Sandwich Particleboard (SPb): effect of particle length on the quality of board

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Abstract. Sandwich particleboard is one of the composite products composed of strength lignocellulose materials for the surface layer and particle as the core layer. This product consists of three layers which are similar to comply. The difference between both products is in the surface layer, which uses veneer or thin plywood as surface. The objective of this research was to evaluate the length particle effect on physical and mechanical properties of SPB. Belangke bamboo, corn stalk bagasse and isocyanate resin were the main raw materials for the manufacturing of SPB. SPB was made in size of 25 x 25 cm with the density and thickness target of 0.7 g/cm\textsuperscript{3} and 1 cm respectively. Amount 8\% level isocyanate resin was applied in the manufacturing of board. Hot pressing parameter such as temperature, time and pressure was set on 160 °C, 5 minutes, and 30 kg/cm\textsuperscript{2} respectively. The results showed that 10 cm particle length resulted in the best bending properties. MoE and MoR value of 10 cm particle length were 42,156 and 333 kg/cm\textsuperscript{2} respectively. Almost all parameters fulfill the JIS A 5908 (2003), except the internal bond and the thickness swelling value.

1. Introduction

Particleboard is a composite product of wood panel made from timber or other lignocellulosic materials, bonded with adhesive and then hot pressed [1]. As stated by Haygreen [2], it has weaknesses in its dimensional stability and strength, influential aspect, especially for the use of structural components of buildings.

This study used raw materials including lignocellulose, corn stalks and belangke bamboo. According to Octaviana [3], corn stalks contain 32.4\% cellulose, 23\% hemicellulose and 16.3\% lignin. Bamboo is used as a coating material due to its advantages in terms of strength. Bamboo has flexural strength of 2,600-8,000 N/mm\textsuperscript{2} [4]. Besides, Papadopoulos and Kasim [5, 6] stated that bamboo could be grown with urea formaldehyde adhesive produce MOE values of 2000 N/mm\textsuperscript{2}.

The focus of this research was to improve the strength of the particleboard through modification on the surface using bamboo as a reinforcement material. Sandwich particleboard consists of three layers of non-wood materials, face, core and back, which stick together with adhesives. This product is similar to com-ply board. What distinguishes it from com-ply board is the fact that it uses veneer or thin plywood.

2. Materials and methods

The study used various materials including corn stalk waste, Belangke bamboo and 8\% isocyanate adhesives.
2.1. Preparation of raw materials
The bamboo strand was cut into a length of measuring 5, 10, 15, 20, and 2.5 cm wide and 0.1 cm thickness. These pieces were then heated to a moisture content of 7.7%. The corn stalks were dried, cut to a particle size of 5 cm, and then dried to a moisture content of 5.3%.

Table 1. Strand particle geometry.

| Strand (cm) | Length (cm) | Width (cm) | Thickness (cm) | Slenderness ratio (p/t) | Aspect ratio (p/l) |
|-------------|-------------|------------|----------------|-------------------------|-------------------|
| 5           | 4.99        | 2.53       | 0.15           | 33.26                   | 1.97              |
| 10          | 9.99        | 2.51       | 0.09           | 111                     | 3.98              |
| 15          | 14.99       | 2.55       | 0.11           | 136.27                  | 5.87              |
| 20          | 20.00       | 2.53       | 0.13           | 153.84                  | 7.90              |

2.2. Board manufacture
The particleboard was made in size of 25 by 25 cm² with the target density and thickness were 0.70 g/cm³ and 1 cm. The strand and particles were mixed with isocyanate adhesive using a rotary blending machine. Furthermore, Belangke bamboo strand and corn stalk particle were used as face and core respectively. The conformation of the sheet composed of face, core and back in the ratio 1: 2: 1 respectively. It was placed between two felt plates and pressed hot to a thickness of 1 cm at a temperature of 160 °C for 5 minutes and pressure of 30 kg/cm². Furthermore, the conditioning was carried out for 14 days at the room temperature to release stress on board and enable the perfect glueing process.

2.3. Testing the physical and mechanical properties of particleboards
The boards were cut into test samples of various sizes according to the JIS A 5908 (2003) standard. It was then tested against such parameters as density and moisture content (MC), water absorption (WA), thickness swelling (TS), internal bond (IB), modulus of elasticity (MoE) and modulus of rupture (MoR).

3. Results and discussions
3.1. Physical properties
The values of the physical properties of the board are presented in table 2.

Table 2. Physical properties of sandwich particleboard.

| Physical properties | Density (g/cm³) | MC (%) | WA (%) | TS (%) |
|---------------------|----------------|--------|--------|--------|
| 5                   | 0.56           | 8.00   | 57.28  | 15.48  |
| 10                  | 0.63           | 7.81   | 47.18  | 14.49  |
| 15                  | 0.60           | 7.76   | 41.27  | 12.18  |
| 20                  | 0.61           | 8.72   | 38.14  | 7.05   |

The density of sandwich particleboard ranged from 0.56 to 0.63 g/cm³, with the highest and the lowest strand lengths are 10 and 5 cm respectively. This value does not close to the density target of 0.70 g/cm³ though it meets the JIS A 5908 (2003) standard that requires a density value of 0.40 to 0.90 g/cm³. The sandwich particleboard density did not reach the target because of the wastage of particles during the manufacturing process as stated by Bufalino [7]. Besides, the failure could also be attributed to the spring back force or the liberation effort from the pressure experienced during pressing. Boards made of lignocellulose instead of wood generally have a large spring back force because the former has bulky properties due to its low density. The average value of spring back sandwich particleboard was 31%.

