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Comparison Study of Mechanical Properties of Wood with the Composite Polyester / Bangkirai Wood Powder (*Shorea Laevifolia Endert*) and Lime Wood (*Dryobalanops Aromatica Gaertn*)

Andromeda Dwi Laksono[1,a)], Basyaruddin[2)], Titin Agustina[1)], Siti Hardianti[1)], Muhammad Rizki Ash-Shidiq[1)], and Isna Yuniar Wardhani[3)]

[1](Material and Metallurgical Engineering, Institut Teknologi Kalimantan, Balikpapan, East Kalimantan, Indonesia)

[2](Civil Engineering, Institut Teknologi Kalimantan, Balikpapan, East Kalimantan, Indonesia)

[3](Faculty of Forestry, Mulawarman University, Samarinda, East Kalimantan, Indonesia)

[a)] Corresponding author: andromeda@lecturer.itk.ac.id

Abstract. The main material of wood has a variety of mechanical properties for various purposes such as the construction of houses, household needs, furniture, panels, accessories, and others. It makes the demand for wood products increase as well as waste which also increased. The increase of the product can be offset by adequate supply, meanwhile, wood in the form of wood chips and sawdust or wood particles is underutilized so that it is necessary to optimize its existence. Creating a new product as a composite is a new development for many researchers. In this research, based composites were used from wood Lime powder (*Dryobalanops Aromatica Gaertn*) and Bangkirai wood (*Shorea Laevifolia Endert*). The woods were analyzed by the 5% NaOH alkalization method. A mixture of sawdust, polyester, catalyst, was printed in the mold using the compression molding method. In this study, the mechanical properties applied to wood and wood composites are tensile strength, bending, and hardness. The Scanning Electron Microscope (SEM) was carried out to check the distribution of the matrix and filler.

INTRODUCTION

Kalimantan island has many kinds of plants one of which is a Lime wood (*Dryobalanops Aromatica Gaertn*) and Bangkirai wood (*Shorea Laevifolia Endert*) [1]. Moreover, Bangkirai woods are widely used by the community. Also, Bangkirai is a type of wood with a category of durable class I-II and strong class I-II with a specific gravity of 0.6-1.13 kg/m^3 and the diameter of the tree can reach 10 meters [2]. However, the abundant waste of Bangkirai wood shavings has not been used optimally [3]. This wood also has properties of all wood namely anisotropic properties, that is the nature of wood that has different behavior and load responses (having properties) if tested according to different directions. Anisotropic wood is divided into three, namely the transversal direction (parallel to the axis of the tree), radial (parallel to the direction of the radius), and tangential (perpendicular to the radius).

Composite is a material that is formed from a combination of two or more materials. In another way, it is a combination of matrix or binder material and reinforcement material. Thus, two or more materials combined in one composite material will produce the properties of the new material which is better than the other material [4]. The particle type composites with compression molding method has the advantage of having isotropic properties, wherein

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a material is said to be isotropic when its properties are the same in all directions or do not depend on the orientation of the axis of reference to the force direction or load applied.

In general, natural powders are hydrophilic in which the polymer is hydrophobic. This can affect the bond between the matrix and natural powders. The alkalization treatment using NaOH with a concentration of 5% can reduce the hydrophilic nature of natural powders so that they have compatibility with polymer hydrophobic materials. Alkalization treatment purpose is to dissolve substances in natural powders such as lignin, to increase the bond between the matrix and natural powders [5]. Polyester resins are used because they can bind to natural powders without causing reactions and gases [6]. Alkaline immersion can increase the tensile strength of powder composites, because composites that are reinforced with fibers without alkalization, then the bond between the fiber and resin becomes imperfect because it's blocked by a layer that resembles a wax (lignin) on the surface of the fiber [7]. It also proved that fiber-based skin treated with NaOH immersion has a greater tensile strength value than without alkaline treatment [8]. Delignification is an initial stage or pretreatment process to break the lignin bonding of cellulose in Lime wood powder and Bangkirai wood powder so that later it will contribute to improving the composite interface.

