

# Quality improvement of laminated board made from oil palm trunk at various outer layer using phenol formaldehyde adhesive

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**Abstract.** Characteristic of laminated board from oil palm trunk (OPT) is very low in quality. The effort to improved it's quality done by using the outer layer from high density wood. The purpose of this experiment was to analyzed the effects of the outer layer on physical and mechanical properties of OPT and to obtain optimum treatment to fulfills JAS 234:2003. All of laminated board was made of 3 layers, and for the middle layer was made by densified-OPT. Then for the outer layer was made of sengon and meranti wood. The sample size was 5 cm (width) x 3 cm (thick) x 45 cm (length). The various outer layer of laminated board were A (OPT/densified OPT/OPT); B (Sengon/densified OPT/OPT); C (Sengon/densified OPT/sengon); D (Meranti/densified OPT/OPT) and E (Meranti/densified OPT/meranti). The results showed that the moisture content, density, thickness swelling, delamination, MOR and MOE were 6.10-8.48%; 0.40-0.63 g/cm<sup>3</sup>; 6.43-13.20%; 0%; 168.79-438.29 kg/cm<sup>2</sup> and 30115-100454 kg/cm<sup>2</sup>, respectively. The moisture content and delamination fulfills JAS 234:2003, while density and thickness swelling did not fulfill standard. Whereas for MOR and MOE value, only type D and E that fulfill standard. There are strength relationship between density and mechanical properties, such as MOR and MOE value. The optimum treatment in this research to made laminated board made from OPT was type D that using the meranti as outer layer.

## 1. Introduction

North Sumatera Province is the second largest province that has oil palm plantation in Indonesia. In 2015, the area has reached 1,06 million ha [1]. When replanting, waste is generated in the form of trunk. The oil palm trunk (OPT) waste are very potential as raw material for wood product. The other hand, OPT has many weaknesses, such as low the density, high shrinkage-swelling, high moisture content and low strength. Erwinsyah [2] reported that 25 years old OPT density was 0.14-0.60 g/cm<sup>3</sup>, while 40 years old OPT was 0.23-0.74 g/cm<sup>3</sup> [3]. The other weaknesses of OPT was very high moisture content, low strength and low durability class [4]. The efforts to improve OPT quality was done by compressed using close system compression [5] and by impregnated of phenol formaldehyde [6]. Through compression and impregnation of phenol formaldehyde into OPT can improve the physical and mechanical properties.

The other efforts to improved OPT quality were made a laminated board. According to Serrano [7], laminated board is a product that was made by making layers and fasten layers and bond together with parallel direction. Many researchers study about laminated boards made from wood, such as laminated



board made from mangium [8], laminated blocks made from oily keruing wood [9], lamina blocks made from Bengkirai wood [10], laminated blocks made from Balsa wood [11], Laminated block made of Malaysian Hardwood of Resak and Kruing [12]. Aside that, laminated board can also made from non wood material such as Petung bamboo [13], *Gigantochloa apus* dan *Gigantochloa robusta* [14], bamboo laminated board made from Andong and Mayan bamboo [15].

Research of laminated boards of OPT was also conducted. Previous research about laminated board made from OPT shows that all of the physical and mechanical properties, such as MOR and MOE did not fulfill standard [16], [17]. This was caused by low quality of OPT, thus laminated board produced using it was also low of quality.

One way to improve laminated boards quality of OPT can be done using outer layer (face/back) from solid wood and densified OPT for core (middle) layer of laminated board. Outer layer using commercial wood such as Sengon and Meranti to improve its mechanical properties. Also the outer layer used to improve decorative values of laminated board.

Adhesives used is phenol formaldehyde (PF) adhesive. The PF is an exterior adhesive that durable against humidity [18]. Delamination test of laminated board made of OPT using PF was 0%. This means that PF is very suitable to be used as adhesive in laminated board production.

Based on that reasons, this research entitled Quality improvement of laminated board at various layer using PF adhesive. It was expected that various layer can improve quality of laminated board made from OPT to fulfills JAS 234:2003.

## 2. Material and Methods

Materials used in this research was boards of OPT, Meranti, Sengon and PF adhesives. OPT logs were obtained from Medan Tuntungan district, Medan city, while meranti and sengon wood was obtained from sawmill around Medan. Adhesives were obtained from PT Pamolite Adhesive Industry. Initial density of inner part of OPT, outer part of OPT, Sengon and Meranti wood were 0.28 g/cm<sup>3</sup>; 0.39-0.43 g/cm<sup>3</sup>; 0.41 g/cm<sup>3</sup> and 0.59-0.64 g/cm<sup>3</sup>, respectively.

