Effect of Varying Resin Content and Board Densities on the Properties of Three Layers Particleboard from Kelempayan

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Abstract

The aim of this study was to investigate the use of *Kelempayan* species in manufacturing three layer particleboard panels. The boards were fabricated with three different densities (500 kg/m^3, 600 kg/m^3 and 700 kg/m^3). The sample also has different level of the resin content (8 %, 10 % and 12 %). The boards produced were evaluated for its' modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB), water absorption (WA) and thickness swelling (TS) in accordance with the Japan industry Standards (JIS) A 5908:2003. The result meet requirement and passed standard value based on JIS A 5908:2003 Type 13 for mechanical properties is board at density 600 kg/m^3 with resin 12 %, the result shown in MOR (14.94 MPa) and IB (0.29 MPa). For density 700 kg/m^3 with resin 8 % and 10 % only MOR and IB passed the standard. At the same density for resin 12 %, the all mechanical properties passed the standard value of JIS. For physical properties, only one parameter combination passed in thickness swelling (11.90 %), i.e. density 600 kg/m^3 and 12 % resin content. It is concluded that the boards with density of 700 kg/m^3 were able to fulfil the JIS requirements.

Keywords: *Kelempayan*; Three layer particleboard; Resin content; Japan industry standards.

1. INTRODUCTION

In current situation, demand for wood and wood based composites is rising.The scientists are working hard to find suitable substitute of timber through researches. Basically the development of particleboard has been based largely on the use of softwood timbers. Wood panel product are used widely in the manufacture of furniture, home constructions, speakers, sliding doors, lock blocks, interior signs, displays, table tennis, pool tables, electronic game consoles, panelling, kitchen worktops, and work surfaces in offices, educational establishments, laboratories and other industrial product applications (Anon., 1996).

In the wood industry, the word composite and reconstituted wood is usually used to explain any wood product that is "glued together". Particleboard is typically made in three layers. The face of the board consists of fine particles, and the core is made of coarse particles. Producing a panel this way improves utilization of the material and the smooth surfaces presents better surfaces for laminating, overlaying, painting or veneering (Ayrilmis, Kwon & Han, 2012).

In view of the need to increases the utilization of wood resources, the industry has diversified into the production of high value-added reconstituted panel products such as particleboard and medium density fiberboard. The particleboard industry has grown and currently there are 16 mills in operation in Malaysia. The industry, over the years has successfully exported its products particularly for use in the furniture industry (Nations, Peninsula & Independence, (2012). Normally in Malaysia, particleboards are generally available as platen pressed with board densities between 600 kg/m3-800kg/m3 and thickness between 6 to 40 mm (Biswas, Kanti & Hossain, 2011).

Kelempayan (Neolamarckia cadamba) is a pioneer forest species which is currently considered as less-utilized species that normally grows wild in the gaps of selective felling, wind damaged areas and by the logging roads or the riving in abandoned shifting cultivation plots (Noor Azrieda et al., 2009). It is light weight hardwood that has good mechanical and working properties and suitable for various utility purposes. This tree has potential to be utilized for sawn timber, veneer, chip, pulp and composites. The timber airs dries rapidly with little or no degrades. The wood is easily preserved by using either open tank or pressure-vacuum systems (Ismail, 1995).

2. MATERIALS AND METHODS

2.1 Field Procedure

Particle preparation starts after felling and moving logs to sawmill for cutting to billet length with chain saw. Debarking was done with cleaver to remove the barks that are useless. The billet was then feed to wood chipper to obtain a desirable thickness and length. Chipped particle were air dried and screened using vibrator screening machine to 0.5 mm, 1.0 mm and 2.0 mm. The fine and dust like particle were removed. Fines tend to absorb more glue and reducing the strength of the board. The face and back was use 0.5 mm, 1.0 mm and core is 0.5 mm, 1.0 mm, 2.0 mm (mixed).

