Properties of Particleboard Made from Wood Waste with Various Size

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Abstract. Particleboard is recognized as the most important products in forest products industry. Recently, utilization of industrial by-products such as waste wood from traditional sawmill is gaining attention. This research was aimed to investigate the physical and mechanical properties of particleboard made from wood waste with several size: coarse (3.360 mm), fine (2.00 mm) and mixed. Particle were oven dried prior to board production, mixing of glue and particle was conducted using drum-mixer then hot pressed with at temperature 150°C for UF and 130°C for PF. Mechanical testing was carried out using universal testing machine. Adhesive used in this study was urea formaldehyde and phenol formaldehyde with several concentration: 8%, 10% and 12%. The produced particleboards were tested for its mechanical and physical properties. Standard that using in this study was Japan Industrial Standard (JIS A 5908:2003). Research results indicated that more amount of adhesive increase both mechanical and physical properties. Boards density was meet the target as well as the thickness. It is also reported that fine size particle with 12% adhesive both UF and PF give the superior properties among others.

1. Introduction

In 2017, production of particleboard is forecasted remain increase. Several publications [17-20] also mentioned that particleboard still be an excellent products of engineered wood based product. The utilisation of wood waste into particleboard give more advantages due to it does not directly result in carbon emissions. Wood waste in from traditional sawmill in Indonesia is considered abundance. The utilization of this waste commonly as boiler or as landfill. Yet, the wood waste can be as an alternative material in particleboard industry. Iwakiri et al. [1] mentioned that wood waste from sawmill industry is a viable alternative in chipboard industry.

In particleboard development, there are several factor that affecting the properties of the board. Particle size and adhesive percentage are among those factors. Sekaluvu et al. [2] studied the effect of resin content and particle size in particleboard production using maize cobs. It is reported that particle size and adhesive affecting the board density, MOE and MOR. In addition, Cheng et al. [3] also investigated the effect of particle geometry and adhesive percentage in mechanical and physical properties of particleboard from peanut hulls. Similar to [3], it is reported that particle geometry, adhesive type and adhesive mass percentage directly affecting the mechanical performance of the board. It is also reported that the type of adhesive consequence to the suitable of particle origin (wood or non- wood) with the adhesive which further affecting the properties of the board.

This research was conducted to figure out the suitability of wood waste with differentiated size from home industry sawmill as raw material for particleboard. The research also aimed to investigate both physical and mechanical properties of particleboard made of different size of wood waste and different type of adhesive.

2. Materials and Method

2.1. Preparation

Wood waste were collected from home industry sawmill in Dramaga district, Bogor. The wood species of the wood were mentioned as kamper, sengon and meranti. After collection, wood waste were sieved and categorized into coarse size which pass 6 mesh or around 3.360 mm and fine size which pass 10 mesh or about 2.00 mm. Wood particle was oven dried for 24 hours at temperature 103±2°C.

Adhesive used for this study were commercial urea-formaldehyde (UF) and phenol-formaldehyde (PF). Percentage for both adhesive were 8wt%, 10wt% and 12wt% of board weight. Solid content of the adhesive were 50% for PF and 45% for UF.

2.2. Board Production

Each type of board were produced in duplo, the matrix are shown in **Table 1** below:

Table 1. Board Production Table

Adhesive type & Percentage	Particle size		
	Coarse (3.360 mm)	Fine (2.00 mm)	Mixture (coarse and fine)
UF 8%	2	2	2
UF 10%	2	2	2
UF 12%	2	2	2
PF 8%	2	2	2
PF 10%	2	2	2
PF 12%	2	2	2

Particle and adhesive were weighted according to the formula, afterward mixture were conducted using drum mixer and spray gun. The mixture were moulded in 25x25 mould before hot pressing process. The hot press was set into 150°C for particleboard with PF and 130°C for particleboard with UF. The pressing time was 10 minutes at 25 kgf/cm^2. After pressing, the board was conditioned for 7 days at room temperature before testing. Targeted density of the board was 0.8 g/cm^3 and targeted thickness was 10 mm.

