International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Properties of Particleboard from Sawmill Wastes and Rubberwood (*Hevea brasiliensis*) with Different Board Thickness and Resin Content

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Abstract: This study investigate the effect of the board thickness and resin content on the properties of particleboard. Single-layered sawmill wastes and rubberwood particleboards bonded with urea formaldehyde (UF) resins were manufactured. The boards were fabricated with three different board thicknesses (15, 18 and 25mm) at three different resin contents (7, 8 and 9%). The boards produced were evaluated for their modulus of elasticity (MOE), modulus of rupture (MOR), internal bonding (IB) and thickness swelling (TS) in accordance with the European Standards. Board thickness does affect the mechanical properties of particleboard. The study revealed that thinner boards gave higher MOE, MOR, IB and TS. No significant effects were found among three resin contents for MOE, MOR, IB and TS. It can be concluded that the particleboard made from mix tropical wood from sawmill waste and with rubberwood were suitable for particleboard manufacturing.

Keywords : Particleboard, Rubberwood, Sawmill Wastes.

I. INTRODUCTION

Wood-based industrial sector ranked third in Malaysia in term of export earnings. The RM26 billion contribution covers export of composites, timber products and furniture [1]. In Malaysia, solid wood industry and wood composite industry are the two main sectors in the wood-based industry. Solid wood industry includes logs, sawn timber, mouldings, builder's joinery and carpentry, while the wood composite industry involved plywood, particleboard, medium-density fibreboard and cement board. In Malaysia, the timbers which include Mahagony, Jati (teak), Shorea, Kembang Semangkuk, Meranti, Merbau and Chengal were mostly used for heavy construction, railway sleepers, furniture, bridges, marine construction, boat building, and for tin mining [2].

The wood composite industry in Malaysia relies heavily on rubberwood as raw material. Rubberwood (*Hevea brasiliensis*) was introduced as raw material in the 1980's so as to utilize the logs available as a result felling of the trees during replanting exercise. The processed has steadily sustained the wood panel industry in Malaysia. Unfortunately, the plantation areas of rubberwood are declining as more area is being replanted with oil palm instead of continuing with rubberwood [3]. Oil palm earning per acre is more than latex contribution making it more attractive for planters to convert to oil palm plantation. The fact that rubberwood is susceptible to attack by fungi decreased its worth further. The staining of fungi is an issue as the attack on the tree could be as fast as within one day of felling. Thus treatments of rubberwood are done by various methods [4]. An additional pressure towards the supply of rubberwood is the popularity it has gained as solid wood source for furniture making. Furniture represents 35% of the export value for Malaysia [1]. As such, supply off rubberwood to the furniture industry will be a priority. Currently, the particleboard industry is facing difficulty in obtaining raw materials because of the shortage in supply created by preferential selling and increase of demand of rubberwood. Options taken by researchers to ease the pressure of raw material source include looking for fast growing species such as Petai Belalang, Kenaf and also oil palm tree residues as a new raw material [5] [6] [7]. Additionally, rubberwood could also be mixed with other tropical hardwood and sawmill waste to a produce wood-based panels [5].

The rapid growth in furniture industry leads to the wastage of the raw materials after being sawn. In wood industry for each log processed, about 65 % become waste and only 35 % can be processed into acceptable sawn timber product. According to [8], there are several companies in which the conversion rate of processed logs approached 80 %, as the demand for quality of acceptance by customer increase. These percentages showed the high volume of unused material produced which translate to the wastage of raw materials. Initiative to convert this waste to wealth is prudent rather than disposing or burning the material, a common practice for sawmill waste control. Researchers had tried making board from the waste of forest residues and wood waste [9] [10] with success in term of board performance.

Manuscript published on November 30, 2019.
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The utilization of mill waste at particleboard industry has been practiced by some mills. The utilization was at times driven by lack of main raw material rather than by design. It is known that particleboard properties are affected by among others, wood species, mixing ratios, production parameters, resin formulation and resin content. The resulting particleboards have not been thoroughly analyzed for the effects of many of the stated parameters.

Hence, this study aims to investigate the influence of two factors; i. Board thickness and ii. Resin content towards the mechanical and physical properties of particleboard produced.