After screening, the particles were oven dried to make sure the particles below 5% moisture content (MC). If not, the boards was blow in the hot press section cause by present of excess water in the particles. The temperature of the oven needed is 80°C and was kept it for 24 hour.

2.2 Board Manufacture

The amount of resin in a product and how effectively it is mixed determines the strength of the board. For this project, Urea formaldehyde (UF) was used as a binder. According to Table 1, the resin specifications are solid content 49.5 %, viscosity 1.38p and free formaldehyde 0.90%. Resin was used at different ratio in board manufacture for surface and core. The face and back used 8%, 10%, and 12% and core is constant at 10% resin content. Prepared dried particles were then used in the blending process. For this step, surface/back was mixed first and continued with core. Blending is the process of mixing resin adhesive with particles using glue mixer.

Resin Grade	Quantity (kg)	pH/30 °C	Viscosity30 °C	Specific gravity/30 °C	Solid content %	Gel time/100 %	Free form.
UF	~5	5.66/m	1.38p	1.195	49.5	-	0.90

Table 1: Resin Specifications

After blending, a mat former with steel slots or slits was used to form the board manually. Before forming, silicon release agent is sprayed onto the tray, so that the particles do not stick on the tray and mould. The size of mould is 350 mm x 350 mm. Target board thickness is 12 mm. The objectives of forming are to lay a mattress which is even in weight along its length and across its width. The production of three-layer boards requires three or more forming stations. The two outer layers consist of particles that differ in geometry from those in the core.

The process was continued to cold press. The advantages of cold press were to reduce the mat thickness and enabling the mat to be handled easily before hot pressing process.
After cold press process, hot press machine was used to press the board at temperature of 165°C for six minutes. In this process, three levels of pressure were used. Table 2 below shown the pressure time and pressure used in making board.

Steps	Times(minutes)	Pressure(psi)
1	3	1800
2	2	1200
3	1	800

Table 2: Hot press time and pressure

Lastly in conditioning process, the samples were left in a conditioning room with a relative humidity of 60 ± 5 % and the temperature 0f 20 ± 2 %.

2.3 Sample Cutting

For sample testing, the panel boards were checked for bonding conformance and thickness tolerance before the side trimmed and cut to accurate dimension using the table saw machine. The line must be drawn on the board according to Figure 1 for the particle board sampling.

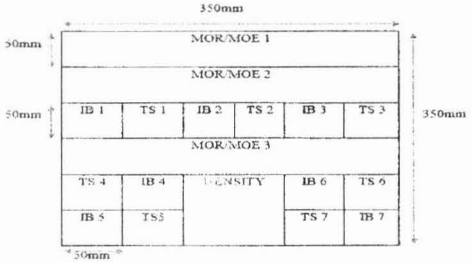

Figure 1: Particleboard sampling pattern

3. TESTING METHODS

3.1 Bending Strength

Bending test is important to obtain Modulus of Elasticity (MOE) value and Modulus of Rapture (MOR). For bending test, the board was marked individually. All measurement of sizes dimension of board such as length and width, and the weight was taken. By using the Bending machine (Instron machine), put the board with the load support of more than 240 mm span width. Test the board until it broke, the results determined in MPa and calculate the bending test by the formula below:

$$\text{Bending strength}\left(\frac{N}{mm^2}\right) = \frac{3PL}{2bt^2}$$

Where, P: maximum load (N)

L: span (mm)

b: width of test piece (mm)

t: thickness of test piece (mm)

