Wahab, R., Fauzi, M. N., Mokhtar, N., Sulaiman, S. M., Ghani, M. S. R., Edin, T. (2020): Enhancing mechanical properties of Rhizophora apiculata through engineered laminated boards. Agriculture and Forestry, 66 (3): 53-64.

DOI: 10.17707/AgricultForest.66.3.05

Razak WAHAB[1]*, Norashikin MOHD FAUZI[2], Nasihah MOKHTAR[2], Mohamad Saiful SULAIMAN[1], Ros Syazmini MOHD GHANI[1], Taharah EDIN[1]

ENHANCING MECHANICAL PROPERTIES OF *RHIZOPHORA APICULATA* THROUGH ENGINEERED LAMINATED BOARDS

SUMMARY

A study in enhancing the strength properties of *Rhizophora apiculata* by turning the solid wood into an engineered laminated board was executed. The matured *Rhizophora* species was selected from peat swamp forest in Sibu, Sarawak. The trunk was segregated into three parts, namely the bottom, middle and top portion and subsequently sawn into wooden planks. The laminated boards were cut into specific thicknesses and immediately bonded with an adhesive by pressed drying. Preparation for solid and laminated boards testing samples followed the ISO and ASTM standards. Properties such as the moisture content, density, basic density, static bending (MOR and MOE) and compression were determined. The results show an improvement in properties from the solid to laminated board. The values in density, MOR, and MOE increased in the range of 2-6%, 29-42%, and 13-36%, respectively. However, the values of the moisture content, basic density, and compression, indicated a vice versa trend ranging from 1-2%, 2-6%, and 8-24%, respectively. The bottom portion was more durable and robust compared to the other portions.

Keywords: *Rhizophora apiculata,* solid wood, engineered laminated boards, physical and strength properties.

INTRODUCTION

Peat swamp mangrove forests inhabited the coastal and riverine shores of the tropics and sub-tropics (Zhang et al., 2015; González 2012; Chandra et al., 2011) and constituted a dominant coastal vegetation community in tropical Asia where Malaysia-Indonesia is the centre of distribution (Abdullah et al., 2018). Seventy species of mangrove plants distributed worldwide and divided into 20 genera (Spalding et al., 2010). According to Duke (2006), *Rhizophora apiculata*

[1]Razak Wahab, (corresponding author: drrazakw5181@ucts.edu.my), Mohamad Saiful Sulaiman, Ros Syazmini Mohd Ghani, Taharah Edin, 1University College of Technology Sarawak (UCTS), 96000 Sibu, Sarawak, MALAYSIA

[2] Norashikin Mohd Fauzi, Nasihah Mokhtar, Universiti Malaysia Kelantan, 17699 Jeli Campus, Jeli, Kelantan, MALAYSIA

Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

Recieved:31/03/2020 *Accepted:01/06/2020*

is a species of plant in the *Rhizophoraceae* family. The main agroforestry uses from this species are soil stabilization, coastal protection, wildlife/marine habitat for marine fauna and also as timber products which are fuelwood, charcoal, dyes, and traditional medicines (Alongi 2008; Mazda et al., 2007). Nowadays, mangrove species can be further enhanced in constructions of dwellings, making furniture, rafts, boats, fences and even as a dying agent from the extracted tannin (Nabihah 2015).

Economically the mangroves forests consist of both monetary and non-monetary such as forest industry, fisheries industry, wildlife conservation, tourism and environment protection (Chandra et al., 2011; Bennet and Reynold 1993). The most typical representatives' species in the mangrove forest are the *Rhizophora apiculata*, *Rhizophora mucronata* and *Rhizophora mangle* (Halim et al., (2013). The mangrove trees is a complex combination of roots, trunk, branches and leaves (Zhang et al., (2015), the trees can grow up to 30 metres in height with trunk diameters up to 0.5 metres in width, elliptic-shaped leaves stained dark green with simple green in the middle and reddish-brown at the base of the leaves, bisexual flowers, round-shaped fruit up to pearl-shaped and brown, 18-38 cm long and 1-2 cm wide (Sugiarto 2019). On properties perception, wood density is a critical characteristic defining the mechanical properties of the wood and its performance with high wood density has been found to decrease vessel implosion by reducing the mechanical stresses associated with the negative pressure in the water column during drought (Santini et al., 2013). Greenwood of the mangrove *R. apiculata* trunk possesses higher density than water, but dry mangrove wood with a lower density floats in seawater and resistance to the marine deterioration (Zhang et al., (2015).

