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The effect of glue spreads and adhesive type on quality of laminated board from oil palm trunk

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Abstract. The objective of this study was to analysis glue spreads and adhesive type on physical and mechanical properties of a laminate board from oil palm trunk and to obtain the optimum glue spread for each adhesive to manufacture laminate board. Adhesive used were polyvenil acetate(PVAc), urea formaldehyde(UF), and phenol formaldehyde(PF). Glue spread variation were 240, 260, 280 and 300g/m^2. On this research, the lamina board consists of three layers. Upper and bottom layer made from the outer part of the oil palm trunks with dimension of 45cm x 5cm x 1cm, the middle layer made from the soft-inner part of oil palm trunks with dimension of 45cm x5cm x2cm and then compressed up to dimension of 45cm x 5cm x 1cm. The results will be compared with the JAS standard 243:2003. The results of this study showed that all of the physical properties fulfilled the standard of JAS 243:2003, except laminate board using PVAc adhesive. The other hand, all of the mechanical properties did not fulfil standard, except the value of MOR with treatment 240g/m² using PF adhesive. The optimum quality in this study using PVAc, UF and PF adhesive using glue spread of 240g/m², 280g/m² and 240g/m², respectively.

1. Introduction

Wood supply from natural forests continues to decline due to increased forest degradation. This will cause a shortage of wood supply for industry. Alternatives that can be developed as raw materials are waste from the plantation, such as oil palm trunk (OPT). This waste was aboundary in Indonesia.Based on the study, when replanting, oil palm plantations can produce 183 m^3/hectare of OPT and can produce 50.1 m^3 of sawn timber from the outer part of OPT [1].

The utilization of OPT has many problems. The most problem was low quality of OPT, such as low density, low strenght, low durability and high moisture content [2]. Hartono [3] reported 40 years old OPT was 0.23-0.74 g/cm^3. The moiture content of OPT was very high, especially the inner part of OPT around 345%-500%. Thie high moisture content of soft-inner part of OPT (S-OPT) caused low dimension stability of OPT[2]. The efforts to improve the quality of S-OPT was done by impregnation PF [4] and by compression or densification technique [5]. TheS-OPT can be densifiedat 37-67% from the original thickness [3]. The compression technique will improve the physical and mechanical properties [5]. The compressed S-OPT can be used as a center layer in the laminated board.

Several previous studies about laminated board reported that the laminated board could be made from wood, such as laminated boardmade from Bengkirai wood [6] and Balsa wood [7]. The laminated board canbe made from non wood, such as laminated board from Mayan and Andong bamboo [8] and Petung bamboo [9].

The quality of the lamina board depends on the quality of the adhesive. The adhesives typewere urea formaldehyde (UF) and phenol formaldehyde (PF). Another adhesive that was widely used by the public is polyphenyl acetate (PVAC) adhesive, because it is widely available in building materials stores. In addition to the type of adhesive, the glue spread was also very important for the quality produced. The utilization of the adhesive type and the glue spread need to be known to produce the lamina board from OPT.The purpose of this study was to obtain the optimum properties of the lamina board from variations in glue spread with 3 types of adhesive, namely PVAc adhesive, urea formaldehyde, and phenol formaldehyde.

2. Materials and Methods

2.1. Material

The OPT used in this studyglwas 40yearold with a diameter of 50 cm from KwalaBekala area, Medan Johordistrict, Medan city. The other material was PVAc, UF and PF adhesive. The UF and PF adhesive from Palmolite Adhesive Industry, Probolinggo.

2.2 Methods

2.2.1. Preparation of materials. The OPT sampel was separated into the outer part and soft-inner part of oil palm trunk (S-OPT). The outer part was cut into pieces 45 cm × 5 cm × 1 cm in length, width, and thickness, respectively. While S-OPT was cut into pieces 45 cm × 5 cm × 2 cm. then compressed with a compression ratio of 50% to become 45 cm × 5 cm × 1 cm. The previous study reported that S-OPT could be densifiedat 37~67% from the original thickness [3], so that the densityin the center layer of laminated OPT can be increased.