II. MATERIALS AND METHODS

A. Preparation of wood raw material for particleboard

Sawmill wastes and rubberwood materials were obtained from Mieco Manufacturing Sdn. Bhd. Gebeng, Pahang, Malaysia. Logs were debarked and cut into required size for the chipping process. Chips were flaked into smaller particles before being dried in a shaded area. The particles were then screened into 0.5 mm, 1.0 mm and 2.0 mm particle sizes. Prior to board making the screened particles were dried at 80˚C in an oven to reduce the moisture content to less than 5 %.

B. Board Making

Three thicknesses (15, 18 and 25 mm) of single-layered particleboards of density of 700 kg/m^3 were fabricated. Particles were blended with 7, 8 and 9 % urea formaldehyde resin and then spread evenly into square box former with caul plate underneath to ensure consistent forming. The resulting mat was cold pressed followed by hot pressed to the designated thickness. All particleboards were kept in a conditioning room for 24 h before they were cut for property evaluation.

C. Evaluation of Mechanical and Physical Properties

Test specimens for bending strength, Internal Bond (IB) and Thickness Swelling (TS) were prepared from the conditioned particleboards as per [11] and [12] requirement. Bending strength and IB tests were conducted using an Instron Universal Testing Machine. Sample thickness was measured at initial stage prior to soaking and immediately after soaking 24hours in water for the determination of TS.

III. RESULTS AND DISCUSSION

Table I shows the mechanical and physical properties of particleboard made from sawmill wastes and rubberwood from different thickness and resin content.

Table I: Properties of Particleboard

Density kg/m³	Thick-ness mm	Resin content %	MOR MPa	MOE MPa	IB MPa	TS %
700	15	7	13.91	2303.5	0.9	10.81
		8	12.5	2185.7	0.76	14.36
		9	12.4	2092	0.83	11.48
700	18	7	11.7	2117	0.76	11.56
		8	11.6	2057.5	0.67	10.26
		9	11.7	1945.7	0.74	8.5
700	25	7	10.9	1830	0.57	13.41
		8	10.7	1886	0.58	9.69
		9	11.8	2235.3	0.77	9.28

Note: MOE-Modulus of Elasticity, MOR-Modulus of Rupture, IB-Internal Bond, TS-Thickness Swelling

Overall, board thickness 15mm performed better than 18 and 25 mm. Resin content 7% also contributed to better performance. Board thickness 15mm and resin content 7 % contributed to the highest board performance in mechanical properties. The values of MOE, MOR and IB are 2303.5 MPa, 13.91 MPa and 0.90 MPa, respectively. Boards fabricated using 18mm board thickness and 9% resin content possessed the lowest TS value of 8.5 %.

A. Statistical Significance

Table II shows the statistical analysis for the effects of board thickness, resin content and their interactions with the board properties. Board thickness was found to affect Modulus of Elasticity (MOE), Modulus of Rupture (MOR), and IB significantly. However, there was insignificant effect of resin content on MOR, MOE, IB and TS. Interaction effect of board thickness and resin content on was significant only for MOE.

Table II: Summary of the ANOVA on Particleboard Properties

SOV	df	MOR	MOE	IB	TS
Board thickness	2	8.29*	115948*	0.09*	11.37ns
Resin Content	2	0.88ns	6449ns	0.03ns	12.36ns
Board thickness × resin content	4	1.45ns	106245*	0.02ns	12.66ns

Note: MOE-Modulus of Elasticity, MOR-Modulus of Rupture, IB-Internal Bond, IB-Internal bond, TS-Thickness swelling SOV = Source of Variance, df = Degree of freedom, *significant at $p < 0.05$, ns =Not significant at $p > 0.05$

B. Effects of Board Thickness

Fig. 1 shows the effects of board thickness on mechanical properties. The MOR of particleboards was observed to decrease significantly with increase in board thickness. Boards made from board thickness of 15 mm had significantly higher MOE compare to 18 and 25 mm. Thinner board had more compact structure, thus it shows higher MOR and MOE due to the stronger bonding among the tightly packed particles.

