Investigate the Possibility of Fabricating a Banana Fiber Roof Thermal Insulation Material

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I. INTRODUCTION

With the economic development of society, demand for better living environment is increasing, which was caused by the increased consumption of energy [1]. The International Energy Agency report says that 32% of energy production in the world is consumed by buildings, mostly for heating or cooling system. Therefore, the need of installing passive insulation is increasing due to concern on the climate changes. The usage of thermal insulators in building roofs helps to decrease the heat loss or gain from the ambient climate [1]. Thermal insulation is the reduction of rate of heat transfer from one object to another by the influence of the specific method, shape, and materials. These insulation materials prevent the heat flow through conduction, convection, and radiation. The insulators are manufactured by using fiber glass, mineral wool fibers, expanded polystyrene (EPS), extruded polystyrene (XPS), etc. Its insulation capability is dependent on the thermal conductivity, density and thickness of the material used [1].

Due to the concern on environmental sustainability and healthy issues, researchers were started to concentrate on developing the insulation material using natural fiber. This research was concluded with finding superior thermal insulation property on cellulosic fiber material such as coconut coir, corn, sunflower stalk, straw, etc [1]. In the order of these natural insulation materials, banana fibers also show minimum thermal conductivity 0.0415 W/mK in 73.4 kg/m3 fiber density [2], [3]. Banana fibers have lower thermal conductivity and are within the required range 0.02W/mK to 0.06W/mK which is range of building thermal conductivity [2]. Banana cultivation is an important agricultural Sector in Sri Lanka. Approximately 50,000 hectares of agriculture land is used for banana cultivation and the yearly banana production in Sri Lanka is about 45,000 tones [4]. A significant amount of pseudo-stem biomass waste has been produced because of the rising acreage and output of bananas due to the expanding demand for them on the global market.[4].

In this research we are going to investigate the possibilities of using banana fibers coated by aluminum foil as roof insulator. Banana fiber and epoxy composite layer was prepared with varying fiber density. Thermal conductivity was tested for varying fiber density and Suitable composite fiber density was determined by testing result. Banana fiber epoxy composite was sandwiched between aluminum foil, which will work a radiant barrier on the surface of the composite. Aluminum foil has capability to reflect 97% heat by radiation [1].

II. LITERATURE REVIEW

A. *How do thermal insulators work?*

Roof insulation works by exhibiting resistance for heat flow by three methods conduction, convection, and radiation from hot to cold area [2],[3]. Heat flow by the convection is reduced by the cellular nature structure materials which are having space within them. Materials having more empty space than solids have the capability to resist the heat flow by conduction. Heat flow by the radiation is reduced by mainly two methods, which are place insulation surface close to the hot surface which absorb the radiation heat and convert into the conductive or convection heat and using the shiny aluminum foil which reflect the radiation heat [3].

B. *Bio insulation materials on research*

1) Insulation made by sunflower stalk, waste cotton and textile waste with epoxy binder.

A study was conducted to develop eco-friendly bio-insulation using sunflower stalk, cotton, textile wastes and epoxy binder. This was produced by a simple procedure, less energy and less costs for production. Thermal conductivity of the material should be less than 0.1 W/mK for use as insulation. Test results on it show that thermal conductivity of the above composite varies within the range 0.2616 to 0.0728 W/mK with the varying number of composites and pressure used to compress [4].

2) Bio-insulator using wheat straw as aggregate and geopolymer as binder.

A study was conducted to develop bio-insulation using wheat straw aggregate and geopolymer binder. Thermal conductivity of this insulation varies between the range from 0.092 to 0.186W /m K, which range have the values less than the 0.1W/mK which is the required range for a material used as thermal insulator [1].

3) Bio-insulators from cotton stalk fibers.

