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Mechanical Properties of Mahang (Macaranga) Wood as a Core Material in Sandwich Composites

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ABSTRACT. In this study, mechanical properties from clear specimens of mahang wood were investigated to determine the congeniality of this species to be used as balsa alternative in the construction of sandwich composite. Several ASTM standards were adopted to establish valid procedures to conduct the experimental investigation. 3-point-bending, compression and tensile tests were executed by using universal testing machine (UTM). The results obtained were compared with balsa wood. It was found that mechanical properties of mahang wood are comparable to balsa except for compressive Young's modulus where it exhibited slightly lower than balsa which signifies mahang wood has lesser elastic properties in compression. The most significant finding to emerge in this study is that mahang wood seems to be a viable alternative to be used as a core in sandwich composite as it possess almost similar mechanical properties as balsa wood.

Keywords: *Mahang wood core, Fiberglass reinforced skin, Bending, Tensile, Compression;*

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1. INTRODUCTION

Low weight structure with high bending stiffness is always desirable in structural construction. In transportation sector especially marine and aerospace, weight reduction means less fuel consumption which translates into cost saving. The most practical way of reducing weight without significantly affecting its bending stiffness is to adopt sandwich structure [1]. The ability to provide less weight structure while maintaining high strength property expand the demand for sandwich composite in the manufacturing industry. Utilization of composite during recent year has been driven by the fact that sandwich composite offers low weight structures with high flexural stiffness. High strength-to-weight ratio balsa wood is among the most widely desired core material of the sandwich structure. It has been extensively used in the most sandwich structure in recent times. Sandwich structure in marine has found its biggest application in the Skjold class vessel which had its body made entirely of sandwich composites [2]. Sandwich composites in Skjold not only contributes to its lightweight structure, it also provides excellent impact properties, low infrared and radar absorbent properties.

Environmental concern raises the urge for the utilization of eco-friendly materials. Natural based materials are always preferable to comply with this demand. Srivaro et al. [3] conducted a study to develop a lightweight sandwich panel from natural resources. It has conclusively been shown that lightweight sandwich panel made from rubber wood veneer skins and oil palm wood exhibited superior dimensional stability and excellent mechanical strength. The study provides important insights into the potential of natural resources in the application of lightweight sandwich panel. In another similar series of study, Azmi et al. [4] have highlighted the relevance of coconut coir fibres in reinforcing polyurethane foam core of sandwich composites. Mechanical properties of sandwich composites with 5 wt% coconut coir fibres showed a significant improvement compared to 0 wt% of coconut coir. Malaysians are blessed with one of the oldest and most myriad biological species tropical rainforest in the world. Most of the high quality woods are being fully utilized in various applications ranging from building construction, furniture, tools and also paper products. However, lesser known wood species (LKS) are not being maximised in terms of utilization due to either lesser quality or lack of information regarding these species. Macaranga or locally known as mahang wood is a lesser known wood species that locally available in Malaysia. It is one of those fast growing pioneering trees that naturally grow naturally in the forest. Due to fast growth, the density is very low, typically varied from 270 to 495 kg/m^3 [5]. Hence this paper aims to investigate the mechanical properties of mahang wood to determine the congeniality of this species to be used in the construction of sandwich composite by comparing the mechanical properties to balsa wood.

2. MATERIALS AND METHOD

A 10 m tall mahang tree with diameter at breast height (DBH, 1.3 m above the ground) of 78 cm was obtained from Agro Park of Universiti Malaysia Kelantan. The age was estimated to be about 8 years based on the periodic annual increment (PAI) of 1.5cm per year. All logs were marked and painted on both end of the cross section to prevent excessive water loss and fungal attack. The process of cutting the logs into small clear specimen was done by the Forest Research Institute Malaysia (FRIM). The logs were cut into lumbers. The lumbers were then cut into blocks for mahang core and also for tensile, compression and flexural specimens according to ASTM standards. Lumbers were pre-dried in a force convection oven at 50 °C for 12 days until 12% moisture content attained.