Wood and modified wood-based materials have long been used in many applications due to their excellent features in aesthetic appearance, reasonable cost, ease of use, low density, high mechanical strength, etc. (Percin et al., 2015). Excellent mechanical properties enable them to be utilized in a broad range of products especially after undergoing modification in the production of layered (laminated) wood with better strength or bending properties (Gáborík et al., 2016). Wood laminating materials are obtained by bonding two or more layers with adhesive and joining the fibre directions of the layers parallel or perpendicular to each other (Cibo et al., 2018). Laminating is a technique that improves the value of the wood material while enabling changes in the wood's properties and can be altered via in various ways which comprise multiple layers of wood, most frequently in the form of veneers (thin slices), glued and pressed together (Gáborík et al., 2016). The established laminated products which are oriented strand board (OSB), laminated veneer board (LVL), Strand-based composites include parallel strand board (PSL), laminated strand board (LSL) and oriented strand board (OSL), and also Glue-laminated timber (GLULAM) (Shmulsky and Jones 2019; Wiegner et al., 2009; Ong 2015). The focal point of this study was to determine the strength of physical and mechanical properties via solid wood and laminated wood. The differences properties between portions (bottom, middle, and top) were also investigated. Previous studies related to cross-laminated bamboo, concentrated on the mechanical properties such as compressive, tensile, shear, and bending resistance no experimental procedure proposed for mangrove species, *Rhizophora apiculata*. More studies on mangrove species are needed by virtue of this study fills the identified research gap by focusing on its mechanical property's enhancement through engineered laminated boards.

MATERIAL AND METHODS

Sample Preparation

The *Rhizophora apiculata* used in this study was harvested from a mangrove forest in Sibu, Sarawak. The mangrove tree with an average height of 15 m and a diameter of 20 cm at dbh was selected. The tree was removed from the soil and cut into three (3) parts namely, the bottom, middle and top portion. The bottom, middle and top parts were part was cut 50%, 30% and 20% of the total length of the respectively. Subsequently, the samples was cut into the measurable sizes for physical and mechanical testing. The samples were divided into two groups namely solid-wood and laminated wood. The samples were cut by using a band saw into specific sizes and thickness. In group 2 (laminated), the samples with specific thickness were bonded together to perform as laminated wood. PVC glue branded, Pye Bond was used for the process. Samples were conditioning for 48 hours using clamping jig to maintain the position and imposed the pressure. The procedure followed the International Organization for Standardization, ISO 3131-1975 (Sulaiman et al., 2018; Wahab et al., 2017a) and the American Standard Testing Method, ASTM D 143 for mechanical testing (Ghani et al., 2018). The test was conducted according to the standard specification, International Organization for Standardization, Wood-determination of Density of Physical Test, ISO 3131-1975 (Sulaiman et al., 2018; Wahab et al., 2017a). The physical tests was carried out to determine the moisture content, density and basic density.

Moisture Content

The method that was used to determine the moisture content was based on oven-dry weight. In this study, the samples were cut into the following measurement of 25 mm x 25 mm x 25 mm with weight approximately 1–8g. All test was carried out according to the International Organization for Standardization which is ISO/TR 22157 (Wahab et al., 2018a; ISO / TR 22157 (2004).

Determination of Density and Basic Density

Density defined as the mass per unit volume, which is the moisture content of sample, at 12%. Basic density is defined as the mass per unit volume in oven-dry condition (Sulaiman et al., 2018; Wahab et al., 2018a). Samples of size 10 mm x 30mm x 30 mm were taken and oven-dried for 48 hours at 105±2°C to attain a constant weight. The samples were then weighed to obtain the oven-dried weight. To determine the green volume, the samples were placed into water under a vacuum of about 700 mm Hg for 24 hours until thoroughly saturated. The volume of the fully saturated samples was then obtained using the water displacement method.

