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Sandwich Composites of Glass Fibre Panel and Polyurethane/Coconut Coir Foam Core (GFRP - PUC)

M. A. Azmi[a] H. Z. Abdullah[b] and, M. I. Idris[c]

Department of Material and Design Engineering, Universiti Tun Hussein Onn Malaysia,

86400 Parit Raja, Batu Pahat, Johor, Malaysia.

[a]azham@uthm.edu.my, [b]hasan@uthm.edu.my, [c]izwana@uthm.edu.my

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Abstract. In this work, sandwich composite properties were investigated by addition of coconut coir (CC). Fibres in the polyurethane foam cores ranges from 0 to 20 wt.%. Glass fibre reinforced epoxy panels were used as a skin and polyurethane foam as a core, these materials adhesively bonded to keep the whole structure attached with each other. Sandwich composite skins and core-skin bonding were attained via adhesive bonding technique. While polyurethane foam reinforced by coconut coir fibres were manufactured by using one shot process and polyurethane moulding method. Sandwich composite panels with different coir fibres compositions were subjected to the density test, weight per area test and flexural testing in order to investigate their physical and mechanical properties. From the experimental results and analysis, it was found that the sandwich composites with 10 wt.% of coir fibres offer higher mechanical properties.

Introduction

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 [1,3]. Moreover, coconut coir is easy to mill to be short fibre or particles [2]. Particles and fibres act as a reinforcement to sustain the applied load and avoid the material from sudden failure.

Sandwich panels have two outer face sheets and core in the middle. The combination of these parts offer sandwich panels a relatively high strength and stiffness at low densities. Face sheets can be made of composite laminate panels, aluminium alloys, titanium steel or plywood. Core is the constituent that requires low density materials such as polymer foams, balsa wood, synthetic rubbers or inorganic cements [5,6]. Commonly sandwich composites were used in aerospace, automotive, sporting goods, marine, construction and civil structures.

In this research, a new hybrid sandwich structure has been developed by adding the coir fibre with a low density into the polyurethane foam core in order to increase the properties of polyurethane foam as the density and weight decreased. This sandwich composites use fibreglass reinforced epoxy as a skin material.

Experimental

Panel Preparation. There are several stages in the construction of the sandwich composites panel of glass fibre and polyurethane/coconut coir foam core (GFRP - PUC):

(i) Coconut coir treatment: The coconut coir fibres were crushed using granulator machine with the fibre length ranging from 2-3mm. Later it has been treated by using alkaline treatment method. The treatment begins when the coir fibres treated with 5 wt.% Natrium Hydroxide (NaOH) and 95 wt.% water. The treatment with NaOH solutions were required to remove impurities from coconut fibre, such as hemi cellulose, lignin and aromatic acids, which could be reduced the adhesion between fibre and matrix. The duration for this treatment was 24 hours at room temperature. Lastly, the coir fibres were cleaned and dried up in oven for 12 hours at 80° [7].

(ii) Polyurethane foam: Three types of polyurethane foam cores were fabricated which are polyurethane foam with 0 wt.% coir fibre, 10 wt.% coir fibre and 20 wt.% coir fibre. The polyurethane foam was produced by mixing the polyol and isocynates by using one shot process. When the mixing of polyol and isocynate were prepared, coir fibres will be added and stirred to ensure the coir fibre was uniformly distributed. Lastly, these mixed components were poured into the mould and cured at a room temperature.

(iii) Skin preparation: Skins were prepared by using hand layup technique with woven glass fibre mat and Dow® epoxy matrix with ratio of 2:1. Skin panels consist of three plies of fibre glass woven mat with panel dimension of 350mm x 350 mm. These panels were then cured for 12 hours at room temperature.

(iv) Sandwich composite construction: Glass fibre skins were ground with 120 grid abrasive paper to provide rough surface with polyurethane foam core. Moreover Araldite® epoxy paste was placed and cured for three hours at room temperatures to ensure excellent bonding between them. Fig. 1 shows the sandwich composites with two skins placed at the outer surface and foam core located between them. Fig 2 and 3 show the polyurethane foam core and sandwich panels at 0 wt.% coir fibres.

