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Application of coconut coir for eco-friendly insulated sandwich panel

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ABSTRACT

Construction of affordable and environmentally-sensible home at fast pace is one of the major demand as natural insulation materials works with low carbon emission and becoming widely recognized for their sustainability. Natural insulation materials often require a greater thickness of insulation in comparison with standard materials. In the present work three types of coconut coir sheets sample are prepared and thermal conductivity measurement experiment is carried out. It is reported that virgin coconut coir sheet had shown the maximum thermal conductivity while double side coated coconut coir sheet has shown least thermal conductivity. The cost effectiveness is also evaluated and it is found that the double side. The double coated coconut coir sheet exhibited various promising parameter being lightweight, impervious to insect and waterproof, able to insulate the core from heat providing good axial compressive strength. Studies still need to be carried out for being fire resistant and for providing better acoustical resistance.

Keyword: *- coconut coir, eco-friendly, thermal insulation, heat transfer, sandwich panel*

1. INTRODUCTION

A sandwich panel is any structure made of three layers: a low-density core and a thin skin-layer bonded to each side. Sandwich panels are used in applications where a combination of high structural rigidity and low weight is required. Sandwich panels are an example of a sandwich structured composite: the strength and lightness of this technology makes it popular and widespread. Its versatility means that the panels have many applications and come in many forms: the core and skin materials can vary widely and the core may be a honeycomb or a solid filling. Enclosed panels are termed cassettes.

1.1 structural insulating panels

A structural insulating panel (SIP) is a form of sandwich panel used in the construction industry.SIP is a sandwich structured composite, consisting of an insulating layer of rigid core sandwiched between two layers of structural board, used as a building material. The board can be sheet metal, plywood, cement, magnesium oxide board (MgO) or oriented strand board (OSB) and the core either expanded polystyrene foam (EPS), extruded polystyrene foam (XPS), polyisocyanurate foam, polyurethane foam or composite honeycomb (HSC). SIPs share the same structural properties as an I-beam or I-column. The rigid insulation core of the SIP acts as a web, while the sheathing fulfills the function of the flanges. SIPs combine several components of conventional building, such as studs and joists, insulation, vapor barrier and air barrier. They can be used for many different applications, such as exterior wall, roof, floor and foundation systems.

1.2 PUF insulation

PUF insulation is the acronym for polyurethane foam insulation. Foam insulation is produced by filling the void of any insulating material by an insulating gas. For normal uses usually air is filled in the polymeric material as the insulating gas. You would find PUF sprays in the market. These are supposed to be sprayed on the surfaces intended to be insulated. The material which is in liquid form inside the container becomes solid once it comes in contact with air.This conversion from liquid to solid causes the trapping of air inside the solid. The conductivity of PUF is small, but if used as continuous media, could lead to a larger thermal contact area and thus giving rise to larger heat in leak. For this reason PUF is preferred over using continuous polymer layers[1].

1.3 Demerits of PUF insulation

PUF Insulation is widely used in industry, PUF having larger demand in market for insulating the shelter, building top, and wall insulation. Though PUF is advantageous material, but it is not an eco-friendly material, it has disadvantages like less durable, emission of toxic fumes which generates odor and creates the health and environmental issues.[2][3].

1.4 Eco-friendly alternatives for PUF insulation

Variety of natural materials that are more eco-friendly and easily recyclable than PUF are available abundantly, some of such materials are Coconut coir or fiber, Sheep's wool, Cork and Cellulose. Coconut coir or fiber is a natural fiber extracted from the husk of coconut and used in product such as floor mats, door mats, brushes and mattresses. Coir is the fibrous material found between hard, internal shell and the outer coat of coconut. Other uses of brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture.

2. LITERATURE SURVEY

Zhang et al. briefly introduces the main properties and four systems of rigid polyurethane thermal insulation foam intended for use in buildings for energy conservation purposes, and application development at home and abroad. Although the applications of polyurethane are widespread in architectural energy conservation, there are some problems just as high price, smoke toxicity, fire safety and so on thus it still occupies a small proportion in buildings for energy conservation purposes [1].

Liang et al. reported that polyethylene foam and polyurethane foam did not meet the requirements of the low fire hazard material and were unfavorable in the building's fire prevention [2].

Singh et al. provides insight into the ignition, combustion, smoke, toxicity, and fire-retardant performance of flexible and rigid polyurethane foams. It has been found by different workers that polyurethane foams are easily ignitable and highly flammable, support combustion, and burn quite rapidly [3].

The coconut tree (Cocos nucifera) is a member of the palm tree family (Arecaceae). Coconut cultivation is concentrated in the tropical belts of Asia and East Africa. Coconut fiber or coir is extracted from the outer shell of a coconut. According to Ministry of MSME Government of India, Currently, the global annual production of coir fiber is about 350,000 metric tons (MT). World's top two producers, India and Sri Lanka account for about 90% of global coir fiber production[4].