2.2.2. Laminated board manufacturing. Laminated boards made of three layers with final size of 45 cm x 5 cm x 3 cm. The upper and bottom layer of laminated board was made from outer part of OPT and the center layer was made from compressed S-OPT.The adhesive used were PVAc, UF and PF with glue spread of 240, 260, 280 and 300 g/cm^2. The glue spread using kape with double spreading technique. The UF adhesive maturing was done at 130^{o}C for 10 minutes and PF was done at 150^{o}C for 10 minutes. While PVAc used a cold press for 24 hours.

2.2.3. Physical and mechanical test. Physical and mechanical properties tested were density, moisture content (MC), delamination, MOE and MOR. The sample size of density, and MC were 3 cm x 2 cm x 3 cm and delamination test with size of 10 cm x 2 cm x 3 cm. While the MOR and MOE size were 45 cm x 3 cm x 3 cm. Test of laminated board quality was referring to JAS 234:2003, Standard of Glued Laminated Timber.

2.3. Data Analysis

The data of physical and mechanical properties were compared with JAS 234:2003, Standard of Glued Laminated Timber [10], as shown at Table 1.

Table 1. The JAS 234:2003

Properties	Standard
Moisture content	Max 15 %
Delamination test	Max 10 %
MOR	≥ 300 kg/cm^2
MOE	≥ 75000 kg/cm^2

3. Results and Discussions

3.1. Moisture Content

Moisture content (MC) of laminated boardwith core from compressed of S-OPT were 6.89-16.08%.The MC of laminated boardwas shown in Figure 1.

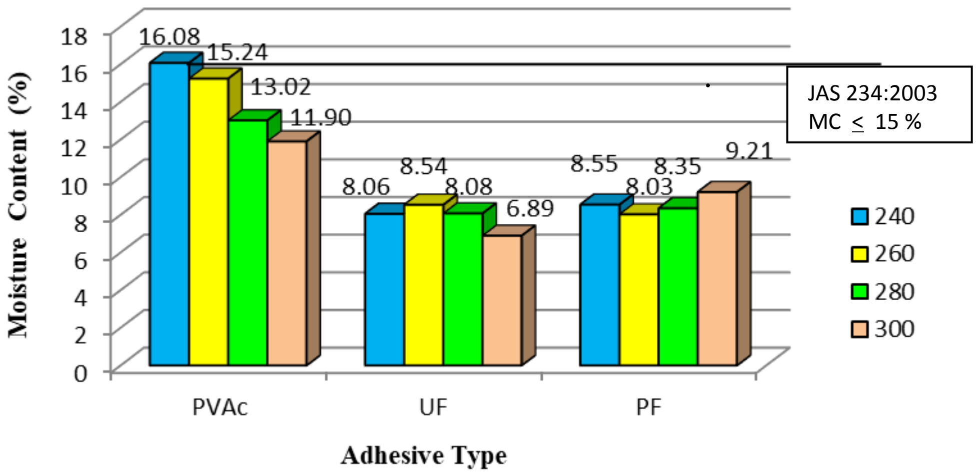

Figure 1. The moisture content of laminated boardwith variation of adhesive type and glue spread

Figure 1 shown that MC for PVAc adhesive is higher than other adhesive with range 10.90-16.08%, whileMC of laminated board with PF adhesive ranged from 6.89-8.54% and PF produced almost same moisture content that is 8.03-9.31

The difference compression technique caused the difference ofMC between PVAc adhesive with UF and PF adhesive. Compression technique can be done by hot pressing or cold pressing. Hot pressing needs relatively short time, however technically difficult for laminated beams, whilecold pressing needs longer time.

Compression technique on laminated board using PVAc adhesive was cold pressing for 24 hours, without using temperature, while UF and PF adhesive using hot pressing.The UF adhesive need temperatur of 130ºC and PF adhesive need temperatur of 150ºC for 15 minutes to curing adhesive. Hot pressing with high temperature will evaporate water in wood. The longer pressing time will increased the water out from OPT.

JAS 234:2003required MC max of15%. Almost all MC value fulfilled the JAS standar, except laminated board using PVAc adhesive with glue spread of 240 g/m^2 and 260 g/m^2. The other research reported that MC of laminated beam from Africa and Mangiumfulfilled the JAS standar with MC of 12.4-12.9% and 12.2-12.8%, respectively[11].

3.2.Density

The density value of laminated boards with core from compressed of S-OPTwere 0.44-0.52 g/cm^3. Density of laminated board was shown in Figure 2.