Mechanical Test

The mechanical test was executed based on the standard specifications, American Standard Testing Method, Standard Test Methods for Mechanical Properties of Wood-based Structural Material, ASTM D 143-2 (Wahab et al., 2018b; Khalid et al., 2015; Anonymous 1974) with modification. Two tests were carried out namely, static bending tests and compression tests in parallel with the grain. The mechanical properties of samples were measured by using universal testing machine (UTM Instron 3639). Prior to the mechanical testing, the labelled samples were stored under a standard temperature of 20 ± 2°C and 65 ± 5% Relative Humidity (RH) or at least in a cold room and uniform temperature.

Statistical Analysis

Results presented as a mean ± standard error. The statistical analyses of experimental findings based on the one-way Analysis of Variance (ANOVA). A significant difference was statistically considered at the level of $P<0.05$. All experiment were triplicated (n=3).

RESULTS AND DISCUSSION

Investigate of Moisture Content

Three (3) types of physical tests conducted on mangrove samples prepared in two groups, namely group 1 (sample in solid-state) and group 2 (sample in double-layer laminate).

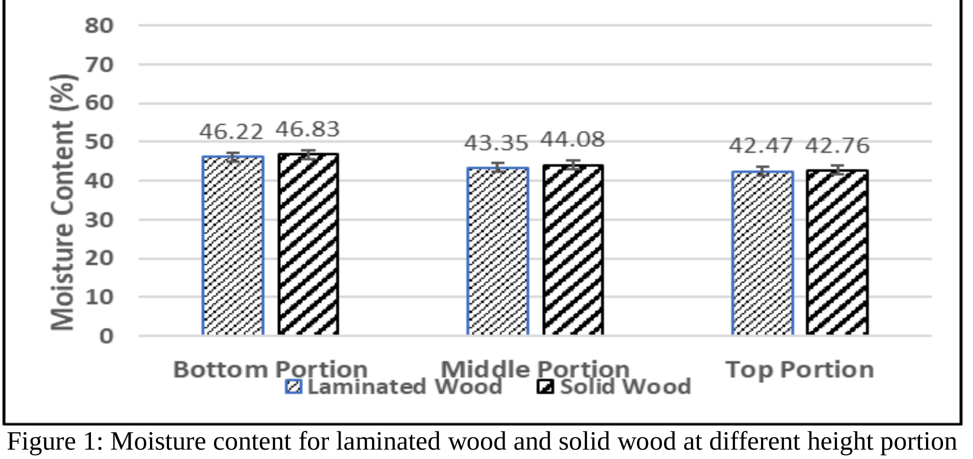

Figure 1: Moisture content for laminated wood and solid wood at different height portion

The measured physical properties comprised of moisture content (% MC), density (g/cm3) and basic density (g/cm3). Overall, the result for moisture content, indicated that the bottom sample recorded the highest moisture content (46.83%). The moisture content of the middle portion was recorded with 44.08%. The lowest percentage of moisture content was shown at the top portion with 42.761%. The graph of moisture content in sample group 2 (double-layer laminate conditions) indicated a similar trend. The highest percentages of moisture content was recorded in the bottom portion with 46.221%, followed by the middle and top portion with 43.352% and 42.473%, respectively. The statistical analysis (Table 1) highlighted there was no significant differences between the portions (bottom, middle, and top) to both groups (solid and laminated).

That result was influenced by different between trees and species or in the same tree. On a single tree, glucose or wood core moisture content or parts of each tree may be different. This may be due to the moisture content of the tree is influenced by the age of the tree, species, external factors such as the condition or area of growth of the tree and internal factors such as the structure of the wooden anatomy. Mangrove tree *Rhizophora apiculata* is a kind of tree where the base of the tree is soaked in a state of stagnant water all year round. The base part of the root, including the root was the closest part to the soil and serves to facilitate the absorption of water to other parts of the tree. Based on the results obtained, the bottom of mangrove trees has the highest percentage of moisture content compared to other parts, due to the presence of water around the habitat. Moisture content significantly affects the mass of the wood, its dimensions, volume, physical, and mechanical properties (strength), and its resistance to attacks by fungi, molds, and insects (Wałach et al., 2015).

