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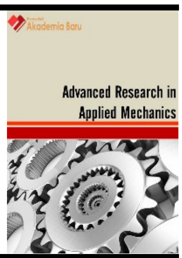

Influence of facesheet thickness of rubber wood honeycomb composites on flexural properties

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ABSTRACT

Honeycomb sandwich composite is a well-known material that receives good responds in the industries due to its low density and excellent mechanical properties. The thickness of the facesheet is one of the highly concerned parameter in the sandwich composite. It is to introduce its optimal mechanical properties with ideal facesheet thickness in terms of layer, so that there is no unnecessary weight from the facesheet added to the composite structure. In this research, the honeycomb composite is fabricated for high strength applications via vacuum bagging. Samples of solid rubber wood without facesheet, open cell honeycomb core and closed cell honeycomb core are investigated. The thickness of the facesheet in terms of number of layers ranging from one to five layers in the sandwich structure is investigated under flexural test according to the ASTM standard. It is noticed that the composite with three or five layers of facesheet have exhibited excellent flexural properties.

1. Introduction

Sandwich composite panel have received good feedback from the industries used for structural applications involving high strength supports. The unique design of honeycomb core definitely has much impact to the structure and contributed to its low density. Honeycomb core has helped to enhance the properties and functionalities of the composites [1-7].

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Light weight is one of the significant properties of a honeycomb composite. In the sandwich structure, the facesheet made up most of the mass compared to the thick core. The function of facesheet is very crucial in mechanical application requiring high strength composites. A thin facesheet can deteriorate its mechanical performance of the overall structure. However, a honeycomb with an extremely thick facesheet may contribute extra weight to the composite.

Thus, facesheet with appropriate thickness is the priority concern for many people in the industries and research field to minimize material wastage and optimal performance. Active researches are going on for this area. For instance, Atas et. al [8] researched on the effect of facesheert thickness on low velocity impact response in composites. Narasimhan et. al [9] focused on the strength and stiffness properties at different plastic facesheet thickness and distance between the flexural supports. Nagasankar et. al [10] investigated the thickness of facesheet for damping purposes. Effect of facesheet and foil on blast resistance subjected to underwater explosion was also studied [11]. The relationship of core-to-facesheet thickness ratio with shear and normal deformation is reported by Madhukar and Singha [12]. On the other hand, Mao et. al [13] explored on the facesheet to core thickness ratio on circular sandwich plate. Yang et. al [14] investigated on the effect of facesheet thickness on the penetration resistance of aluminium sandwich panels. The analysis of facesheet thickness on sound transmission loss characteristic of sandwich is carried out by Arunkumar et. al [15].

In general, the mechanical properties increase with the thickness of facesheet. However, it is important to determine its optimal thickness for tensile and flexural properties. The focus of this research aims to investigate the thickness of facesheet in the honeycomb composites by finding out the suitable number of facesheet layers for excellent tensile and flexural performance in the honeycomb sandwich composite.

2. Material preparation and experimental set up

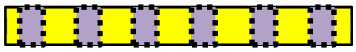
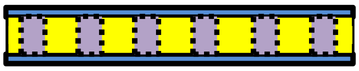
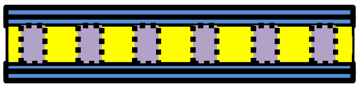
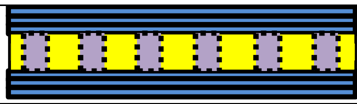
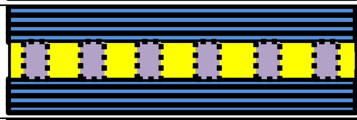
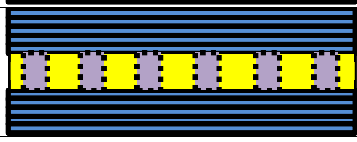
2.1. Fabrication

There are three types of samples were fabricated for flexural test: solid rubber wood without facesheet, open cell honeycomb core rubber wood (without facesheet) and closed cell honeycomb core with different facesheet thickness. Dimension of rubber wood sized 1000 mm x 100 mm x 8 mm was prepared. The rubber wood was prepared with the laser cutter to form hexagonal shape of honeycomb core. Glass fiber was used as the facesheet material with different thickness ranging from two to ten layers with the increment of two layers, forming one to five layers on each side of the facesheet. The glass fiber was laid layer by layer and reinforced by the unsaturated polyester resin. The desired number of layer of glass fiber was laid on one side of the facesheet, the rubber wood honeycomb core was placed and after that the rest of the glass fiber was spread as depicted in Table 1. The composite was then compressed in the vacuum bagging process for 8 hours at the room temperature and left to further cure for one day. After that the composite was cut into its required dimension for the test.

