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Utilization of Palm Oil Fiber (POF) as Thermal Insulated Roof Ceiling Panel

Muhamad Fazli Mohd Diah[1], **Mohd Luthfi Ahmad Jeni**[1]*, **Hilmi Kosnin**[1]

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: Climate change is a major concern in the twenty-first century. In other words, this resulted in increased of energy usage on household cooling appliances. The Malaysian government's enforcement of Movement Control Orders (MCO) during the worldwide pandemic exacerbated the issue, with household energy usage increasing by about 50.00 %. The use of thermal insulated panels is an excellent solution to this problem. However, commercial thermal insulated panels are too expensive for the majority of Malaysians, particularly those in the B40 group. Palm Oil Fiber (POF) will be employed in the construction of a thermally insulated roof ceiling panel in this study. The initial objective is to investigate the mechanical properties of POF as an insulated material for thermal insulated roof ceiling panel. This study also to determine the optimum content of POF to be used as thermal insulated ceiling panel which was a second objective in this study. To produce the ceiling panel, three samples with varying amounts of POF were combined with gypsum powder. Each sample contains a different percentage of POF, ranging from 10.00 % to 15.00 % to 20.00 %. The thermal conductivity of the panel was determined for each sample using the Guarded Hot Plate test. Water absorption is the last test for the ceiling panel. This test will determine the amount of water absorbed by the panel after a short and extended duration of immersion in water. All tests were carried out in accordance with ASTM C 177, ASTM C 473, and ASTM D 1037.

Keywords: Thermal Insulated Panel, Palm Oil Fiber (POF), Thermal Insulated Roof Ceiling Panel, ASTM C177, ASTM C473 and ASTM D1037

1. Introduction

One of the most alarming topics that arises throughout the year is global warming. As a result, the demand for air conditioners per house has increased. Thermal insulated panels are required in most residential buildings to assist reduce energy consumption per dwelling. However, the materials widely used in the sector, such as Polyurethane Foam, Stone Wool, Expanded Polystyrene, and Extruded

*Corresponding author: luthfi@uthm.edu.my

Polystyrene, are too expensive for the majority of Malaysians. A less expensive alternative is required to encourage the installation of thermal insulated panels in every home.

Palm oil fiber (POF) is one of the materials that might be utilized to replace typical materials in thermal insulated panels. Many studies on POF have recently been reported and carried out, particularly in bio advanced composites [2]. This option is practical since Malaysia is one of the world's leading producers of palm oil and is seeing rapid growth in new plantations and palm oil mills through a variety of government and private firms. The waste by-product of the palm oil production process grows on an annual basis, with palm oil accounting for just 10.00 % of total biomass in the palm oil mill, while the other 90.00 % is squandered. Oil palm biomass is generically classified as oil palm fronds (OPF) and trunks (OPT), empty fruit bunches (OPEFB), palm kernel shells (PKS), mesocarp-fiber (MF), and palm oil mill effluent (POME) [28].

Palm oil fiber (POF) is a lignocellulosic biomass that contains 18.00 % to 23.00 % lignin, 20.00 % to 30.00 % hemicellulose, and 35.00 % to 50.00 % cellulose [6,8]. OPEFB is a large source of biomass that contains around 73 percent fibers and is extracted using the retting method. The chemical make-up of OPEFB is shown in table 1 below. This contributes to OPEFB's biodegradability, insulating properties, and improved thermal properties, among other benefits.

Gypsum is a soft sulphate mineral that is widely mined and utilized in a wide range of goods including plaster, chalk, dry wall, and blackboard. It is a hydrated calcium sulphate with the chemical formula CaSO4.H2O in its pure state. To become a viable construction material, natural gypsum will go through a partial dehydration process known as hemi-hydrate [27]. Gypsum, like POF, is an environmentally beneficial, biodegradable, renewable, and recyclable material. When combined with insufficient insulation, it can behave as a thermal insulator.

Gypsum board is commonly used in the building industry as insulation materials connected to the exterior surface of construction parts to keep structural material strength and stiffness when subjected to high temperatures [11]. Both POF and gypsum are non-hazardous to the environment. As a consequence, when combined, it may result in better material qualities.

The purpose of this research is to determine the mechanical characteristics of palm oil fiber (POF) as an insulated material for thermally insulated roof ceiling panels. Aside from that, the goal of this research is to find the optimal palm oil fiber content for usage as a thermally insulated ceiling panel.