Differentiation of Density and Basic Density

Figures 2 and 3, the result in group 1 (solid) indicated the highest density at a bottom portion with 0.91 g/cm^3 and followed by the middle and top portion with 0.88 g/cm^3 and 0.86 g/cm^3, respectively. In group 2 (laminated), the density were recorded as 0.93 g/cm^3, 0.91 g/cm^3, and 0.83 g/cm^3 for the bottom, middle, and top, respectively. According to Table 1, statistical analysis shows there was not significantly different between the portions at group 1 (solid). There was significant differences between portions at group 2 (laminated) with value $p \leq 0.05$. Nevertheless, the graph indicated that the trend of basic density in group 1 (solid) decreasing from bottom to the top with 0.80 g/cm^3, 0.76 g/cm^3, and 0.705 g/cm^3. In group 2 (laminated), it indicated that the highest basic density at the bottom of 0.752 g/cm^3 followed by the middle and top portions with 0.74 g/cm^3 and of 0.68 g/cm^3, respectively. The statistical analysis (Table 1) shows there were significant differences between portion for both groups (solid group and laminated group) with value $p \leq 0.05$. The difference in density of wood in parts is influenced by the structure of the wood anatomy, size and arrangement of cells, length and density of fiber, cell wall thickness and chemical content in the wood (Desch 1989). In addition, the moisture content in wood cells can affect the value of wood density, the specific gravity of wood, wood dimensions and other wood strengths. High moisture content increases the density value (Thelandersson and Larsen 2002). Based on the results obtained from the physical properties test, it can be explained that the laminated wood has slightly higher in density compared to the solid wood.

Figure 2: Density for laminated wood and solid wood at different height portion

Figure 3: Basic density for laminated wood and solid wood at different height portions

Table 1: Data analysis for physical tests in group 1 (solid) and group 2 (laminated)

Group	Tests Type	Sum of square	Mean square	P-Value	Sig. level
Solid	MC	34.5386	17.2693	0.1448	ns
	Density	0.0057	0.00288	0.1465	ns
	Basic Density	0.0170	0.0085	0.0261	*
Laminated	MC	30.7368	15.3684	0.2981	ns
	Density	0.0229	0.0114	0.0188	*
	Basic Density	0.0110	0.0055	0.0124	*

*** : significant at $P < 0.01$; * : significant at $P < 0.05$; ns ; not significant*

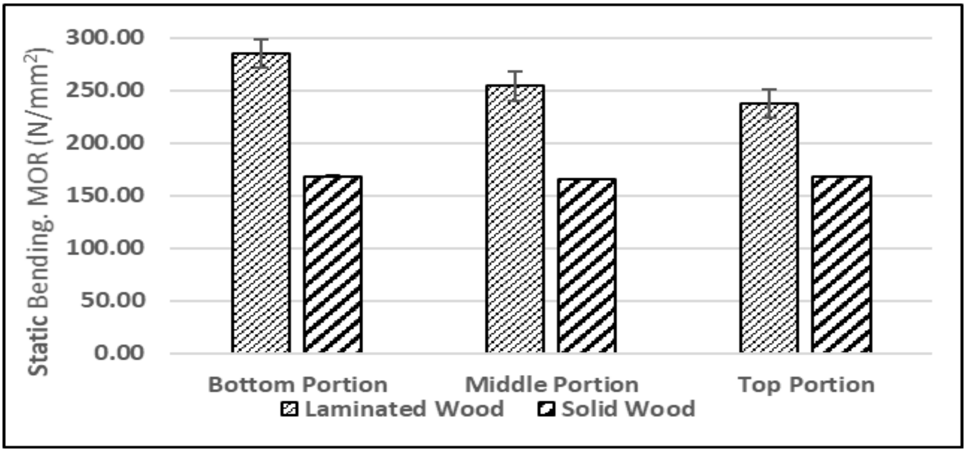

Figure 4: MOR for static bending test on laminated wood and solid wood solid at different height portions.

