International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I7P213
Volume 69 Issue 7, 86-91, July, 2021

Mechanical Properties of Commercial Particleboard from Rubberwood (*Hevea brasiliensis*) and Recycle Mix- Tropical Wood with Different Board Density

Nur Wafa Amalina bt Amali[#1], Nor Yuziah bt Mohd Yunus[*2], Wan Mohd Nazri b Wan Abdul Rahman[#3]

[#1]*Faculty of Applied Sciences, Universiti Teknologi MARA Shah Alam, Malaysia.*

[*2] *Faculty of Applied Sciences Universiti Teknologi MARA Pahang, Malaysia.*

[#3] *Faculty of Applied Sciences, Universiti Teknologi MARA Pahang, Malaysia.*

[1]nwaamali@gmail.com, [2] noryuziah@uitm.edu.my, [3] wmdnazri@uitm.edu.my

***Abstract** — In this study, the mechanical properties of commercially manufactured hybrid particleboard from mix-tropical wood and rubberwood with four different densities at 25mm thickness have been investigated. The particleboard sample cutting and testing were in accordance with EN312:2013. The density of particleboard is identified with interval of 10kg/m3 for different densities which include 660kg/m3, 670kg/m3, 680kg/m3 and 690kg/m3. Particleboards were made with the ratio of 40:60 for mix-tropical wood particle and rubberwood particle, respectively. The particleboards were prepared with urea-formaldehyde (UF) with E1 formulation with the addition of wax and hardener. Increment of 10kg/m3 density for each particleboard led to an increase in internal bonding (IB), bending testing include modulus of rupture (MOR) and modulus of elasticity (MOE), surface soundness (SS), and screw edge (SE) withdrawal. It was found that with a board increment of 10kg/m3, the improvement was not statically significant except that for MOR. All panels met the minimum requirements of the standard.*

Keywords — *Particleboard, Mechanical Properties, Board Thickness, Board Density*

I. INTRODUCTION

Wood, both generated by managed planting or reforestation, is known as renewable resources. Wood is strong and is easy to handle for the carving, joining, cutting, or finishing process for furniture making. Sadly, using solid wood as the primary raw material in furniture production is nearly impossible and less common nowadays [8]. Solid wood is fast becoming a rare material and quite limited in supply to satisfy the requirements of furniture production. This phenomenon forced the manufacturer to find and acknowledge others alternatives to replace traditional wood [16]. Prior to the 1990s, particleboard in Malaysia utilizes the off-cuts from sawmilling as the resource of particles. In the early 19190's, the particleboard industry embarked on the utilization of rubberwood in Malaysia. During this time, the rubberwood plantation in Malaysia has reached their viable latex production time and need to be replanted. The replanting created an issue in pollution when the felled trees were burnt on-site during clearing. The introduction of rubberwood as a cheap and non-forest species to the wood-based industry creates an impetus on its utilization. So much so, the industry grows in the production of particleboard, medium-density fiberboard, and furniture. As the industrial usage of rubberwood expands, two main issues arise. First, the increase of the company that utilizes the resource caused the increase in raw material price, and second, and the resource volume shrinks with respect to user requirement. To make matter worse, the birth of a more lucrative palm oil industry change the priority toward replanting of ex-rubberwood plantation with oil palm trees. Due to lack of choice in raw materials, researchers or factories resort to selecting other biomass resources which may be acquired from agricultural residues such as corn stalk, bagasse and oil palm biomass. This is in addition to use of forest residue including thinning from young stud, cutting from the top, bark or branches and tree stumps. Other than residue, lesser known fast growing species was also reported to be able to replace the wood supply needs. [26] reported a successful use of fast growing trees *(Leucaena*) for particleboard commercial trial production in Malaysia. Additionally, studies by [24] identified Rubberwood (*Hevea brasiliensis*), Kelampayan (*Neolamarckiacadamba*) and Acacia (*Acacia spp.*) combination as species that could potentially meet the requirements.

