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Rigid Polyurethane Foam Reinforced Coconut Coir Fiber Properties

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Abstract: This research work studied the properties of composite foam panels. Coconut coir fibers were used as reinforcement in polyurethane (PU) foam in order to increase the properties of foam. This composite foam panels were fabricated by using polyurethane molded method. The polyurethane foam panels reinforced from 5 to 20wt% coconut coir were produced to investigate the physical and mechanical test via density test and three point bending test respectively. It was found that the density test results show the composite foam panel density decreases as fiber content increased. The composite foam panels with 15 wt% coconut coir fibers offered less density with average value of 76.78 kg/m3. Result from mechanical test shows that the flexural properties were increased at 5wt % of coconut coir fiber with average value of maximum force and shear stress at 88N and 60 KPa. It was revealed that the coconut coir fibers at 5wt% significantly increased the physical and mechanical properties of composites foam panel.

Keywords: Polyurethane foam, mechanical properties, coconut coir

1. Introduction

Polyurethane foam is a thermoset polymer with high volume percentage of small pores [1]. Foam usually used in automotive panel and cushion, furniture and thermal insulations. Main compositions in polyurethane foams are Polyols and Isocyanates, different compositions of these components separate polyurethanes into three categories which are flexible polyurethanes, semi rigid polyurethanes and rigid polyurethanes with different properties, characteristic and applications [2]. Polyurethane foams can be fabricated using slabstock process, polyurethane molding and spraying. However, fabrication method depends on particular type of polyurethane foams [2].

In previous study, the polyurethane foam reinforced with various type of glass fiber [2]. But the usage of the synthetic fibers will increase the material cost due to processing cost to produce those fiber, especially carbon and Kevlar fiber. In last decades researchers started to find an alternative for synthetic fibers. Natural fibers become new interest in research to increase the constituent material properties. Natural fibers offer a good properties and those fibers are sustainable natural resources. In addition, due to the ease of gaining natural fibers, the cost of the material will be decreased [3].

Agricultural products appear to be new and inexpensive materials with a great acceptable in both commercial and environmental areas. One of the agricultural sources which can be potentially used as reinforcement in the polymer matrix composite is coconut coir fibre. This is due to the natural fibres such as coconut fibre exhibit high tensile strength, high toughness, low density, and recyclable [4, 5]. Moreover, coconut coir is easy to mill to be short fibre or particles [6]. Particles and fibres act as a reinforcement to sustain the applied load and avoid the material from sudden failure. Coir or also known as coconut husk categorized in seed fiber since the fiber gained from the coconut palm fruit, scientific name of this plant is Cocos Nucifera and categorized in Palmae family. Coir fibers are resilient, strong, and highly durable due to high lignin but low cellulose content [7]. Coir is one of the toughest fiber available, it does not pill, highly abrasion and fungal and bacteria resistant [8]. In order to produce better adhesion between fiber and matrix, coir fibers need to be treated. Alkaline treatment is the best treatment to remove fiber wax and offer good surface for better bonding between matrix and fiber [9].

2. Experimental

2.1 Panel Preparation

There are several stages in the construction of the polyurethane/coconut coir foam:

i. Coconut coir treatment: The coconut coir fibers were crushed using granulator machine with the fiber length ranging from 500-100mm. Later it has been treated by using alkaline treatment method. The treatment begins when the coir fibers treated with 5wt% Sodium Hydroxide (NaOH) and 95wt% water. The treatment with NaOH solutions were required to remove impurities from coconut fiber, such as hemi cellulose, lignin and aromatic acids, which could be reduced the adhesion between fiber and matrix. The duration for this

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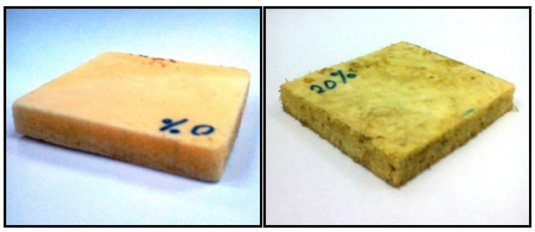
treatment was 24 hours at room temperature. Later, the coir fibers were cleaned and dried up in oven for 12 hours at 80 C [10].

ii. Polyurethane foam fabrication: Three types of polyurethane foam cores were fabricated which are polyurethane foam with 0, 5, 10, 15, 20 wt% coir fiber. The polyurethane foam was produced by mixing the polyol and isocynates. When the mixing of polyol and isocynate were prepared, coir fibers will be added and stirred to ensure the coir fiber was uniformly distributed. These mixed components were poured into the mould and cured at a room temperature. During foaming, mould rotated constantly to produce uniform foam cell. Fig. 1 shows the cured polyurethane foam without / with fibers.



