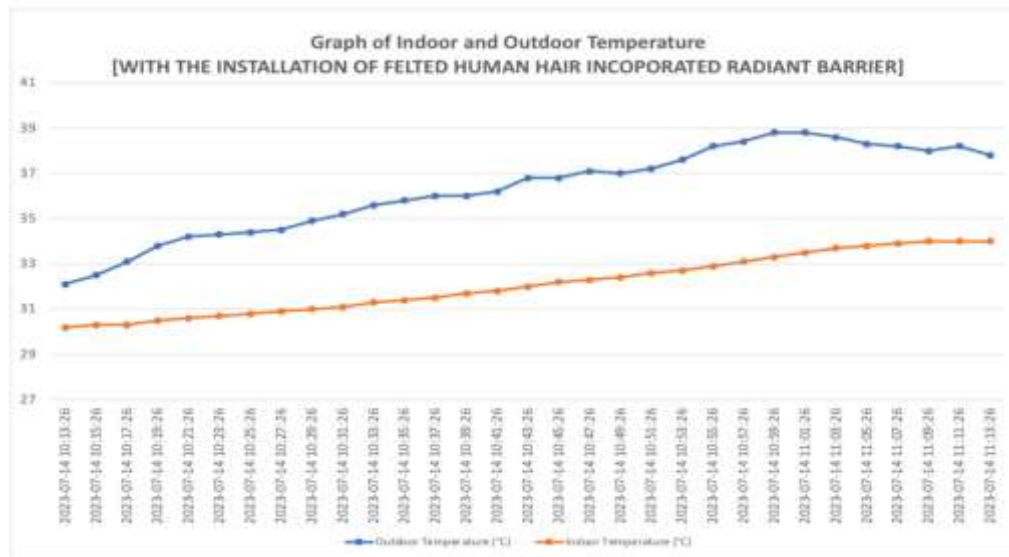


Figure 8. Graph of Indoor and Outdoor Temperature with the installation of Felted Human Hair incorporated Radiant Barrier

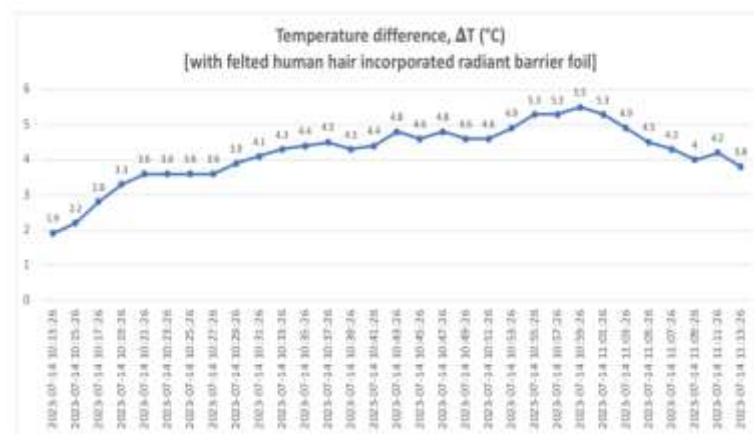


Figure 9. Graph of Indoor vs. Outdoor Temperature difference with the installation of Felted Human Hair incorporated Radiant Barrier

Based on Figure 8 and Figure 9, it can be seen that there is a significant difference in temperature of indoor and outdoor when felted hair incorporated radiant fiber is installed. During the one-hour duration, the incorporation of felted hair in the middle layer of the regular radiant barrier reduces the heat transfer from surrounding.

Based on the comparison of maximum temperature difference value for different materials as shown in Table 1, it is apparent that the incorporation of coconut fiber in radiant barrier foil have the highest difference in temperature for outdoor and indoor, followed by the incorporation of felted human hair in radiant barrier foil, as compared to the uninsulated control set and regular radiant barrier foil. This implies that the modified radiant barrier foil is more effective to minimize heat transfer rate.

Table 1. Data tabulation for maximum temperature difference for different insulating materials.

Insulating material	Maximum Temperature difference (°C)
Regular radiant barrier foil	3.9
Coconut fiber + regular radiant barrier foil	6.6
Felted human hair + regular radiant barrier foil	5.5

4. CONCLUSION

In conclusion, the incorporation of coconut fiber and felted human hair in the middle layer of the existing radiant barrier foil is effective in minimizing heat transfer from the roof as depicted by the significant indoor temperature drop in comparison with the outdoor temperature. Although the integration of felted human hair shows slightly lower temperature difference when compared to the coconut fiber, the temperature readings shows more consistency as depicted from the graph of temperature difference.

For the purpose of future investigation, other possible natural fiber or agricultural waste such as *Imperata cylindrica* sp. (alang grass), kapok fiber etc. or even waste material such as used clothes can be used to explore their potential in terms of heat insulation. Other potential material that could be explored is felted animal fur and felted wool. Another way to extend this investigation is to use different types of prototype houses made from other materials to determine the applicability of the radiant barrier modification to other types of building materials. The duration of data collection can also be made longer, for example, in this project the temperature data was collected for one hour duration due to time constraints. When the duration of data collection is longer such as 24 hours/1 day, we can study the trend or pattern of the readings which may help in unveiling the prospects for radiant barrier modifications.

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