OPT was cut into boards and separating the inner part (soft density) and the outer part (hard density). The the inner part of OPT were dried and cut into 5 cm (width) x 2 cm (thickness) x 45 cm (length) and densified with compression level of 50%, thus resizing it to 5 cm x 1 cm x 45 cm. The inner part of OPT can be compressed until compression level of 50% [19]. While the outer part of OPT, meranti and sengon wood was cut into 5 cm x 1 cm x 45 cm. After compression, the density of densified OPT became 0.45-0.48 g/cm<sup>3</sup>.

Laminated boards made of three layers with final size of 5 cm x 3 cm x 45 cm. Middle layer of laminated board was made of densified OPT. Spread weight of PF was 240 g/m<sup>2</sup>. PF spread using kape with double spreading technique. PF adhesive maturing was done at 150°C for 15 minutes. Various layer for laminated boards was made into five type as seen in Figure 1.

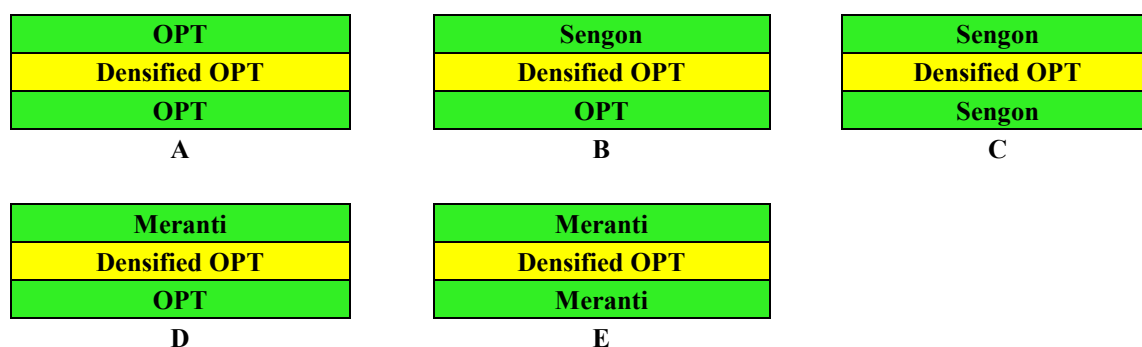


Figure 1. Various Outer Layer of OPT laminated boards

Physical and mechanical properties tested were moisture content, density, thickness swelling, delamination, MOR and MOE. Test of laminated board quality was referring to JAS 234:2003, Standard of Glued Laminated Timber [20]

### 3. Results and Discussion

The physical and mechanical properties in this reseach were moisture content, density, delamination, thickness swelling, MOR, and MOE. The result of physical and mechanical properties were as shown in Table 1.

**Table 1.** Physical and Mechanical properties of lamina board

Treatment	MC (%)	Density (g/cm <sup>3</sup> )	Delamination (%)	TS (%)	MOR (kg/cm <sup>2</sup> )	MOE (kg/cm <sup>2</sup> )
A	8.48 (0.21)	0.42 (0.01)	0 (0)	13.20 (2.79)	168.79 (29.28)	30115 (5166)
B	6.10 (0.80)	0.40 (0.03)	0 (0)	12.00 (3.02)	186.52 (25.47)	33375 (7256)
C	8.06 (0.35)	0.44 (0.06)	0 (0)	10.60 (1.16)	251.55 (25.89)	51808 (7795)
D	6.29 (1.35)	0.60 (0.04)	0 (0)	10.79 (2.03)	327.24 (54.69)	82947 (9041)
E	6.85 (0.37)	0.63 (0.02)	0 (0)	6.43 (1.17)	438.29 (24.10)	100454 (11118)
JAS 234: 2003	< 15	-	< 10	-	> 300	> 75000

Every value were mean value of three samples. Values inside brackets reflect one standard deviation, MC = moisture content, TS = thickness swelling, MOR = modulus of rupture and MOE = modulus of elasticity,

Moisture content of five type of laminated boards ranged from 6.10% to 8.48%. All laminated board moisture content fulfills JAS 234:2003 which set forth maximum of 15%. The Laminated boards using the outer layer of OPT was tend to have highest moisture content when compared to laminated boards using sengon and meranti. The moisture content is one factor of physical properties which affect the mechanical properties. When moisture content is reduced, the mechanical properties increased. Moody and Liu [21] reported that maximum range in moisture content between layer is 5% to minimize thickness swelling changes dimention.