The resources stated are being converted engineered wood rather than used as solid wood. Particleboard, medium density board (MDF), plastic board, oriented strand board (OSB) are examples of commonly used wood based panel for furniture and structural application. Lack of solid wood triggers researches in recent years with high focus on particleboard. The studies focused on mechanical properties such as internal bonding (IB), flexural strength (modulus of rupture (MOR), modulus of elasticity (MOE)), surface soundness and screw-withdrawal plus physical properties of thickness swell and water absorption [2]; [13]; [1]; [17]. The main reason to conduct researches on particleboard properties was to determine the strength and stiffness of particleboard and match its performance to user requirements.

Particleboard properties may be affected by species of wood, density of board, type of resin, dosage of resin, sizes of particle, addition of wax and hardener content. Board density is one of the main property in particleboard manufacturing as by extending the factor, the functional board properties may be improved [7] and [28]. As stated by [20], the higher the density, the higher the mechanical properties of board. This is because the stiffness of board is higher and it is harder to break the board.

Effect of density on wood product has been widely studied. There are significant differences in the mechanical and physical properties for density increment. Mechanical properties generally tend to increase with increase of density and the physical properties also showed improvement. In most of the analysis done with density to performance relationship, the quantum or gap between densities has been in the 50's or 100's step increment [12] and [23]. With large increment of density, the impact of the change is easier to be seen. For smaller gap, laboratory production is harder to perform. In order to see the sensitivity of the density, board from production could be selected and analyzed.

This paper focused on mechanical properties of commercial board made up of wood waste from recycled mix-tropical wood and rubberwood. The sensitivity of density of particleboard was looked at four different densities with an increment of $10kg/m^3$ selected. The densities were $660kg/m^3$, $670kg/m^3$, $680kg/m^3$ and $690kg/m^3$. Local particleboard manufacturer target was to utilize waste generated from recycle mix-tropical wood with supplement of rubberwood with E1 type of urea-formaldehyde adhesive to meet the minimum board properties requirements of customer.

II. LITERATURE REVIEW

A. Particleboard

Wood composite also called engineered wood and manmade wood is manufactured by wood or plastic with binding agent. Wood composite offer less cost than solid wood, more resistant in humidity and temperature when coated ease installation, more durable and uniform in term of stiffness, strength and dimension stability which less twist, shrink or wrap in board. Plywood, veneer board, medium density fiberboard (MDF) and particleboard are most common engineered wood used in industry [14].

Particleboard has been made with woodland material for many years. With the diminishing of these raw material and increasing the bulk demand of particleboard, it forces the manufacturer or researcher move to fast growing species, agriculture based-material or mixture the raw material with wood residue like branches, fines, barks or wood crops. With advantages of sound and fire resilient, built in board, resist to warping, high quality of product and low cost made particleboard one of composite board choose by manufacturer for making furniture [15].

B. Particleboard density

All There are 2 types of particleboard properties, mechanical and properties and physical properties. Mechanical properties are tested to study the strength, stiffness of board under pressure and include shear test, bending test, internal bonding (IB) test and hardness test. While for physical properties, it done to determine the ability of board under moisture environment and include thickness swell test and water absorption test [21]. Density of particleboard is measure by compactness of particle in board. An increasing weight of particle, diameter of particle, geographical or defect of wood affecting the density of particleboard. According to [10], there is relationship between board density and particleboard properties. According to author, in mechanical properties, increasing of particleboard density will increase the value of IB and bending result (MOE and MOR). Supported by [7], particleboard is strongly influenced and highly correlated to density of board. This happen when additional $100kg/m^3$ shows an increment in IB and bending. For physical properties, stated by [29], the higher the density of particleboard, on water absorption testing shows lower absorption occur. As stated by researchers, with increment $50kg/m^3$ on density of particleboard, it is shown decreasing in thickness swell properties for 2 hours and 24 hours. This phenomenon occurred when density of board is increasing and resulting the lower compactness between particles and pores.

