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## Effect of Layer Structure on Physical and Mechanical Properties of Binderless Composite Plywood

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# Effect of Layer Structure on Physical and Mechanical Properties of Binderless Composite Plywood

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**Abstract.** Binderless composite plywood has been developed to produce formaldehyde-free composite product. Our previous research has shown that the application of oxidation treatment can be applied in the manufacture of composite plywood without adhesive. Presence of veneer in solid sheet are potentially to complicate in the oxidation process due to the reaction was very affected by accessibility of chemical component of raw materials. The main objective of this study was to determine characteristic of binderless composite plywood of Sengon wood. Variations in the physical and mechanical properties with respect to veneer layer construction and oxidant composition of veneer and particle were analyzed.. Composite plywood were produced consist of various layers, they were 3, 5, and 7 layers means each type using 2, 3, and 4 veneers layers respectively. There were four oxidant composition between veneer and particles, namely 1 : 3, 1 : 4, 1 : 5 and 1 : 6. The results showed that the differences of composite plywood structure layers affect the characteristics of produced composite plywood. 7-layer structure and 1 : 3 of oxidant composition was the optimum combination to produce composite plywood with the best characteristics.

## 1. Introduction

Formaldehyde emission has been an issue for the particleboard industry because it could cause hazard to human health including sensory irritation and risk of developing cancer [1]. There have been many studies to reduce the risk of the emission including find formaldehyde-free adhesive such as natural resin as well as binderless particleboard. Binderless particleboard technology is one of the attractive ways to overcome emission problems of particleboard. Some researchers have been intensively developing various methods of binderless production as well as utilizing various wood or lignocellulose as raw materials. Those methods including; steam injection [2] or enzymatic activation of particle [3]. Development of direct hot pressing method using oil palm have been reported by several researchers [4-6]. Another promising method to produce binderless particleboard is oxidation method to activate particle [7]. Binderless produced board by oxidation method has several advantages such as high dimensional stability, modulus of elasticity, and internal bond. However, the modulus of rupture relatively low.

The most common work to overcome problems related to low modulus of rupture is applying veneer layer on both side of particleboard surfaces which is called composite plywood. The modulus of rupture of composite plywood may increases due to the presence of veneer layers. The outer layers of composite plywood will receive highest tensile load when panel receiving bending load. The existence of thin

layer of veneer on the surface will increase the boards ability to withstand the bending loads significantly.

This study was focussed on developing binderless composite plywood products using oxidation method. Nonetheless, the feasibility of oxidation method application in producing composite plywood remain questioned. Oxidation process need to access the chemical component of wood, so there is no guarantee that solid shape material such as veneer can be oxidized successfully. The main objective of this study was to evaluate the effect of layer structure on physical and mechanical properties of binderless composite plywood. This work also focus on determining the optimum oxidant proportion between veneer and particles

## 2. Material and Methods

Veneer and particles were prepared from Sengon wood (*Paraserianthes falcataria*). The average thickness of the veneer was 0.97 mm<sup>2</sup> and particles used were dried particle which passed 10 mesh of sieve screening. Veneer binderless composite plywood was manufactured with oxidation method [8] using 15% of hydrogen peroxide and 7.5% of ferrous sulphate as oxidant. The composite-plywood was produced in size 30 x 30 x 0.7 cm with 0.75 g/cm<sup>3</sup> of targeted density. We used two variable productions of veneer layer construction and oxidant proportion. Variation of veneer layer was 3, 5 and 7 layers while oxidant composition applied to veneer and particles layer was 1 : 3, 1 : 4, 1 : 5 and 1 : 6 (w/w). The board were hot pressed for 12 minutes at the temperature of 180°C with pressure of 25 kgf/cm<sup>2</sup>. For testing the specimens, produced composite plywood were conditioned for 2 weeks. Evaluation of physical and mechanical properties of composite plywood were conducted according to Japanese Industrial Standard (JIS) A 5908 2003 A 5809-2003[9].

## 3. Result and Discussion

The results showed that the physical properties parameters which fulfilled JIS A 5809-2003 were density and moisture content while all mechanical properties parameters did not fulfill the standard. The physical and mechanical properties of the composite plywood boards which did not meet the required standards were thickness swelling, MoR, MoE, Internal bond and screw holding capacity.

