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Development of Oriented Strand Board from Acacia Wood (*Acacia mangium* Willd): Effect of Pretreatment of Strand and Adhesive Content on the Physical and Mechanical Properties of OSB*1

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ABSTRACT

Acacia wood *(Acacia mangium* Willd.) is the most popular fast growing tree species planted in timber estate in Indonesia and is considered to be very valuable raw materials for structural composite products. The objective of the research was to evaluate the properties of OSB prepared from *A. Mangium* wood with or without immersing the strands to hot water at 80°C for 2 hours. MDI adhesive was used in 3 levels i.e., 3%, 5%, and 7%. The moisture content of strand was 7%. The results indicated that immersing strands in hot water for 2 hours at 80°C prior to manufacture OSB improved significantly the mechanical peoperties (i.e., MOR and MOE) of OSB. The higher the adhesive content resulted in the better the dimensional stabilisation (i.e., water absorption and thickness swelling) and the mechanical properties (i.e., MOR, MOE and IB) of OSB. OSB prepared from hot-water immersed strands with 5% adhesive content has met all parameters requirement on the JIS A 5908 (2003) standard.

Keywords : OSB, *Acacia mangium*, pretreatment, adhesive content, dimensional stability, mechanical properties

1. INTRODUCTION

The fact showed that the trend of wood supply for wood industries from natural forest in Indonesia in the last decade showed sharply decreased. It is noted that in 1995/1996 the log production from natural forest is about 16.944 million m^3 and decreased to about 5.720 million m^3 in 2005. On the other hand, wood supply from timber estate for the same period increase sharply from 0.515 million m^3 in 1995/1996 to 12.818 million m^3 in year 2005 (Manurung *et*

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al., 2007). On the other hand, due to the lack of wood supply as raw material for wood indutry in Indonesia, the cost of wood reached to about 60～65% from the product price (BRIK, 2007). It was reported that up to the first quarter 2008, the total area of timber estate developed in Indonesia is around 3.032 million hectares (Ministry of Forestry of Indonesia, 2008). It is predicted that in the near future the supply of wood from timber estate and community forest will play a dominant role for substituting the wood supply from natural forest in Indonesia.

One of the most popular fast growng tree species planted in timber estate is *Acacia mangium*. *A. mangium* wood has bulk density around 0.53～0.61 with medium strength and belong to non durable wood. Furthermore, the extractive contain of *A. mangium* after dissolved in cold water, hot water and in 1% sodium hydroxide (NaOH 1%) were 5.75%, 7.28% and 20.17%, respectively. *A. Mangium* wood can be used for solid wood, wood composites products such as plywood, laminated veneer lumber/LVL, particle board, cement bonded particleboard, and medium density fiberboard (MDF), fuel wood and pulp and paper (Awang and David, 1993). It was also reported that the wettability of *A. Mangium* wood was low and it required physical and chemical treatments to improve it's wettability property prior to be bonded for wood composite products (Alamsyah *et al*., 2005).

Since its debut in 1978, oriented strand board (OSB) has gained rapid acceptance as a structural panel. OSB has virtually replaced plywood in new residential construction in many areas of North America. Today, the model building codes in U.S. and Canada recognize OSB panels for the same uses as plywood on a thickness by-thickness basis. It was reported that in 2004 in North America there are 64 OSB industries with production capacity is about 27 mill.sq.ft (Structural Board Association, 2005). OSB based on fast growing tree species especially *A. mangium* is promising to be developed for substitution of solid wood and plywood in Indonesia.

The objectives of this research were to investigate the effect of hot-water immersion on the strand and adhesive content on the physical and mechanical properties of OSB prepared from *A. mangium* wood.

2. MATERIALS and METHODS

2.1. Materials

Ten (10) years old of *A. Mangium* wood was collected from Arboretum of Faculty of Forestry, Bogor Agricultural University, Bogor, Indonesia. The diameter and spesific gravity (SG) of *A. mangium* wood were about 25～30 cm, and 0.41, respectively. The strands were produced by using disk flaker. The size of strand used was 60～70 mm (l), 28～30 mm (w), and 0.6～0.7 mm (t). MDI adhesive was used in 3 levels i.e., 3%, 5%, and 7%. The moisture content (MC) of strand was 7%.

2.1.1. Treatment of Strand

A part of strands was immersed in hot water at 80ºC in water bath for 2 hours, and then they were dried in the oven at 75～80ºC for several days to reach the MC about 7%. For comparison, untreated strands were also prepared.