Laminated board density ranged from 0.33 g/cm<sup>3</sup> to 0.44 g/cm<sup>3</sup>. The highest density value was type E with face and back layer from Meranti wood which is having a density of 0.63 g/cm<sup>3</sup>. The lowest density value was type B with face layer from Sengon with density of 0.40 g/cm<sup>3</sup>. Type E with face and back layer from meranti was higher than sengon and OPT layer. This caused by difference of density of materials used in each lamina. Meranti density is the higher than OPT and sengon density. In the contrast, Sengon wood density was lower than OPT and Meranti density.

Meranti wood density was categorized high with the value of 0.63 g/cm<sup>3</sup>. This wood will have cellular structure with thicker cell wall and smaller pore. According to Mandang and Pandit [22], Meranti wood was categorized to strength class of II-III, and durability class of III-IV and was suitable to be used as door and window, ship material, furniture, musical instrument, structural building.

Thickness swelling of laminated boards was around 6.43–13.2%. The highest value of thickness swelling was laminated board of OPT with type A using face and back outer layer from OPT, which is 13.20%. The lowest thickness swelling was laminated boards of OPT with type E using face and back outer layer from Meranti wood, which is 6.43%.

Thickness swelling was affected by the type of laminated board composition. Woods with low density will absorb more water when compared to those of higher density. The laminated boards

composed from OPT layers, there were highest thickness swelling, such as type A has high water absorbance and moisture content. Bakar [4] stated that OPT will be able to sustain moisture content of 250 to 350%.

If compared the outer layer of laminated board between Sengon and Meranti wood, the thickness swelling of laminated boards using Meranti wood as outer layer was lower than Sengon wood. This was caused by the difference of density of each laminated board material. Meranti wood density was highest when compared to OPT and sengon wood. In contrast, Sengon wood has lowest density when compared to OPT and meranti wood.

Delamination reflects the quality of adhesive and bonding strength of laminated boards. Results showed that delamination value of all treatment was 0% and fulfills JAS 234:2003 which set forth maximum of 10%. It means there is no bonding that was damaged or breached during immersion in water for 6 hours. This was caused by the use of PF adhesive was higher qualities compared to UF or natural adhesives. Ruhendi et al. [18] stated that PF adhesives has resistance from water, high humidity and temperature. Then, double spread technique was also enabling adhesives to perfectly spread on both fastened surfaces. This technique have good adhesion between adhesive and boards, it is preferable to use double spreading technique on both side of the surface. Variance of the outer layer and amount of adhesives does not cause different value. The OPT, Sengon and Meranti was able to be fastened with a high bonding strength using PF adhesives.

The mechanical properties in this research were modulus of rupture (MOR) and modulus of elasticity (MOE). Table 1 shown that MOR values of laminated board produced was around 168.79–438.29 kg/cm<sup>2</sup>. MOR value for laminated board type D and E with meranti as the outer layer fulfills JAS 234:2003. This type exceed the minimum requirement of 300 kg/cm<sup>2</sup> set forth by JAS 234:2003, with MOR value were 327.24 kg/cm<sup>2</sup> (type D) and 438,29 kg/cm<sup>2</sup> (type E). This was caused that meranti has higher density than OPT and sengon density. Wood density value contributed and had relationship with MOR value.