2.3. Board Testing

The testing was conducted both for physical and mechanical. Board density, water absorption and thickness swelling were parameters measured for physical properties. Board mechanical properties were measured for its flexural strength, internal bond and screw withdrawal. Mechanical properties were tested using Shimadzu Universal Testing Machine. Standard occupied in this research was Japan Industrial Standard (JIS) A 5908-2003 [4]

3. Results and Discussions

3.1. Physical Properties

Thickness swelling is the main parameter to describe the stability of dimension for particleboards. The thickness swelling of particleboards in this research were decreased with the increased percentage of the adhesive, both for PF and UF (**Figure 1**).

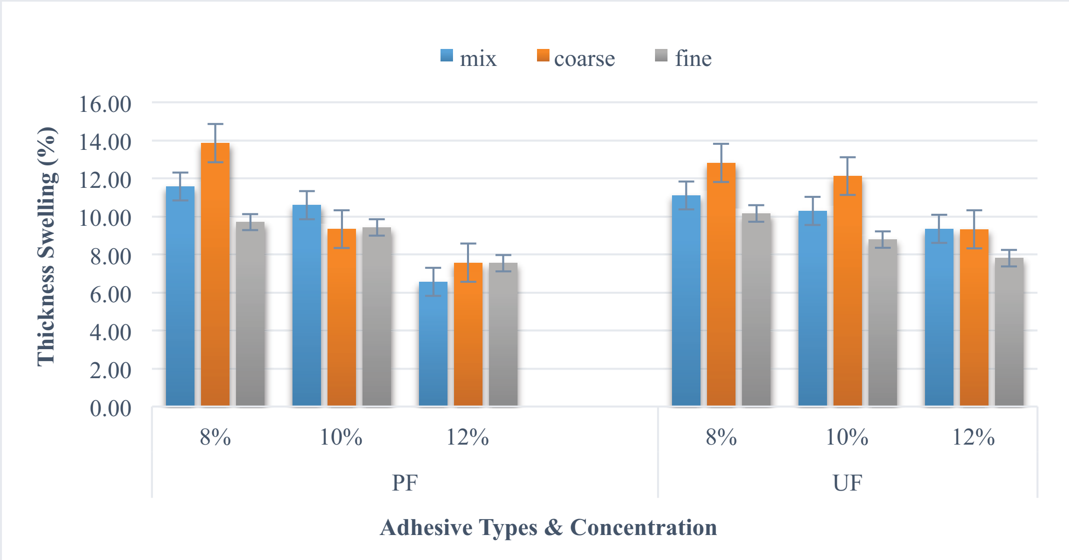

Figure 1. Thickness swelling of the particleboards

The similar results also reported by Li *et al*. [5], it is mentioned that thickness swelling have better value with the increase amount of adhesive. The significance decrease of TS was shown by coarse size particle with PF. It reduced from 13.85% to 7.56%, therefore the decrease was approximately 45.4%. It is also reported that three boards type were not meet the JIS A 5908:2003 standard for TS on particleboard. All those boards are from coarse size particle with 8% PF, 8% and 10% UF. According to Nemli*et al*. [6], the high percentage of thickness swelling can be enhanced by increasing the percentage of adhesive or coating application using hydrophobic materials on the board. On the other hand Amini [7] argue that thickness swelling of particleboard were more depends on the board density rather than type of adhesive.