3.2 Internal Bonding

The purpose of internal bonding (IB) is to determine the tensile strength of the board panels. For IB, the board was sized to 50mm x 50mm, marked and all of its data recorded before testing. For testing preparation, board surface was sanded to avoid surface failure during the test. Then, test samples must be glued to glue the steel test block. For this testing, two part epoxy glue at mix ratio 1:1 was used. Glued sample was allowed to cure for 2 hours. Lastly, it was tested by using Instron machine where the machine pulled the two sides of block until it break at the middle of sample. We can calculate the IB using the formula below:

$$\text{Internal bond } (N/mm^2) = \frac{P'}{2bL}$$

Where: P' = Maximum load (N) at the time of failing force

b = Width (mm) of sample

L = Length (mm) of sample

3.3 Thickness Swelling

For thickness swelling (TS), all of the samples must be precisely soaked into the water to make sure that the overall of the samples were properly soaked. The board sized was about 50 mm X 50 mm and all the data recorded. Then after the board had been marked it was be soaked in the water until all part of the board submerged for 24 hours. The formula that was used in calculation to know the TS is as given:

$$\text{Thickness swelling: } \frac{\text{Final dimension} - \text{Initial dimension}}{\text{Initial dimension}} \times 100$$

3.4 Water Absorption

The purpose of water absorption (WA) testing is basically to determine how much water was absorbed by the particles. This WA testing also indicates how durable the particleboard is to the water. The formula that used in calculation to know the percentage of WA is as shown below:

$$\text{Water absorption: } \frac{\text{Final weight} - \text{Initial}}{\text{Initial weight}}$$

4. RESULTS AND DISCUSSIONS

4.1 Mechanical and physical properties of particleboard from Kelempayan sp

Table 3: Mechanical and physical properties of particleboard from *Kelempayan* sp.

Board density	Resin content	MOR (MPa)	MOE (MPa)	IB (%)	TS (%)	WA (%)
500	8	5.64	903	0.12	23.99	139.72
	10	5.88	972	0.15	19.15	131.10
	12	8.93	1353	0.19	14.14	114.48
600	8	7.97	1218	0.07	25.22	151.58
	10	12.02	1755	0.18	19.56	114.20
	12	14.94	2076	0.29	11.90	97.31
700	8	18.47	2554	0.21	25.46	103.87
	10	19.61	2474	0.32	22.61	90.51
	12	21.94	2692	0.49	12.53	77.60
Type 13		>13.00	>2500	>0.2	<12.00	n.a

(Sources: JIS A 5908:2003)

Table 3 show the mechanical and physical properties of particleboard from Kelempayan species. The result were compared to meet minimum requirement for strength properties of particleboard panels based on JIS A 5908:2003 particle Boards. Based on Table 3, the density of particleboard affected the strength of board. The highest of MOR (21.94 MPa), MOE (2692 MPa) and IB (0.49) is for the board density 700 kg/m3 with 12 % of resin content. The board with density 500 kg/m3 had the lowest of MOR, MOE and IB for mechanical properties in board with 8 % of resin content. The result is 5.64 MPa (MOR), 903 MPa (MOE) and 0.12 MPa (IB). The following results passed requirement standard of JIS A 5908:2003 Type 13 for mechanical properties. Board with 600 kg/m3 with resin 12 %, for in MOR (14.94 MPa) and IB (0.29 MPa), density 700 kg/m3 with resin 8 % and 10 % for in MOR and IB and density 700 kg/m3 for resin 12 % passed all mechanical properties.

In physical properties, for TS, density 600 kg/m3 with resin 12 % have lowest value at 11.90 % while the highest was 25.46 % for density 700 kg/m3 with 8 % of resin content. Lowest WA of 77.6 % was for board density 700 kg/m3 with resin 12 %. Then for highest WA (151.58 %) the value was for board with density 600 kg/m3 and 8 % resin content. For physical properties, only board with density 600 kg/m3 and 12 % resin content passed the TS for JIS requirement.

4.2 Statistical significant for Particleboard

Table 4 shows the analysis of variance (ANOVA) of the effect resin content on board density. The result shows that the resin content significantly affects the MOR, MOE, IB and WA values. TS effect was not significant.