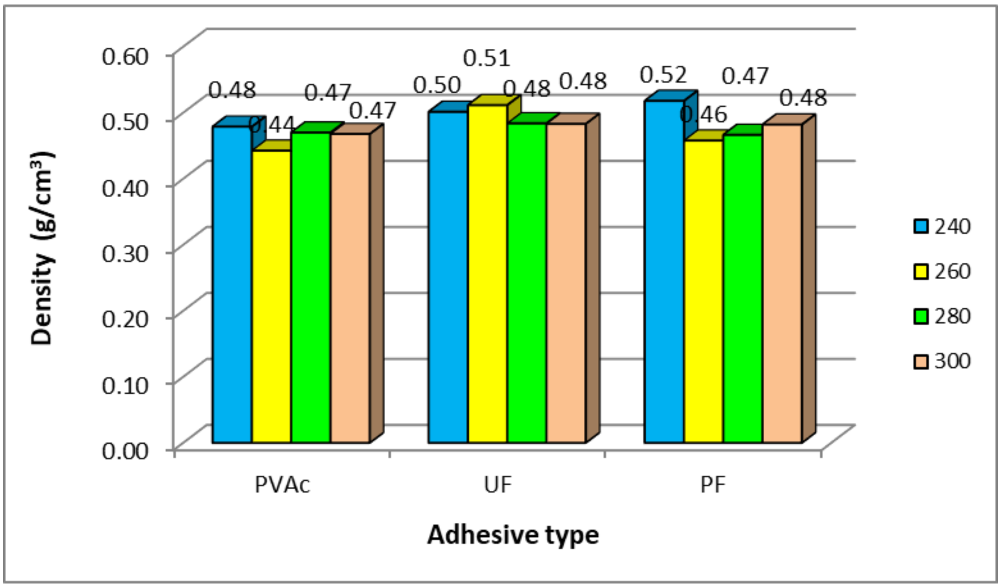

Figure 2. Density of laminated board with variation of adhesive type and glue spread

Based on Figure 2 shown that density of lamina boards using PVAc are lower compared to UF and PF adhesive. Maybe this caused by occuring spring backon the laminated board after released from cold press. This is supported by the high moisture content on the laminated board with PVAc adhesive. While on laminated board with UF and PF adhesive doesn't happen spring back. The density of laminated boards from OPT with PVAc adhesive ranged from 0.44-0.48 g/cm^3, with UF adhesive ranged from 0.48-0.51 g/cm^3 and with adhesive PF ranged from 0.46-0.52 g/cm^3.

The density values were really vary and tend to be more influenced by the presence of glue spreads. The highest density values from glue spread for PVAc, UF,and PF were 240 g/cm^2, 260 g/cm^2 and 240 g/cm^3, respectively.

3.3. Delamination

Delamination value of the laminated board withcore from compressed of S-OPT were 0-83.33%. Delaminationvalue of the lamina boardwas shown in Figure 3.

Based on figure 3, it can be seen that the PVAc adhesive has a very large delamination value of 61.10-83.33%. While for UF adhesive the delamination value ranged from 0-7.64% and for PF adhesive, delamination value was zero.These shown that PF adhesives were very resistant to water and high humidity. The delamination value was an indicator of adhesive resistance to the presence of development pressure and shrinkage due to high humidity and heat[12]

PVAc adhesive was an adhesive that it was not resistant to water, so that when soaked for 6 hours, stretching occurs on the adhesive line. This can be seen from the high delimination test results on the lamina board with densification range between 61.10-83.33%.

Furthermore, the adhesive whichdeliminated was UF adhesive. The delimitation that occurs in the lamina board with core from compressing S-OPT ranges from 0-7.64%. UF adhesive includes a type of adhesive that did not resistent water and high humidity. Generally UF adhesives are widely used in the plywood industry. This adhesive is not resistant to weather changes compared to phenol and melamine adhesives [13]. The weakness of urea formaldehyde adhesive is that it can only be used for interior needs, where no high resistance to water and moisture is required. It was due to the ease of UF experiences hydrogen bond damage due to the influence of moisture and acid, especially at medium and high temperatures. In cold water the rate of damage to the resin structure was very slow but at temperatures above 40^{o}C the damage was accelerated and above 60^{o}C the process was very fast[14].