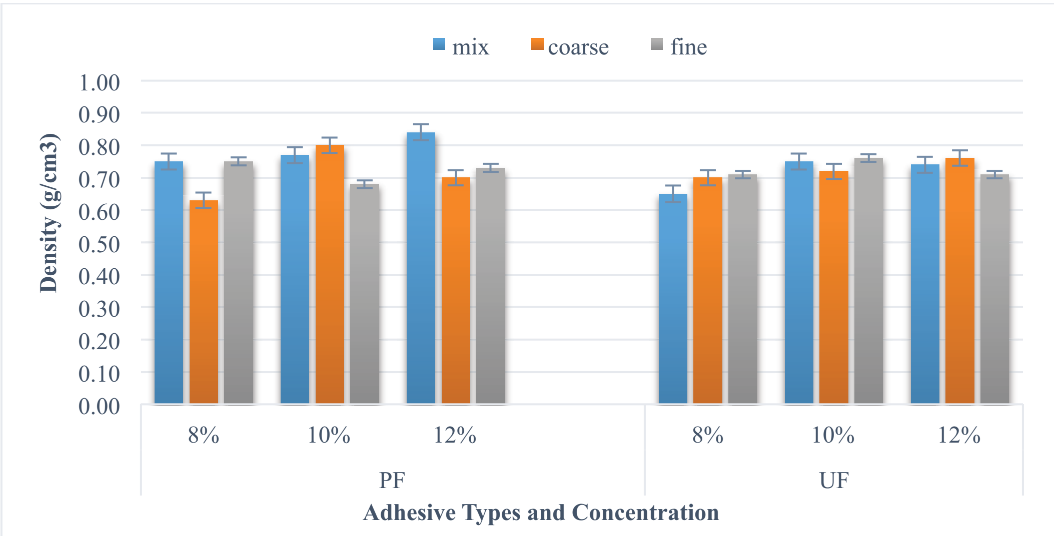

Figure 2. Density of the particleboards.

Targeted density of boards for this study was 0.8 g/cm^3. The range density of boards on this study was 0.63-0.8 g/cm^3 (**Figure 2**). The standard according to JIS was on the range 0.4-0.9 g/cm^3. Several studies report that low density particleboard correspondence to the high mechanical properties (Sellers et al. 1993[8]; Xu et al. 2004 [9]. Yet different result reported by Liao et al [16], it is argued that higher density board has a larger amount of particles per unit volume than that of lower density board; thus it shows higher MOR due to the superior bonding among the tightly packed particles. This explains that density of board has a role on mechanical properties.

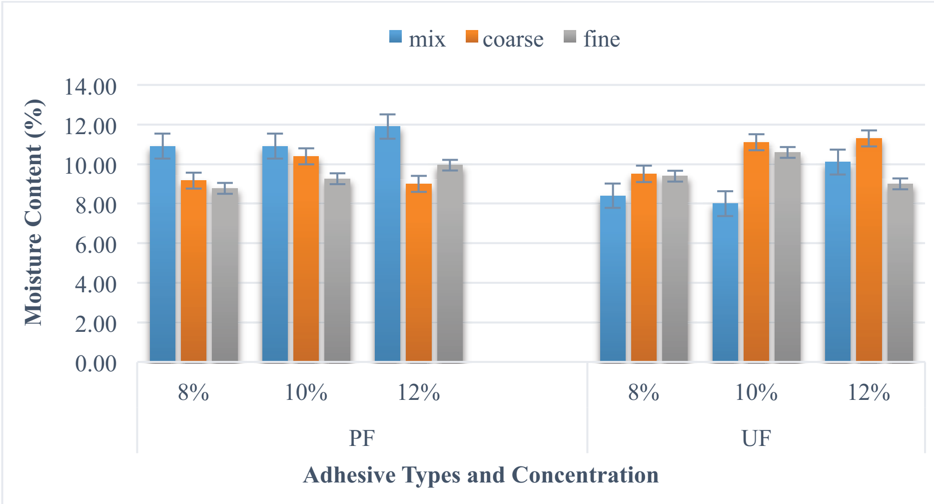

Figure 3. Moisture content of the particleboards.

Figure 3 shows that moisture content value of the board ranged between 8 – 11.9%. The highest value of water content was performed by mixed particle with 12% PF. All the boards are meet the requirement of JIS for water content value. It is observed that particleboard with PF adhesive have higher percentage of water content compare to those with UF.

3.2. Mechanical Properties

There are three particleboard types based on JIS A 5908:2003: type 8, type 13 and type 18. The higher number of type the better mechanical properties of the board. Result of flexural strength both MOR and MOE are shown in **Figure 4** and **5**.