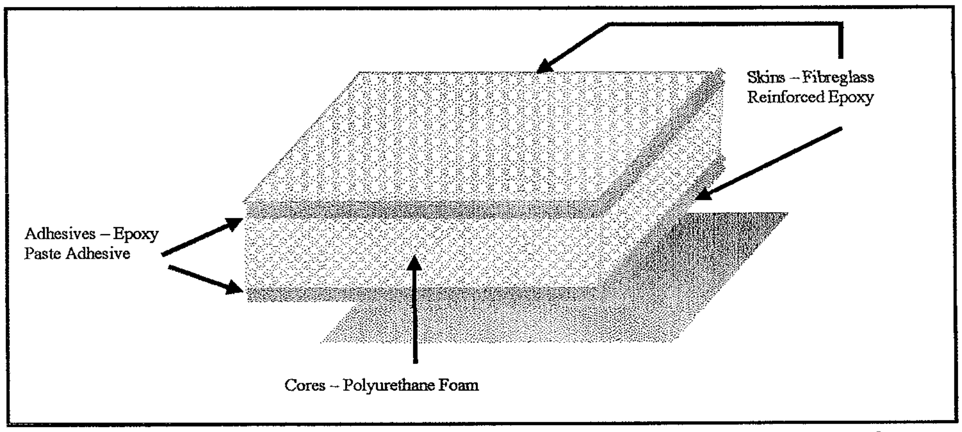

Fig. 1 Sandwich composites panel of glass fibre and polyurethane/coconut coir foam core (GFRP - PUC).

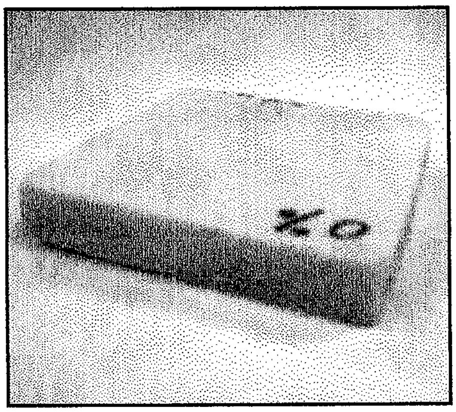

Fig. 2 Polyurethane foam core at 0 wt.% coir fibres

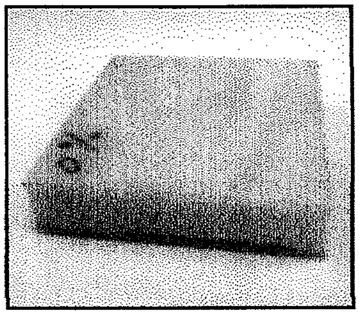

Fig. 3. Sandwich Panel at 0 wt.% coir fibres

Test Method

Density Test. The objective of this test is to determine the density of core materials. The density test was conducted under ASTM C 271. The samples dimensions were 300x300x18 mm^3. In this test, panels were tested to determine the effect of coir fibre to the panels' density. The density was measured as the mass of the panel divided by its volume [8].

Weight per Area Test. This test method covers the determination ratio of weight per area for each of specimens. This test measures the lightest structure among the samples which have the similar dimension but with different weight properties. All specimen sizes are 300x300x18mm^3. In this test the sample weighted and divided by its area.

Flexural Test. The flexural test conducted by using three point bending test (ASTM C 393). The objectives of this test are to determine the flexural strength and stiffness properties of sandwich composites panels. For this test, the specimen dimensions were 350x75x18 mm^3 and the test velocity was 2mm/min [9].

Result and Discussion

Lightweight Properties. It can be clearly seen that the density of the sandwich panel decreased as the percentage of coir fibre in polyurethane foam increases (Fig. 4). The density of sandwich panel reduced as 2.66% and 3.3% when the coir fibre was added 10 wt.% and 20 wt.% in the polyurethane foam cores, respectively. This is mainly due to the plant fibres properties that have low density as compared to synthetic fibres [10].

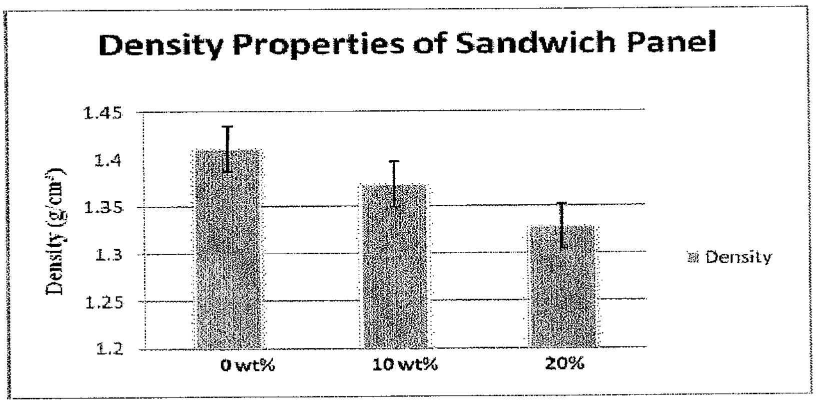

Fig. 4 Density of sandwich panel with different percentage of coir fibres

As well as in the weight per area result, it was also found that the weight of sandwich panel decreased by the addition of coir fibre in the polyurethane foam cores. It is means that the higher percentages of coir fibre in the polyurethane foam cores resulted in a lower weight of sandwich panels. Fig.5 shows that the weight per area result of sandwich panel with 0 wt.%, 10 wt.%, 20 wt.% coir fibre in the polyurethane foam cores. The average weight per area of sandwich panels with 0 wt.% fibres was 0.098 g/cm^2. While for the average weight per area test result for sandwich panels with 10 wt.% fibres was 0.096 g/cm^2. For 20 wt.% fibres sandwich panels, the average value of weight per area was 0.093 g/cm^2.

