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Microstructure and Physical Characterization of Mahang (*Macaranga*) Wood as a Core Material in Sandwich Composites

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ABSTRACT. Mahang *(Macaranga)* wood is one of the lesser known wood species (LKS) available in Malaysia. It is one of those underutilized fast-growing pioneering species. Categorized as light hardwood timber, mahang wood is considered as a viable alternative to be utilized in the construction of sandwich composite. Typically, the core of sandwich composite is made of balsa wood. This study aims to investigate the physical properties of mahang wood in attempt to employ this underutilized species as a core in sandwich composite. Samples of mahang wood were analysed for physical properties and the microstructure was observed under scanning electron microscope (SEM). Density of wood and core were evaluated by considering the oven dried mass and green volume of the specimens. Immersion of sample in tap water was carried out for determination of water absorption properties by considering the density change after period of immersion. Several ASTM standards were adopted to establish a valid procedure to conduct the experimental investigation. The results obtained were compared with balsa wood. Results showed that density of mahang wood falls within the range of balsa wood density. Water absorption test revealed the water absorption properties of mahang is less than balsa wood which signifies that water resistant properties of mahang is obviously better than balsa wood. Microstructure of mahang wood observed under SEM showed a resemblance between mahang and balsa wood. The relevance of mahang wood as a core in sandwich composites is clearly supported by fact that mahang wood possesses almost similar physical properties as balsa wood.

Keywords: Mahang (Macaranga) wood, Water absorption, Density, Sandwich composites;

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1. INTRODUCTION

The increased significant of weight reduction expand the demand for sandwich composite in the manufacturing industry. Utilization of composite during recent year has been driven by the fact that sandwich composites are capable to offer low weight structures without compromising the bending stiffness. The high bending stiffness of sandwich structure can be explained by the separation of the two adjacent skins by a thick lightweight core. Commonly used materials for sandwich composite core are balsa wood, nomex honeycomb or polyurethane foam [1,2]. Separation of skins by the core increases the moment of inertia whereby no significant weight added to the structure [3]. Moment of inertia is a measure to indicate the ability of a profile to resist bending. The higher the moment of inertia the more efficient the structure can resist bending and buckling loads. Adoption of sandwich composites offers a benefit of weight saving, which in turn economically reduce the fuel consumption of naval structure. Sandwich composites in naval structure often concentrated on woven fibreglass and vinyl ester face skins with balsa wood core [4]. The applications of sandwich composites in naval structure are diversified since World War II. Some applications include patrol boats, hovercraft, deckhouse, mine counter measure vessels (mcmv) and corvettes [5].

In moving towards environmental sustainability, eco-friendly materials are always preferable. Wang et al. [6] introduced an ingenious hollow sandwich columns made of glass fiber reinforced polymer skins and a naturally growing paulownia wood core. They used paulownia wood as a core due to fast growing, low density, low price, and biodegradability of paulownia wood. Likewise, Srivaro et al. [7] performed an analysis on the nature based sandwich composite made of oil palm wood core with rubber wood veneer skins. The mechanical strength tested under three point bending is predominantly depends on the core density. Taken together, these studies emerged as reliable predictors on the potential of nature based materials in sandwich composites.

Malaysia's rainforest cover about 70% of total land area and it play host to highly diverse and unique biological species. The lesser known wood species (LKS) are still under-utilized by wood based industries due to either lesser quality or lack of information regarding these species. Focus has been placed on high quality wood such as acacia, teak, and rubber wood. Mahang *(Macaranga*a) wood is one of those LKS massively emerged in pioneering species in Southeast Asia [8]. It belongs to hardwood category with density typically varied from 270 to 495 kg/m^3 [9]. It exhibit low density, fast growing and biodegradeable qualities therfore, the main objective of this study is to investigate the microstructure and physical characterization of mahang wood in attempt to utilize this species as a core in sandwich composite.

2. MATERIALS AND METHODS

2.1 Materials and Core Fabrication. Samples were extracted from a 10 m tall mahang tree with diameter at breast height (DBH, 1.3 m above the ground) of 78 cm obtained from Agro Park of Universiti Malaysia Kelantan. Based on the periodic annual increment (PAI) of 1.5 cm per year; the age of mahang tree was estimated to be about 8 years. Prior to cutting and surfacing, the logs were marked and painted on both end to avoid excessive water loss and fungal attack. The process of cutting the log into lumbers was done by the Forest Research Institute Malaysia (FRIM). Lumbers were pre-dried in a force convection oven at 50 °C for 12 days until 12% moisture content attained. Physical tests were carried out on the clear specimens of mahang wood and core of sandwich composite (Fig. 1). Blocks of mahang wood with dimension 100 mm x 100 mm in length and width were combined into panel measures 300 mm x 300 mm for the core of sandwich composite. Epoxy resin from Fiberglast Company was used to adhesively combine the blocks. The panel was then left for 24 hours for curing process.