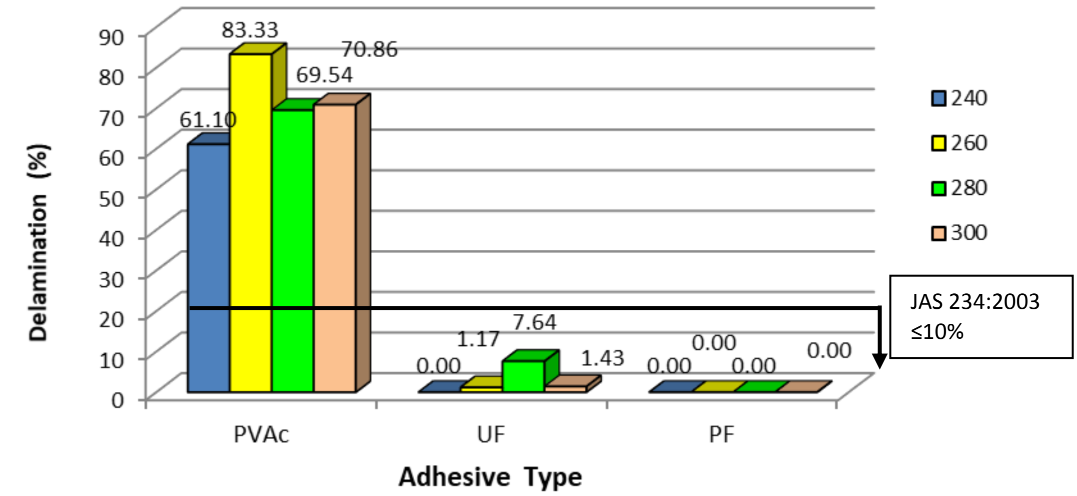

Figure 3. The delamination value of of laminated board with variation of adhesive type and glue spread.

Adhesives that did not deliminatedwas PF adhesives. PF adhesives are resistant to moisture and weather. The PF adhesive has a low viscosity, making it possible to penetrate into the wood pores and serves as a mechanical anchor in gluing. PF is also able to react chemically and bind to hydrogen with wood, as well as with lignin. All contribute to the adhesive strength of wood with PF adhesives, so that the cohesive strength of PF exceeds the strength of wood cohesiveness [15].

Based on the JAS 2003 standard requires a maximum delimitation of 10%. Based on the resulting delimination value, all lamina boards with PVAc adhesive did not fulfill the standards. In contrast, all lamina boards with UF and PF adhesives fulfilled JAS standards.

3.4. Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

The MOE value of the laminated board was 22935-49042 kg/cm^2 and and MOR value was 136-313 kg/cm^2. The value ofthe lamina board MOE shown in Figure 4 dan Figure 5

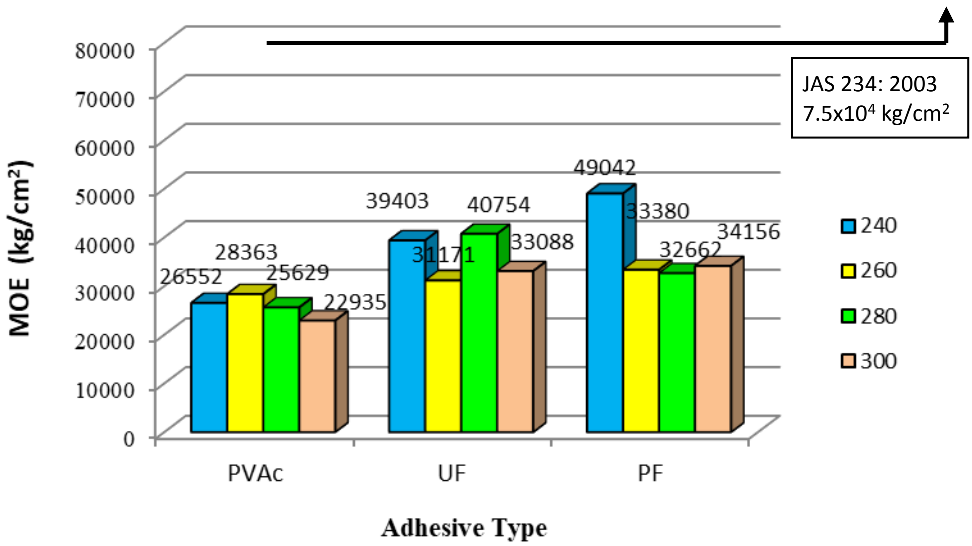

Figure 4. The MOE value of of laminated board with variation of adhesive type and glue spread.