(a) (b)

Fig. 1 (a) Polyurethane foam without fibers, (b) Polyurethane foam with fibers.

2.2 Test Method

2.2.1 Density Test

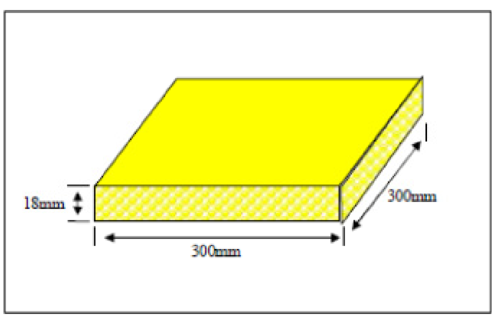


Fig. 2. Dimension of density test sample.

The objective of this test is to determine the density of core such as polymer foam. The density test was conducted under ASTM C 271 - 99. Fig. 2 shows the samples dimensions for density test. In this test, panels were tested to determine the effect of coir fiber to the panels' density. The density was measured as the mass of the panel divided by its volume [11]. The equation for density determination is:

$$d = \frac{1000000w}{v} \quad (1)$$

Where:
d = density, kg/m^3
w = final mass, g
v = final volume, mm^3

2.2.2 Flexural Test (Three Point Bending)

The flexural test conducted by using three point bending test (ASTM C 393 - 00). The objectives of this test are to determine the shear stress and maximum load of polymer foams. For this test, the specimen dimensions were 350x75x18 mm¬3 and the test velocity was 2mm/min [12]. Fig. 3 shows the testing schematic diagram.

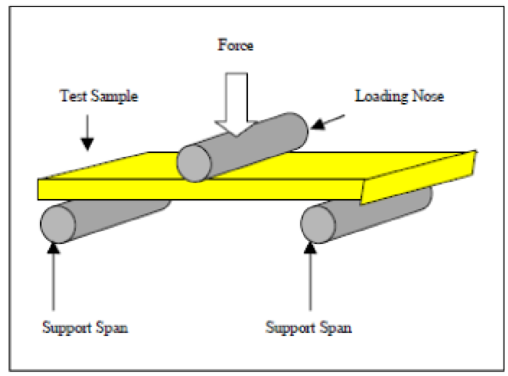


Fig. 3 Three point bending testing schematic diagram.

In order to determine the shear stress of panel, following equation was applied:

$$\tau = \frac{P}{cb} \quad (2)$$

Where:
τ = shear stress, MPa
P = load, N
c = thickness, mm
b = width, mm

3. Result and Discussion

3.1 Microstructure Analysis

3.1.1 Fiber Surface

To provide better fiber-matrix adhesion, lignin, waxes and hemicelluloses have to be removed in order to produce rough surface [10]. The morphology changes in the surface of treated fiber were observed by scanning electron microscopy (SEM). Fig. 4. shows the untreated coir fiber surface, while Fig 5 shows the treated coir fiber surface. As a result at 75X magnification, treated coir fibers have more crevices and imperfections on its surface compared to untreated fiber. This is due to lignin, waxes, and hemicelluloses were completely removed and dissolved in NaOH solution during alkaline treatment [10].