2.2. Flexural test

The specimens were prepared into the dimension of 220 mm x 30 mm x t mm (t is the respective thickness) as according to the procedures in ASTM C393 for the flexural properties performed using the Universal Testing Machine (UTM). The three-point bending is the most common flexural test for composite materials. The crosshead speed was set to 2 mm/min. Force was applied on the specimens until the specimens fractured and broken as shown in Fig. 1. The test was carried out at the condition of 23 ± 3°C and average operating humidity of 50 ± 5 %. Five specimens from each sample were tested to obtain the results calculated using Eq. 3, and Eq. 4.

Table 1
The glass fiber and rubber wood honeycomb core arrangement

Serial Number	Predicted Thickness	Arrangement
Control 1 Solid Rubber Wood (without facesheet)	(0.46 mm × 0) + 8 mm = 8.92 mm	
Control 2 Open Cell Honeycomb Core Rubber Wood (without facesheet)	(0.46 mm × 0) + 8 mm = 8.92 mm	
SN 1 (Honeycomb core + 1 layer of fiber glass)	(0. 46 mm × 2) + 8 mm = 8.92 mm	
SN 2 (Honeycomb core + 2 layers of fiber glass)	(0. 46 mm × 4) + 8 mm = 9.84 mm	
SN 3 (Honeycomb core + 3 layers of fiber glass)	(0. 46 mm × 6) + 8 mm = 10.76 mm	
SN 4 (Honeycomb core + 4 layers of fiber glass)	(0. 46 mm × 8) + 8 mm = 11.68 mm	
SN 5 (Honeycomb core + 5 layers of fiber glass)	(0. 46 mm × 10) + 8 mm = 12.6 mm	

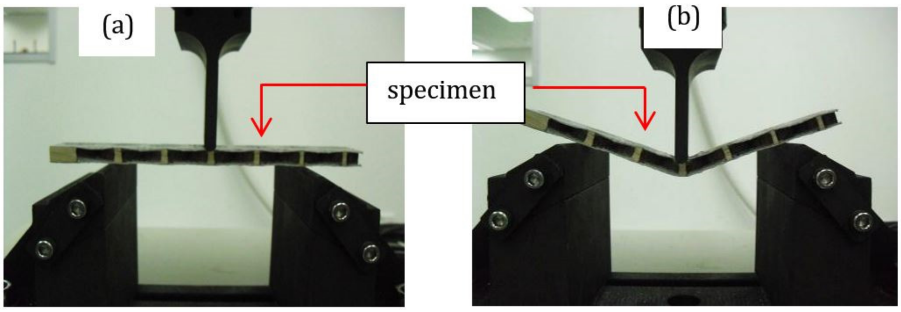


Fig. 1. Flexural test (a) beginning of test (b) ending of test

$$\text{Flexural Strength, FS (MPa)} = \frac{3FL}{2bd^2} \quad (3)$$

$$\text{Flexural Modulus, } E_f \text{ (MPa)} = \frac{L^3F}{4bd^3} \quad (4)$$

In these formulas the following parameters are used:
b = width of beam
d = thickness of beam
F = Load at failure
L = Beam span between the supports

3. Results and discussion

3.1. Flexural test

Table 2
Results of flexural test

No	Width, b (mm)	Thickness, d (mm)	Beam between Span, L (mm)	Density, ρ (kg/m^3)	Maximum Force, F_{max} (N)	Flexural Strength, FS (MPa)	Flexural Modulus, E_f (MPa)
Control 1	31.2700	7.1000	53.5	631.5314	700.00	35.6368	2394.3990
Control 2	33.5900	8.1700	52.0	171.7636	34.17	1.18874	65.5721
SN 1	30.1050	9.2267	53.9	372.9751	255.31	8.0567	423.0618
SN 2	30.0433	9.8367	53.9	535.3931	300.00	8.3463	411.0914
SN 3	30.1533	10.7417	54.1	713.5053	681.39	15.8881	721.0673
SN 4	29.8700	11.7600	53.9	817.1179	746.15	14.6080	601.8359
SN 5	30.7760	12.6500	54.2	844.8623	1112.82	18.3706	711.0155

Flexural strength which is also known as the bend strength or modulus of rupture is the maximum stress experienced in the composite at its moment of failure. On the other hand, flexural modulus is the ratio of stress to strain in flexural deformation during bending. In terms of density in Table 2, Control 1 is ranged between SN 2 and SN 3. However, its flexural strength and modulus are much higher than SN 3 as well as SN 5 which has the thickest facesheet. In this case, solid rubber wood as in Control 1 exhibits excellent flexural properties. It is because solid rubber wood has significant bending performance within it [16].