C. Uses of particleboard

In general, uses of particleboard can be classified into two categories, structural and non-structural. Structural use was found in heavy duty work like construction or building part. This types normally have to be produced with resins such as melamine formaldehyde (MF), phenol formaldehyde (PF) or isocyanate. Use of phenolic (more popular) and isocyanate also allow used of board in external environment. Meanwhile, non-structural uses commonly used in light or interior uses. It is more sensitive to moisture as in majority; board is produced with urea formaldehyde (UF) based or slightly fortified UF. Urea formaldehyde is known to have the lowest resistance to moisture compared to MF and PF. It can be found as interior material of used in light furniture like chair and table, packaging like boxes, floor panel and wall, or musical instrument like piano, guitar and organ part.

D. Urea formaldehyde

Adhesive or glue is divided into 2 types, synthetic adhesive and natural glue. Natural glue or bio-adhesive is derived from organic sources like animal, vegetable starch or tree. While synthetic adhesive can be classified into two categories, thermoplastic and thermosetting. Thermoplastic also known as plastic polymer is softening when heated and hard when cold. The process can be repeated and found in polyethylene, polystyrene, PVAs or polypropylene. Thermosetting adhesive has or can undergone chemical reaction by action of ultraviolet, infusible state heat or catalyst. Example of thermosetting adhesive are PF, melamine formaldehyde, epoxy resin or UF.

Urea formaldehyde resin is synthesis first time by Hölzer, and Bernhard Tollens in 1884. This resin commonly used in fabric, textile, fertilizer or molded material like particleboard or MDF. Urea formaldehyde is known as high tensile strength, excellent water solubility and thermal properties, versatility and fast curing where at some temperature, it can be cure as fast as 2 seconds [11] and [27]. It lower cost compared to MF, PF and isocyanate is the reason why it favored by the user. The UF which become colorless after curing also make it popular for making core-board in lamination process.

III. METHODOLOGY/MATERIALS

A. *Material preparation*

Wood particle were prepared by local particleboard manufacturer. Wood waste was obtained from both forest residue or mill residue and rubberwood from selected mill. Raw materials were debarked, as and when required, cut into targeted size prior to being chipped. Chipped wood were then flaked into small particle before screening process. The oversize and undersized material were removed to ensure good particle packing and enhanced resin blending efficiency respectively. The sample was then cut into smaller size according to standard requirement.

B. *Method*

Particleboards manufactured by local particleboard manufacturer and consist of two main materials, wood particle and adhesive. Wood particle were classified into two types, rubberwood and mix-tropical wood and utilized in mix-ratio of 60:40. This study used E1 typed urea formaldehyde resin. Addition of ammonium chloride as hardener, fasten curing process to increase board strength and wax helps reduced board's swelling. Boards were formed in 3 layers (top, core and bottom) targeting thickness of 25mm. The densities of particleboard selected were 660kg/m³, 670 kg/m³, 680 kg/m³, and 690 kg/m³. The process of commercial production of particleboard is shown in Figure1. After hot pressed, the samples underwent sanding to the required thickness and cut to size 120 mm x 240 mm. The cut panels were then stacked in bundles and allowed to cool in the warehouse for 24 hours prior to final quality control inspection. A panel selected was then randomly collected and the test specimen prepared for testing.

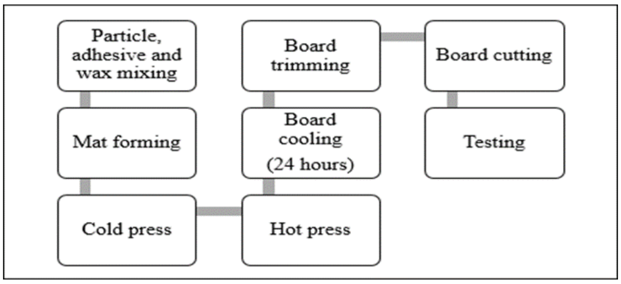

Fig. 1 Commercial Production

C. *Mechanical Strength Characterization*

Wood Particleboards manufactured by local particleboard manufacturer and consist of two main materials, wood particle and adhesive. Wood particle were classified into two types, rubberwood and mix-tropical wood and utilized in mix-ratio of 60:40. This study used synthetic E1 typed urea formaldehyde resin. Addition of ammonium chloride as hardener, fasten curing process so as to increase board strength and wax helps reduced board's swelling. Boards were formed in 3 layers (top, core and bottom) targeting thickness of 25mm. The densities of particleboard selected were 660kg/m³, 670kg/m³, 680kg/m³, and 690kg/m³. The process of commercial production of particleboard is shown in Figure 1. Board used in testing was collected after board cutting. All specimen was conditioned at 65% relative humidity at 20°C for 24 hours prior to testing.