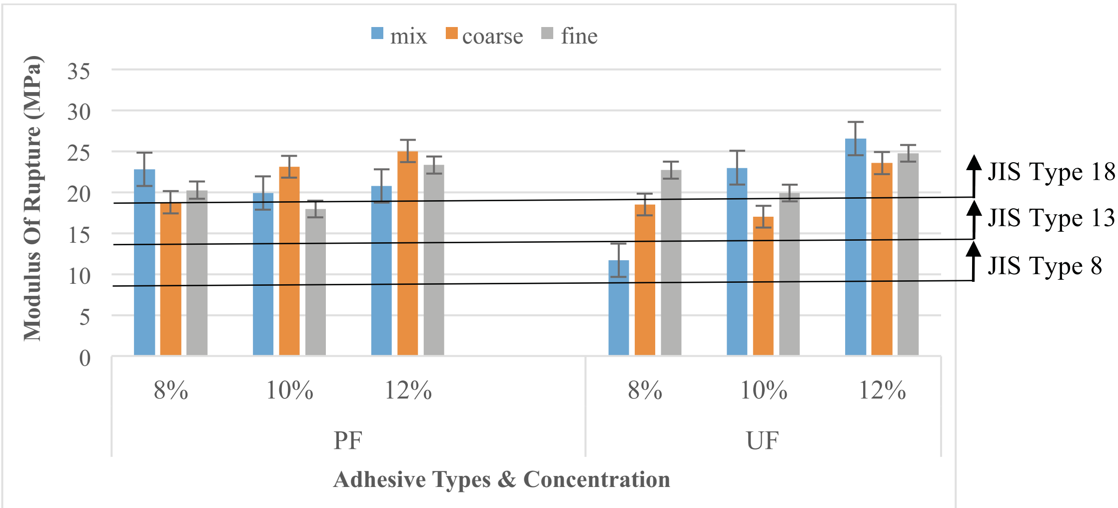

Figure 4. MOR value of the boards.

The value of MOR of all boards were meet the requirement of JIS type 8. The value were range from 11.69 – 26.54 MPa. The highest MOR is performed by mixed size raw material and 12% UF and the lowest MOR is given by board with mixed size raw material and UF 8%.It is observed that the higher percentage of adhesive, the higher value of MOR. **Figure 4** also shows that both PF and UF result in nearly similar value of MOR. Particle size also affects the MOR value, fine particle size gives higher value of MOR. This result correspondence to the research by Mohsen [10] and Samson [11] that reported MOE and MOR are influenced by panel density, percentage of adhesive and particle geometry. In the context of adhesive effect, high percentage of adhesive increases the bond contact between individual particles [12]. Slenderness ratio (chip length to thickness, SL) was a factor that influenced the MOR properties. The increased SL ratio gave high MOR value [13]. Different MOR values in different studies were due to different SL ratios.