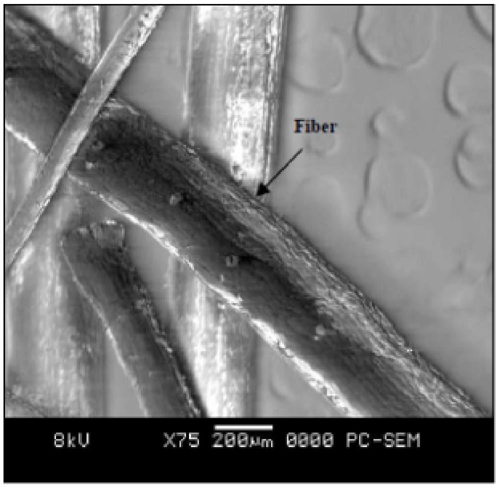
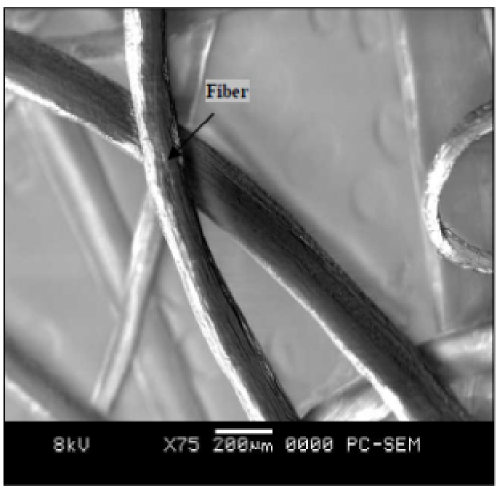
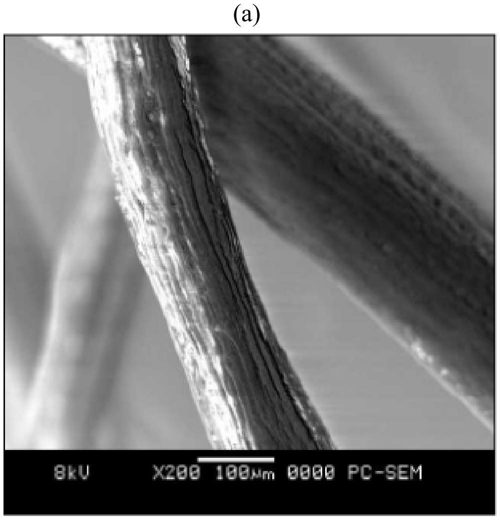


Fig. 4 Untreated coir fiber surface at 75× magnification.



(a)



(b)

Fig. 5 (a) Treated coir fiber surface at 75× magnification, (b) Treated coir fiber surface at 200× magnification.

3.1.2 PU Cell Size

PU cell was studied in order to characterize the foam cell that had been produced. Fig. 6 shows the PU cell surface. It can be seen that PU cell shows the closed cell characteristic and foam cell shape was clarify as wet foam type [13]. The cell size measurement result shows that the average size of cell was 250µm.

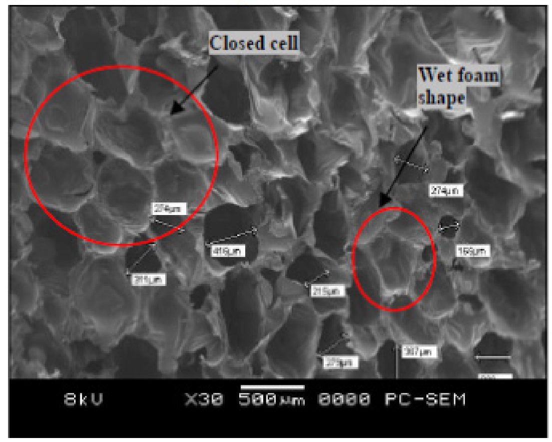


Fig. 6 PU cell surface.

3.2 Density

It can be clearly seen that the density of the polymer foam decreased as the percentage of coir fiber in polyurethane foam increases (Fig. 7) With the low density value of coir fiber at 1.15-1.46 g/cm3 it reduced averagely 16% of polymer foam panel density when 15wt%. coir fiber was added. This is mainly due to the plant fibers low density as compared to synthetic fibers [14]. The density decrement by fiber addition was limited to 15 wt% only, since the density increase with 20wt% of fiber.

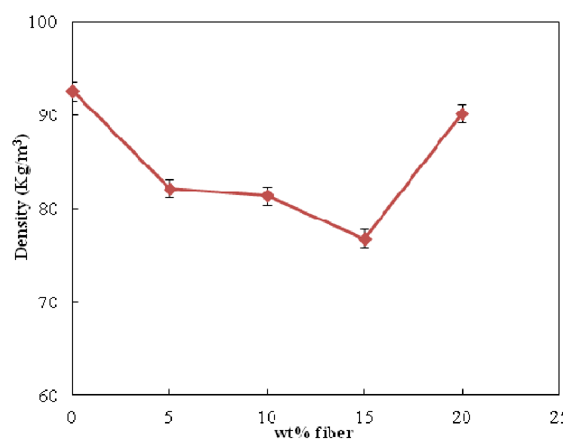


Fig. 7 Density of PU/coir at different fiber wt%.

3.3 Maximum Force and Shear Stress

The result of maximum force and shear stress were obtained from the three point bending test on the polyurethane foam are shown in the Fig. 8 and Fig. 9. Polyurethane foam cores consisted of 5wt% coir fibers exhibits highest maximum force and shear stress at 88N and 60KPa respectively as compared to the others. This result demonstrates that the contribution of coir fiber content able to increase the properties of the polyurethane foam since it provides a sufficient fibre-matrix adhesion in order to resists deformations and shear [9, 15]. However, the fiber addition limited to 5wt% only. The properties of panel decreased at 10wt% of fiber. In previous study, it was observed that there was a limit of coir fibers content in the composites, if the fibers content exceed the limit, it could led weaker interface and poor wetting, then, crack propagation will occur [9].