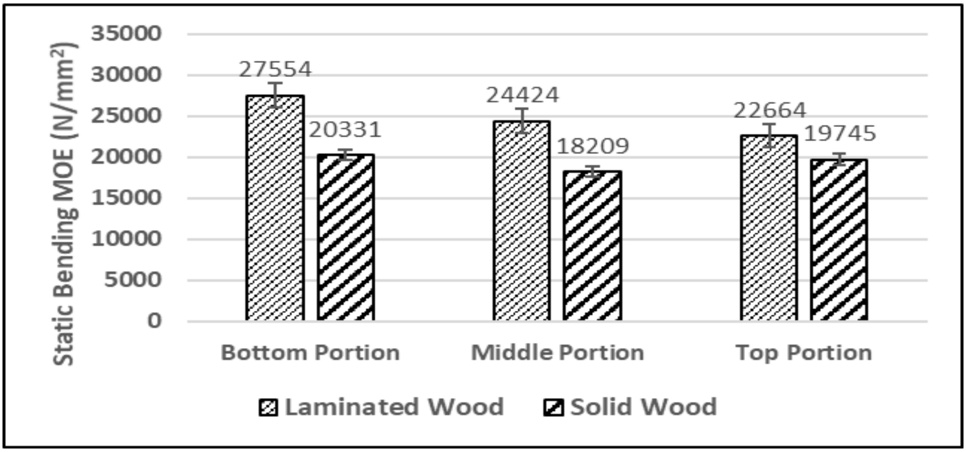

Figure 5: MOE for static bending of laminated wood and solid wood at different height portions.

The results supported by Percin et al., (2015), highlighted that density of the laminated wood materials has more superior values than the solid wood materials which were representing their kinds. The increase was assumed to be due to glue usage and layered structure.Determination of Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) on Static Bending Test.

The result (Figure 4) in group 1 (solid) indicated that bottom portion has the highest MOR value with 168.200 N/mm^2 and followed by the top and middle portions which were167.875 N/mm^2 and 165.275 N/mm^2, respectively. Whereas in group 2 (laminated), it indicated the trend of MOR value decreasing from bottom to the top, with the value of 284.825 N/mm^2, 256.850 N/mm^2 and 237.350 N/mm^2, respectively. There was no significant difference between portions in group 1 (solid) (see Table 2). Notwithstanding, there was a significant difference between portions in group 2 (laminated) with value of p≤0.05. Figure 5 indicated the MOE in group 1 (solid) has a higher value on the bottom portion with 20330.805 N/mm^2 and followed by the top and middle portion which is 19744.858 N/mm^2 and 18208.875 N/mm^2, respectively. Meanwhile in group 2 (laminated) highlighted the MOE value in decreasing order from bottom to the top, which is 27553.660 N/mm^2, 24424.423 N/mm^2, and 22664.093 N/mm^2, respectively. Nevertheless, (Table 2) the statistical analysis in group 1 (solid) and group 2 (laminated) highlighted there was no significant difference between a portion (p≥0.05).

Table 2: Table 1: Data analysis for static bending tests in group 1 (solid) and group 2 (laminated).

Group	Test	Sum of square	Mean square	P-Value	Sig. level
Solid	MOR	20.5617	10.2808	0.945	ns
	MOE	4.9065	2.45325	0.616	ns
	Compression	65.838	32.919	0.2301	ns
Laminated	MOR	4647.43	2323.72	0.0289	*
	MOE	9.60688	4.80344	0.155	ns
	Compression	472.178	236.089	0.0007	**

*** : significant at P < 0.01; * : significant at P < 0.05; ns ; not significant*

The factor that influence the evaluation of wood strength is density. The mechanical characteristics or wood strength, such as static wood bending is closely related to the density of the wood (Rasat et al., 2011; Haygreen and Bowyer 1930). The static flexural strength of the wood will increase by increasing the density from the base to the top. It can be explained that the base portion of mangrove trees Rhizophora apiculata has the highest static bending test value also has the highest density value. The strength of wood is also influenced by other factors such as genetics, tree parts, presence of timber knots, wooden anatomy structures, length and density of cells, tree age or species (Desch 1989; Khalid et al., 2010).

