OSB (Oriented Strand Board Green Building): Utilization of OSB Betung Bamboo (Dendrocalamus asper (Schult. F.) Backer ex Heyne) by Testing Physical and Mechanical Properties to Optimize Eco-Friendly Construction in Indonesia

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Abstract. The National Institute of Building Science (US) states that building materials that come from nature can produce greenhouse gas emissions such as 35% of carbon dioxide, 49% of sulfur dioxide, and 25% of nitrogen oxides. These gasses cause the construction will be unfriendly for the environment, so we need a green construction materials. Bamboo is one of the alternative green constructions because the easiest way to build, elastic and resistant to earthquake, as well as easily repaired in case of damage. OGB (Oriented Strand Board Green Building) is a solution in the use of betung bamboo for green building construction by conducting several tests. This test aims to determine the physical and mechanical properties of betung bamboo by using phenol-formaldehyde (PF) with adhesive contents of 6%, 7%, and 8%. The results showed that the differences in adhesive content of 6%, 7%, and 8% significantly affect the value of density, moisture content, water absorption, thickness, and internal bonding. OGB can be used as a solution for improving eco-friendly building construction in Indonesia.

1. Introduction
According to Singh et al [1], construction using materials such as cement, sand, aggregates, steel are materials that are directly produced from nature will continually increase in the future. These materials enhancement affect greenhouse gas emissions which causes construction activities will be unfriendly for the environment. The National Institute of Building Science (US) states that buildings which come from nature can produce greenhouse gas emissions such as 35% of carbon dioxide, 49% of sulfur dioxide, and 25% of nitrogen oxides. The development index that continues to increase in the current era of globalization must be balanced with efforts to reduce greenhouse gas emissions and increase the eco-friendly construction buildings. It can be conducted by utilizing construction materials that are more efficient and reduce the increase in greenhouse gas emissions.

One of the materials that can be used as green construction is by making an Oriented Strand Board (OSB) from bamboo. Oriented Strand Board (OSB) is a panel made of wooden strands, glued with exterior type adhesive and hot-pressed [2]. Bamboo has great potential to be used as raw material for OSB. According to Akbar & Supomo [3], the strength of bamboo can be used as a construction material. This is since bamboo has almost the same tensile strength the same as mild steel at the yield point. Cellulose is the main component present in bamboo which is the main source of mechanical properties.
properties of bamboo. Besides, bamboo also has a relatively fast-growing period that sustainably supports the creation of OSB.

The use of Bamboo OSB is often used for exterior purposes that are waterproof. There is some adhesives that are used to make OSB such as methylene di-phenyl in isocyanate (MDI), phenol-formaldehyde (PF) and resorcinol formaldehyde (RF). Based on Sahroni’s research (2008) about oriented strands Betung bamboo board using exterior adhesive MDI has reached the standard. However, the use of MDI and RF adhesives is lacking economically profitable because the price is relatively expensive. Phenol-formaldehyde adhesive has less price than methylene di-phenyl in isocyanate and resorcinol formaldehyde adhesive. This study aims to analyze the physical and mechanical properties of OSB at three different adhesive levels by 6%, 7%, and 8%. The results of this study can be used as information about the effect of adhesive levels on physical and mechanical properties.

2. Methodology

2.1. Place and time of research
This research was conducted at the Biocomposite Laboratory, Biocomposite Division, Department of Forest Products, Faculty of Forestry, IPB University, Dramaga, Bogor. The study was conducted in November-December 2018.

2.2. Materials and Tools
The materials used in this study were bamboo and phenol-formaldehyde adhesives. The main equipment used in this study consisted of a spray gun, a mold measuring 30 cm x 30 cm, aluminum foil, hot press, caliper, oven, rotary blender, desiccator, measuring cup, digital scale, UTM brand mechanical test instrument type 3369.

2.3. Research procedure

2.3.1. Material Preparation
Preparation of adhesives and paraffin. The adhesive used is a phenol-formaldehyde (PF) adhesive with an adhesive content of 6%, 7%, and 8%.

2.3.2. Strand Making
The bamboo was made into strands and had size 6-7 cm, 1-2 cm wide with a thickness of 0.1-0.2 cm. Strand put into a sack. Determination of the aspect ratio (ratio of length and width of strand) and slenderness ratio (ratio of length and thickness of the strand) was done by taking strand randomly for 100 strands in each type then measuring the length, width, and thickness of the strand. Strand under dry conditions air was put into the oven to reach the dry water content of the furnace (BKT) for approximately 3 days.