Table 1. Sample size for each testing

Testing	Size (l x w x t)
IB test	50mm x 50mm x 25mm (EN 319)
Bending test (MOE, MOR)	290mm x 50mm x 25mm (EN 310)
Edge screw withdrawal test (SE)	75mm x 75mm x 25mm (EN320)
Surface soundness test (SS)	50mm x 50mm x 25mm (EN311)

IV. RESULTS AND FINDINGS

Particleboards with thickness of 25mm were tested at four different densities (Table 2 and Table 3) in accordance to EN 310/311/319/320:2013. Mechanical testing results included modulus of rupture (MOR), modulus of elasticity (MOE), IB, surface soundness (SS) and screw edge (SE) withdrawal. All densities meet minimum requirement of EN312:2013 standard. According to Table 2 and Table 3, density of 690kg/m³ gave the highest result with 12.26MPa (MOR), 2176.46MPa (MOE), 0.70MPa (IB), 1.1N/mm² (SS) and 432.15N (SE). While the lowest result was for 660kg/m³ with 10.88MPa (MOR), 2045.50MPa (MOE), 0.63MPa (IB), 1.07N/mm² (SS) and 421N (SE). This is as predicted, due to lower board compaction. Results given is similar to study done by [7], MOE, MOR and IB result shows increased as well as the density of board is increasing. As shown in Table 3, IB for 660kg/m³ and 670kg/m³ shared same result with 0.63MPa. The density of 680kg/m³ with 690kg/m³ both showed SS value of 1.10N/mm². In a nutshell, higher density generally exhibits higher result for mechanical testing.

Table 2 and Table 3. Sample size for each testing

Density (kg/m³)	Thickness (mm)	MOR (MPa)	MOE (MPa)
660	25	10.88	2046
670	25	11.32	2090
680	25	11.50	2130
690	25	12.26	2176
EN312:2013	>20 to 25	10.5	1500

Density (kg/m³)	Thickness (mm)	IB (MPa)	SS (N/mm²)	SE (N)
660	25	0.63	1.07	412
670	25	0.63	1.09	427
680	25	0.66	1.10	430
690	25	0.70	1.10	432
EN312:2013	>20 to 25	0.30	0.8	400

Keywords: MOR: Modulus of Rupture, MOE: Modulus of Elasticity, IB: Internal Bonding, SS: Surface Soundness, SE: Screw-withdrawal Edge.

Table 4 summarized the analysis of variance (ANOVA) on effect of the density of particleboard interaction with properties of hybrid particleboard. The results shown the summary of 4 different densities of particleboard includes 660kg/m^3, 670kg/m^3, 680kg/m^3 and 690kg/m^3. There was no significant effect observed on summary of analysis of variance (ANOVA) on the particleboard properties (MOE, IB, SE and SS) except for MOR. The 7% differential in value is enough to make the MOR statically different.

Table 4. Summary of ANOVA on particleboard properties

SOV	Df	Bending		IB	SE	SS
		MOE	MOR			
Density	3	2.04^{ns}	3.84*	0.45^{ns}	0.52^{ns}	0.66^{ns}

Keywords: MOR: Modulus of Rupture, MOE: Modulus of Elasticity, IB: Internal Bonding, SS: Surface Soundness, SE: Screw-withdrawal Edge, ns: not significant, * : significant