Sandwich composites skin laminate were manufactured from plain woven E-glass fabric (0.166 kg/m^3, Fibreglast Company) and epoxy resin (Fibreglast Company) using hand lay-up process. Resin was applied by using hand brush and roller was used to remove trapped air bubble and excess resin. 50:50 fibre-matrix volume ratios were used to impregnate the fabric. Individual blocks of mahang wood measure 100 × 100 mm were adhesively combined into panels of 300 × 300 mm for sandwich core. The core grains were aligned in the through-thickness direction. The core was bonded to the skin laminates using epoxy resin. The sandwich panel was then consolidated by using vacuum-bagging process. The consolidation process was left to run for 24 hours. Once consolidated, the sandwich panel was post-cured in an oven at temperature 80 °C for 2 hours.

(a) (b)

Fig.1 (a) Mahang core of sandwich composite and (b) Sandwich composite with fibreglass face skin and mahang core

The specimens for mahang wood were prepared based on ASTM D-143: Standard Test Method for Small Clear Specimen of Timbers, section 16 which specifies the methods and procedures for handling tension parallel to grain test [6]. Specimens were tested by using UTM (Testometric M500-50CT). The machine was set to elongate the specimen at a uniform rate of 1 mm/min. Samples for sandwich composite were prepared in accordance to ASTM D-3039: Standard Test Method for Tensile Properties of Polymer-Matrix Composite Materials [7]. The dimension measures 250 mm in length and 25 mm in width with thickness of 10 mm as required by the standard. A standard head-displacement rate of 2 mm/min was set to elongate the specimens.

Axial compression test were carried out using UTM as per ASTM D-143 section 9 for compression parallel to grain. The specimens measure 50 × 50 × 150 mm³. The tests were performed using UTM through a 5 kN load cell. Compression was continuously applied at crosshead speed of 0.305 mm/min. Sandwich composite were tested according to ASTM C-365: Standard Test Method for Flatwise Compressive Properties of Sandwich Cores [8]. The specimens were made into 90 × 90 × 45 mm³. The specimens were compressed at standard head-displacement rate of 0.5 mm/min.

Mahang beams with dimensions 25 × 25 × 410 mm were tested in static bending test. 3-point bending test was performed in accordance with ASTM D-143, section 8 which specifies the methods and procedures for conducting static bending test. Testing was conducted UTM with loading span of 360 mm equipped with 222 N load cell. The loads continuously applied at a rate of 1.3 mm/min. Specimens for sandwich composites were prepared and tested according to standard requirement of ASTM C-393: Standard Method for Core Shear Properties of Sandwich Construction by Beam Flexure [9]. The specimens measure 200 mm in length and 75 mm in width and thickness of 20 mm. The displacement rate was set at 6 mm/min to deflect the beam under load.

3. RESULTS AND DISCUSSIONS

Tensile test assessed the strength and stiffness of mahang wood and sandwich composite in breaking under tension. The results of tensile strength and tensile modulus for mahang wood and sandwich composite consisting mahang core and fibreglass face skins are shown in Fig. 2.

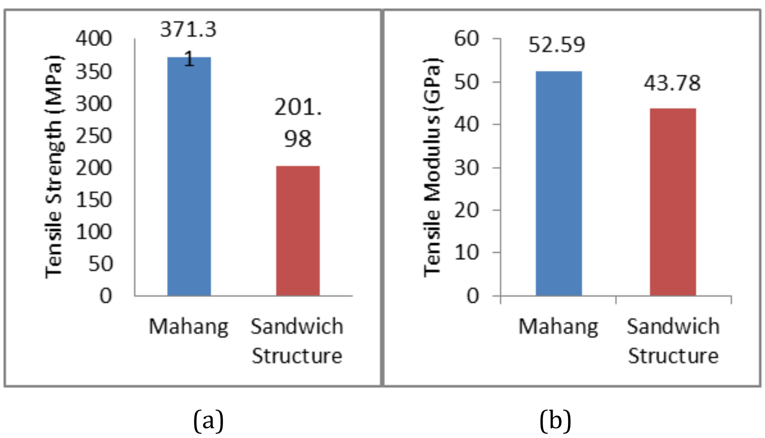


Fig. 2 Results of (a) tensile strength and (b) young's modulus comparison for mahang wood and sandwich structure.