### 3.1 Physical properties

Figure 1 shows several boards have meet the target density of 0.75g / cm<sup>3</sup>. This study has been designed to achieve same target density for all the type veneer layer constructions. However the results revealed varying densities. This could be caused by unevenly particles distribution on the mat, causing density variations in some parts of the board. In addition, the uneven distribution of oxidant on the particles caused less bonding between particles and veneer. Another factor which allow variation in the board density was the thickness of sengon veneer which used where the veneer was very thin and undergone shrinking after oven drying. Drying sengon veneer tends to shrink and resulting curved plywood product [10].

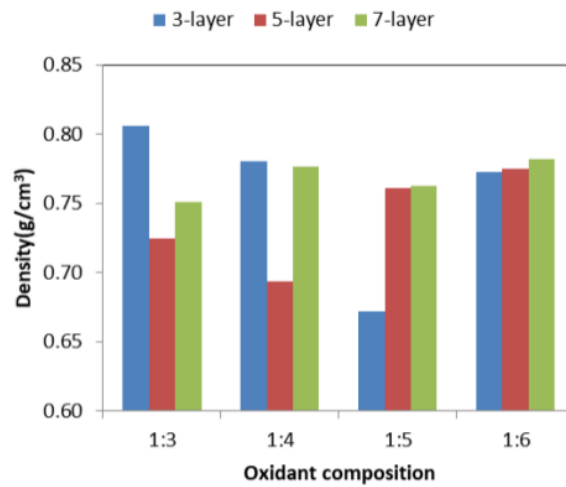


Figure 1. Density of the produced composite plywood

Density is one of the important indicators for the quality of composite boards. Density greatly affects most composite board properties [11]. Factor causes density differences is also due to spring back state. The much number of veneer layer used the higher density obtained. The results of this study revealed that composite plywood with 7 layers has a high average density value. The relation of veneer layer construction on the moisture content value is showed in Figure 2. The more layers are given, the lower moisture content produced. There was clear effect of the layer number on the moisture content.

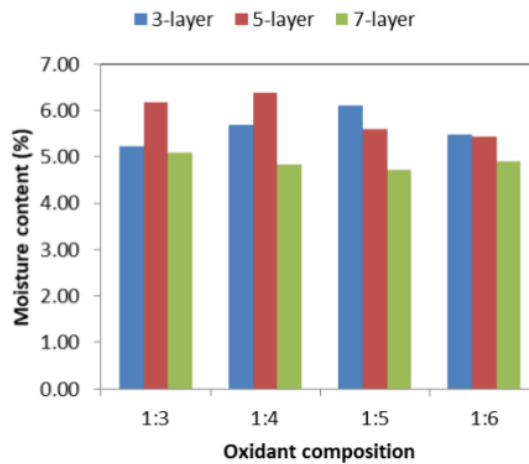


Figure 2. Moisture content of the produced composite plywood

Figure 2 shows that the lowest moisture content composite plywood occur on 7 layers of veneers for all type oxidant . proportions. Existing of veneer as a face-back and core decreased moisture content as the result of the less surface of the particles to contact with water due to the covering veneer (face-

back). The oxidant composition of 1: 3 and 1: 4 on composite plywood with 5 layers have slightly higher moisture content than that of composite plywood of 3 layers. This could be caused by uneven distribution of the oxidant solution when spread to particles and veneer. However, moisture content value for all the composite plywood construction have met the JIS A 5809-2003 standard, which required of 5-13%. This meant that moisture content did not affect the physical properties of the produced boards.