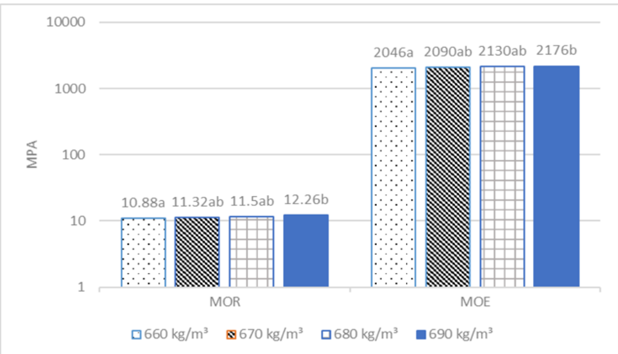

Fig. 2 Effect of particleboard density on bending strength

As density is one of the most important factors affecting wood composite, 25mm particleboard densities impact was examined. Four densities with 10 kg/m^3 differential were selected (660kg/m^3, 670kg/m^3, 680kg/m^3 and 690kg/m^3). The increment is crucial as board production at commercial level is normally controlled within a set variation. This could be by design or due to machine default. The interaction and difference in the values at small densities variation will ensure in-specification product and cost effectiveness in production. Figure 2, showed the effect of particleboard density on bending strength in form of MOR and MOE. It is evidenced that increasing the density will improve the strength characteristic of MOE and MOR. According to Figure 2, the highest value for MOE and MOR belongs to 690kg/m^3 with 2176MPa and 12.26MPa respectively. While the lowest value for both MOE and MOR was 660 kg/m^3 with 2046MPa and 10.88MPa respectively. Differential of 40 kg/m^3 between lowest and highest reading was significant at $p \leq 0.05$. In addition, 670kg/m^3 and 680kg/m^3 shared the same grouping and were not significantly different from the maximum or minimum densities. The graph shows the trending of increment in bending strength is proportional to density of particleboard. This trending is supported by [20], [19] and [25], where the increasing of density will increase the strength of mechanical properties of particleboard. The reason of this phenomenon is the contact between wood particle and compression factor was improved by the upward increment of density of board. In adhesion, compatibility of material is most important. However, the compatibility will not be effective if the substrate to be bonded could not have intimate contact with the resin used. By having higher density, the surface area of contact could be improved due to the compaction of the substrate [9].

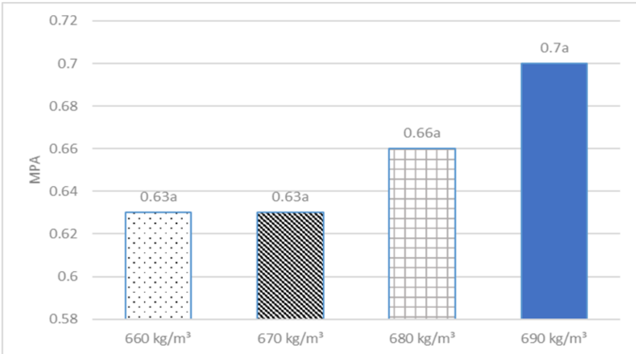

Fig. 3 Effect of particleboard density on IB

Figure 3 shows the effect of particleboard density toward IB of the four different densities. All densities of board passed the minimum EN310 standard. The highest strength values for IB were seen for 690kg/m^3 panel with 0.7MPa which is highest board density among all densities. While the lowest strength values for IB were shared by 660kg/m^3 and 670kg/m^3 panel with 0.63MPa which were the lower densities. The trend of the performance of board strength of IB increased by increment of 10kg/m^3 density is seen but at a lower scale. The data also shows there is no significant values on increasing density as all densities are grouped as one by DMRT. This phenomenon can also be seen on [20] study where increment of 5kg/m^3 density shows insignificant change in IB properties.

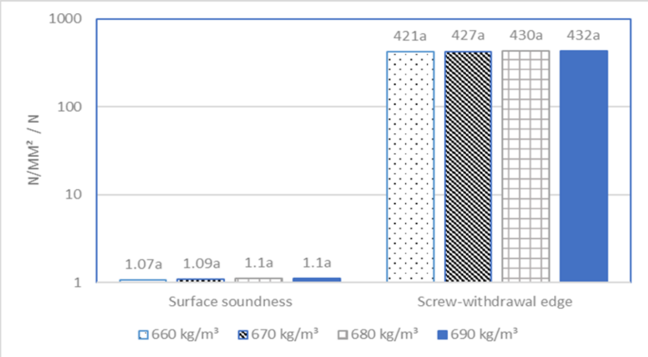

Fig. 4 Effect of particleboard density on surface soundness and screw-withdrawal edge