2.3.3. Strand and Adhesives Mixing
The mixing process used the rotary blender, while a spray gun was used to put adhesive into the rotary blender and then it was also mixed with 1% paraffin content.

2.3.4. Sheet Making
The OSB sheets consist of faces, cores, and backs in the ratio of 1: 1: 1 each. The strand direction of the face and back layers was aligned according to the length of the panel, while the core layer was perpendicular to the face and back layers. This is to improve the stability of the formed OSB dimensions. This made OSB sheet measures 30 cm x 30 cm x 0.9 cm with a strand density of 0.7 g/cm³.
2.3.5. Compression
Pressing used a hot press with a temperature of 135° C and pressurization of 25 kg/cm$^3$ with a pressing time of 9 minutes. Pressing used a hot press, because the adhesive used was a PF adhesive which is a thermosetting adhesive that hardens when given heat treatment. The purpose of this compression was to obtain a solid and hard panel bond and obtain the desired thickness of 0.9 cm.

2.3.6. Conditioning
After the pressing process, the OSB panel sheets were treated by conditioning for about 14 days so that the moisture content of the board reaches equilibrium and the adhesive can harden properly. After two weeks, the board will be cut according to the sample size. The cutting pattern of the test sample can be seen in Figure 1.

![Test sample cutting pattern](image)

**Figure 1.** Test sample cutting pattern.

Information:
A, D : test sample for MOE and MOR perpendicular to dry and wet fiber conditions (20 cm x 5 cm x 1 cm)
B, C : test sample for MOE and MOR parallel fiber dry and wet conditions (20 cm x 5 cm x 1 cm)
E : test sample for water content and density (10 cm x 10 cm x 1 cm)
F : test sample for screw holding strength (10 cm x 5 cm x 1 cm)
G : test sample for developing thickness and water absorption (5 cm x 5 cm x 1 cm)
H : test sample for internal bond (5 cm x 5 cm x 1 cm)
I : reserve (5 cm x 5 cm x 1 cm)

2.3.7. OSB Physical Properties Testing
**Water content.** Water content testing was carried out on a test sample measuring 10 cm x 10 cm x 0.9 cm based on the JIS A 5908 standard (2003). The test sample was weighed the initial weight ($m_1$), then the test sample was dried in an oven at 103 ± 2° C for 24 hours. The test sample was put into the desiccator so that the weight will be constant then to weigh it ($m_2$). Water content was calculated using the following formula: WC (%)=$\frac{m_1-m_2}{m_2} \times 100\%$.

**Density.** Density testing used wood measuring 10 cm x 10 cm x 0.9 cm based on the JIS A 5908 standard (2003). The volume of the test sample was calculated based on the multiplication of the
length, width, and thickness of the average test sample. Then the test sample was weighed to get the
value of m1. The density was calculated by the equation: $D (%) = \frac{m1}{v}$.

Thickness Expansion. The test sample used in this thickness expansion test was a test sample measuring 5 cm x 5 cm x 0.9 cm and following the JIS A 5908 standard (2003). Thickness development was based on the initial average thickness ($t_1$) measured on all four sides under dry air conditions and thick after soaking ($t_2$) in cold water for 2 hours and 24 hours. Value of thickness expansion can be calculated using the equation: $TE (%) = \frac{t_2-t_1}{t_1} \times 100\%$.

Water Absorption. The test sample used in testing water absorption was a test sample measuring 5 cm x 5 cm x 0.9 cm based on the JIS A 5908 standard (2003). The test sample was weighed initially ($m_1$), then immersed in cold water for 2 hours and 24 hours, then it was weighed ($m_2$). The water absorption value was calculated using the following equation: $WA (%) = \frac{m_1-m_2}{m_1} \times 100\%$.