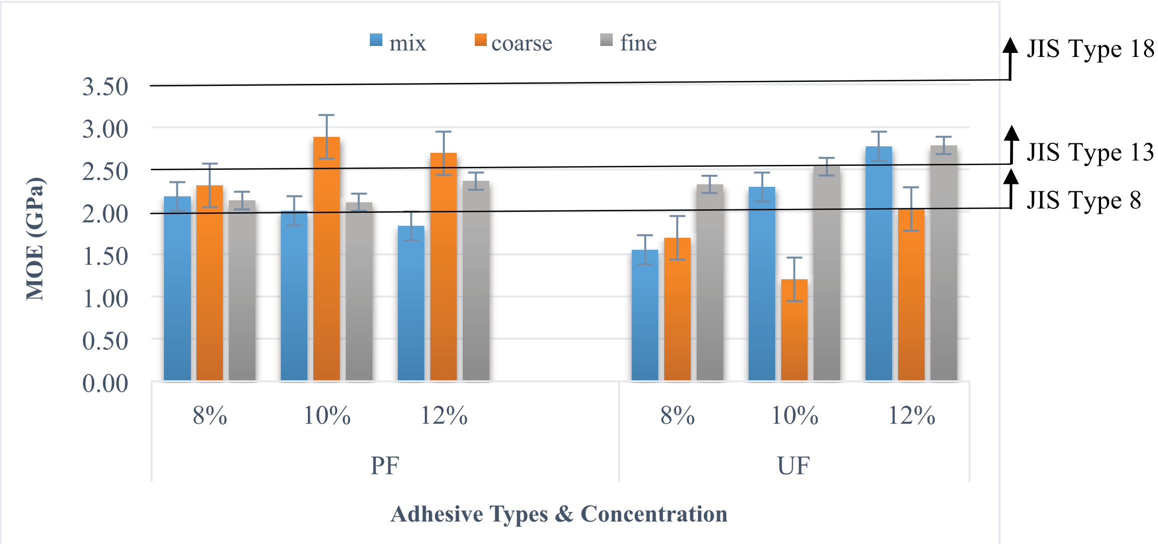

Figure 5. MOE value of the boards

Figure 5 depicts that only several boards meet the requirement of JIS A 5908 for board type 8 and 13. There are no board meet the standard for board type 18. The highest MOE value is performed by coarse size particle with 10% PF, followed by mix and fine particle with 12% UF. The graph also shows that PF adhesive gives better average on MOE value. Maloney [14] mentioned that MOE was affected by several factors such as adhesive content, adhesive type, bonding performance and fiber length.

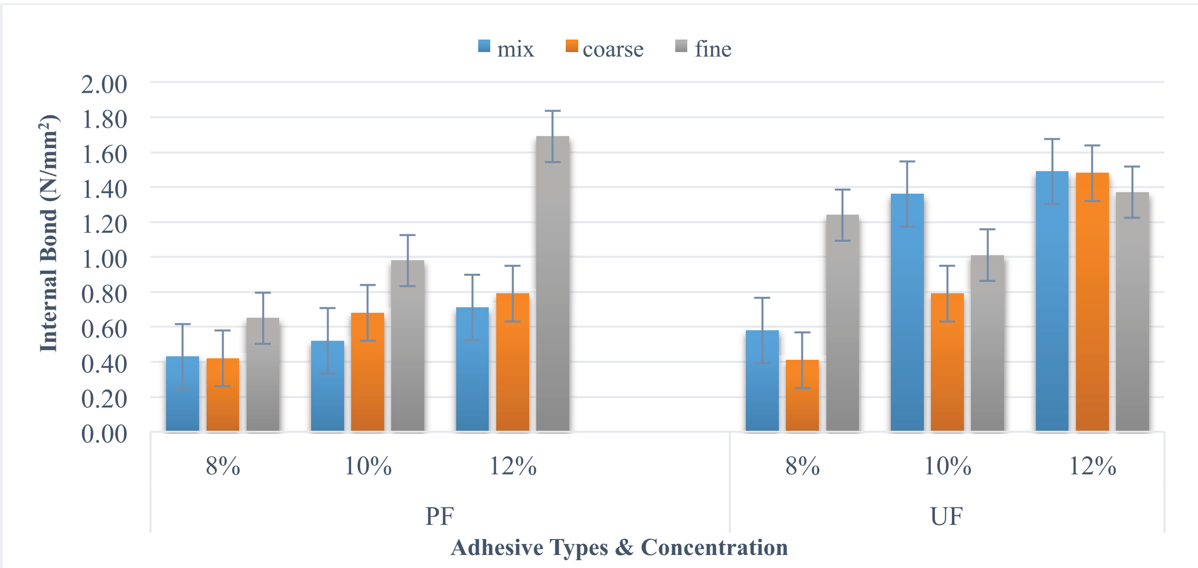

Figure 6. Internal bond value of the boards

Internal bond (IB) values of the boards in this study were range between 0.41-1.69 N/mm2. The highest IB was performed by fine particle with 12% PF whilst the lowest was from coarse particle with 8% UF. The graph illustrate that IB value of board with PF and fine size particle gives better result in every adhesive percentage. This condition difference with IB value from board with UF adhesive. It is showed that for UF adhesive, mix particle perform better IB value. Umemura et al. [15] mentioned that the adhesiveness on the inner layer of particleboard influence the internal bond value. In addition, adhesiveness of the surface layer of particleboard affecting the bending properties. Higher bonding strength properties of the composites made from uniform particle can be related to better glue line development due to their geometry. Uniformity of particle enhanced MOR, MOE and IB values of the composites.

