

# Effect of Several Exterior Adhesive Types on Dimensional Stability of Bamboo Oriented Particleboard

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(Received January 10, 2018 : Revised July 4, 2018 : Accepted April 10, 2019)

**Abstract** The objective of this research is to evaluate the effect of adhesive types on dimensional stability of bamboo-oriented particleboard. The materials used in this research are bamboo tali (*Gigantochloa apus* J.A & J.H. Schult. Kurz), UF/MDI (8, 10, 12 % level), and MF, MDI, and PF at 7 % level. Particle and adhesive are mixed using a blending machine; then, mat forming and hot pressing processes are performed using adhesive-suitable temperature and time references. MDI resin is set at 160 °C temperature for 5 minutes. PF resin and MF resin are pressed at 170 °C for 10 minutes, and 140 °C for 10 minutes, respectively, while UF/MDI sets at temperature of 140 °C for 10 minutes. The results show that particleboard using PF resin produces the lowest thickness swelling value. The particleboard using UF/MDI resin also produces good response for thickness swelling value. Interesting things happen in that UF/MDI adhesive produces a thickness swelling value better than that of MDI resin. FTIR analysis on particleboard bonded by UF/MDI resin combination shows the presence of carbonyl group C=O vibration on multi substitution of urea at wave number of around 1,700 cm<sup>-1</sup>.

**Key words** bamboo, adhesives type, oriented particleboard, dimensional stability.

## 1. Introduction

Increasing population growth resulted in increased need for wooden products such as wood panels. Data released by European Panel Federation showed that within one year at the European Union and European Free Trade Association (Austria, Denmark, Norway, Portugal, Sweden, Switzerland and United Kingdom) there was an increase on wood panel production as much as 3 % in 2015. Global demand of particleboard was predicted would increase as much as 3 % in a period of 2015-2019. Particleboard's global demand was around 57 % of total production of wood-based panel industries.<sup>1)</sup> However, this condition was not supported by availability of raw materials forest's to supply for wood industries.

Bamboos are one of non-wood lignocellulosic materials as alternative raw material for particleboard. Bamboos

can grow well and have wide area of purposes. Bamboo tali (*Gigantochloa apus* J.A & J.H. Schult. Kurz) is one of bamboo species that prospective to be utilized. There were 160 bamboo species in Indonesia, 38 species were exotic and 122 was native species. The potency of bamboo forest area in Indonesia reached 2 million hectares and has yielded more than 3.8 tons/hectares/year.<sup>2)</sup>

Most of particleboard industries use of urea formaldehida (UF) as adhesive in particleboard manufacturing. However, this particleboard has low dimensional stability. Particleboard bonded with UF resin resulted low dimensional stability.<sup>3-5)</sup> Thus, it needed some treatments to increase this stability. To improve its dimensional stability, some studies have been conducted. Dimensional stability of particleboard can be improved by addition of melamine-formaldehyde (MF), phenol-formaldehyde (PF), and polymeric diphenylmethane diisocyanate (pMDI) into UF resin.<sup>6)</sup>

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The addition 40 % of isocyanate into UF to obtain better water resistant properties compared to MF adhesive<sup>7)</sup>. This study has different blending technique of particle and adhesive compared to the previous reports. In this research, UF and MDI were mixed separately in particle blending. UF was first blended with particle then followed by MDI. Based on some reason mentioned above, this research was conducted to compare the effect of several adhesive types on dimensional stability bamboo oriented particleboard.

**2. Experimental**

**2.1 Materials**

Bamboo(*Gigantochloa apus* J.A & J.H. Schult. Kurz) as materials was obtained from Medan, North Sumatra, Indonesia. Commercial adhesives including UF, MDI, MF and PF were used in this study.

**2.2 Methods**

**2.2.1 Raw Material Preparation**

Bamboos were cut into particle size of 5 cm in length, 0.5 cm in width, and 1 mm in thickness. The particles then oven-dried until reach 5 % moisture content(MC). The adhesive combination of UF and MDI was prepared in UF/MDI ratio of 70/30(% w/w) with the adhesive levels of 8, 10, and 12 %. Furthermore, the adhesive level for MF, MDI and PF were 7 % respectively.

