ISSN 1996-3343

Asian Journal of Applied Sciences

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Asian Journal of Applied Sciences 3 (5): 310-316, 2010
ISSN 1996-3343

Properties of Particleboard Produced from Admixture of Rubberwood and Mahang Species

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Abstract: Particleboard is one of the major timber products exported from Peninsular Malaysia. Apparently, the increasing price and lack of supply of rubberwood has forced the particleboard manufacturers to look for new alternative raw material to produce particleboard. Hence, the production of particleboard through mixture of fast-growing wood species will be a good solution to the depleting wood supply issue. The objective of this study was to investigate the physical and mechanical properties of particleboard produced from admixtures of rubberwood and Mahang at different proportion levels and the properties were evaluated based on the Japanese Industrial Standard for particleboard (JIS A 5908-1994). The physical and mechanical data presented here, were analyzed using Analysis of Variance (ANOVA) and Least Significant Difference (LSD), to determine the significant differences of the variables. From the study, an increase in density resulted in increase of thickness swelling of particleboard. In addition, the water absorption for particleboard with density 500 kg m^{-3} was higher. For bending properties, admixture particleboard of rubberwood and Mahang had significantly lower wet and dry bending property. In terms of internal bond strength, decrease in rubberwood proportion resulted in decrease in the internal bonding strength of the particleboard.

Key words: Mixed species particleboard, rubberwood, Mahang, physical and mechanical properties, thickness swelling, internal bonding strength

INTRODUCTION

The export volume of particleboard has been increasing over the past few years and it is one of the major timber wood products exported from Peninsular Malaysia. During the 70s and 80s, the raw material supply was in abundance and this can be attributed as the success of particleboard in wood-based industry in Malaysia (Rahman, 2002). In year 2008, the export volume of particleboard in Peninsular Malaysia had reached 483,517 m^3 or 16% of the total timber export at the particular year, which is 3 times of the export volume of particleboard in year 2000 (Anonymous, 2001, 2009). Traditionally, Rubberwood (*Hevea brasiliensis*) is the main raw material used for particleboard production due to its favorable medium-density hardwood and natural light color (Balsiger *et al*., 2000).

However, in recent years, the wood supply in Peninsular Malaysia has been decreasing rapidly. The rubberwood logs that available around 1.2 million m^3 annually in the early 1990's (Hong, 1996). However, despite the increasing demand for rubberwood, the total plantation

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area has been declining as much as 25.5% or 313,680 hectares from year 1998 till 2007 (Anonymous, 2008). The declining supply of rubberwood is caused by the logs are utilized to manufacture variety types of products (MDF, plywood, sawntimber etc.) and the rubber plantation area is getting smaller due to unattractive price (Norini, 2001). As such, particleboard manufacturers are forced to search for new alternative fast-growing wood species as replacement of raw material to produce particleboard.

When, the supply of traditional and popular rubberwood for particleboard production is declining, utilizing lesser known and fast growing species such as Mahang would be promising alternative raw materials in the future for particleboard processing. In brief, Mahang (*Macaranga* sp.) is a pioneer tree species and light-density hardwood which emerge in sizeable quantity in logged-over forest in Southeast Asia. The commercial possibilities of Mahang as a source of timber for manufacturing products such as particleboard comes with its density 270-495 kg m^{-3} and long fibers.

In Malaysia, Mahang is not in abundance and commercially available at the moment. Thus, mixing rubberwood and small volume of Mahang to produce particleboard would be ideal. This would create an easy adaptation to the current rubberwood particleboard production line without any major changes of parameters. Nevertheless, the application of mixed wood species for particleboard production is not common in Peninsular Malaysia. Due to the contrary wood density between two species, defects of particleboard would turn up. This is because density variation between the two wood species has influenced binder consumption and the bulk of particles to be consolidated. As such, strength and the surface smoothness of the board will be influenced (Xu and Suchsland, 1998).

To compare the characteristics of particleboard from mixed species with those of particleboard from a single species, average density of the mixture used must be determined. For instance, at a given board density, an increase in raw material density causes a decrease of particleboard strength properties and an increase in linear expansion and thickness swelling. In order to produce quality mixed species particleboard, there is a need to find the appropriate proportion of mixing rubberwood to Mahang at different density levels.

Therefore, the main objective of this study was to investigate the physical and mechanical properties of particleboard produced from admixtures of rubberwood and Mahang at different proportion and density levels.