Eco-friendly thermal insulation was manufactured by fibers extracted from the cotton stalks. This material was manufactured without using any binders [5]. Fiber boards with 25mm thick and density ranged from 150-450 kg/m^3 were tested for their thermal insulation properties, which shows thermal conductivity value varying within the range from 0.0585 to 0.0815 W/m K which is less than the 0.1 W/mK which required maximum thermal conductivity value for allowed to use as thermal insulation [5].

4) Banana fiber

Banana fibers are cellulosic fibers which show better insulation property which is comparable to the conventional insulation material. Banana fiber 38mm thick layer was prepared by randomly 10cm banana fibers horizontally to form insulation batt in a polystyrene frame and their thermal conductivity values were tested with varying density within the range from 20 Kg/m^3 to 120 Kg/m^3 and varying temperature range between from 20˚C to 40˚C. Banana fiber thermal conductivity is vary with the above behavior within the range 0.0415-0.07597 W/m K. Banana fiber's thermal conductivity with the increase of density until reach the minimum value then increases with the density as shown in the graph below. Minimum thermal conductivity value 0.0415 W/m. K is obtained with density 73.4 Kg/ m^3 .

III. Materials and Methods

A. Materials

Musa spp. (Ambul) is commonly popular banana in Sri Lanka. Its' stems were selected, and 1 kg fiber was extracted for this testing. Epoxy resin was used with the combination of hardener. Epoxy resin shows a low thermal conductivity level around 0.2 W/ (m. K) compared to other resins. Thin aluminum foil(0.0027mm) was used to sandwich banana fiber epoxy composite.

B. Methods

Mold was prepared with 6cm diameter and 1cm thickness PVC. Banana fibers were cut in 5cm length. Epoxy and hardener were mixed in 2:1 ratio. Banana fibers were mixed with epoxy resin in a 1:1 ratio. Banana fiber insulation web samples with density 70 kg/m^3, 75 kg/m^3, 80 kg/m^3, 85 kg/m^3, 90 kg/m^3 were prepared in the dimension of mold. Another set of samples with fiber density 70 kg/m^3, 75 kg/m^3, 80 kg/m^3, 85 kg/m^3, 90 kg/m^3 were prepared and sandwiched by aluminum foil. Three Samples in each fiber density were prepared. The required mass of fibers and resin mass were measured by using balance. Samples were fabricated by hand lay method at room temperature. Table 1 shows the mass of material used for obtaining certain fiber density.

Sample	Mass of fiber	Mass of resin	Mass of hardener
70 kg/m^3	1.979g	1.319g	0.660g
75 kg/m^3	2.121g	1.414g	0.707g
80 kg/m^3	2.262g	1.508g	0.754g
85 kg/m^3	2.40329g	1.602g	0.801g
90 kg/m^3	2.545g	1.697g	0.848g

Table 1. Mass of materials used

Figure 1 Test Samples

Thermal conductivity of this banana and epoxy composite sample were evaluated by Lee's disk apparatus method [6]. thermal conductivity value was calculated.

$$K = \frac{m \times C \times \frac{\partial T}{\partial t} \times L}{A \times (T1 - T2)}$$

Equation 1 for thermal conductivity value

K – Thermal conductivity, A – Cross section area of insulation sample, L – thickness of sample, m – mass of top brass disk, C– specific heat capacity brass, ∂T/∂t – cooling rate, T1- Steady state bottom disk temperature, T2- Steady state top disk temperature.

IV. Result and Discussion

Sample (Fiber density) (kg/m^3)	Steady state T1-T2 (˚C)	Cooling Rate (∂T/∂t)	Thermal conductivity Value (W/mK).
70	57.3	0.0044	0.0888041
75	57.8	0.003843	0.08329
80	59.6	0.002083	0.0420
85	58.2	0.0022727	0.04697
90	58	0.0023	0.051851

Table 2. Thermal conductivity of samples without Al foil

The table 2 shows the thermal conductivity values of specimens with fiber density 70 kg/m^3, 75 kg/m^3, 80 kg/m^3, 85 kg/m^3 and 90 kg/m^3 without aluminum foil. Sample with fiber density 70 kg/m^3 shows the higher thermal conductivity value 0.0888041 W/mk and fiber density with 80kg/m3 shows lowest thermal conductivity 0.0420 W/mK. According to the above test results composite panels with fiber density 80 kg/m^3, 85 kg/m^3 and 90 kg/m^3 were within the required range 0.02 W/mK to 0.06 W/mK to use as thermal insulator [7].