Determination of Compression Test

Figure 6 shows the highest value of compression on group 1 (solid) at a bottom portion with 71.593 N/mm^2 and followed by the top and middle portion with respectively around 68.715 N/mm^2 and 65.855 N/mm^2. The result in group 2 (laminated) indicated that the compression value decreasing from bottom to the top portion with 65.955 N/mm^2, 64.653 N/mm^2, and 52.045 N/mm^2. The statistical analysis result (Table 2) highlighted that there was no significant differences between portions in group 1 (solid) whereas group 2 (laminated) indicated that there was a significant differences between portions with value p≤0.01.

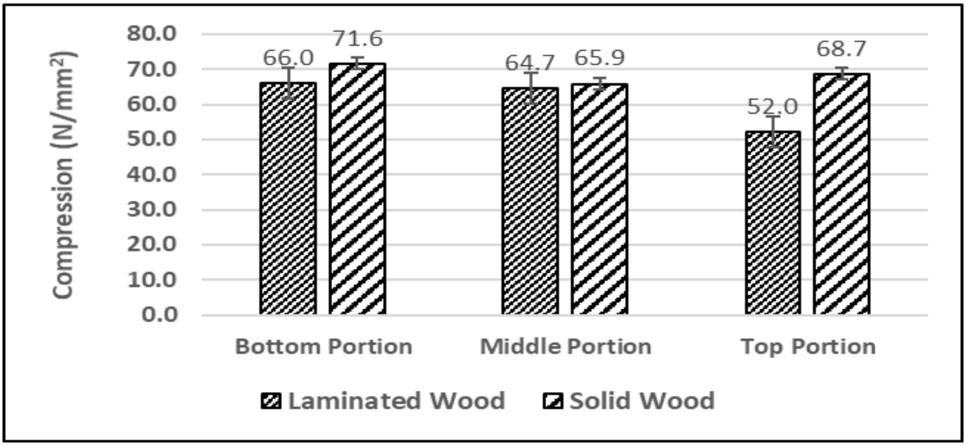

Figure 6: Compression test on solid wood and laminated wood at different height portions.

High density is an important factor that influences the results. Mechanical characteristics or wood strength such as wood compression strength are closely related to the density of wood in which the density of wood is an important feature in determining the strength of a tree (Wahab et al., 2017b; Haygreen and Bowyer 1930). The compressive strength of the wood will increase with increasing density from the base to the top. Thus, it can be explained that the apiculata mangrove root base has the highest compression test value also has the highest density value. However, the strength of wood is also influenced by internal factors such as genetics, tree parts, presence of timber book, wood anatomy structure, length and density of cells, tree age or species and external factors such as growth areas (Desch (1989).

CONCLUSIONS

Results of the study on different properties of matured *Rhizophora apiculata* indicated an improvement in the physical and mechanical properties from solid to the engineered laminated wood. In the physical properties, the moisture content highlighted that the decreasing order from bottom to the top and from solid wood to the laminated wood in the range 1-2%. Density indicated an increase in values from solid to the laminated wood with a variety of around 2-5% while the basic density shows the vice versa results in a variation of 2-6%.

In the mechanical properties, the static bending highlighted the MOR and MOE value improved the strength from solid to the laminated by the range 29-42% and 13-26%, respectively. The compression strength, however, shows the solid wood are stronger compared than laminated wood with a range of around 8-24%.

The study also found that the bottom portion indicated the highest value in physical and mechanical testing.

The factor that influenced the results may be due to the natural morphological in *R. apiculata* with content, high fibre strength and also complex microstructure at the bottom portion.