2.1.2. Manufacturing of OSB

Three (3) layers OSB was produced with the size of 30 cm × 30 cm × 1.0 cm and the target density was 0.6 g/cm^3. Commercial MDI adhesive was used to bond the strands to OSB. The MDI adhesive was varied in 3 levels (i.e., 3%, 5% and 7%) and prepared based on oven dry

(OD) weight of strand. Rotary drum blender was used for mixing strand and adhesive. The board was hot pressed at 160ºC, 25 kg/cm^2 presure for 6 min. After that, the board was conditioned for 7 days in room adjusted at 25～30ºC and 60～65% R. H. Four (4) boards were prepared for each treatment.

2.2. Methods

2.2.1. Determination of Physical and Mechanical Properties

Two series of experiments were conducted namely 1) Physical and mechanical properties of OSB prepared from *A. mangium* strands with or without immersing in hot water prior to be manufacture; 2) Physical and mechanical properties of OSB prepared from *A. mangium* strands under various resin content.

Prior to physical and mechanical property tests, specimens were conditioned for ten days at room temperature. The physical and mechanical property of OSB were measured according to JIS A 5908 (2003) standard. The board parameters measured were air-dry density, moisture content (MC), water absorption (WA), thickness swelling (TS), modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB).

Mechanical properties - MOE, MOR and IB were tested by using UTM equipped with a load cell with a capacity of 10,000 N. The dimension of specimen in bending test is 185 by 50 by 9 mm^3. Evaluation of MOE and MOR were done both in their long dimension parallel and perpendicular to the major axis of panel. While for IB test, the dimension of specimen is 50 by 50 × 9 mm^3. Evaluation of MOE, MOR and IB were done at 28°C and 60% R.H. The crosshead speed was adjusted at 10,000 mm/min.

The dimension of specimen for evaluation air-dry density and MC of board is 100 by 100 by 9 mm^3. The specimens were immediately weighed and dried in the oven at 103 ± 2°C until they reached constant weight. For water absorption and thickness swelling tests, the dimension of specimen is 50 by 50 by 9 mm^3. The specimens were immediately weighed. Average thickness was determined by taking several measurements at specific locations. After 2 and 24 hours of submersion, specimens were dripped and wiped cleaning of any surface water. The weight and thickness of specimens were measured.

For physical and mechanical properties, all multiple comparisons were subjected to an analysis of variance (ANOVA). Highly significant ($\alpha \leq$ 0.01) and significant ($\alpha \leq$ 0.05) differences between mean values of the untreated and treated specimens were determined using Duncan's multiple range test.

3. RESULTS and DISCUSSIONS

3.1. Physical and Mechanical Properties of OSB Prepared from *A. mangium* Wood Strands with or without Treated in Hot-water

In the first experiment, the physical and mechanical properties of OSB prepared from *A. mangium* wood strands were evaluated with or without immersed in hot water at 80°C for 2 hour prior to be manufactured. The mean values of air-dry density, MC, WA, TS, MOR, MOE, and IB of OSB were presented in Table 1.

Both OSB prepared from treated and untreated strands in hot water for 2 hours at 80°C prior to be manufactured showed similar values of air-dry density. The mean value of air-dry density was about 0.59 kg/cm^3. The mean value of MC was 5.44% and 4.80%, respectively for treated and untreated specimens. The mean value of WA of specimens after immersing in wa-

Table 1. Effect of pre-treatment of strands on the properties of OSB prepared from *A. mangium* wood strands

Treatments	Physical and mechanical properties										
	Moisture content (%)	Air-dry density (kg/m³)	Water absorption (%)		Thickness swelling (%)		Modulus of rupture (kg/cm²)		Modulus of elasticity (kg/cm²)		Internal bond (kg/cm²)
			2H	24H	2H	24H	∥	⊥	∥	⊥	
NHWI	4.80 (0.31)	0.58 (0.02)	6.81 (0.23)	27.51 (0.94)	4.19 (1.00)	12.47 (2.05)	514* (28.15)	176* (14.80)	48110 (2505)	12503* (629)	4.06 (0.82)
HWI	5.44 (0.10)	0.59 (0.02)	5.94 (0.98)	26.32 (5.12)	3.95 (0.12)	11.88 (1.09)	556 (24.21)	228 (40.20)	51053 (2416)	14634 (745)	4.72 (0.55)
JIS A 5908 (2003) Standard	5～13	0.4～0.9	-	-	-	≤ 25	245	102	40800	13260	3.06

Note: Adhesive content: 7%; NHWI: Non hot water immersed; HWI: Hot water immersed; *: Highly significant ($\alpha \leq 0.01$) difference between NHWI and HWI treatments. ∥: Parallel to the grain direction; ⊥: Perpendicular to the grain direction; Values in parentheses are standard deviation.