Sample (Fiber density) (kg/m^3)	Steady state T1-T2(˚C)	Cooling Rate (∂T/∂t)	Thermal conductivity Value (W/mK).
70	55.6	0.00295	0.0637
75	55.9	0.00269	0.05830
80	56.7	0.002083	0.04351
85	55.8	0.00227	0.04914
90	54	0.00271	0.0603

Table 3. Thermal conductivity of samples without Al foil

The table 3 shows the thermal conductivity values of specimens with fiber density 70 kg/m^3, 75 kg/m^3, 80 kg/m^3, 85 kg/m^3 and 90 kg/m^3 with aluminum foil. Sample with fiber density 70 kg/m^3 shows the higher thermal conductivity value 0.0637 W/mK and fiber density with 80kg/m3 shows lowest thermal conductivity 0.04351 W/mK. According to the above test results composite panels with fiber density 75 kg/m^3, 80 kg/m^3 and 85 kg/m^3 were within the required range 0.02 W/mK to 0.06 W/mK to use as thermal insulator.

In this study, banana fiber & epoxy composite works as bulk insulation material and resist the heat transfer by the conduction and convection. The trapping air principle is used in the bulk insulation to resist the heat flow. Air is a poor conductor of the heat, which is held within the tinny porous structures in the bulk material. In the bulk insulation, ability to transfer heat by the heat convection is reduced by hold the air into the perfect tinny porous structures in the material [8]. It might be a reason why low conductivity was obtained in the above testing results at certain density.

V. CONCLUSION

The main objective of this research was investigating the possibility of fabricating thermal insulation material using banana fibers. Thermal conductivity testing is the main part in investigating possibilities of fabricating thermal insulators. For this research banana fiber epoxy resin composite was developed by blending banana fiber and epoxy resin in 1:1 weight ratio**.** Samples were prepared in varying fiber densities 70kg/m^3, 75kg/m^3, 80kg/m^3, 85kg/m^3 and 90kg/m^3 . Thermal conductivity testing was conducted on the above samples. All the sample except fiber density 70 kg/m^3 and 75kg/m^3 without sandwiched by the aluminum foil exhibits positive sign for use them as thermal insulation material. The lowest thermal conductivity value 0.0420 W/mK was exhibited by sample with fiber density 80kg/m^3. After that, banana fiber and epoxy composite were sandwiched between aluminum foil, which will protect the banana fiber and epoxy composite from flame and moisture. And aluminum foil works as radiant barrier in the surface of the composite. After sandwiching the banana fiber and epoxy composite by aluminum foil, a thermal conductivity test was conducted. In the testing for aluminum foil sandwich panels, the lowest thermal conductive value 0.04351 W/mK was observed in the 80kg/m^3 sample.

Banana fiber based thermal insulation material was developed successfully through this project. Moreover, some other properties should be included in this material for its' advance performance. This research will contribute to the development of semi eco-friendly and sustainable insulation material specially using the natural cellulosic banana fiber and epoxy resin, which will satisfy the insulation requirements in the many applications.

VI. LIMITATIONS AND RECOMMENDATIONS

Composite was made by hand lay method. Therefore, evenness of density along the sample was not ensured. In the future developments samples should be made by using pressure apply machine. Aluminum foil resist the heat by the radiation. Therefore, impact of aluminum foil on the surface of the insulation couldn't test by Lee's disk apparatuses, which should be test in future.

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