2. Gypsum Ceiling Panel Properties

2.1. Gypsum Property

Gypsum is a water-soluble mineral that comes in a range of colours based on its purity. Some are clear, colourless, grey, or yellowish in appearance. Gypsum is resistant to fire in the natural setting, which decreases the risk of fires and provides life safety. The gypsum product's fire resistance is aided by the presence of water within it. For example, a 15mm thick plasterboard holds around 3L of crystallized water. When a fire gets close to water, it evaporates, generating an overlaying protective layer that helps to keep the flames from spreading.

It also has thermal properties that helps in managing a high degree of temperature and humidity steadiness in the home. Construction materials such as gypsum plasterboard give additional insulating properties. Plasterboard acts as a vapour barrier within the building, preventing internal dampness and high temperatures from entering the home.

2.2 Palm Oil Fiber Property

From the extraction of OPEFB using retting process, it is shown that OPEFB is a huge supply of biomass comprising about 73% fibers. POF is an unpolluted biodegradable substance that is non-carcinogenic and devoid of waste contaminants. The fibers' morphological characteristics of the POF indicated that it closely mimics short-fiber hardwoods such as eucalyptus, a fast-growing evergreen tree native to Australia [29]. The summary of the mechanical and physical properties of the fibers is as in the table below.

	Ramlee et al., 2019	Shinoj et al., 2011	Gunawan et al, 2009	Mohamed Yusoff et al, 2009
Diameter (μm)	250 – 610	150 – 500	400 – 720	250 – 550
Density (g/cm3)	0.7 – 1.55	0.7 – 1.55	-	-
Tensile Strength (MPa)	60 – 81	50 – 400	92.5 - 246.2	71
Young Modulus (GPa)	1 – 9	0.57 – 9	Average of 11.88	1.703
Elongation at Break (%)	8 – 18	4 – 18	-	11

3. Material and Method

POF, gypsum powder, and water are the primary components utilized. The POF is extracted from a rejected fruit bunch (EFB). The fiber content of each sample is computed as a percentage of the weight of the gypsum powder, which is 10%, 15%, and 20% for each sample, respectively. Gypsum powder is commonly sold in 25kg ready-to-use bags with a 25 to 30 minutes setting time. The construction of a 300mm X 300mm X 20mm mould will be the initial stage in the sample preparation process. The following is a description of the sample preparation procedure:

1. The weight of POF and gypsum powder is determined using a weighted scale based on the ratio shown in Table 3.3.
2. One kilogram of gypsum powder will be used to mix the control sample. 500mL of water is slowly added to the mixing bucket while the mixture is continually agitated.
3. For samples 1, 2, and 3, the gypsum powder will be combined with the POF in a mixing bucket in the ratio shown in Table 3. 3. The materials were initially mixed in their dry state.
4. Slowly, 500mL of water is added into the mixture and stirred continuously.
5. The mixture is then placed in the mould. The mould is then covered, and a load is applied on top of it to produce a flat specimen.

Table 3.3: Summary of Sample Mixture Ratio

Sample (Mixture Ratio)				Mass, m (kg)
No.	POF (%)	POF (kg)	Gypsum Powder (kg)	
Control	0	0	1	1
1	10	0.10	1	1.10
2	15	0.15	1	1.15
3	20	0.20	1	1.20

4. Discussion

4.1 Thermal Conductivity

The thermal conductivity of gypsum ceiling panels that have been combined with POF as an addition is tested. The bar graph (Figure 1) clearly shows that increasing the amount of POF in the combination reduces thermal conductivity. These findings are consistent with a review of the literature, which discovered that POF, owing to the chemical makeup of the fibre, which comprises lignin, cellulose, and hemicellulose, can help lower the heat conductivity of gypsum ceiling panels. The control sample, the first specimen, has the maximum conductivity value of 0.68 W/mK. Meanwhile, sample number 1 had a conductivity of 0.64 W/mK. It recorded values of 0.63 W/mK and 0.61 W/mK for samples 3 and 4, respectively.