**2.2.2 Board Manufacturing**

The particleboards were made with size of 25 cm by 25 cm. The density and thickness target were 0.75 g/cm<sup>3</sup> and 1 cm, respectively. Bamboo particles were sprayed with each of adhesive types. Especially for UF/MDI adhesive combination, UF was first sprayed into the particles and then followed by MDI. To form the mats, particles were inserted into 25 cm by 25 cm mold with perpendicular particle orientation to each other between the layers. The face/core/back ratio was set in 1:2:1. Furthermore, the mats were pressed at temperature of 160 °C, 5 minutes for MDI; 170 °C, 10 minutes for PF; 140 °C, 10 minutes for MF; and 140 °C for 10 minutes for UF/MDI combination. The formed particleboard then conditioned for 7 days at room temperature. The process of cutting, testing and measurement of density, moisture content, thickness swelling, water absorption, and internal bond properties was according to JIS A 5908(2003) standard.<sup>8)</sup>

**3. Results and Discussions**

**3.1 Density and Moisture Content(MC) of Boards**

The density value of boards in this research ranged from 0.66 to 0.72 g/cm<sup>3</sup>, lower than that the target value

of 0.75 g/cm<sup>3</sup>(Fig. 1). This lower value of board compared to target can caused by springback after conditioning process before testing. Lost of raw material during manufacturing process also presume as factor that affecting the particleboard not fulfilled the target value. The lower density value of particleboard was caused by lost of particles during the manufacturing process.<sup>9)</sup>

Wood types, hot press pressure, adhesive level and additive were factors that affect of board density.<sup>10)</sup> Statistical analysis showed that adhesive types have significant effect( $p < 0.05$ ) on board density.

Generally, UF/MDI type in all levels produced the lowest of moisture content value. It indicates that board had low ability to absorb of water vapor. Regression analysis presented in Fig. 2 shows the correlation is 50 %. It means that particleboard density contributed only 50 % in affecting of moisture content value. The initial moisture content of raw material has important role in determining moisture content of particleboard.<sup>11)</sup> Statistical analysis indicated that adhesive types significantly affected moisture content of board( $p < 0.05$ ).

**3.2 Thickness Swelling(TS) and Water Absorption(WA)**

Thickness swelling value ranged from 7.84 to 15.70 %

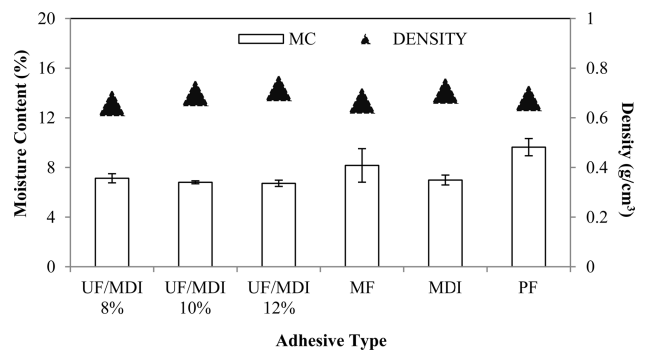


Fig. 1. Density and moisture content of particleboard.

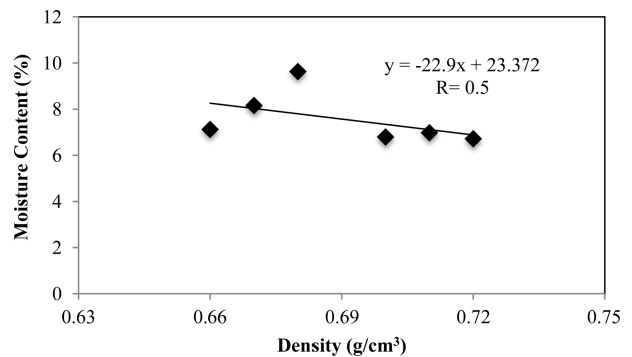
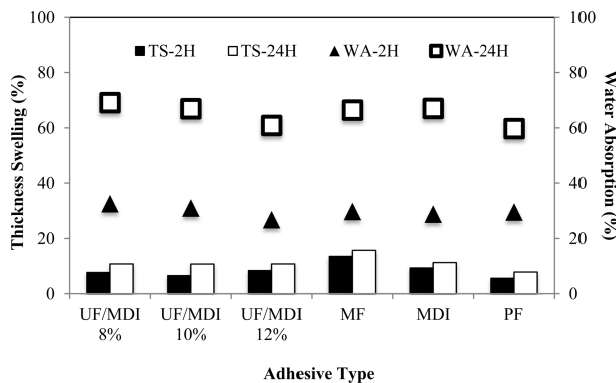


Fig. 2. Correlation between density and particleboard moisture content.