Table 4: The summary Analysis of variance (ANOVA) for particleboard from *Kelempayan* sp

SOV	df	MOR	MOE	IB	TS	WA
Resin content	2	367.628**	258.679**	31.687**	0.198ns	79.267**
Density	2	41.617**	33.773**	24.642**	104.386*	65.938**
Density x Resin content	4	3.487**	3.366**	3.521**	1.652ns	3.734**

Note: *-significant, **-very significant, ns- not significant.

4.3 Effect of board density on mechanical and physical properties

Effect on increasing the strength of board based on board density can be seen in Figure 2. The highest of MOR, MOE and IB is 20.3 MPa, 2543 MPa, 0.33 MPa at board density 700 kg/m3. The lowest in density 500 kg/m3, the result being 6.9 MPa (MOR), 1076 MPa (MOE) and 0.16 MPa (IB). For density 600 kg/m3, the result is 11.3 MPa (MOR), 1619 MPa (MOE) and 0.17 MPa (IB). The increase in the mechanical properties is due to more resin being available for bonding of particles (Deng et al., 2014).

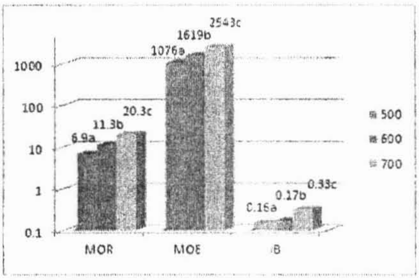

Figure 2: Effect of board density on mechanical properties

Figure 3 showed the effect of board density on physical properties of particleboard from Kelempayan sp. There is no significant effect for TS. For WA, it is significant. The lower value of board density had higher percentage of TS and WA. Based on Figure 3, the value decrease when then board density increase. The trend indicates in WA is same with TS. The larger board density will give the lowest WA value. Therefore, the lower density will give bad performance toward WA. According to the Nemli & Öztürk (2006), the lower density board, easily absorb water compared to higher density board.

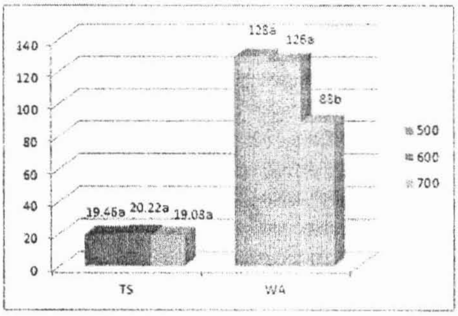

Figure 3: Effect of board density on physical properties

4.4 Effect of resin content on mechanical and physical properties

From Figure 4, increasing in resin content can increase the MOR, MOE and IB values. It was shown with an increase in resin content; all mechanical properties were significantly affected. Figure 4 show that, 12 % of resin content gives high strength compare with 10 % and 8 %. The value for 12 % of resin content is 15.7 MPa, 10 % is 13.5 MPa and 8 % is 9.5 MPa. For MOE result, the values for 8 % of resin content is 1359 MPa, for 10 % is 1811 MPa and 12 % is 2060 MPa. Testing for IB also increases when the applied resin on board increased. For 8 % is 0.11 MPa, 10 % is 0.24 and 12 % is 0.32 MPa. According to Akyüz et al, (2010) the value of IB increases if resin content increase, the resin content 12% were significantly higher than 10% and 8%.

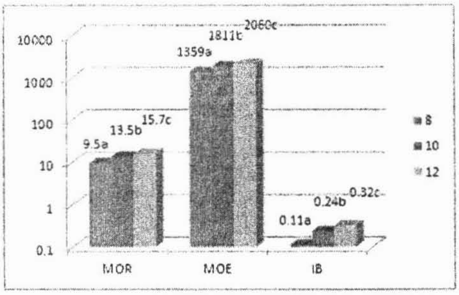

Figure 4: Effect of resin content on mechanical properties

Figure 5 shows the effect of resin content on thickness swelling and water absorption. From the result, increasing in resin content can affect the WA and TS values. Higher amount of resin available increases bonding between the particles and decreases the ability of water absorption. Based on Figure 5, the trend was decreased for treatment with 8 %, 10% and 12 %, with values of 25.48 %, 21.64 % and 13.08 % respectively. Low resin content gives higher value of physical properties of board. The decrement in the UF resin content resulted in higher TS values because swelling induced stresses which caused the separation of the particles within the board and hence failure of the resin bond between particles occurred (Ayrilmis et al., 2012). Same affected is seen in WA values, the resin content 8 % (138 %) show the high of percent of water absorption, followed by 10 % (110 %) and 12 % (95 %)