Coconut fiber is being utilized for coconut-based light weight cement board, wall panels made of gypsum and cement as binder and coconut fiber as the reinforcement, coconut fiber boards are utilized for replace construction materials such as tiles, bricks, plywood, and asbestos and cement hollow blocks. It is used for internal and exterior walls, partitions and ceiling. It can also be used as a component in the fabrication of furniture, cabinets, and boxes. Apart from applications in engineering, coconut fibers are also used in yarn, ropes, mats, mattresses, brushes, sacking, caulking boats, rugs, geo-textiles, insulation panels and packaging[5].

Coconut fiber has excellent characteristics of thermal insulation and sound absorption. In building panels, the coconut fiber is often mixed with binders to improve the characteristics of rigidity, anti-fungus, and flammability[6].

Lertwattanaruk et al. investigated the properties of natural fiber as a composite building material applicable for hot and humid climatic regions. These materials were made of cement mortar containing coconut coir fiber and oil palm fiber, they thermal conductivity of the natural fiber cement sheets was 60% less than that of the control specimen [7].

Mintorogo et al. reported that concrete rooftops covered with coconut fibers have lower surface heat fluxes during the daytime and are faster to release the stored heat due to the natural perforating material of coconut fiber, coconut fibers rooftops experience a lower indoor air temperature during the daytime but not at the nighttime. Coconut fiber is a natural material, therefore it decomposes faster and more easily. Coconut fibers can be recycled as a natural material. Coconut fibers can be introduced as insulation to flat concrete rooftops besides straw and fiber reeds[8].

Khedari et al. (2003) reported the development of new particleboards from tropical fruit peels and coconut coir with low thermal conductivity as a component of construction panels for energy conservation of building. In general, the effect of adhesive type on the properties of boards was not obvious whereas that of the density was more significant on most properties of boards[9].

Khedari et al. (2005) developed a new type of soil–cement block using coconut coir with low thermal conductivity of 0.6510 W/mK compare to commercial product with 1.5 W/m K cement block, the corresponding decrease of thermal conductivity is 54%[10].

Panyakaew et al. reported the production of low density thermal insulation boards made from coconut husk and bagasse without the use of chemical binding additives. The aim of this study was to develop a thermal insulation with lower environmental footprint than conventional materials. They concluded that insulation boards have thermal conductivity values ranging from 0.046 to 0.068W/mK which were close to those of conventional insulation materials such as cellulose fibers and mineral wool[11].

Alavez-Ramirez et al. evaluated the potential use of coconut fiber as thermal isolating filler for ferrocement panel walls in sandwich configuration of schools and houses' roofing in Puerto Escondido, Oaxaca, Mexico. Thermal conductivity measurements were performed to compare the thermal behavior of ferrocement panel walls filled with coconut fiber to other typical building materials of the region. Measured thermal conductivities for red clay brick, hollow concrete block and lightweight concrete brick panel walls are0.93, 0.683 and 0.536 W/m K respectively. Thermal conductivity of the proposed configuration is0.221 W/m K and that is lower than typical materials used for home-buildings in this region[12].

Kochhar et al. proposed coconut fiber as low cost building thermal insulation. Thermal properties were explored by conducting thermal conductivity tests. Results revealed that at a mean temperature of 39 °C, a minimum thermal conductivity of 0.058 W/mK occurred at an optimum density of 85 kg/m3. These results show that air dried coconut fiber has far reaching potential for use as an effective building thermal insulation[13].

Ayrilmis et al. studied the physical, mechanical, and flammability properties of coconut fiber reinforced polypropylene (PP) composite panels for automotive interior applications. The results suggest that an optimal composite panel formulation for automotive interior applications is a mixture of 60 wt % coir fiber, 37 wt % PP powder, and 3 wt % MAPP [14].

3. METHODOLOGY

Pure coconut coir lacks the required strength and rigidity to be used as insulating material for sandwich panels. In order to improve the strength and rigidity and to reduce the moisture absorption tendency of coconut coir, Epoxy resin glue is applied to coconut coir sheets. Thermal conductivity of coconut coir fiber is determined by using thermal conductivity measure anapparatus. Objective of the experimentation is to determine the effect of application of resin glue on the thermal conductivity of coconut coir sheets.

3.1 Sample preparation

In this experiment three types of coconut coir sheets sample are prepared

1. Normal or virgin coconut coir sheet (S0)
2. Coconut coir sheet with epoxy resin applied on one side (Single side coated coconut coir sheet, S1)
3. Coconut coir sheet with epoxy resin applied on both side (Double side coated coconut coir sheet, S2)

Commercially available Haksons resin and hardener were used to get the resin coating on coconut coir sheet.Mixing ratio of 2:1 is maintained while preparing the Haksons epoxy resin and hardener clear coat as specified by manufacturer.