ter for 2 and 24 hours were 5.94% and 26.32% and 6.81% and 27.51%, respectively for specimen treated and untreated. Furthermore, the mean value of TS of specimens after immersing in water for 2 and 24 were 3.95% and 11.88%; and 4.19% and 12.47%, respectively for treated and untreated specimens (Table 1). Immersing the strands in hot-water for 2 hours at 80°C prior to be OSB manufactured showed no differences in all physical parameters measured (i.e., air-dry density, MC, WA and TS). However, it is interesting to note that pre-treatment of strands in hot water for 2 hours at 80°C tend to decrease the values of WA and TS after 2 hours and 24 hours immersing in water. The values of MC, air-dry density and TS obtained in this experiment did not exceed the OSB minimum property requirement according to JIS A 5908 (2003) standard.

The mean values of MOR of specimens both in parallel and perpendicular to the grain direction were about 556 kg/cm² and 228 kg/cm², and 514 kg/cm² and 176 kg/cm², respectively for treated and untreated OSB. Furthermore, the mean values of MOE of specimens both in parallel and perpendicular to the grain direction were about 51,053 kg/cm², 14,634 kg/cm², 48,110 kg/cm², and 12,503 kg/cm², respectively for treated and untreated OSB. The mean values of IB of specimens prepared from treated and untreated strands were 4.72 kg/cm² and 4.06 kg/cm². It is clear that pre-treatment of strands in hot water at 80°C for 2 hour significantly improve the quality of OSB, particularly for MOR values both in parallel and perpendicular to the grain direction, and MOE value at perpendicular to the grain direction. Pre-treatment of strands in hot water increased the value of IB in some extent. However, this improvement is not yet significantly different compared to untreated OSB.

Extractives are not part of the wood structure. They include tannins and other polyphenolics, coloring matters, essential oils, fats, resins, waxes, gums, starch, and simple metabolic intermediates (Maloney, 1993). They can be removed by use of appropriate solvents. Urea formaldehyde resin and isocyanate binder is very sensitive to pH, buffering capacity and extractives of each species (Kwon, 2007; 1994).

Extractives can cause some problems in particleboard manufacturing i.e., consumption of resin and its curing rate, poor water resistance properties of the finished products, and blow problem during the pressing. It is known that immersing the strands in hot water dissolved wood extractives. The value of extractive of *A. mangium* dissolved in hot water is varied in the range of 0.9～9.98% (Awang and David, 1993; Peh *et al*., 1982). The presence of extractives that can block the adhesive penetration into the wood particles resulted in the lower mechanical properties of particle board achieved (Maloney, 1993). It was also reported that the wettability of *A. mangium* was low (Alamsyah *et al*., 2005). Immersing the strands in hot water resulted in improvement of the surface tension of strands and improved the adhesion of strands and adhesive. It was reported that the strength of OSB prepared from *Melia excelsa* wood and flake board prepared from red meranti wood (*Shorea leprosula*) was much improved after the particles were immersed in hot water for 2 hours (Iswanto, 2008; Hadi, 1988). All the mechanical parameters of OSB prepared from treated strands were higher than the minimum property requirement according to JIS A 5908 (2003) standard. However, for OSB prepared from untreated strands, the MOE value at perpendicular to the grain direction can not reach the minimum property requirement according to same standard.

3.2. Physical and Mechanical Properties of OSB Prepared from Pre-treated *A. mangium* Wood Strands under Various Adhesive Contents

In the first experiments, hot water immersed of strands prior to be OSB manufactured significantly improved the mechanical prperties of OSB and the values exceeded the minimum property requirement according to JIS A 5908 (2003) standard. Resin level is closely associated with board properties. However, because of the cost, minimum levels are normally used except for specialty products. In order to reduce the amount of adhesive, in the second experiment the physical and mehanical properties of OSB prepared from pre-treated strands under various adhesive contents were examined. Three (3) level of adhesive contents, namely 3%, 5%, and 7% were introduced in this experiment.

The mean values of air-dry density and MC of the specimens prepared under various adhesive contents ranged between 0.57 and 0.59 kg/cm^3 and 5.44 and 6.31%, respectively (Table 2). OSB prepared under various adhesive contents showed similar values of air-dry density and MC.