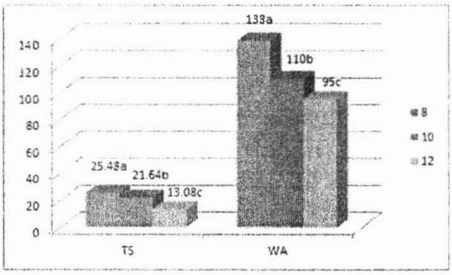

Figure 5: Effect of resin content on physical properties

5. CONCLUSIONS

In this study of effect of resin content and board density on the properties of three layer particleboard from Kelempayan sp, the mechanical properties of board at density 700 kg/m3 and 12 % resin content give the best performance for MOR, MOE and IB based on Japan Industry Standard, JIS A5908:2003. The mechanical strength value increased significantly as resin content changed from 8 % to 12 %.

For effect of resin content on board, the result of physical properties (TS and WA) for density 600 kg/m3 with 12 % resin meet requirement standard. However, for thickness swelling and water absorption, the result showed decrease when the resin contents were increased from 8

% until 12 %. This study also proved that different board density can give affects the strength of board. The higher the board density, the higher is the strength especially with suitable resin content. Board density is a priority of factor in manufacture of particleboard as it is related with mechanical and physical properties of particleboard.

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REFERENCES

Akyüz, K. C., Nemli, G., Baharoğlu, M. & Zekoviç,E. (2010). Effects of Acidity of the Particles and Amount of Hardener on the Physical and Mechanical Properties of Particleboard Composite Bonded with Urea Formaldehyde. International Journal of Adhesion and Adhesives, 30(3), Pp166–169

Anonymous. (1996).Particleboard National Association

Ayrilmis, N., Kwon, J. H., & Han, T. H. (2012). Improving Core Bond Strength and Dimensional Stability of Particleboard Using Polymer Powder in Core Layer. Composites Part B :Engineering, 43(8)

Biswas, D., Kanti, S., & Hossain, M. M. (2011). Adhesives Physical and Mechanical Properties of Urea Formaldehyde-Bonded Particleboard made from Bamboo Waste. International Journal of Adhesion (31),Pp84–87.

Deng, S., Du, G., Li, X., & Pizzi, A.(2014). Performance and Reaction Mechanism of Zero Formaldehyde-Emission Urea-Glyoxal (UG) Resin. Journal of the Taiwan Institute of Chemical Engineers, (45), p4

Ismail, J. (1995). Anatomical Variation in planted Kelempayan (Neolamarckia cadamba,rubiaceae). IAWA Journal ,Vol. 16 (3). 1995: 277- 287, 16(3), Pp277–287.

Japanese Industrial Standard (JIS A 5908:2003), Particleboards, Japanese Standard Association/ 4-1-24, Akasaka, Minato- Ku, Tokyo, 107-8440 Japan

Nations, S. A., Peninsula, M., & Independence, S. (2012). Market Watch 2012. The Timber Sector in Malaysia General Information about Malaysia Pp. 1–13

Nemli, G., & Öztürk, İ. (2006). Influences of some factors on the formaldehyde content of particleboard. Building and Environment, 41(6), Pp770–774

Noor Azrieda A.R, Razali A.K, Izran K, R. S. & A. A. M. (2009). Particleboard from Start to Finish. Gaithersburg Borneo Science 25: September 2009, Pp47–58