MATERIALS AND METHODS

This study was conducted from June 2006 to June 2007. Rubberwood and Mahang species that were chosen for this study were prepared separately. The rubberwood particles were obtained from commercial particleboard plant in Nilai, Negeri Sembilan. Mahang particles were prepared in laboratory where the trees were harvested in Hutan Air Hitam, Puchong, Selangor. The tree was bucked into smaller segments before it is chipped by using a commercial chipper. The Mahang chips were then reduced into particles using laboratory type hammermill in Wood Composite Laboratory, Universiti Putra Malaysia. Urea formaldehyde resin with 64.5% solid content supplied by Malayan Adhesives and Chemicals Sdn Bhd., Shah Alam, Selangor was used as binding agent. Single-layer boards were made using each species alone as well as mixtures of species. The particleboards in this study were made with target density of 600 and 500 kg m^{-3}.

Table 1 shows the different proportion levels of rubberwood to Mahang used for producing particleboard in this study. Three replicates for each species alone and each combination were produced.

Table 1: Proportion of rubberwood and Mahang

Type	Proportion of RW:Mahang*
1	100:0 (control)
2	90:10
3	70:30
4	50:50
5	0:100

*Based on oven-dry weight

Air-dried rubberwood and Mahang particles were screened on a vibrator screen machine to obtain the sizes of particles of 0.5-1.0 and 1.0-2.0 mm. The accepted particles were dried in an oven with temperature of 60°C to achieve Moisture Content (MC) of 4-6%. A pre-weighted amount of particles comprised of rubberwood and Mahang were blended initially without binder to enable it to mix thoroughly prior to spraying of the furnish that comprised of urea formaldehyde resin, wax emulsion and catalyst of ammonium chloride (NH_4Cl). Urea-formaldehyde resin was applied at a resin content of 10% resin solids based on oven-dry weight of wood particles. The wax emulsion was applied at 1% based on the weight of the resin and catalyst of ammonium chloride (NH_4Cl) act as hardener was applied at 1% based on the resin content.

After blending, the particles were spread evenly into 340×340 mm wooden box former using metal caul plate as the base to produce a loose mat. Silicone release agent was sprayed onto the caul plate to prevent the panel from sticking to the plate during hot pressing. The mat formed was initially pre-pressed manually to consolidate the thickness. Distance bars were placed at both sides of the mat in order to get the targeted board thickness during hot pressing. The mat was then hot pressed in a thermal-oil heated hydraulic hot press at an elevated temperature of 145°C with a specific pressure of 18 kg cm^{-2} to achieve target thickness 12 mm. The mat was hot-pressed for 5 min based on the recommendation of the resin supplier.

After hot-pressed, the boards were then conditioned in a conditioning room maintained at a relative humidity of 65±5% and 20±2°C for 7 to 10 days prior to properties evaluation. The physical and mechanical properties of the particleboard produced were evaluated based on the Japanese Industrial Standard for particleboard (JIS A 5908-1994). The physical and mechanical data presented here were analyzed using Analysis of Variance (ANOVA) to determine the significant difference of the variables used on the properties. The means were further analyzed by Least Significance Difference (LSD) to determine the significant level of the variables used in this study.

RESULTS

The board density varied from 394 to 511 kg m^{-3} with a mean density of 465 kg m^{-3} for targeted density of 500 and 481 to 637 kg m^{-3} with a mean of 562 kg m^{-3} for targeted density 600 kg m^{-3}. The average physical and mechanical properties for all type of particleboard are summarized in Table 2. These properties were corrected to the targeted density before subjected for statistical analysis. The Eq. 1 for corrected strength properties as below:

$$\text{Strength}_{cor} = \text{Strength}_{act}+(\text{Density}_{tar}\text{-Density}_{act})\times\text{Radian of strength vs. Density} \quad (1)$$

Where:

Strength_{cor} = Strength corrected
Strength_{act} = Strength actual

Table 2: Physical and mechanical properties of all type of particleboard

Density ($kg\ m^{-3}$)	Proportion (RW:MR)	Moisture content (%)	Thickness swelling (%)	Water absorption (%)	WMOR1 ($N\ mm^{-2}$)
500	100:00	8.67±0.15	11.88±1.17	89.78±14.68	3.6±0.5
	90:10	7.40±1.47	16.18±2.42	132.51±34.70	5.3±1.6
	70:30	8.50±0.26	14.35±1.00	89.69±9.71	4.9±0.6
	50:50	7.93±0.32	17.07±3.75	96.61±14.37	4.2±1.2
	0.100	8.53±0.47	12.71±0.78	78.62±12.06	6.7±1.3
600	100:00	9.33±0.96	13.19±2.00	69.39±11.56	8.8±3.10
	90:10	9.17±1.55	21.03±6.42	98.49±20.29	8.41±0.70
	70:30	11.00±1.04	13.25±1.45	63.07±16.08	6.61±0.91
	50:50	9.93±0.93	22.71±7.71	97.69±27.39	9.30±2.34
	0.100	10.63±0.65	13.23±1.02	65.19±9.21	13.14±2.26