(Fig. 3). Compared with particleboard bonded by MDI adhesive, mixed UF/MDI type provided better thickness swelling value than fully MDI resin. However, this value was still higher than PF resin type board.

According to Fig. 3, PF particleboard produced the lowest thickness swelling value for 2 and 24 hours. Lower molecule weight of PF adhesive has good penetration in cell walls of wood.<sup>11)</sup> Low molecule weight facilitates the mobility of molecule chain in enhancing flexibility of polymer network(Osemeahon et al., 2007).<sup>12)</sup> In order to obtain high strength bonding, resin has to penetrate into cell wall and functional group on thermosetting adhesive has to react to hydroxyl group(OH) of lignocellulose particles.<sup>1)</sup>

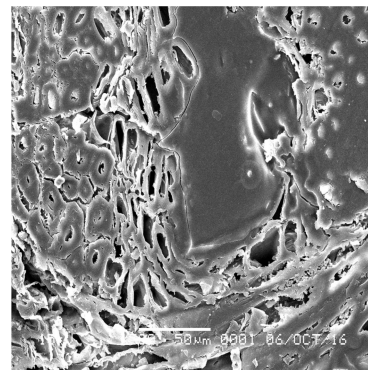
Interesting phenomenon occurred when UF/MDI particleboard produced lower thickness swelling value than fully



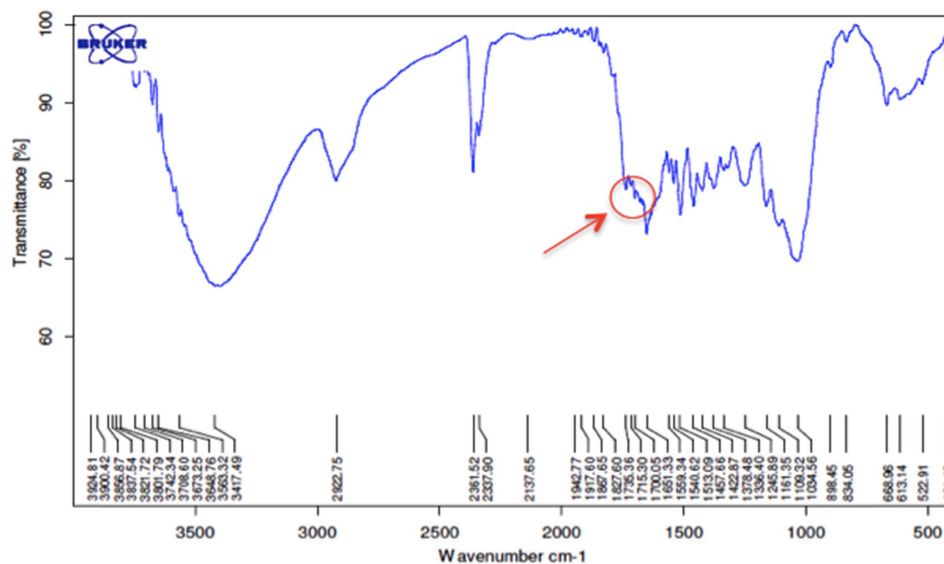
**Fig. 3.** The Thickness swelling and water absorption of particleboard. TS-2H : thickness swelling-2 hours, TS-24H : thickness swelling-24 hour, WA-2H : water absorption-2 hour, WA-24H: water absorption-24 hours.

MDI resin. This was caused by the distribution of MDI adhesives are able to cover of UF resin as presented in Fig. 4. SEM analysis of UF/MDI resin type in Fig. 4 showed that MDI adhesive coverage to UF. MDI adhesive spread evenly, resulting in low value of thickness swelling and water absorption. MDI chemically was bonded with OH group and blocking the water and vapor accessibility. Its chemical bonding creates the bonding strength between particles and adhesive thus it can reduce the weakness of UF resin.