Figure All panels examined in this study passed the minimum screw edge-withdrawal and surface soundness requirement of EN 320 and EN319 (2013) respectively of 400N and 0.8N/mm^2 respectively. The SE and SS graph shows insignificant difference at additional increase of 10kg/m^3 for all densities. In terms of actual SE values, there is still small increment on both strength properties. According to [22], increasing particleboard density offered more compact board and thus create higher strength on screw-withdrawal force. Study by [18], shows reducing particleboard density by 7% which is from 625kg/m^3 to 580kg/m^3 gives no significant different value in SS with slightly different of 0.08N/mm only. This statement supports the graph shown on SS where additional of 1.5% of board densities present increment of 0.02N/mm values.

V. CONCLUSIONS

In this study, commercial particleboard or hybrid particleboard from rubberwood and mix-tropical wood with E1 type of urea formaldehyde with 25mm thickness was examined. There are four different board densities include 660kg/m^3, 670kg/m^3, 680kg/m^3 and 690kg/m^3 to acknowledge the mechanical strength. The following is conclusion resulted:

i) Increasing of particleboard density shows increasing values for all testing which include IB, SS, SE and bending test (MOE and MOR).

ii) There are no significant different shows on increment of 10kg/m^3 or 1.5% of each density except for MOR.

The slight or no difference in the board performance identifies the tolerance level for density target in production. A control ranges of 40 kg/m^3 is critical as the manufacturer could target for lower density which will allow better saving in production cost.

ACKNOWLEDGMENT

We would like to express special thanks to Mieco Manufacturing Sdn. Bhd. Based in Balok, Pahang for providing particleboard and UiTM Jengka, Cawangan Pahang for granting permission for operating testing.

REFERENCES

[1] Bazzetto, J. T. d. L., Bortoletto Junior, G., & Brito, F. M. S. Effect of Particle Size on Bamboo Particle Board Properties. Floresta e Ambiente, 26(2) (2019).

[2] Cinar, H., Effects of temperature and thickness of wood based boards on formaldehyde emission. Wood Res, 63(5) (2018) 895-908.

[3] EN310., Wood-based panels, Determination of modulus of elasticity in bending and of bending strength, In: European Committee for Standardization, Brussels, Belgium, (1993).

[4] EN311., Wood-based panels, Determination of surface soundness of particleboards In: European Committee for Standardization, Brussels, Belgium, (1992).

[5] EN319., Particleboards and fibreboards, Determination of tensile strength perpendicular to plane of the board. In: European Committee for Standardization, Brussels, Belgium, (1993).

[6] EN320., Wood-based panels, Determination of resistance to axial withdrawal of screw. In: European Committee for Standardization, Brussels, Belgium,(1993).

[7] Eslah, F., Enayati, A., Tajvidi, M., & Faezipour, M., Regression models for the prediction of poplar particleboard properties based on urea formaldehyde resin content and board density, (2012).

[8] Guzel, T. A., Consumer Attitudes toward Preference and Use of Wood, Woodenware, and Furniture: A Sample from Kayseri, Turkey. BioResources, 15(1) (2020) 28-37.

[9] Halip, J. A., Hua, L. S., Tahir, P. M., Al Edrus, S. S., Ishak, S. M. M., Selimin, M. A., & Ab Hamid, A. A. R. Kenaf and Kenaf-Rubberwood Hybrid Particleboards.

[10] Hegazy, S. S., & Ahmed, K., Effect of date palm cultivar, particle size, panel density and hot water extraction on particleboards manufactured from date palm fronds. Agriculture, 5(2) (2015) 267-285.

[11] Henriques, A., Coelho, C., Ferra, J., Martins, J. M., Magalhaes, F. D., Molina, S., . . . Song, X., Wood composites: materials, manufacturing and engineering , Walter de Gruyter GmbH & Co KG, 6 (2017).

[12] Hong, M.-K., Lubis, M. A. R., & Park, B.-D., Effect of panel density and resin content on properties of medium density fiberboard, Journal of the Korean Wood Science and Technology, 45(4) (2017) 444-455.