Density ($kg\ m^{-3}$)	WMOE2 ($N\ mm^{-2}$)	MOR3 ($N\ mm^{-2}$)	MOE4 ($N\ mm^{-2}$)	IB5 ($N\ mm^{-2}$)
500	319.00±119.3	7.50±3.1	699±92.4	0.74±0.20
	521.00±151.2	9.70±4.1	1099±325.0	0.58±0.35
	452.00±38.0	9.60±1.8	1014±143.4	0.49±0.15
	418.00±152.9	6.80±2.1	824±277.0	0.40±0.17
	657.00±228.2	12.60±2.7	1287±353.0	0.66±0.15
600	725.00±233.24	23.40±14.29	2447±1144.8	1.30±0.51
	842.48±100.36	16.43±4.17	1903±420.4	0.99±0.29
	575.22±166.96	10.90±2.88	1251±278.9	0.58±0.18
	650.73±151.42	15.52±3.80	1768±309.9	0.44±0.10
	892.97±219.69	19.37±4.37	1796±343.1	0.83±0.09

Data is expressed as Average±SD. Values in brackets indicate Standard Deviationm [1]WMOR: Wet modulus of rupture, [2]WMOE: Wet modulus of elasticity, [3]MOR: Modulus of rupture, [4]MOE: Modulus of elasticity, [5]IB: Internal bond strength

$Density_{tar}$ = Target density
$Density_{act}$ = Density actual

The moisture content of the particleboard produced in this study ranges from 8 to 11%. Increasing board density had similar effects on the bending properties and IB. Boards made with 600 $kg\ m^{-3}$ had higher bending properties and IB compared to those 500 $kg\ m^{-3}$.

Dimensional Stability

The thickness swelling of particleboard made with density 500 and 600 $kg\ m^{-3}$ were ranging from 11.88 to 17.07% and 13.19 to 22.71%, respectively. The highest thickness swelling was observed for particleboard produced from admixture of 50% rubberwood and 50% Mahang at both density levels. Particleboard produced from rubberwood alone was more dimensional stable than other combination at both density levels.

In 24 h water absorption test, particleboard made with Mahang alone had lower water absorption than other combination for both density levels. Lowest water absorption was observed for boards with proportion of 90:10 and 50:50 at both density levels. Overall, the particleboard made with target density 600 $kg\ m^{-3}$ had less water absorption than particleboard made with target density 500 $kg\ m^{-3}$.

Bending Properties

ANOVA revealed that no significant difference was observed for the interaction between the proportion and density. Therefore, the density's variable been grouped together to run the statistical analysis in this study. Table 3 shows the means comparison of WMOR, WMOE, MOR and MOE for all the particleboards.

As shown in Table 3, particleboard produced from Mahang alone had the highest wet and dry bending properties compared to other combination. The particleboard produced from admixture of rubberwood and Mahang had significantly lower wet and dry bending properties compared to that of homogenous particleboard.

Table 3: Effect of proportion on dry and wet bending properties of the particleboard

Proportion (RW:MR)	WMOR	WMOE	DMOR	DMOE
	---------------------------	----------(N mm^{-2})----------	---------------------------	
100:0	6.2^{b}	522^{b}	15.4^{ab}	1574^{a}
90:10	6.8^{b}	682^{a}	13.0^{abc}	1501^{ab}
70:30	5.7^{b}	514^{b}	10.2^{c}	1132^{b}
50:50	6.7^{b}	534^{b}	11.1^{bc}	1290^{ab}
0:100	10.0^{a}	775^{a}	15.9^{ab}	1541^{a}
LSD	1.4	137	4.5	377

Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$ according to Least Significance Difference (LSD)

Table 4: Effect of proportion on particleboard's internal bonding strength

Proportion (RW:MR)	IB (N mm^{-2})
100:0	1.02^{a}
90:10	0.79^{b}
70:30	0.54^{c}
50:50	0.42^{c}
0:100	0.74^{b}
LSD	0.13

Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$ according to LSD

Internal Bond Strength

Table 4 shows the means comparison of internal bond for different combination of particleboard in this study. ANOVA revealed that no significant difference was observed for the interaction between the proportion and density. Therefore, the density's variable been grouped together to run the statistical analysis in this study. IB strengths generally decreased with decrease in rubberwood proportion, but the IB was higher when either rubberwood or Mahang alone was used to produce particleboard.