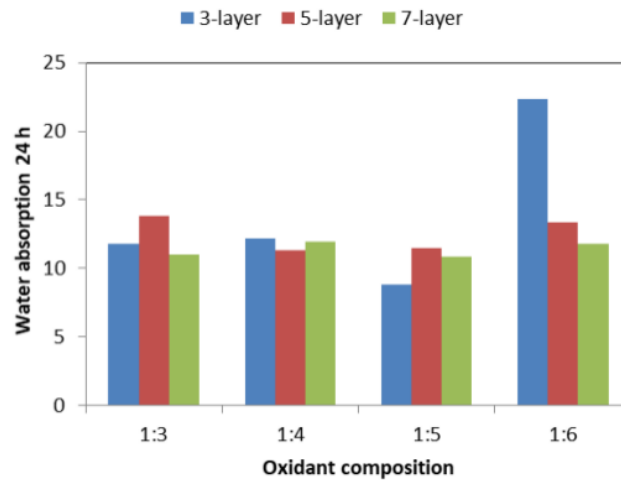


Figure 3. Water absorption of the produced composite plywood

Water absorption parameter is not required in JIS A 5809-2003, however, this value related to ability of the board in absorbing water. The value of water absorption composite plywood was founded quite high, ranging 45% -92% for 24-hour water immersion test (Figure 3). The high value of water absorption is influenced by the low density of produced board. One of the most factors affect this value is the number of veneer layers. Increasing number of veneer layer results decreasing water absorption and so in conversely.

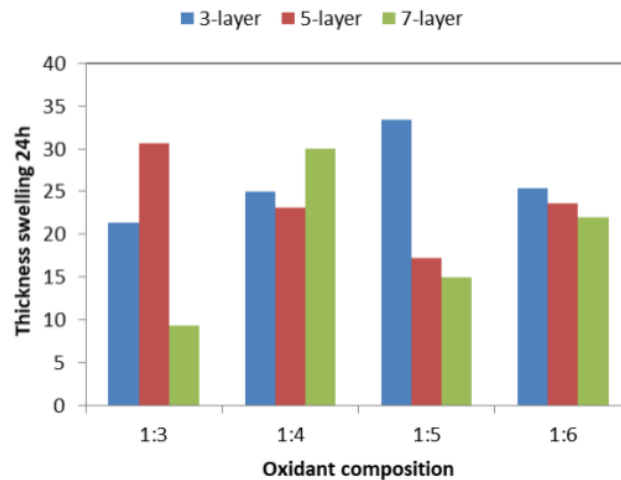


Figure 4. Thickness swelling of the produced composite plywood

Thickness swelling is one of the important physical properties because it will determine whether the produced can be used for interior or exterior. The thickness swelling value (Figure 4) of the produced boards did not meet the standard, except of 7-layer board with 1: 3 oxidant composition after 24 hours water immersion test, which requires maximum 12% of thickness swelling. These high value of thickness swelling could be caused by uneven distribution of particles and oxidants which affected weak bonding between particles. Larger thickness swelling and linear expansion values illustrate that produced composite plywood board has low dimensional stability.

### 3.2 Mechanical Properties

Modulus of elasticity values both parallel and perpendicular to grain did not fulfill JIS 5908-2003 which requires values for parallel of  $4.08 \times 10^4$  kgf / cm<sup>2</sup> and MOE perpendicular of  $2.86 \times 10^4$  kgf / cm<sup>2</sup>. It can be seen in Figure 5 and 6, the value of MOE increased with increasing the number of veneer layer. All the composite plywood types with 7 layers and oxidant compositions have high values. Larger MOE value means the board more resistant to shape changes so it requires higher load, otherwise small MOE value means the board does not resistant to shape changes then it requires lower load [12].