ACKNOWLEDGEMENTS

This study was financed by the University College of Technology Sarawak Grant (UCTS/RESEARCH /4/2017/01). The authors expressed their gratitude to University College of Technology Sarawak (UCTS) and Forest Research Institute Malaysia (FRIM) for permission on using their laboratory and workshop equipment in the preparation and analysis parts of the study.

REFERENCES

Abdullah F, Shaari H, Satyanarayana B, Khalik WMAWM, Jaafar MZM (2018). Macro, Micro, and Non-Essential Elements in Different Parts of *Rhizophora Apiculate. Malaysian Journal of Analytical* Sciences, 22(4): 570 – 578. DOI: 10.17576/mjas-2018-2204-01.

Alongi DM (2008). Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science, 76(1), 1-13.

Anonymous (1974). *The Strength Properties of Timber*. MTP Construction. England: Medical and Technical Publishing Co. Ltd.

Bennet EL and Reynold CJ (1993).The value of a mangrove area in sarawak. Biodiversity Conservation, 2: 359-375. DOI:10.1007/BF00114040.

Chandra IA, Seca G, and Abu Hena MK (2011). Aboveground Biomass Production of *Rhizophora apiculate* Blume in Sarawak Mangrove Forest. American Journal of Agricultural and Biological Sciences 6 (4): 469-474.

Cibo C, Altay C, Özçifçi A, Baysal E, Toker H (2018). Determination of Some Mechanical Properties of Laminated Wood Material Reinforced with Carbon Fiber (CFRP). Mesleki Bilimler Dergisi (MBD), 7 (2): 123 – 132.

Desch HE (1989). *Struktur, Sifat dan Penggunaan*. Terjermah oleh Mohd. Zin Jusoh and Mohd. Hamami Sahri. Edisi ke enam. United Kingdom: The Macmillan Press.

Duke NC (2006). *Rhizophora apiculata, R. mucronata, R. stylosa, R. X Annamalai, R. X lamarckii* (Indo-West Pacific stilt mangrove).

Gáborík J, Gaff M, Ruman D, Záborský V, Kašíčková V, Sikora A (2016). Adhesive as a Factor Affecting the Properties of Laminated Wood. Adhesive and lamination, *BioResources* 11(4), 10565-10574. DOI: 10.15376/biores.11.4.10565-10574.

Ghani RSM, Wahab R, Azmi SNB, Wi KM, Mokhtar N, Sulaiman MS (2018a). Comparison of Properties between Solid and Laminated Mahang Wood. *Advanced Journal of Technical and Vocational Education*, 2(2): 24-28.

González NSS (2012). Structure and function of wood in mangroves. Thesis in Doctor of Philosophy at the University of Queensland.

Halim NHA, Abidin NAZ, Me R (2013). A Study of Chemical Compounds in *Rhizophora apiculata. The Open Conference Proceedings Journal*, 2013(*4)*, (Suppl-2, M24) 108-110.

Haygreen JG, Bowyer JL (1930). Introduction to Forest Product and Wood Science, Subtitled by Suhaimi Muhammed and Sheikh Abdul Karim Yamani Zakaria. Ampang Press Sdn. Bhd., Kuala Lumpur.

ISO / TR 22157 (2004). Bamboo: Determination of Physical and Mechanical Properties.

Khalid I, Sulaiman O, Hashim R, Wahab R, Jumhuri N, Rasat MSM (2015). Evaluation on Layering Effects and Adhesive Rates of Laminated Compressed Composite Panels made from Oil Palm (*Elaeis guineesis*). Journal of Materials and Design. 68: 24-28. DOI:10.1016 / j.matdes. 2014.12.007, Elsevier Science Direct UK.

Khalid I, Wahab R, Mahmud S, Othman S, Affendy H, Hanim RA & Andy RM (2010). Chemical Changes in 15-year-old Cultivated *Acacia hybrid* Oil-Heat Treated at 180, 200 and 220°C. International Journal of Chemistry 2 (1). Pp. 97-107. Feb. 2010. ISSN: 1916-9701. Canadian Center of Science and Education.