DISCUSSION

Dimensional Stability

Particleboard made with target density 600 kg m^{-3} has higher thickness swelling rate than 500 kg m^{-3} board. High swelling values for high density boards are very common, as Khedari *et al*. (2003), for example, found an increase in swelling with increase in density of particleboard.

Overall, the particleboard made with target density 600 kg m^{-3} had less water absorption than particleboard made with target density 500 kg m^{-3}. This phenomena may be explained by the theory of more void over volume found in particleboard with lower density than the high density that provide more space for water storage.

Bending Properties

There is no significant difference for the interaction between the proportion and density. Wong *et al*. (1999) stated that at a given board density, an increase in raw material density causes a decrease of particleboard strength properties. This is related to the volume of wood substance compacted to form a board. Although, of the same density, a greater amount of wood was pressed to form the board using Mahang species.

For the wet and dry bending properties between admixture and homogenous particleboard, Xu and Suchsland (1999) reported that the bending properties of mixed species particleboard were less than the single species counterpart. The major disadvantages of mixed species particleboard may relate to the variation of density that affects the resin uptake by different species particles. During mixing, lighter density particles have tendency to flow on top of the mixing tank and hence absorb more resin than the heavy particles. This attribute to the poor adhesion interference between the heavy and lighter particles after formed into particleboard.

Internal Bond Strength

Internal bond is known to be influenced by the wood species used to produce particleboard. Internal bond strengths decreased with decrease in rubberwood proportion, as Ashori and Nourbakhsh (2008) stated that low density wood species will gave poor internal bonding strength compare to much higher density wood. The presence of increasing quantities of low density wood particles in the mix will cause a significant reduction of internal bond strength. This theory was further supported when with the increasing of Mahang proportion decreased the internal bonding of the particleboard in this study. The low density wood in the mixtures exerted the controlling influence on IB.

CONCLUSION

Conclusively, it is possible to mix species of a wide range of density and produce acceptable particleboards in several rubberwood and Mahang combinations. Mixtures of species for particleboard and other products can be a partial answer for increased utilization of the timber of tropical forests and overcome the shortage of rubberwood.

REFERENCES

Anonymous, 2001. Department of statistic Malaysia. http://infotree.library.ohiou.edu/single-records/2787.html.

Anonymous, 2008. Department of statistic Malaysia. Malaysian External Trade Statistics October and January-October 2008. http://www.statistics.gov.my/portal/index.php?lang=en.

Anonymous, 2009. Department of statistic Malaysia. http://www.stat.wmich.edu/news/colloquium.html.

Ashori, A. and A. Nourbakhsh, 2008. Effect of press cycle time and resin content on physical and mechanical properties of particleboard panels made from the underutilized low-quality raw materials. Ind. Crops Prod., 28: 225-230.

Balsiger, J., J. Bahdon and A. Whiteman, 2000. Asia-Pacific Forestry Sector Outlook Study: The Utilization, Processing and Demand for Rubberwood as a Source of Wood Supply. FAO, Bangkok,.

Hong, L.T., 1996. Rubberwood utilization: A success story. Paper presented at the 20th World Congress of the International Union of Forestry Research Organizations, Aug. 6-12, Tampere, Finland, pp: 160-160.

Khedari, J., S. Charoenvai and J. Hirunlabh, 2003. New insulating particleboards from durian pee and coconut coir. Build Environ., 38: 435-441.

Norini, H., 2001. Supply and demand of timber for the wood-based panel industries in Malaysia. Proceedings of the 3rd National Seminar: Wood-Based Panel Products, July 10-11, Kuala Lumpur, Forest Research Institute Malaysia, pp: 8-18.

Rahman, S.O., 2002. Wood-based panel product in the 21st century: Prospects and challenges. Proceedings of the 3rd National Semiar: Wood-Based Panel Products, July 10-11, Kuala Lumpur, Forest Research Institute Malaysia, ISBN: 983-2181-31-3, pp: 1-7.

Wong, E.D., M. Zhang, Q. Wang and S. Kawai, 1999. Formation of the density profile and its effects on the properties of particleboard. Wood Sci. Technol., 33: 327-340.

Xu, W. and O. Suchsland, 1998. Variability of particleboard properties from single- and mixed-species processes. Forest Prod. J., 48: 68-74.

Xu, W. and O. Suchsland, 1999. Within-panel variability and selected property relationships of particleboard from single-and mixed-species processes. Forest Prod. J., 49: 36-40.