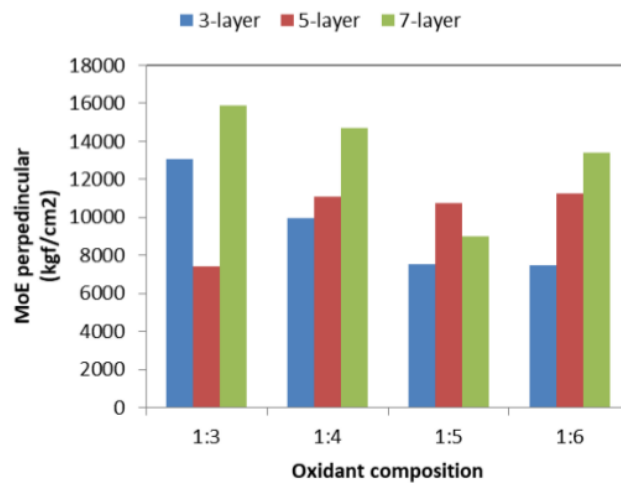


Figure 5. MoE perpendicular to grain of the produced composite plywood

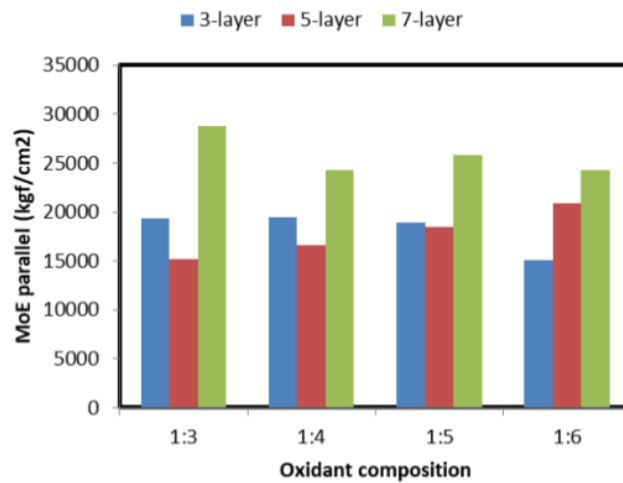


Figure 6. MoE parallel to grain of the produced composite plywood

MOR value (Figure 7-8) of produced composite plywood board either parallel or perpendicular to grain, all board type did not meet the standard which required MOR parallel at least 306 kgf/cm<sup>2</sup> while MOR perpendicular to grain at least 153 kgf/cm<sup>2</sup>. The low value of MOE and MOR is influenced by the veneer raw material, in this case the dimension of sengon veneer was very thin and has curve surface. Uneven oxidant distribution which sprayed throughout particles and veneer was also one of the factors could causes the low values of MOE and MOR.

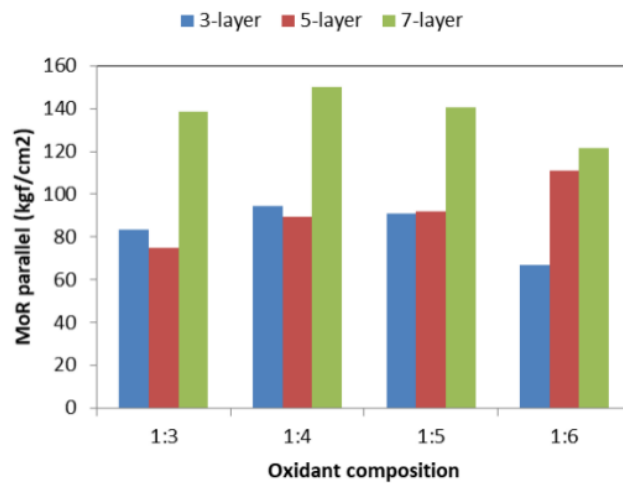


Figure 7. MoR parallel to grain of the produced composite plywood

MOE and MOR of produced composite plywood in this study have low values. This could be caused by the present of lathe check on the veneer and would be easily broken when got pressure.

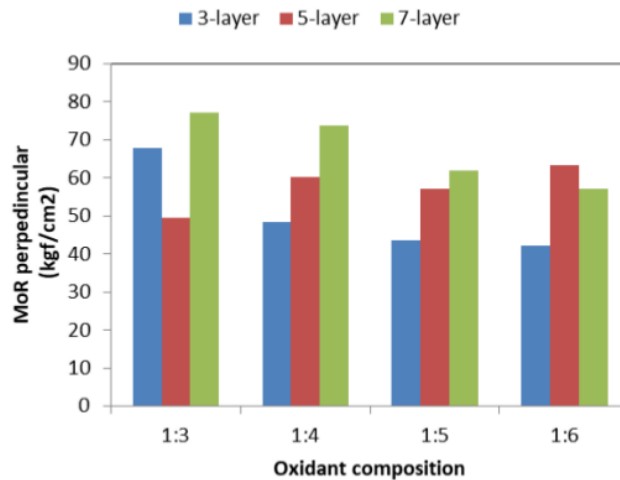


Figure 8. MoR perpendicular to grain of the produced composite plywood

Internal bond is one of the most important mechanical properties shows bonds strength between particles and veneers on the board. The internal bond values of the produced composite plywood did not fulfill the standard, which required of 3.1 kgf/cm<sup>2</sup>, except of 7-layer board with 1: 3 of oxidant composition. This was similar to other mechanical properties, where increasing number of veneer layers also increase the internal bond of the composite plywood. Figure 9 shows 7-layer board has higher internal bond value than that of 3-layer and 5-layer boards.