Fig. 5 showed that at the wave number of  $1,700\text{ cm}^{-1}$ , the vibration of carbonyl group C=O inside the multi substitution of urea is occurred(circle). The carbonyl group of urethane bridge is formed as reaction between the groups of  $\text{-N=C=O}$  dan  $\text{-CH}_2\text{OH}$ , it has similar case that had been reported by Dziurka et al.<sup>6)</sup> Polycondensation of UF/MDI resins as an indication of hydrophilic hydroxymethylene reaction from UF and MDI groups resulting in reduced hydrolysis. This is why the mixture



**Fig. 4.** SEM analysis of UF/MDI in 500 x magnification.



**Fig. 5.** FTIR analysis of particleboards bonded by combination of UF and MDI adhesive.

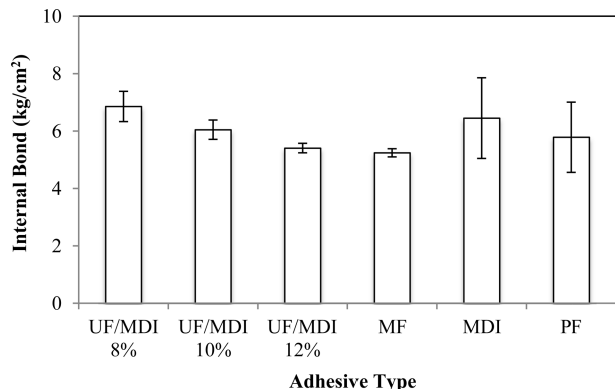


Fig. 6. Internal bond of particleboard.

of UF and MDI adhesives results in better dimensional stabilization values.<sup>6)</sup> Statistical analysis showed that adhesive types did not significantly affected TS and WA value of the board ( $p < 0.05$ ). Thickness swelling value of this research had fulfilled JIS A5908-2003 that is equal to maximum 12 %, with the exception of MF resin.

Although the adhesive has strong properties for exterior utilization, WA value of observed board is still high. It caused by no water repellent addition in board manufacturing. Hemicellulose is the most influential factor to water absorption compared to cellulose and lignin.<sup>13)</sup> Hemicellulose content on bamboo Tali ranged between 28 to 36 %.<sup>14)</sup>

### 3.3 Internal Bond

The internal bond (IB) value ranged from 5.24 to 6.86 % (Fig. 6). The highest IB was obtained in particleboard bonded with UF/MDI combination. The UF/MDI resin type was suitable to be applied for wooden panel products, including particleboard and fiberboard.<sup>15)</sup>

The higher UF/MDI combination level resulted in the lower IB. It is suggested that the higher levels of adhesive used, the amount of isocyanate adhesive is also increase. Thus it resulted in not cured perfectly on temperature of 140 °C. The ideal temperature for MDI adhesive is 150 to 160 °C.

Internal bond is one of important parameters that indicate the successful of adhesive mixing, mat forming and also pressure process.<sup>16)</sup> A good mixing will strengthen interparticle bonding. In contrary, the strong interparticle bonding contributes positively into thickness swelling value of particleboard. The correlation between IB and thickness swelling is presented in Fig. 7. The polynomial regression correlation shows that the IB and thickness swelling has the correlation coefficient of 40 %. It means that the bonding strength only contributes 40 % in influencing the TS value and 60 % was caused by others (wood type, particle acidity, type and level of adhesive, etc).

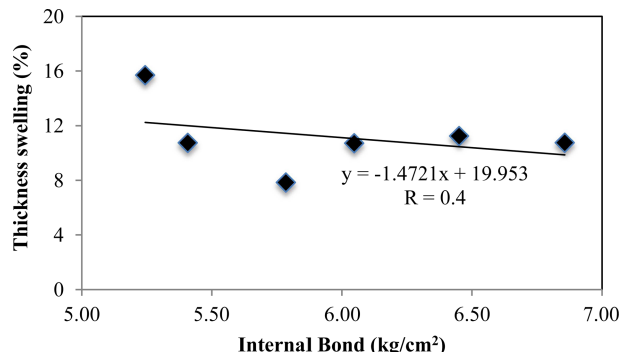


Fig. 7. The correlation between internal bond and thickness swelling.

## 4. Conclusion

The exterior adhesive types of PF and MDI produce a good dimensional stability particleboard. However, interesting phenomenon occurred in combination of UF and MDI adhesive that also similar produced good dimensional stability. UF/MDI combination with the level of 8 % results the best IB value, but an increase proportion of MDI at the same hot pressing condition will cause the decrease of IB value. The FTIR analysis shows that the vibration of carbonyl group C=O inside the multi substitution of urea occurred at the wave number of 1,700 cm<sup>-1</sup>.

## Acknowledgments

We would like to express my sincerely thanks to University of Sumatera Utara for funding support through to the BPPTN Research Grant year 2016 (Number: 6049/UN5.1.R/PPM//2016, date: July 19, 2016).

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