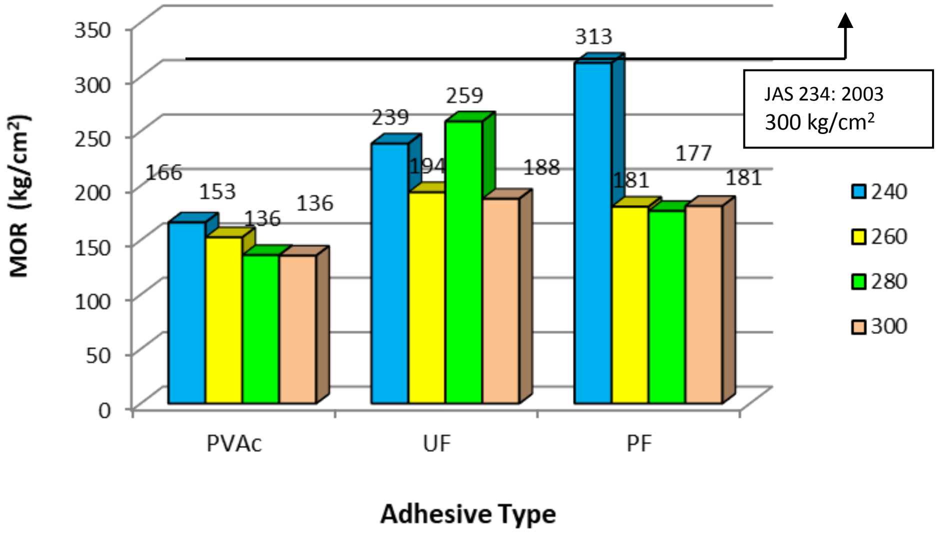

Figure 5. The MOR value of of laminated board with variation of adhesive type and glue spread.

Based on Figure 4 and Figure 5shown that MOE and MOR value of laminated board with PVAc adhesive was lower than the laminated board using UF and PF adhesives. The JAS standard requires an MOE value of the laminated board for structural 75000 kg/cm^2 and for required of MOR value was 300 kg/cm^2. Based on the MOE value (Fig 4), there was no MOE value of the laminated board from OPT fulfilled standards. While MOR value, only one traetment that fulfilled JAS standar that was laminated board using PF adhesive with glue spreader of 240 g/cm^2.

The low MOE and MOR value of the Laminated board from OPT was because of the density of OPTwas low. Bakar [2] reported that density of S-OPTwas 0.2-0.35 g/cm^3.The MOR and MOE increase with increasing of specific gravity and density.

When compared with other woods, it turns out that the MOE value of the lamina board from OPTwas lower than that of other wood lamina boards. The average MOE value of the laminatedsengon board was 60364.04 kg/cm², the laminatedmanii board was 84956.59 kg / cm², the acacia lamina board was 100503.96 kg / cm² and the acacia-sengon lamina board was 75872.79 kg / cm², and acacia-manii mixed lamina board is 84458.45 kg / cm² [16].

Then MOR value of laminated board fromsengon, manii, Acacia, mixed Acacia-Acacia-mix and sengonmanii did not fulfill the standards of JAS 2003. The MOR value of laminated board fromsengon, manii, Acacia, mixed Acacia-Acacia-mix and sengonmaniiwere 197 kg/cm^2, 240.05 kg/cm^2, 253.26 kg/cm^2, 150.03 kg/cm^2, 204.51 kg/cm^2, respectively [16].

Different research results showed the average MOR value of laminatedboard from Acaciawas 516-687 kg/cm² [17]. From the results of research conducted that the MOR value obtained higher than other researches. The difference in the MOR value with other research mainly relate to the characteristics of the wood used. Wood with higher density also has a higher strength compared to the wood with lower density.

4. Conclusion

Almost all of the physical properties of laminated board from OPT with core from compressed of S-OPT fulfilled JAS 234 (2003) standards except for lamina boards which use PVAc adhesive. The other hand, all mechanical properties of the lamina board did not fulfille the standards, except the MOR value on the lamina board using PF adhesive with glue spreader of 240 g/m^2. The optimum glue spreader for PVAc, UF and PF were 240 g/cm^2, 280 g/cm^2, and 240 g/cm^2, respective

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