Table 4.1: Thermal conductivity test result

Samples (mixture ratio)			Mass, m (kg)	Heat Flow, Φ (W/m^2)	Hot Plate Temperature, t_h (K)	Cold Plate Temperature, t_c (K)	Thermal Conductivity, k (W/mK)
Sample No.	POF fiber (kg)	Gypsum (kg)					
Control	0.00	1.00	1.00	77	343.15	318.15	0.68
1	0.10	1.00	1.13	73	343.15	318.15	0.64
2	0.15	1.00	1.16	71	343.15	318.15	0.63
3	0.20	1.00	1.21	69	343.15	318.15	0.61

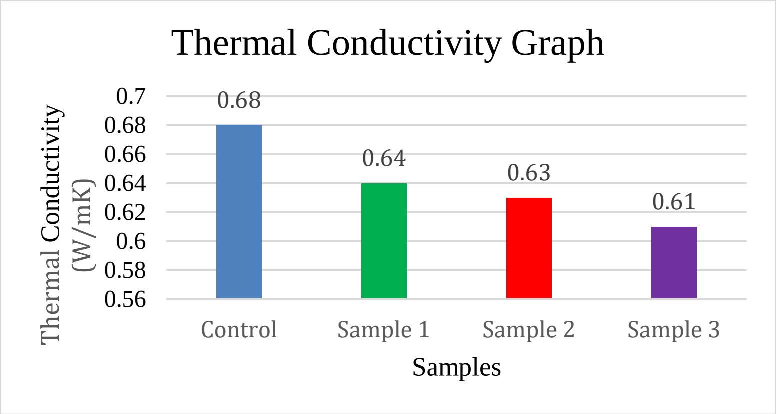

Figure 1: Thermal conductivity graph

4.2 Water absorption

All samples measuring 300mm × 300mm X 20mm were subjected to water absorption testing. The test was initiated only after the thermal conductivity test. Tables 4.2 indicate the outcomes of the tests that were carried out. The proportion of water absorbed by the gypsum-POF ceiling panels during 2+22 hours of immersion was plotted on the graph shown in figure 2.

Table 4.3: Water Absorption test result (%)

Sample No.	Dry Mass (Before Immersion), m (kg)	After 2 hours of immersion, m (%)	After 24 hours of immersion, m (%)
Control	1.00	22	37
1	1.13	20	31
2	1.16	18	26
3	1.21	15	24

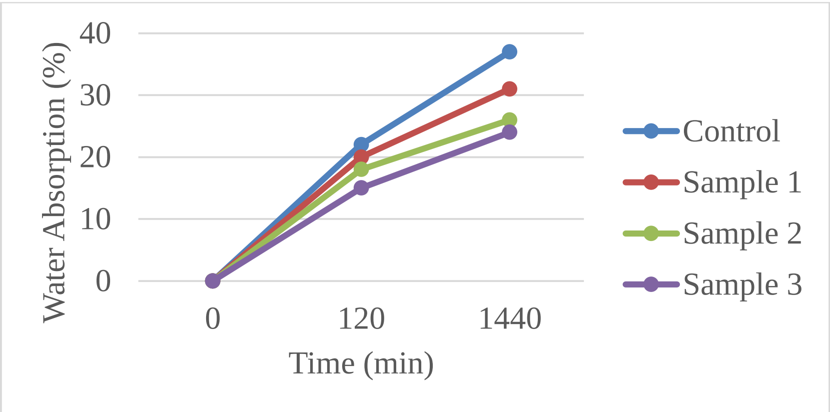

Figure 4.2: Graph of percentage of water absorption test vs time

As seen in the graph above, the proportion of water absorbed by the gypsum-POF ceiling panels decreases as the amount of POF used in the combination increases. When POF is introduced at a rate of 10% to 20%, the rate of reduction begins. The control sample absorbed 22% of the water after 2 hours and 37% after 24 hours, whereas sample 1 absorbed 20% and 31% after 2 hours and 24 hours, respectively. Furthermore, for both 2 hours and 24 hours, samples 3 and 4 acquired values of 18% and 26%, as well as 15% and 24%, respectively. The principal cause of this depreciation, according to Rahmanian (2011), is most likely connected to the porosity of the gypsum [33]. By filling such porosities, the POF reduces the risk of the panel absorbing water.

5. Conclusion

Based on the laboratory findings, the following conclusions may be consistent with the respective objectives put forth at the commencement of this study. According to the findings, adding POF to gypsum ceiling panels reduced both water absorption and the thermal conductivity of the ceiling panels. POF from various sections of the palm oil tree, however, appears to work sufficiently and falls within the permitted range as an addition, implying that POF from various portions of the palm oil tree might be utilized as addictive chemicals for gypsum ceiling panels. A varied proportion of POF might be employed to identify the ideal percentage for improving the ceiling panel's thermal resistance.

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