[13] İstek, A., & Siradag, H., The effect of density on particleboard properties. Paper presented at the International Caucasian Forestry Symposium, (2013).

[14] Kashima, M., Tsuchikawa, S., & Inagaki, T., Simultaneous detection of density, moisture content and fiber direction of wood by THz time-domain spectroscopy, Journal of Wood Science, 66 (2020) 1-8.

[15] Kawai, S., Sasaki, H., Nakaji, M., Makiyama, S.-s., & Morita, S., < Original> Physical Properties of Low-density Particleboard. Wood research: bulletin of the Wood Research Institute Kyoto University, 72 (1986) 27-36.

[16] Laskowska, A., & Mamiński, M., The properties of particles produced from waste plywood by shredding in a single-shaft shredder. Maderas. Ciencia y Tecnología, 22(2) (2020) doi:10.4067

[17] Leng, W., Hunt, J. F., & Tajvidi, M., Screw and nail withdrawal strength and water soak properties of wet-formed cellulose nanofibrils bonded particleboard. BioResources, 12(4) (2017) 7692-7710.

[18] Lengyel, K., Barbu, M. C., Campean, M., Badin, N., & Bedelean, B., Improving properties of particleboards with reduced density. BioResources, 13(1) (2018) 1289-1302.

[19] Lias, H., Kasim, J., Johari, N. A. N., & Mokhtar, I. L. M., Influence of board density and particle sizes on the homogenous particleboard properties from kelempayan (Neolamarckia cadamba), International Journal of Latest Research in Science and Technology, 3(6) (2014) 173-176.

[20] Maraghi, M. M. R., Tabei, A., & Madanipoor, M., Effect of board density, resin percentage and pressing temprature on particleboard properties made from mixing of poplar wood slab, citrus branches and twigs of beech. Wood Research, 63(4) (2018) 669-682.

[21] Melo, R. R. d., Stangerlin, D. M., Santana, R. R. C., & Pedrosa, T. D. Physical and mechanical properties of particleboard manufactured from wood, bamboo and rice husk, Materials Research, 17(3) (2014) 682-686.

[22] Miljković, J., Popović, M., Điporović-Momčilović, M., & Gavrilović-Grmuša, I., Edge screw withdrawal resistance in conventional particleboard and OSB: Influence of the particles type, Glasnik Šumarskog Fakulteta , (95) (2017) 109-117.
[23] Pham Van, T., Schöpper, C., Klüppel, A., & Mai, C., Effect of wood and panel density on the properties of lightweight strand boards, Wood Material Science & Engineering, (2019) 1-9.
[24] Rahman, W. M. N. W. A., Sa'ad, M. F., Suffian, M., Sofian, N. N., & Yunus, N. Y. M., Wood and Veneer Properties of Fast Growing Species from Batai, Eucalyptus and Kelampayan, International Journal of Management and Humanities (IJMH), 4(8) (2020) 65-71.
[25] Rahman, W. M. N. W. A., Tamat, N. S. M., & Kasim, J., The suitability of fast growing tree species for particleboard production, International Journal of Recent Technology and Engineering (IJRTE), 8(1) (2019) 3156-3161.
[26] Sa'ad, M. F., Yunus, N. Y., Ab Rahman, H., & Rahman, W. M. N. W. A., Leucaena Particleboard: A Commercial Trial. BioResources, 14(2) (2019) 3506-3511.
[27] Xing, F., Lu, Z., & Zhang, S., Study on the characteristics of formaldehyde emission from MDF, Journal of Building Materials, 4 (2015) 688-691.
[28] Yunus, N. Y. M., Amali, N. W. A., Tamat, N. S. M., & Rahman, W. M. N. W. A., Flexural influence on screw withdrawal behaviour of selected commercial particleboard, International Journal of Engineering and Advanced Technology (IJEAT), 9(1) (2019) 5948-5951.
[29] Zheng, Y., Pan, Z., Zhang, R., Jenkins, B. M., & Blunk, S., Properties of medium-density particleboard from saline Athel wood. Paper presented at the ASAE Annual Meeting, (2005).