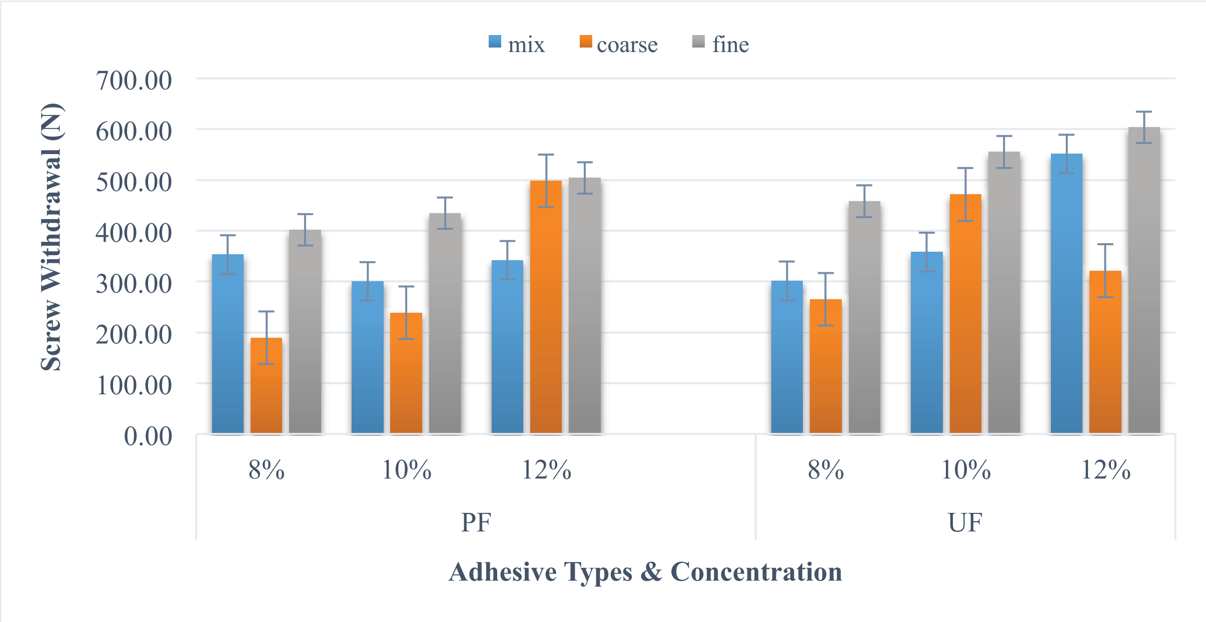

Figure 7. Screw withdrawal values of the board.

Another properties that investigated on this study was screw withdrawal values. The values were range between 189.06-650.13 N. There were three boards that did not meet the JIS Standard for particleboard type 8: board with coarse particle size and 8%PF, coarse with 10%PF and coarse with 8% UF. The highest screw withdrawal was given by board with fine particle and 12%UF. Poor screw withdrawal on coarse size particleboard due to the wide surface area of particle lead to low adhesive absorption.

4. Conclusion

In conclusion, wood waste from home industry sawmill can be utilized as raw material for particleboard. Dimensional stability of the boards increases with the increase of adhesive concentration. Physical properties of the boards mostly meet the requirement of standard (JIS A5908-2003). The amount of adhesive affects the mechanical properties of the boards. 12% adhesive performs higher properties both physical and mechanical. Urea formaldehyde (UF) adhesive was more suitable with wood waste since it gives better testing result. Fine size particles (6 mesh or 2.00 mm) with either UF or PF 12% give superior board properties.

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