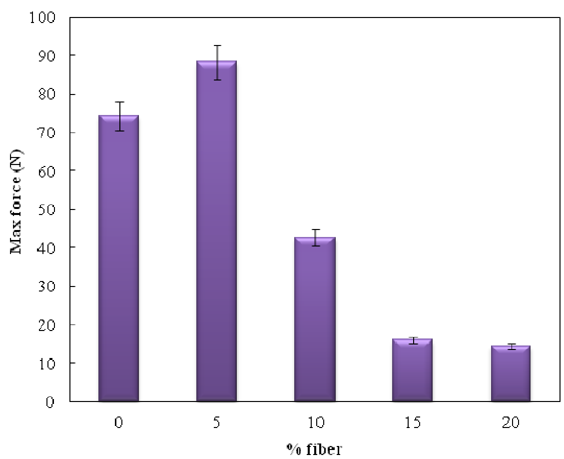


Fig. 8. Maximum force of pu/coir panel at different fiber wt%.

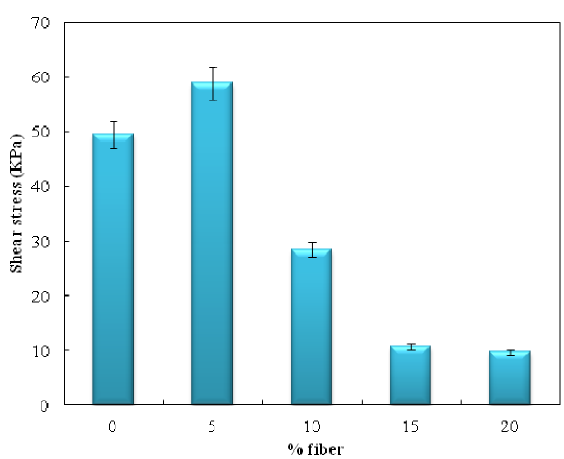


Fig. 9. Shear stress of pu/coir panel at different fiber wt%.

The tested sample of three point bending testing show that the failure occurred in the middle of the panel (Fig. 10) and the crack propagation start at the bottom of the sample (Fig. 11). During testing, the compressive stress may exceed the foam yield stress at locations on the compressive surface and fracture propagates on the tensile surface where the highest stress located [13]. Fig. 10 shows the testing sample at failure and Fig. 11 shows the tensile failure on composite foam panel.

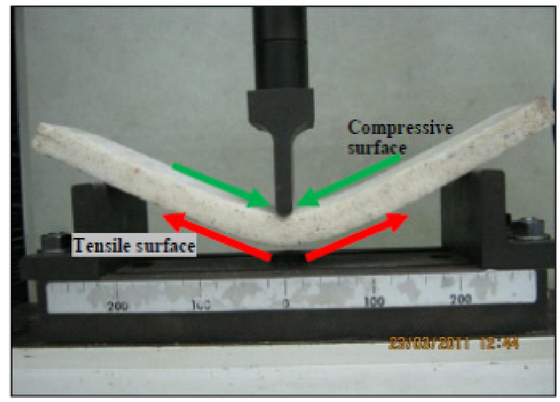


Fig 10. Testing sample at failure

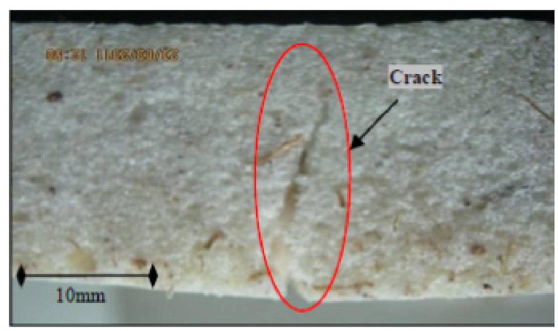


Fig. 11. Tensile failure on composite foam panel

4. Conclusion

From the physical test, it was found that the addition of the coir fiber produced lighter polyurethane foam. While for mechanical test, the result had shown that the contribution of 5 wt% coir fiber able to increase the properties of the polyurethane foam. In future, as a further investigation on polyurethane / coconut coir foam panel, the contribution of panel as core in sandwich composites will be investigated.
performed.

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