The mean value of WA of specimens after immersing in water for 2 and 24 hours of specimens prepared under various adhesive contents ranged between 5.94 and 8.16%; and 26.32 and 38.00%, respectively. The higher the adhesive content resulted in the lower the WA of specimens. Furthermore, the average value of TS of specimens prepared under various adhesive contents after immersing in water for 2 and 24 ranged between 3.45 and 3.95%; and 11.88 and 15.56%, respectively. Increasing the amount of adhesive significantly improved the WA and TS values of specimens after immersing in water for 24 hours. Lower WA and TS values for specimens with higher adhesive content resulted from the more the surface areas of strands was covered by adhesive and restricted the water to penetrate. The values of MC, air-dry density and TS obtained in this experiment did not exceed the OSB minimum property requirement according to JIS A 5908 (2003) standard.

The mean values of MOR of specimens both in parallel and perpendicular to the grain direc-

Table 2. Effect of resin content on the properties of OSB prepared from hot-water immersed (HWI) strands of *A. mangium* wood

Treatments	Physical properties						Mechanical properties				
Adhesive content (%)	Moisture content (%)	Air-dry density (kg/m^3)	Water absorption (%)		Thickness swelling (%)		Modulus of rupture (kg/cm^2)		Modulus of elasticity (kg/cm^2)		Internal bond (kg/cm^2)
			2H	24H	2H	24H	∥	⊥	∥	⊥	
3%	6.21a (0.43)	0.57a (0.02)	8.16a (1.37)	38.00a (4.21)	3.75a (0.95)	15.56a (2.13)	350a (46.46)	181a (38.85)	40198a (7679)	11229a (1051)	3.11a (1.07)
5%	6.31a (0.27)	0.58a (0.03)	5.99a (1.73)	33.69ab (6.30)	3.45a (0.88)	14.15ab (0.69)	457b (49.65)	195ab (35.51)	49149b (7792)	13595b (1084)	3.87ab (1.61)
7%	5.44a (0.10)	0.59a (0.02)	5.94a (0.98)	26.32b (5.12)	3.95a (0.12)	11.88b (1.09)	556c (24.21)	228b (40.20)	51053b (2416)	14634b (724)	4.72b (0.55)
JIS A 5908 (2003) Standard	5～13	0.4～0.9	-	-	-	≤ 25	245	102	40800	13260	3.06

Note: Adhesive content: 3%, 5%, 7%; Homogeneity group: Same letters in each columns indicated that there is no significant difference between the samples according to the Duncan's multiple range test. p: 0.01. ∥: Parallel to the grain direction; ⊥: Perpendicular to the grain direction; Values in parentheses are standard deviation.

tion prepared under various adhesive contents ranged between 350 and 556 kg/cm^2; and 181 and 228 kg/cm^2, respectively. The mean values of MOE of specimens both in parallel and perpendicular to the grain direction prepared under various adhesive contents ranged between 40,198 and 51,053 kg/cm^2; and 11,229 and 14,634 kg/cm^2, respectively. It is clear that increasing the adhesive contents resulted in increasing the values of MOR both parallel and perpendicular to the grain direction linearly. Similar phenomenon was occurred on the MOE parameter. Increasing the amount of adhesive significantly improved the MOR and MOE values. However, specimens prepared from 5% and 7% adhesive contents showed similar values both in MOR and MOE parameters. The mean values of IB of specimens prepared under various adhesive contents ranged between 3.11 and 4.72 kg/cm^2. Increasing the amount of adhesive significantly improved the IB values. Specimen prepared from 3% adhesive content showed no differences with specimens prepared from 5% adhesive content but they are significantly difference with specimens prepared from 7% adhesive content (Table 2).

Properties of the board are reflected by the quality and quantity of glue bond formed. Properties of the board were improved with an increase in resin content, up to the point where the resin approaches filling all voids. Increasing the amount of resin in some extent resulted in the rise of MOR and IB and dimensional stability of board (Maloney, 1993). These results met the above statements. Pre-treated of strands in hot water at 80°C for 2 hours can minimize the usage of resin. All the mechanical parameters of OSB prepared from 5 and 7% adhesive contents were higher than the minimum property requirement according to JIS A 5908 (2003) standard.

4. CONCLUSION

1) Immersing the strands of *A. mangium* in

hot water at 80° C for 2 hours prior to manufacture OSB improved the MOR. MOE and IB values of OSB.

2) Increasing the adhesive content from 3 to 5% improved the dimensional stability (WA and TS) and mechanical (MOR, MOE and IB) properties of OSB prepared from pretreated *A. mangium* wood strands in hot water at 80°C for 2 hours.

3) Utilization of treated strands in hot water at 80°C for 2 hours for OSB manufacturing reduced the consumption of adhesive used.

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