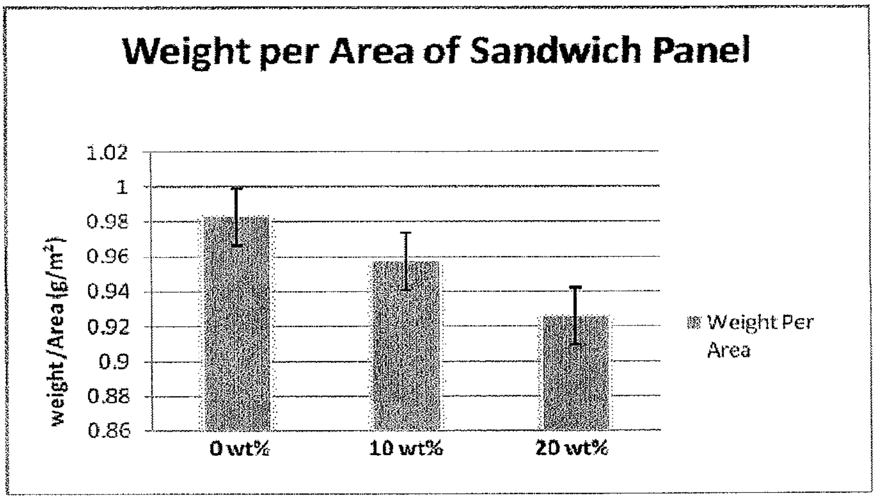

Fig. 5 Weight per area of sandwich panel with different percentage of coir fibre

Flexural Properties. The result of maximum load was obtained from the three point bending test on the polyurethane foam cores is shown in the Fig. 6. The maximum load of polyurethane foam cores consisted of 0 wt.% coir fibres exhibits highest maximum load of 100.86 N as compared to the others. This result demonstrates that the contribution of coir fibre content is not significant since it is not able to increase the properties of the polyurethane foam.

On the other hand, the maximum load of the sandwich panels consists of 10 wt.% coir fibre offer a better result with the maximum load of 518.28N (Fig. 6). However, the addition of 20 wt.% coir fibre decreased the sandwich panel properties when the maximum load was recorded at 375.47 N. This is due to the maximum contribution of fibre in polyurethane foam core. In previous study, it was observed that the optimum coir fibre in the composites were 25 wt.%. They revealed that the properties were decreased if the fibre amount exceed 25 wt.% due to the weaker interface and poor wetting, then led to interface crack [11].

The comparison for the maximum load between polyurethane foam cores and sandwich panels is also shown in the Fig. 6. It was found that the maximum load for sandwich panel is higher than the maximum load for polyurethane foam core. It is obviously shows that the coir fibres at 10 wt.% offer a higher properties to sandwich panels because it provides a sufficient fibre-matrix adhesion in order to resists deformations and shear perpendicular to the face plane [11, 1]. In addition, the construction of sandwich panel with the fibreglass skins also led to the higher strength since skin acts as the main component to sustain most of the in-plane loading and any transverse bending stress [1].