2.3.8. OSB Mechanical Properties Testing

Modulus of Elasticity Static (MOEs). This static modulus elasticity test was carried out by using the Universal Testing Machine of the Instron brand by using a buffer distance of 15 times nominal thickness, but not less than 15 cm. The test sample used was 5 cm x 20 cm x 1 cm based on the JIS A 5908 standard (2003), which is in the longitudinal direction (in the direction of the strand orientation of the OSB surface layer) and the transverse direction (perpendicular to the strand orientation in the OSB surface layer). Examples of tests used in wet and dry conditions. Loading was given at a speed of 10 m/minute. MOEs can be calculated using the equation: $MOEs (\text{kgf/cm}^2) = \frac{\Delta P L^3}{4btybt^2}$

Information:

$MOEs$ : Modulus of elasticity (kgf/cm$^2$)
$\Delta P$ : Load in proportion (kgf)
$L$ : buffer distance (cm)
$\Delta Y$ : deflection at load P (cm)
$B$ : width of the test sample (cm)
$T$ : Test sample thickness (cm)

Modulus of Rupture. MOR testing was carried out together with MOE testing and uses the same test sample. In this test, the loading on the MOE test was continued until the sample test was broken or damaged. MOR can be calculated using the following equation: $MOR (\text{kgf/cm}^2) = \frac{\Delta PL^2}{2bYbt^2}$

Information:

$MOR$ : Modulus of Rupture (kgf / cm$^2$)
$P$ : maximum load (kgf)
$L$ : buffer distance (cm)
$b$ : width of test sample (cm)
$T$ : Test sample thickness (cm)

Internal Bond. The test of Internal Bond used a 5 cm x 5 cm x 0.9 cm sample test on the JIS A 5908 standard (2003). The test sample was glued to two aluminum beams with epoxy adhesive and allowed to dry for 24 hours. The two beams then pulled perpendicular to the surface at a speed of 2 mm/min to maximum load. Stickiness (IB) can be calculated using the following equation: $IB (\text{kgf/cm}^2) = \frac{P}{bL}$

Information:

$IB$ : Internal Bond (kgf / cm$^2$)
$P$ : maximum load (kgf)
$L$ : length of the test sample (cm)
$b$ : width of the test sample (cm)
2.3.9. Data Analysis
This research used simple random design data analysis with 1 factor. The adhesive contents were 6%, 7%, and 8% and repeated 3 times. Data analysis was used with the help of the SPPS 17.0 computer program. The general design model used is as follows: \( Y_{ij} = \mu + (AB)_{ij} + \epsilon_{ij} \)

Information:
- \( Y_{ij} \): the response value at the i-level of the type of wood used and at the j-level the size of the board made
- \( \mu \): average value of observation.
- \( (AB)_{ij} \): the effect of the interaction of the preliminary treatment factor at the level i and the factor of the variation of the adhesive level at the level j
- \( \epsilon_{ij} \): error (error) trial.

3. Result and Discussion

3.1 Physical Properties of OSB Board

3.1.1 Density
Density is the mass or weight of a volume unit where the higher the density on board the higher the strength [4]. The result of OSB density values ranged from 0.67-0.71 g/cm\(^3\) (Figure 2). The lowest density value was found on OSB boards with 6% adhesive content and the highest is on 8% adhesive level.

![Figure 2. The result of OSB density values.](image)

3.1.2 Water Content
Water content obtained from the test results ranged from 6.9-7.6% (Figure 3). The difference in adhesive content affects the water content of a board. Boards with more adhesive content will facilitate better bonding between materials and bamboo, thereby reducing the board's ability to absorb water. The amount of water on the board depends on the level of drying during the manufacture and the surrounding environment when making the board [4].
The results of the diversity analysis show that the adhesive content factor has no significant effect on OSB water content. Whereas based on other studies, it shows that the adhesive content significantly affects the moisture content of the OSB produced. This difference can be caused by several factors, one of the factors is the process of making OSB in this study which is less than perfect and following the standards.

3.1.3. Water Absorption
The test results that have been carried out for 2 hours and 24 hours show the results of water absorption, respectively 12.46–20.86% and 36.09–46.67% (Figure 4 & 5).
Figure 5. The result of water absorption (24 hours).

Based on Figure 4 & 5, water absorption value for 2 and 24 hours show that the level of adhesive has a significant effect on water absorption at a confidence interval of 95%. Duncan further test results stated that 6% and 7% adhesive levels had the same effect on OSB except for 8% adhesive content which gave a different effect.