(a) (b) (c)

Fig - 1 Coconut coir sheet a) Sample S0, b) Sample S1 c) Sample s2

Table 1 indicates the specifications of samples

Table -1:Sample details

Sample Type	Length (mm)	Width (mm)	Thickness (mm)	Weight (gm)	Amount of resins applied (gm)
S0	150	100	9.5	15.88	0
S1	150	100	10	35.98	20.1
S2	150	100	10.5	59	43.12

3.2 Thermal conductivity measurement

Figure 5 shows the experimental setup for measurement of thermal conductivity of coconut fiber sheets, it consist of center heater sand witched between two sheets. Three type of slab are provided on both side of heater which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between slabs. A diameter stat is provided for varying the input to heater and measurement of heat input is carried out by voltmeter, ammeter. Thermocouples are embedded between interference of slab and connected to multichannel digital temperature indicator to read the temperature at the surface.

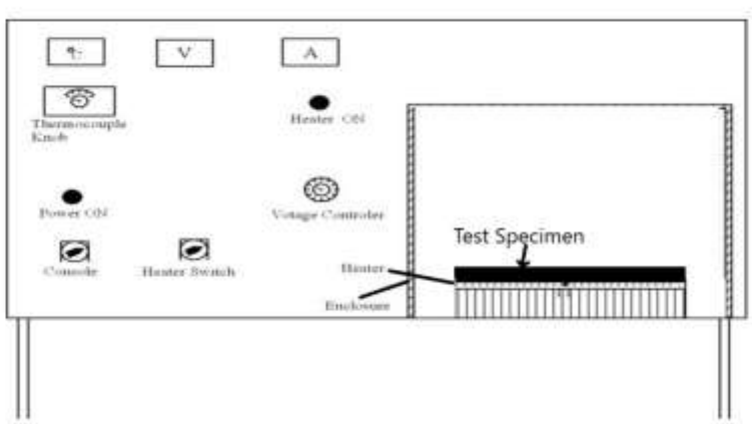

Fig - 2 Experimental set-up for measurement of thermal conductivity of coconut fiber sheets

Details of experimental set-up are mentioned in Table 2.

Table -2: Experimental set-up details

Component	Specification
Heater	300 W nichrome heater wound
Heater control unit	0-230 V
Voltmeter	0.100 – 200V
Ammeter	0.2A
Dimmer Test	0.2A , 0-230 V
Temperature Indicator	0-200 Celsius Digital Type
Thermocouple	Chromel Aluminum

Before started the each test perfect contact between the plates and sample was ensured by applying manual pressure. In order to apply uniform heat input initially voltage was set to 36 V for whole process.Temperatures reading were recorded at every 10-minute interval until there are no variations in the reading. Final steady temperature values across the plates are considered for further calculations.

3.3 Calculating the value of Thermal conductivity

Thermal conductivity is calculated based on Fourier's law of heat conduction which is an empirical law[15]. Mathematically, it can be represented by the equation:

$$Q = -k.A.\frac{dt}{dx}$$

Where, Q is Heat flow through a body per unit time (in watts), A is surface area of heat flow (perpendicular to the direction of flow), dt is the temperature difference of the faces of block (homogeneous solid) of thickness 'dx' through which heat flows, °C or K. dx is the thickness of body in the direction of heat flow in m. and k is the constant of proportionality and is known as thermal conductivity of body.

4. RESULTS

Table 3 indicates the observations of experiments conducted for all three samples. T1 and T2 are the temperature (in degree centigrade's at inlet and outlet of coconut coir for three samples respectively.

Table -3: Observation Table

Sr. No.	Voltage	Current	S0-T1	S0-T2	S1-T1	S1-T2	S2-T1	S2-T2
1	36	0.24	29	29	29	29	29	29
2	36	0.24	31	29	31	29	31	29
3	36	0.24	34	29	34	30	32	30
4	36	0.24	35	30	34	30	35	30
5	36	0.24	36	31	36	31	36	31
6	36	0.24	37	32	37	31	38	31
7	36	0.24	39	33	39	32	39	32
8	36	0.24	40	34	40	32	40	32
9	36	0.24	41	34	41	33	41	32
10	36	0.24	42	35	42	34	42	33
11	36	0.24	42	35	43	35	42	33
12	36	0.24	42	35	43	35	42	33

Values of thermal conductivity for three samples are shown in table 4.

Table -2: Thermal conductivity of coconut coir samples

Sample	Thermal Conductivity (W/mK)
1. Normal or virgin coconut coir sheet (S0)	0.390
2. Single side coated coconut coir sheet (S1)	0.342
3. Double side coated coconut coir sheet (S2)	0.304

5. CONCLUSIONS

In the present work three types of coconut coir sheets sample are prepared and thermal conductivity measurement experiment is carried out. It is concluded that virgin coconut coir sheet had shown the maximum thermal conductivity while double side coated coconut coir sheet has shown least thermal conductivity. The double coated coconut coir sheet exhibited various promising parameter being lightweight impervious to insect and waterproof, able to insulate the core from heat, providing good axial compressive strength. Studies still need to be carried out for being fire resistant and for providing better acoustical resistance. Organic insulation materials in the form of coconut coir is proposed as effective insulation material as it is renewable, recyclable, non-toxic, environmentally friendly and require very low resource production techniques.

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