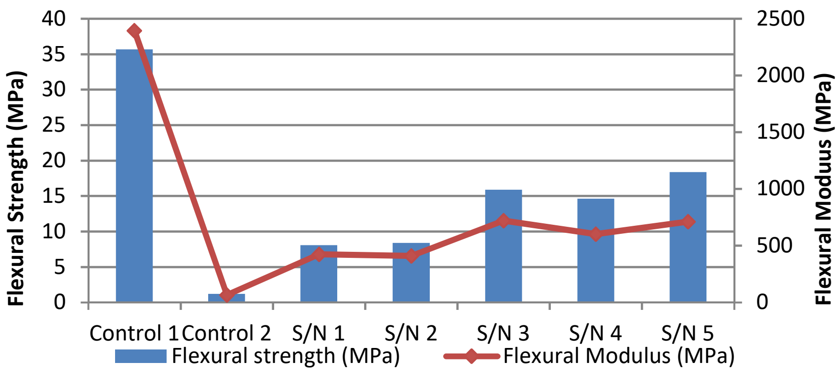


Fig. 2. Flexural strength and flexural modulus versus different composites

Comparison in terms of flexural strength and flexural modulus between Control 1 and Control 2, it is found out that Control 1 is the highest as well as 30 and 36 times higher than Control 2. On top of that, Control 2 possesses the lowest flexural properties among all of the specimens due to the absence of facesheet as shown in Fig. 2. Besides, Control 2 is open cell honeycomb rubber wood without facesheet. SN 1 is the structure of Control 2 added with a layer of facesheet. Facesheet made up the most of the weight, therefore, the density of SN 1 is more than one fold higher than Control 2. The flexural strength and modulus of SN 1 is more than six folds of Control 2.

The flexural strength and modulus of SN 1 and SN 2 only differ by approximately 1 % and 3 % respectively with addition of a layer of glass fiber and slight increase in density. On the other hand, flexural strength and modulus of SN 4 drop 8 % and 16 % respectively as compared to SN 3.

Meanwhile, SN 5 and SN 3 have the highest flexural strength and modulus respectively in terms of closed cell honeycomb core.

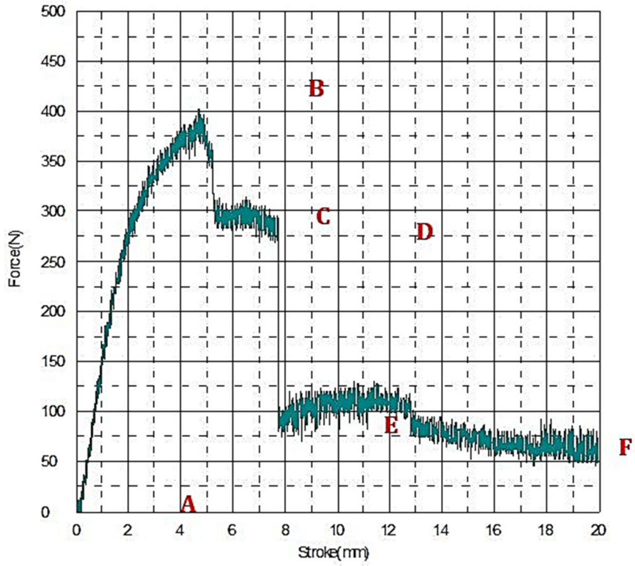
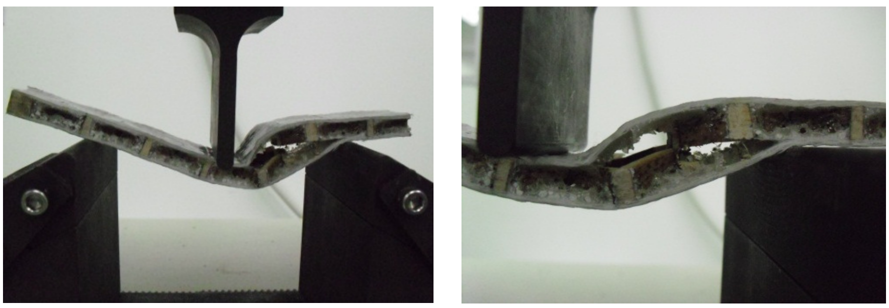