3.1.4 Thickness Expansion

The results tests of thickness expansion that have been carried out for 2 hours and 24 hours show the results of water absorption respectively ranged from 4.53 to 8.71% and 10.94-13.60% (Figure 6 & 7). According to Massijaya et al. [5], if the resulting board has a high thickness development value, it can cause low dimensional stability and cannot be used for exterior products for a long period time because the mechanical properties will decrease significantly in a short time. According to Putra's research [6], the higher the adhesive content, the lower the thickness development. It is thought that the more adhesives used, the strata between strands will be more compact so water will be difficult to penetrate.

Figure 6. The result of thickness expansion (2 hours).
3.2 Mechanical Properties Testing

3.2.1. Modulus of Elasticity (MOE)
Modulus of elasticity (MOE) is a material capability to maintain its original form due to external loads that can change the size and shape of objects. Parallel MOE values based on testing ranged from 79877–132336 kg/cm². While the perpendicular MOE value ranged between 9950–14494 kg/cm².

Figure 7. The result of thickness expansion (24 hours).

Figure 8. The result of parallel MOE.
According to Kelly [7], several factors influence the value of the MOE are the type of raw material, the density of the material, the dimensions of the strand, the orientation of the strand in the sheet, the resin content, the moisture content, the compressing procedure and the density of the board. The greater amount of glue used will cause a high MOE value on the OSB [6]. The results of the diversity of MOE values perpendicular fiber and MOE values of parallel fiber show that the variation of adhesive content has a significant effect on the perpendicular fibers and parallel fiber. Duncan's further test results on MOE parallel to the fiber show that the adhesive content of 6% and 7% have the same effect while for the adhesive content of 8% have a different effect.

3.2.2. Modulus of Rupture
Modulus of Rupture (MOR) is the maximum load capacity that can be held by the material. The parallel MOR values based on the test ranged from 478-865 kg/cm² (Figure 10). While the perpendicular MOR value ranged from 156-246 kg/cm² (Figure 11).
According to Maloney [8] states that the MOR value is influenced by the content and type of adhesive used, adhesive strength and fiber length. Meanwhile, according to Tsoumis [9] that can affect the MOR value on the particleboard is the amount of adhesive, the size, and orientation of the particles as well as the moisture content. The results of the diversity of MOR values parallel fibers and perpendicular fibers indicate that the adhesive content has a real influence on the values of MOR. Further results of the Duncan test on fiber-parallel MOR show that the effect of 6% adhesive level was equal to 7% but different from 8%.

3.2.3. Bonding

Internal bonding (IB) is the strength of the bond between particles after being bonded using an adhesive. The results of the sticking constancy test ranged from 2.13 to 8.61 kg/cm² (Figure 12).

IB strength will increase with the addition of the amount of adhesive used in the particleboard manufacturing process [10]. One of the factors that influence the IB value of the resulting OSB is the presence of steam treatment on strands that can remove extractive substances that interfere with the...
adhesion process [6]. The results of the diversity of IB values showed that the adhesive level had a significant effect on the value of IB in the OSB produced.

With physical and mechanical testing that has been carried out on OGB, it can be said that OGB which has a lot of adhesive content tends to be stronger and suitable for use in green building materials in Indonesia. Unfortunately, green building has not been built much, beside of the reason that there has been no stipulation from the government in the form of a law, green building in the view of Indonesian people is still only considered as a building that has large green land and difficult maintenance [11]. In fact, green building has a meaning as a building that maximizes energy savings, protects the environment, reduces pollution, maintains health, utilizes space effectively, and is in harmony with nature in its life cycle [12]. Green building refers to buildings that minimize resource consumption, improve the quality and diversity of the environment so that they can simultaneously achieve the goals of the Sustainable Development Goals which are the goals of the United Nations today. The combination of the use of betung bamboo as the basic ingredient of oriented strand board in the concept of applying green building can be an innovation step in realizing an eco-friendly Indonesia.

4. Conclusion
OSB boards made from Betung Bamboo (Dendrocalamus asper) which use 8% adhesive content are better than 6% and 7% adhesive content. The more adhesive content is used to produce boards with high density values and better physical and mechanical properties compared to 6% and 7% adhesive content. Based on that, OGB with a high adhesive level can be used as a solution for improving eco-friendly building construction in Indonesia.

5. Suggestion
It is necessary to do analysis and inspection of work procedures to determine the greatest risk of procedural errors in making OSB from betung bamboo so that the resulting data can be valid and not too diverse. Research needs to be done by analyzing physical and mechanical properties with other factors in OSB such as the number of strands used, the type of material used, various pretreatments and various other variation factors.

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