(a) (b)

Fig. 1 (a) mahang wood and (b) mahang core of sandwich composite

2.2 Density. Samples of mahang wood measures 25 mm × 25 mm × 25 mm conforming to ASTM D2395 (method A) [10] were evaluated for basic density. Oven dry mass of wood sample and green volume were recorded and applied in the basic density formula as follow:

$$\rho = \frac{m}{l \times w \times t} \quad (1)$$

Where:

ρ = Density

m = Oven dried mass of specimen

l = Length of specimen

w = Width of specimen

t = Thickness of specimen

The green volume refers to the freshly felled logs or the log that contained most of the moisture. In this experimental work, the green volume was recorded as soon as the cutting process is done to avoid any further loss of the moisture to the surrounding. The samples were then oven-dried in a force convection oven at 103 ± 2 °C until constant mass attained as required by the standard [11]. The constant mass was recorded as oven-dried mass.

Densities for mahang core specimens were evaluated as per ASTM C271 [12]. Test specimens of dimension 300 mm × 300 mm × 18 mm were pre-conditioned in an oven at temperature 40 ± 3 °C. Following this, samples were placed in a desiccator and be brought to room temperature. The samples were then carefully weighed by using electronic balance and measured the dimensions by using callipers. Recorded values were applied in the Eq. 1.

2.3 Water absorption. Water absorption test for mahang wood was carried out in accordance to ASTM D1037 [13]. Samples of mahang wood with dimensions 50 mm × 50 mm × 20 mm were immersed in tap water at temperature of 20 ± 3 °C for 24 hours. While for mahang core, samples with dimensions 75 mm × 75 mm × 15 mm as per ASTM C272 [14] were immersed in tap water of 23 ± 3 °C for 24 hours. The mass each sample was manually recorded before immersion. Since the wood and core samples were less dense than water, wire net was used to cover the sample to avoid the samples from floating on the surface of the water. Beaker was placed in a desiccator to avoid evaporation of water to the surrounding. After 24 hours, the mass of the wood samples immersed in tap water were recorded to determine the density change. Water absorption (WA) was calculated by using the following equation:

$$\mathrm{WA}(\%) = \left(\frac{m_1 - m_0}{m_0}\right) x\ 100 \quad (2)$$

Where,

m_o = Mass of specimen before immersion

m_1 = Mass of specimen after immersion

2.4 Scanning Electron Microscopy. Samples of mahang wood were observed under JEOL JSM-IT100 SEM for microstructural observation. The microscope operated at an accelerating voltage of 5-20 kV to develop an image by scanning the sample with a focused beam of high energy electrons. The samples to be observed were cut by using an industrial razor blade. A clean cut surface of mahang wood was used to obtain a fine cell detail.

3. RESULTS AND DISCUSSION

3.1 Density. As shown in Fig. 2, average density of mahang wood obtained in this study is 320 kg/m^3 while mahang core shows a slightly higher density.

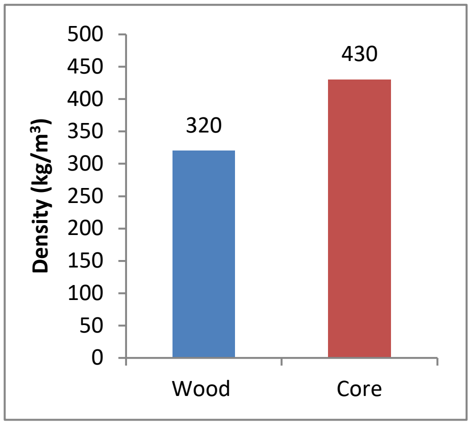


Fig. 2 Density of mahang wood and core

Based on Malaysian Grading Rules (1984) mahang wood is classified as light hardwood (LHW) which categorized all timbers with density less than 720 kg/m^3 under the same class [15]. Previously published study on physical properties of mahang wood revealed the density of mahang is in the range of 270 kg/m^3 to 495 kg/m^3 [16]. In comparison to balsa, mahang wood lies in the range of balsa density which has a minimum density of 60 kg/m^3 and reaching up 380 kg/m^3 [17]. The difference in the density value between wood and core is due to the addition of epoxy resin as an adhesive to combine the blocks together while forming core. Thus, making core denser than wood. However, it is still consider as lightweight panel with density less than 500 kg/m^3 [18]. Low density of mahang wood and core is desirable in the construction of sandwich composite which promotes high strength to weight ratio properties when combined with high strength skins.