Fig. 3. Force-stroke curve for SN 1-6 for flexural test

The graph of force versus stroke for SN1-6 for flexural test is shown in Figure 3. Point A is the starting of the test. The force is increased from point A to B to approximately 400 N with less than 5 mm stroke. Point B is the maximum force required to exert to the honeycomb composite in order to break the composite. In this region, crack is initiated and propagated. From point B to C, the force is slightly decreased due to the initial break between fiber and matrix. After that, there is almost the similar amount of force is applied to the specimen for further bending seen from point C to D. The force is dropped drastically from point D to E as the result of bending from the previous stage with most of the cracked fiber and core as shown in Fig. 4. The force continues to drop with its core unable to withstand bending force as the stroke increases as seen from point E to F.



(a) (b)

Fig. 4. Failure of core and glass fiber facesheet

In the flexural test, there are two extreme outer layers which are subjected to two different forces. The top layer experiences maximum compressive stress while the bottom layer of facesheet is under maximum tensile stress [17-19]. Meanwhile, the central honeycomb core is the neutral plane is experiencing shear stress as a result of a gradient of two opposite stresses at the interface [20]. The top and bottom layers of facesheet in this condition is known as extreme fibers [21-23]. As the force is increased, the stresses on the extreme fiber increase until the tensile strength of the composite is reached [24]. Therefore, this causes flexural cracking of the specimen.

When a composite structure is under bending test, the phenomenon of top layer facesheet often is the first to experience skin wrinkling compared to the bottom facesheet [25,26]. It is due to the extreme compressive stress exerted on the top layer of facesheet as depicted in Fig. 5 [26-28]. Part of the skin begins to detach from the honeycomb core as the bending force is increased.

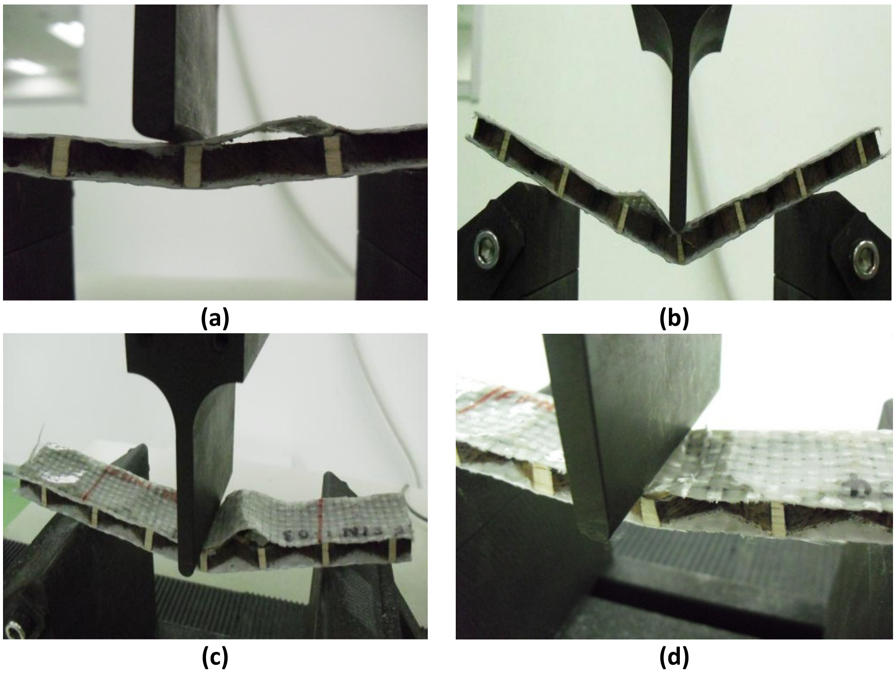


Fig. 5. Delamination at the top facesheet of specimen

4. Conclusion

Solid rubber wood, open cell honeycomb core and closed cell honeycomb core with different facesheet layers ranging from one to five layers were tested for the flexural properties. Rubber wood exhibited excellent flexural performance especially in the form of solid rubber wood. Whereas in the form of sandwich composite, it is realized that the honeycomb core with three or five layers are having excellent flexural properties with its corresponding core thickness of 8 mm.

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