The moisture content value of sandwich particleboard produced ranged from 7.76 to 8.72%. The highest moisture content was 10 cm strand length while the lowest was 15 cm. This value meets the JIS A 5908 (2003) standard of moisture content value of 5 to 13%. As stated by Maloney [1], the aspects
that influence the values obtained are: the raw materials used, the species of plants from where the raw materials were obtained, and the area of raw materials were obtained.

The water absorption value of the sandwich particleboard produced ranged from 38.14 to 57.28%. The highest value was 5 cm strand length while the lowest was 20 cm. The results showed that sandwich particleboard with longer strands had lower values. It could be caused by the particleboard's surface that was narrower and denser; therefore, the particle cavity could not easily get in and out of water. The high absorption of water in sandwich particleboard was attributed to the hygroscopicity of lignocellulose material. Lignocellulose material is very hygroscopic and can expand and shrink because of the absorption and loss of water and steam respectively, something that occurs under the conditions of fiber saturation [8]. The most responsible factor in water absorption is hemicellulose, even though lignin and cellulose play significant roles as well [9].

The thickness swelling of sandwich particleboard ranged from 7.05 to 15.48%, with the highest and lowest values strand length were 20 cm and 5 cm respectively. The lowest value meets the quality standard requirement of the JIS A 5908 (2003) with a value of ≤ 12%. The longer strands led to lower thickness swelling of sandwich particleboard value. It occurred because the number of strands of each treatment was long with different weight. It is in agreement with Maulana [10] who stated that a smaller strand size requires more particles than a longer one with the same particle weight. A large number of particles used affect the thickness swelling of a board. It is because the more particles used to upsurge the potential it has to absorb water, facilitating the thickness swelling. The geometry of particles with the large surface area has better contact to prevent board thickness swelling [11].

3.2. Mechanical properties
The values of the mechanical properties of the boards are presented in table 3.

| Mechanical properties | Bamboo Strand Length (cm) |
|-----------------------|---------------------------|
|                       | 5            | 10           | 15           | 20           |
| MoR (kg/cm²)          | 71.45        | 333.97       | 309.94       | 322.32       |
| MoE (kg/cm²)          | 20,311       | 42,156       | 35,360       | 30,875       |
| IB (kg/cm²)           | 0.73         | 1.00         | 1.14         | 1.21         |

The MoR value of sandwich particleboard produced ranged from 71.45 to 333.97 kg/cm², with the highest and lowest values of strand lengths were 10 and 5 cm respectively. The value meets the quality standard of JIS A 5908 (2003) which requires of $\geq 80$ kg/cm². Nevertheless, in the treatment of Belangke bamboo with the strand length of 5 cm did not fulfill the standard required. Also, the strand length had the lowest MoR value compared to the others because the particleboard had much space between the arranged units, leading to weak fracture. The MoR value of 5 cm strand also lessened slenderness ratio (SR) than the other strands. The higher SR value results in a better contact area on the mechanical properties of the particleboard [12]. According to Koch [13], the factors that influence the brokenness of particleboard include wood specific gravity, particle geometry, adhesive content, the water content of the mat, and the pressing procedure. According to Lias [14], the higher density value of particleboard is affected by the MoR properties leading to high MoE.

The MoE values of sandwich particleboard produced ranged from 20311.30 to 42156.44 kg/cm². The highest value was 10 cm strand length while the lowest one was 5 cm. This value meets the quality standard requirements of JIS A 5908 (2003) with a value of $\geq 20000$ kg/cm². According to Haygreen [2] that apart from the density and adhesive content playing significant roles, particle geometry is the main characteristic that determines the nature of MoE produced, especially the slenderness ratio (SR) of the particle used [9]. The low MoE value in the 5 cm strand was due to the fact that it had more pith than the others within the core.

The IB value produced ranged from 0.73 to 1.21 kg/cm². The highest value was 20 cm strand length with the lowest was 5 cm. The IB value of the particleboard does not fulfill the JIS A 5908 (2003) quality standard with a value of kg 1.5 kg/cm² because the corn stalk particles containing bark significantly
lessened the IB value on the board. Corn stalks are hydrophobic and contain inorganic silica on the bark, ensuring that water and isocyanate adhesives do not wet the surface of the stalk. This might be the reason why the stickiness of the particles was low. According to Iswanto [12], hydrophobic particles interfere with the penetration of the adhesive in particles and weaken the bonds between them. The internal adhesive strength indicates whether or not the bonds between the particles in sandwich particleboard are good. The force obtained during testing led to a higher IB value than the particleboard with smaller bamboo strands and lesser dimensions. The large dimensional particles have higher values of adhesive constancy than small dimensional particles [10]. The higher of IB value resulted in better and stronger bond between particles in sandwich particleboard. Similarly, the length of the bamboo strand was due to the increase of IB value. This is in accordance with Viswanathan [15] that the manufacture of particleboards from large dimensional unit shows better mechanical properties.

4. Conclusion
The physical and mechanical value of the sandwich particleboard was carried out to establish that the board with a 20 cm strand length was the best.

5. References
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