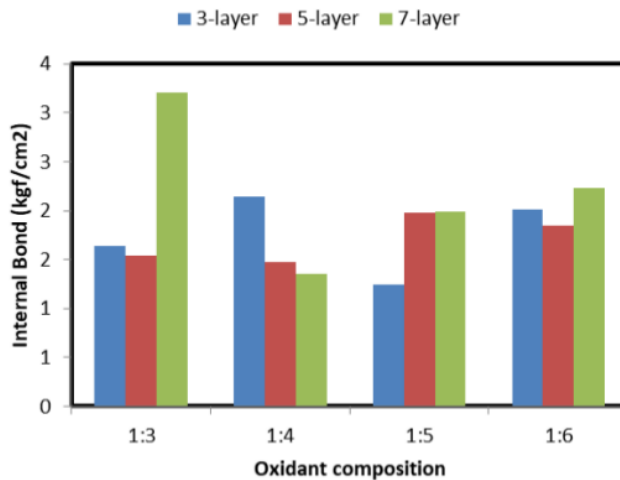
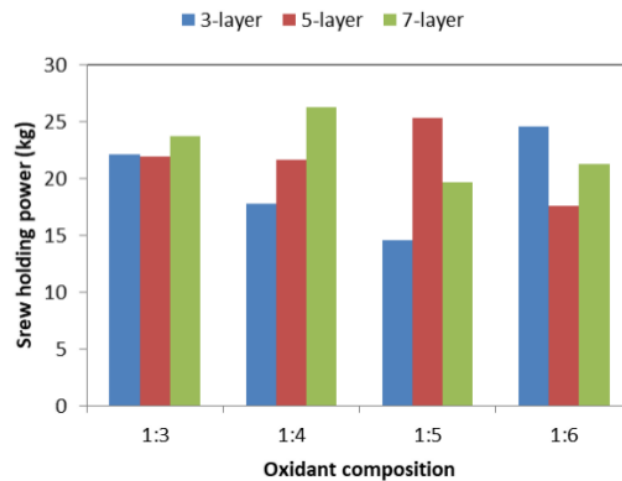


Figure 9. Internal bond of the produced composite plywood

The value of screw holding capacity (Figure 10) revealed that all the board types did not meet the JIS A 5809-2003 which required minimum of 0.51 kgf / cm<sup>2</sup>. The low value of screw holding capacity due to uneven distribution of particles in mat then caused existence of some void and resulted decreasing screw holding capacity. The value of the screw holding capacity varied greatly for each layer and each composition of the oxidant used.



**Figure 10.** Screw holding capacity of the produced composite plywood

The lack characteristics of produced composite plywood in this study could be due to several factors. One of those factors was the thickness of sengon veneer used is very thin with average  $0.97 \text{ mm}^2$ . As for the oxidation process, it was expected that all oxidant composition were able to cover all the particles and veneer, however it occurred in some area in the mat. This caused low adhesion between veneer and particles. The strength of the particle board is basically determined by the strength of the bonds and the strength of each particle [13].

#### 4. Conclusions

Physical and mechanical properties of produced composite plywood have fulfilled JIS A 5809-2003 on density and moisture content while thickness swelling, MOR, MOE, Internal bond and screw holding capacity have not met the standard. Layer structure affected composite plywood characteristics and the optimum layer structure was 7-layer while the best oxidant composition between veneer and particles was 1: 3 (w/w). A one weight portion of oxidant was used to oxidize veneer while 3 weight portions were used to oxidize particles.

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#### **Acknowledgement**

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