Mazda Y, Wolanski E, Ridd PV (2007). The Role of Physical Processes in Mangrove Environments: Manual for the Preservation and Utilization of Mangrove Ecosystems. Terrapub, Tokyo, 598 pp.

Nabihah A (2015). Bioactivities of Methanol Extracts from *Rhizophora apiculata* Blume and *Rhizophora mucronata* Lam. Barks. BSc. Thesis. Universiti Malaysia Sarawak (UNIMAS).

Ong CB (2015). Glue-laminated timber (Glulam). In Wood Composites (pp. 123-140). Woodhead Publishing.

Percin O, Sofuoglu SD, Altunok M (2015). Effect of Heat Treatment on Some Physical and Mechanical Properties of Laminated Wood. The XXVII International Conference Research for Furniture Industry, Ankara, Turkey.

Rasat MSM, Wahab R, Sulaiman O, Janshah M, Aminuddin M, Tamer AT, Izyan K (2011). Properties of bio-composite board from oil palm frond agricultural waste. Bioresources Journal 6(4): 4389-4403. Sep. 2011.

Santini NS, Schmitz N, Bennion V, Lovelock CE (2013).The anatomical basis of the link between density and mechanical strength in mangrove branches. *Functional Plant Biology*, 2013, 40, 400–408. doi.org/10.1071/FP12204.

Shmulsky R, Jones PD (2019). Forest products and wood science: an introduction. John Wiley & Sons.

Spalding M, Kainuma M, Collins L (2010). World atlas of mangroves. Earthscan, London.

Sugiarto A (2019). Supplemental materials for preprint: Pertumbuhan Akar Propagul Rhizophora apiculate Blume Pada Medium Air Tawar. Retrieved from osf.io/krpa.

Sulaiman MS, Ramle SFM, Hashim R, Sulaiman O, Amini MHM, Geng BJ (2018). The classical mechanics engineered of *Bambusa vulgaris* and *Schizostachyum brachycladum.* Journal of Tropical Resources and Sustainable Science 6:57-61.

Thelandersson S, Larsen HJ (2002). *Timber Engineering*. John Wiley & Sons, Ltd.

Wahab R, Ghani RSM, Samsi HW & Rasat MSM (2017b). Changes in the Features of Oil Heat Treated 18-Years Old *Acacia mangium*. Research Journal of Pharmaceutical, Biological and Chemical Sciences 8 (2): 2093-2106. ISSN: 0975-8585.

Wahab R, Mokhtar N, Ghani RSM, Sulaiman MS, Samsi HW (2018a). Changes in Strength Characteristics and Durability on 4-Year-Old Tropical Bamboo *Gigantochloa Scortechinii* through Heat Treatment. *Asian Journal of Science and Technology, 9(5):8227-8233.*

Wahab R, Rasat MSM, Samsi HW, Mustafa MT, Don SMM (2017a). Assessing the suitability of Agro-Waste from Oil Palm Empty Fruit Bunches as Quality Eco-Composite Boards. Journal of Agricultural Science 9 (8): 237-247. ISSN 1916-9752 E-ISSN 1916-9760. Doi: 10.5539/jas. v9n6p251. Published by Canadian Center of Science and Education.

Wahab R, Sulaiman MS, Mokhtar N, Ghani RSM, Samsi HW, Yusuf M (2018b). Properties of *Hibiscus cannabinus* and *Elaeis guineesis* fronds fibers Eco-

Composites boards. International Journal of Current Research 10 (5): 69770-69775. ISSN: 0975-833X.

Wałach D, Jaskowska-Lemańska J, Dybeł P (2015). The impact of the moisture content of wood on the results of non-destructive tests. Forestry and Wood Technology № 92: 448-454.

Wiegner K, Wilke O, Jann O, Brödner D, Scheffer H, Kalus S, Till C (2009). Study on VOC-emissions from oriented strand boards (OSB). In Proceedings of the 9th International conference Healthy Buildings.

Zhang X, Chua VP, Cheong HT (2015). Hydrodynamics in mangrove prop roots and their physical properties. Journal of hydro-environment research. 9(2):281-294. DOI: 10.1016/j.jher. 2014.07.010.