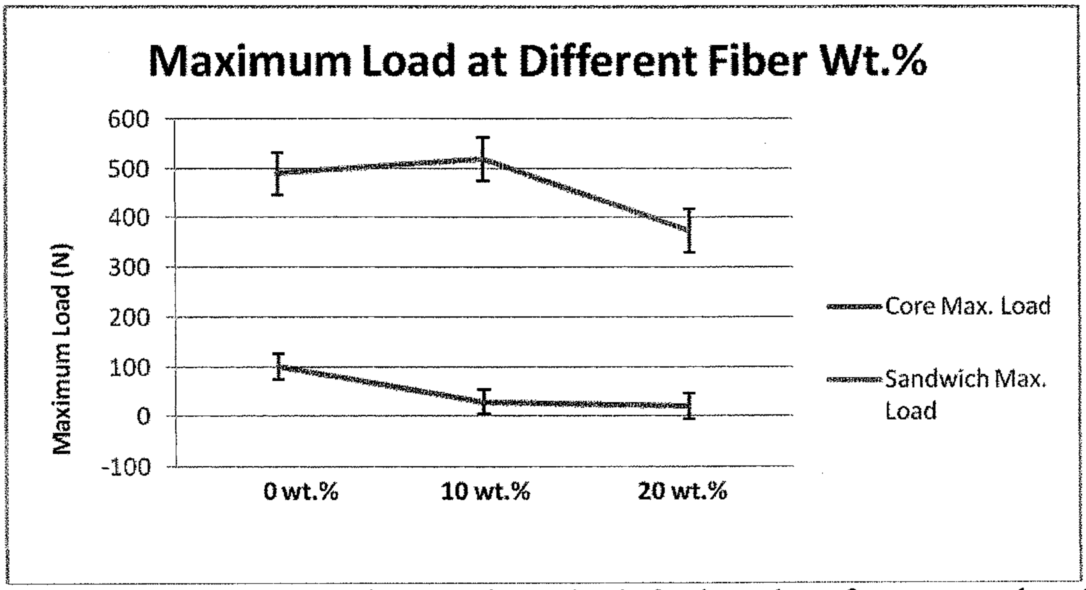

Fig. 6. Comparison of the results from maximum load of polyurethane foam core and sandwich panel with different coir fibre percentage

Fig. 7 shows the comparison of maximum strength between polyurethane foam cores and sandwich panels. The maximum strength was 2.72MPa for polyurethane foam cores without addition of coir fibres and the polyurethane foam cores with 20 wt.% coir fibre gives the lowest maximum strength of 0.56MPa. While for the sandwich panels, the highest maximum strength was 6.57MPa when added with 10 wt.% coir fibres and the lowest maximum strength is 4.90MPa when the sandwich panel consisted of 20 wt.% core fibres. The similar reason is also applicable as previous when the higher strength obtained from 10 wt.% of coir .

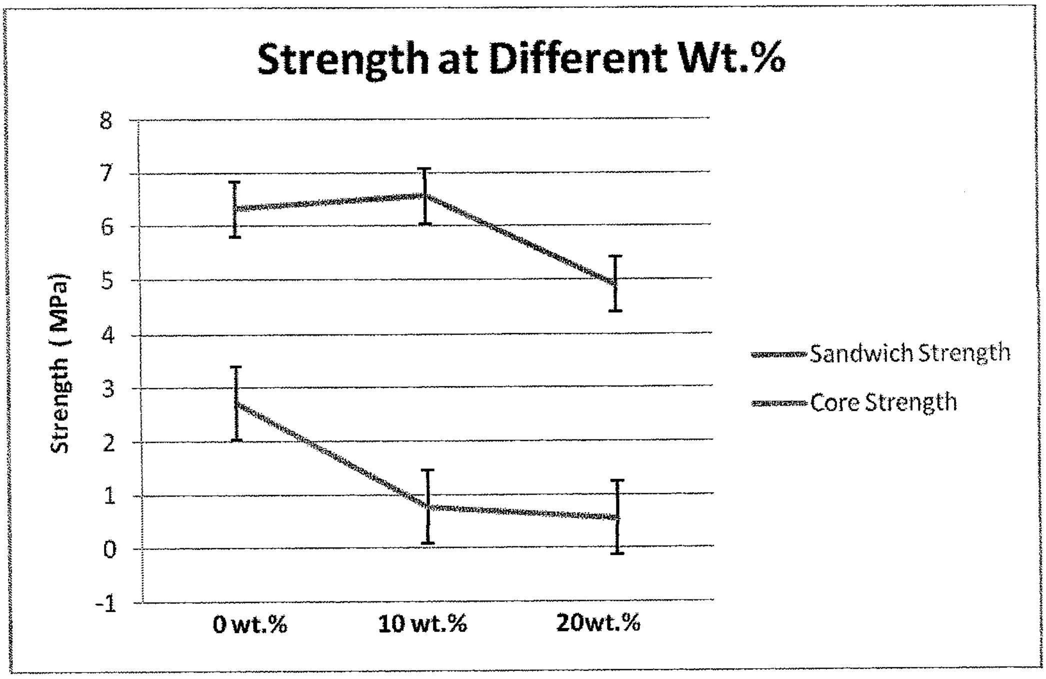

Fig. 7. Comparison of the results from maximum strength of foam core and sandwich panel with different coir fibre percentage

Summary

From the physical tests, it was found that the addition of the coir fibre produced lighter polyurethane foam cores and sandwich panels. Then, the maximum load and strength results reveal that the sandwich panels with 10 wt.% coir fibre offer the highest performance as compared to the others.

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