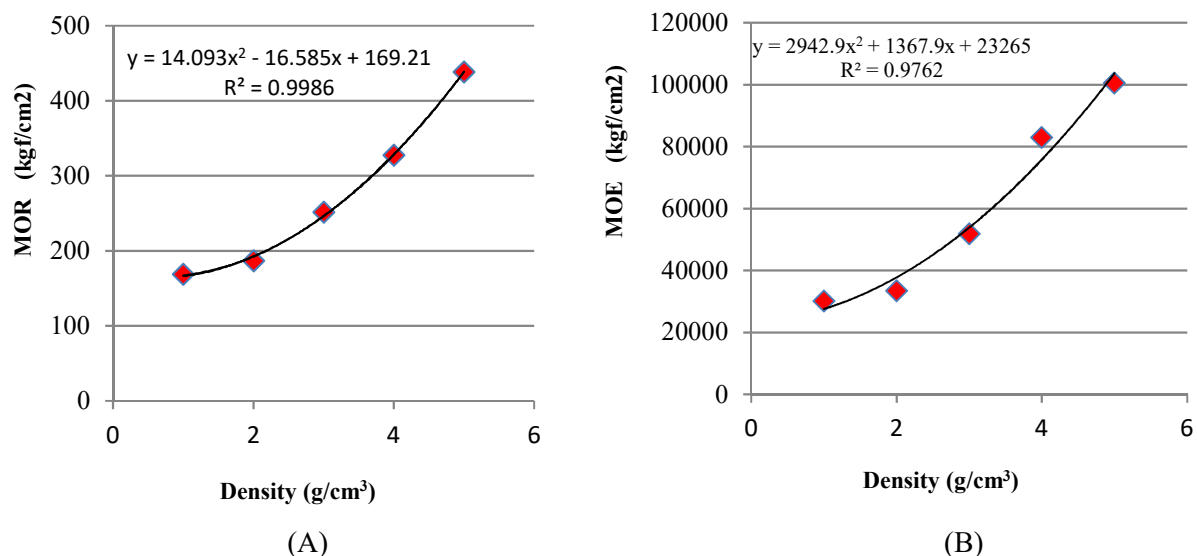
Herawati et al. [8] stated that MOR of woods was affected by some factors, namely density or specific gravity, wood knot and oblique fibres. A study by Karlinasari [23] shown that african wood had many knots and MOR value affected by design of laminations arrangement.

MOE values of laminated boards was 30115–100454 kg/cm<sup>2</sup>. MOE value for laminated board type D and E exceed the minimum requirement of 75000 kg/cm<sup>2</sup> set forth by JAS 234:2003, with MOE value was 82947 kg/cm<sup>2</sup> and 100545 kg/cm<sup>2</sup>, respectively. It caused that outer layer of meranti which high density. The initial density of meranti in this study was 0.61 g/cm<sup>3</sup>. Meranti layer contributed to MOE value, both to type D (only top layer) and also type E (top and bottom layer).

Previous research by Herawati et al. [8] showed that laminated board of African wood was having MOE of  $7.3 \times 10^4$  kg.cm<sup>-2</sup> and those of mangium wood was having values ranged  $8.41 \times 10^4$  to  $3.67 \times 10^4$  kg/cm<sup>2</sup>. They stated that MOE was affected by density, same as MOR value. Based on MOR and MOE values it can be concluded that laminated boards of OPT with Meranti wood as the outer layer was higher than the outer layers made from OPT and Sengon wood. Wood density was proportional with MOR and MOE. The use of high density wood will produce high mechanical properties, whereas low-density wood will produce low mechanical value. Bodig and Jayne [24] stated that factor that affected wood strength was density. The higher density, the higher strength will be resulted.

Mechanical properties were attributable to density. The higher density resulted in the higher MOR and MOE. Figure 2 shows the relationship between density with mechanical properties. The regression analysis showed that the correlation between density and MOR, also density and MOR could be described by a second-order polynomial.

Figure 2 showed that density increased the MOR and MOE, which resulted in a strong relationship, as shown by high values of the coefficient of correlation (R<sup>2</sup>) of 0.99 and 0.97 for the MOR and MOE, respectively. Similar statement was uttered by Bowyer et al. [25] that mechanical properties will increase with the increase of wood density.



**Figure 2.** Relationship between density and MOR (A) and density and MOE (B)

Based on the mechanical properties, to improve the quality of laminated board made from OPT must used wood with high density for the outer layer, such as meranti wood. From this result showed that optimum of treatment was type E with used meranti as the outer layer for laminated board.

#### 4. Conclusion

The physical properties such as moisture content and delamination of laminated boards of all various outer layer fulfilled JAS 234:2003. The other hand, density and thickness swelling has not fulfilled standard. Whereas mechanical properties (MOR and MOE values), only type D and E that fulfilled JAS 234:2003. There are strength relationship between density and mechanical properties (MOR and MOE). The optimum treatment in this reseach to made laminated board from OPT was type D that using the meranti as outer layer.

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