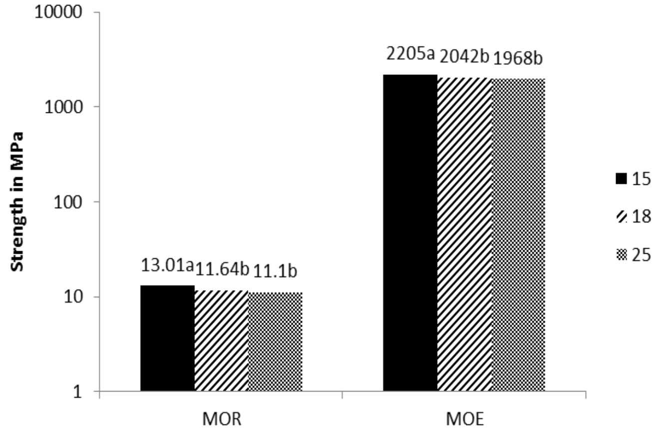

Fig.1: Effects of board thickness on MOR and MOE. Letters a, b and c indicate values in cluster to be significantly different at p < 0.05

Retrieval Number: D5227118419/2019©BEIESP
DOI:10.35940/ijrte.D5227.118419
Journal Website: www.ijrte.org

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By comparing between board thicknesses on IB, it was seen that the particleboards manufactured from 15 mm board thickness was superior in IB, exceeding that of 18 and 25 mm board thickness (Fig. 2). The higher IB found from thinner particleboards because of low porosity within the boards which lead to compact structure and high contact between the wood particles.

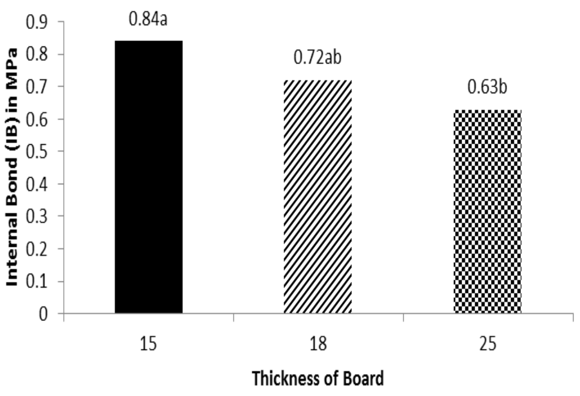

Fig. 2: Effects of board thickness on IB. Letters a and b indicate values in cluster to be significantly different at $p < 0.05$

Fig. 3 shows the effects of board thickness on TS behavior of particleboard. Non-significant difference is observed between all board types for the TS values. The board thickness plays an important role as it will affect the rate percentage of thickness swelling whether the board absorbs water more or less. Boards manufactured from board thickness 18 mm had lower TS when compared to the boards manufactured from board thickness 15 and 25 mm. Low TS of particleboard from 18 mm board thickness is related to better crosslinking of the particles resulting in restricted water absorption into the board.

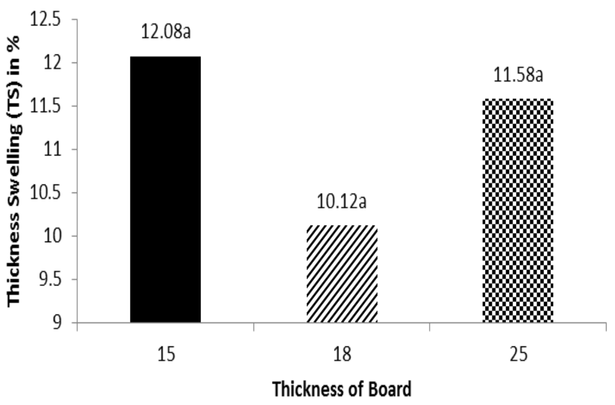

Fig. 3: Effects of board thickness on TS. Single letter a indicate values in cluster have no significant difference at $p < 0.05$

C. Effects of Resin Content

Fig. 4 display the results resin content influence on particleboard bending properties. The MOR and MOE values showed insignificantly different to each other. Boards at 7 % resin content had higher MOR than 8 and 9 % resin content. Boards with higher resin content had higher MOE than the boards with lower resin content. According to [13], the increase of resin content provides opportunity for to more bonding sites and hence increase the bending properties of the boards. Research by [14] also found resin content increment to give a similar behaviour.