The ultimate tensile strength (UTS) corresponds to the maximum tensile stress a material can sustain prior to failure is often referred as tensile strength. Tensile strength and young's modulus of mahang wood obtained in this study are 371.31 MPa and 52.59 GPa respectively. Tensile properties of mahang wood in this experimental work is significantly higher than tensile properties of balsa wood as reported by Soden and McLeish [10]. They reported the value of 31.5 MPa for tensile strength and 5.17 GPa for tensile modulus. Mahang wood exhibited ten times stronger than balsa wood. Both tensile strength and tensile modulus of wood are slightly higher than sandwich structure. Although sandwich structure incorporating fibreglass face skins, the grain alignment in sandwich structure is perpendicular to the direction of tensile loading which make it weaker as it easily tearing apart the wood fibres. As for wood tensile tests, the grain aligned parallel to the direction of tensile loading. As a results, the wood cells working together in axial direction and act as tiny column or tubes to resist tensile loads. The load-elongation curve obtained from tensile test is presented in Fig. 3. The first part of the graph shows slightly linear elastic behavior before plastic deformation occurs which transform the linear graph to curvature. Finally, a sudden drop occurs to signify an almost brittle rupture [11].

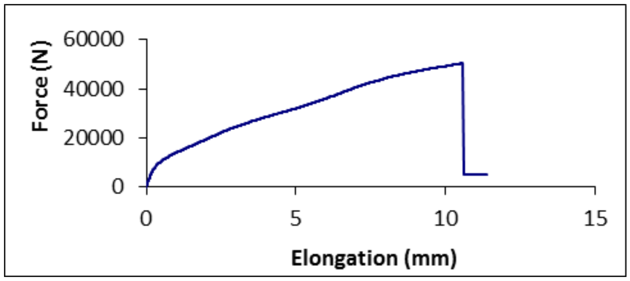
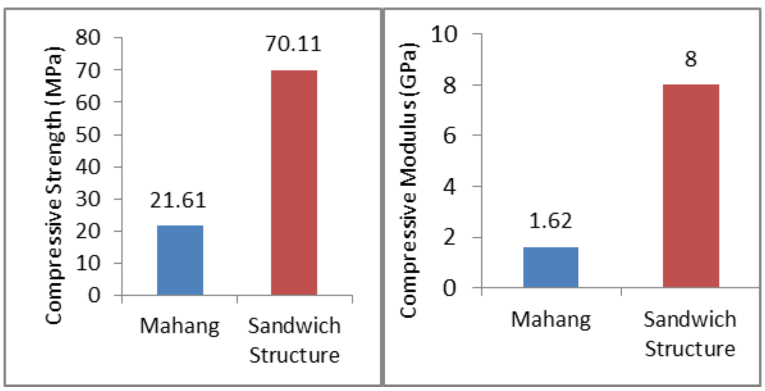


Fig. 3 Load-elongation curve for mahang wood specimen in tension

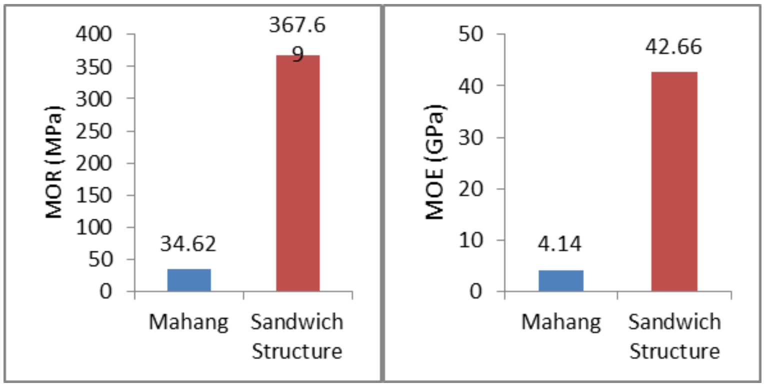
Compression test was used to determine the reaction of mahang wood and sandwich structure under compressive loading. The compressive strength and compressive modulus for mahang wood and sandwich composite is presented in Fig. 4.