3.2 Water absorption. The effect of water absorption on density change of mahang wood and core is shown in Fig. 3. Water absorption for mahang wood and core are 38.15% and 25.57%, respectively.

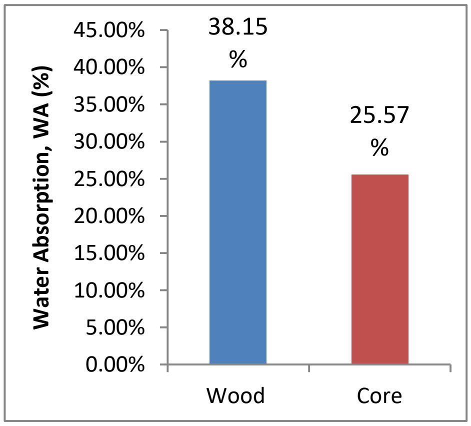
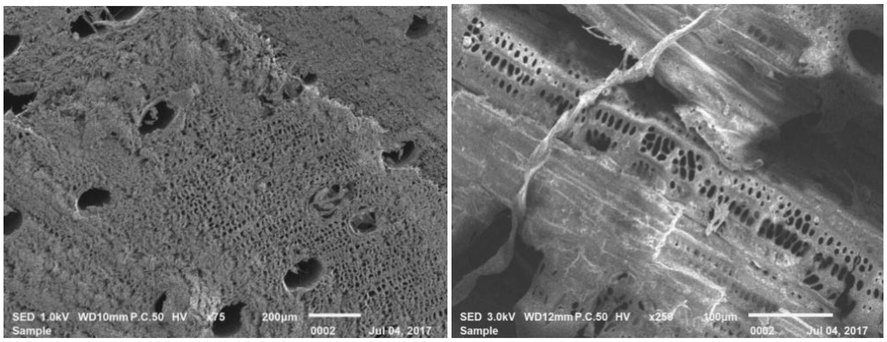


Fig. 3 Comparative percentage of weight gain by mahang wood and core specimens after 4 hours immersion in tap water

After 4 hours of immersion in tap water the wood specimen density increases by 38.15% from original density of 325.37 kg/m^3. The increase in density following the immersion is due to the water absorption by the vessels which mainly function as water conducting tissue in plant. Sadler et al. [19] investigated the effect of water absorption on the density change of balsa wood. It was found that balsa density immensely increase by 74% after 4 hours immersion in water. Water absorption rate of balsa wood is significantly higher than mahang wood. This finding signifies that mahang wood has better water resistance relative to balsa. The relative density of balsa is in the range of 2.7% - 26% while relative density of mahang wood in this experimental work is 22%. The low relative density reveals that balsa wood contains most of the empty spaces in the cellular structure compare to mahang wood [20]. Water occupied the empty spaces and consequently increase the density of balsa wood tremendously. Water absorption of mahang core is rather less than mahang wood. This is due to the presence of epoxy resin which partially occupied the empty spaces and leaving the vessels with less capacity for water absorption.

3.3 Scanning Electron Microscopy. Microstructure of mahang wood in Fig. 4 depicted the main type of cells showing the presence of vessels, rays and fibers similar to Balsa wood.



(a) (b)

Fig. 4 SEM micrographs of mahang wood showing the main type of cells in (a) cross-section view and (b) longitudinal view (magnification: 500x)

Fibers are long hexagonal prismatic cells that run axially along the trunk. In most hardwood species, fibers are the main constituents of the wood pulps. It functions exclusively as mechanical supporting cells to support the tree. Unlike fibers, rays run radially from the central pith of the trunk. It forms brick like parenchyma cells that responsible for sugar storage. Vessels are another important cells in mahang wood. It is much larger than rays and fibers which mainly responsible to transport fluids from the roots to the crown. It runs axially along the trunk similar to fibers. The presence of vessels or known as porosity in the stem hypothesized the low density of mahang wood.

4. SUMMARY

The physical properties of mahang wood were investigated. The average density of mahang wood proved the viability of mahang wood as a biodegradable and lightweight core material. Mahang wood has lower water absorption properties than balsa wood. In the construction of sandwich composite, core material with less water absorption is desired to avoid deterioration of sandwich composite due to swelling effect. The idea of utilizing mahang wood as core in sandwich composite is strengthen by the fact that microstructure of mahang wood resembles the microstructure of balsa wood. The experimental results presented in the paper provide new insights into the potential of mahang wood as an alternative to be used as a core in sandwich composite as it possess almost similar physical properties as balsa wood. The study has gone some way towards utilizing LKS in attempt to add value to those species.

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