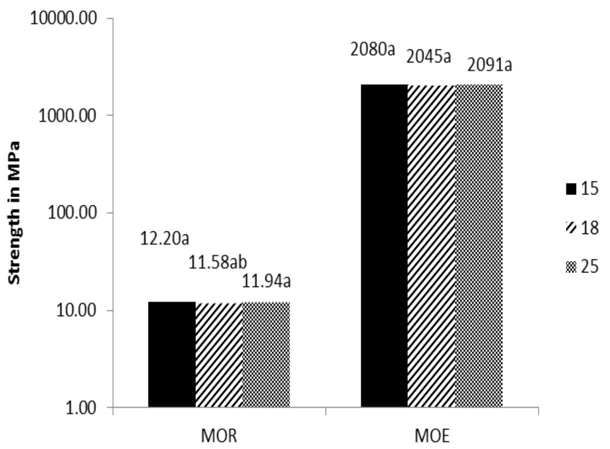

Fig. 4: Effects of resin content on MOR and MOE. Single letter a indicate values in cluster have no significant difference at $p < 0.05$

The effects of resin content were observed to be insignificant (Fig. 5). The IB values showed insignificantly different to each other. Resin at 9 % in the board gave the highest IB of 0.78. The result of the resin content is a bit varied, with 8 % resin giving lowest value. As the difference is insignificant, the result of the resin effect is similar. Theoretically, IB is proportional to the resin content in board produced. As more resin is available, more contact point is viable. Previous studies found that more resin availability lead to better interaction of particle to resin, which help improve the mechanical strength of particleboard [15], [16], [17].

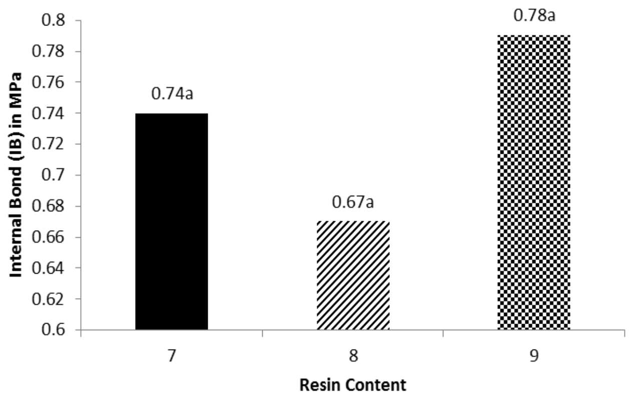

Fig. 5: Effects of resin content on IB. Single letter a indicate values in cluster have no significant difference at $p < 0.05$

It can be seen in Fig. 6, that the TS of the boards was not significantly improved by increasing resin content. ANNOVA done on the board showed no difference. However, the value of the TS is seen to be inversely proportional to the content of the resin used. Increases in resin content normally result in decreases in TS.

High resin content bonds the particles tightly. The tight bond help reduce capillary action which absorb water into composites. Tight bond also resist the bulking of particles better by resisting the hydrogen bond formation between water and cellulose structure in the wood particles. This result is in agreement with the finding of [18].

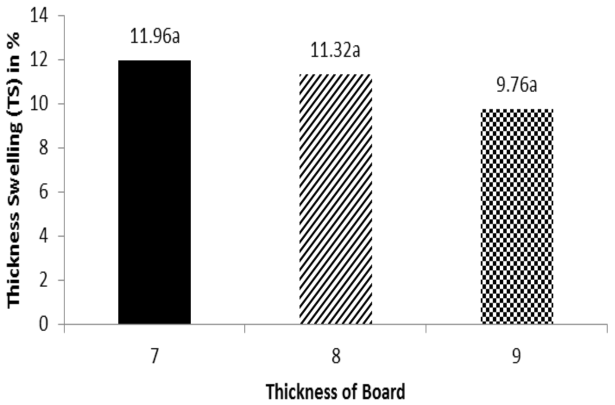

Fig. 6: Effects of resin content on TS. Single letter a indicate values in cluster have no significant difference at $p < 0.05$

IV. CONCLUSION

From this study, the higher the board thickness, the lower is the strength properties of particleboard. Board thickness does affect the mechanical properties of particleboard. However, the physical properties in thickness swelling give no significant difference.

Resin content does not show effect mechanical properties of particleboard. Decreasing result on the thickness swelling affected by resin content shows that the higher amount of resin content, react to lower particleboard swelling. It could be concluded that the particleboard made from mix tropical wood from sawmill waste and rubberwood were suitable for particleboard manufacturing.

ACKNOWLEDGMENT

Acknowledgement is given to Mieco Chipboard Bhd. at Gebeng, Pahang Malaysia for their assistance with raw materials and facilities for the experimental work.

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Her thesis involved evaluation on the effects of particle size, board density, resin content, hot press temperature and alkaline concentration on properties of Kelempayan (*Neolamarckia cadamba*) particleboard. She published her work in Scopus-Index Journals, Open-Access Journals, Book Chapter and International Conference Proceedings.

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