(a) (b)

Fig. 4 Result shows (a) compressive strength and (b) Young's modulus comparison for mahang wood and sandwich structure

Compressive strength of mahang wood obtained in this study lies in the range of compressive strength of balsa wood established in previous research [10,12]. They reported minimum value of 14.7 MPa and maximum of 43 MPa while this study yield a value of 21.61 MPa. When load is subjected at axial direction or parallel to grain, the fibres can support load greater than their weight [13]. However, compressive modulus of mahang wood in this experimental work is lower than balsa. Da silva and Kyriakides in their study revealed a value of 6.62 Gpa for balsa wood whereas mahang wood in this study has a maximum deflection at 1.62 Gpa. This result suggests that balsa wood has better elastic properties and better in resisting deformation than mahang wood. The graph in Fig. 4 shows that there has been a steep increase in the value of compression strength and modulus for sandwich structure in comparison to wood. Sandwich composites with mahang core offer ten times higher compression properties compared to mahang wood itself. Sandwich structure can support a distributed load up to 70.1 Mpa. Efficiency of sandwich structure to resist compression load is due to the fact that high strength fiberglass face skin act as protective shield to protect less strength core material. 3-point bending test was performed to evaluate the bending strength and stiffness of mahang wood and sandwich structure. Fig. 5 shows the results of modulus of rupture (MOR) and modulus of elasticity (MOE) of mahang wood and sandwich structure.



(a) (b)

Fig. 5 (a) MOR and (b) MOE comparison for balsa wood and sandwich structure

MOR is a measure of the maximum load a material can sustain in bending before rupture. The flexural stress at which fracture occur is corresponding to the MOR It determines the maximum strength while MOE determines the stiffness of the wood whereby it measures the amount of deflection a load causes in a material. It can be seen from the graph in Fig. 5 that the results obtained for mahang wood are 34.62 MPa and 4.14 GPa. During bending, the wood fibres on the upper part experience compression and the wood fibres on the lower part experience tension. Fig. 6 depicts the crack propagation started from the bottom of the specimen due to fibres failure in tension rather than in compression.

Fig. 6 The crack at the lower parts of the specimen that explains the wood fibres fails due to tension stress during bending

Such failure mode is termed as 'cross-grain tension' as specified by ASTM D-143. Previous studies on the bending properties of balsa wood has reported the strength of balsa is in the range of 21.6 to 70 MPa while MOE in their investigation yield a value of 3.4 to 8 GPa [12,14]. These results suggest that mahang and balsa wood are comparable in terms of bending strength. Bending properties of sandwich structure increase by 10 times compared to wood, similar to compression properties. This can be explained by the presence of core and skins in resisting buckling when subjected to load [15].

4. SUMMARY

The mechanical properties of mahang wood were investigated. Bending strength and stiffness of mahang wood are comparable with balsa as it lies in the range of strength and stiffness of balsa wood. The mechanical strength is considerably high that it yields high strength to weight ratio properties of mahang wood. Tensile strength in this study emerges substantially higher than balsa wood. This indicates the outstanding resistance of mahang wood in breaking under tension. However, young's modulus in compression shows otherwise. The relevance of mahang wood in core of sandwich composite is clearly supported by the excellent mechanical properties. The findings of this investigation add to a growing body of literature on the potential of lesser known wood species as a core in sandwich composite. In general, therefore it seems that mahang wood can be considered as a practical applications for the construction of sandwich composite core.

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