RESEARCH METHODS

Preparation of Samples

The materials used in this study are Bangkirai and Lime wood powder, polyester resins (Yukalac 157 BQTN-EX), catalysts, NaOH crystals, and distilled water. Preparation of specimens for testing mechanical properties (Tensile, Bending, and Hardness Test) on the sample are made according to ASTM D143-14 wood testing standards.

The following research methods used 30 mesh composite particles and the alkalization process with 5% NaOH soaked for 2 hours (Fig. 1). The alkalization process serves to delignification that is a pretreatment process to break the bonds of lignin in cellulose in Lime and Bangkirai wood powders so that it will contribute to improving the interface properties of the composite.

FIGURE 1. Delignification process on wood powder when soaking with 5% NaOH for 2 hours.

Composite Manufacturing

There were a few processes of making composite particles from Bangkirai and Lime wood powder. First, setting up the mixing container, stirrer, resin, catalyst, Lime wood, and Bangkirai wood powder to be made into a composite with the volume fraction of 40% powder and 60% polyester. Second, the pouring of mixed ingredients (resin, catalyst, and sawdust) into the mold shown in Fig. 2 using a Siempelkamp press machine.

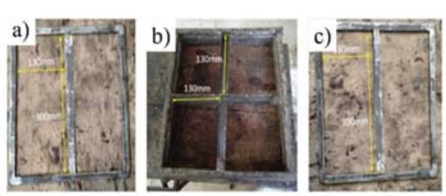

FIGURE 2. Mold specimen (a) Tensile Test thickness of 25 mm, (b) Hardness Test thickness of 50 mm, (c) Bending Test thickness of 40 mm.

Third, a compression molding process was carried out on a composite dough that had been placed on a mold using a pressure of 400 kN/m^2 and 100° C curing temperature for 15 minutes and then cool at room temperature. Then, release the sample from the composite mold. Continue to be kept in a constant room for about 5 days. Finally, the composite board was cut according to composite testing specimens for ASTM D3039 Tensile test, D790 bending test, and minimum hardness of the identification point to the other identification is 25 mm.

RESULT AND DISCUSSION

Test Result of Raw Materials

The results of the specific gravity test showed the results before and after the powder was carried out an alkalization process using 5% NaOH for 2 hours.

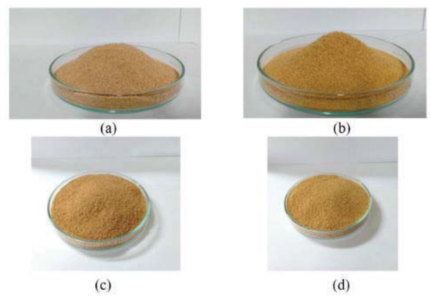

FIGURE 3. Bangkirai wood powder (a) before, (c) after the alkalization process. Lime wood powder (b) before, (d) after the alkalization process.

Visually it can be observed for the Bangkirai powder from Fig. 3(c) shows the results after the alkalization process colors tend to be a little too dark. As seen in Lime wood from Fig.3 (d) shows the color tends to look dark compared to Fig. 3(a) and Fig. 3(b). Li et al state that the treatment of chemical solutions (alkali treatment) on the powder aims to eliminate the layer of lignin on the surface of the powder. That layer can cause low bonding between the reinforcing powder and the matrix [9]. From the results, theoretically, the color changes in Lime and Bangkirai wood powder affected by the presence of chemical reactions that occur during the process of alkalization using NaOH.

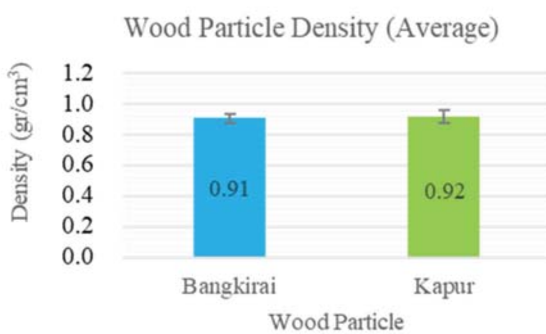

FIGURE 4. Graph of specific gravity of Bangkirai and Lime powder after an alkalization process.

In Fig. 4 shows the results of the Bangkirai and Lime wood powder testing graph after the alkalization process which is 0.91 gr/cm^2 and 0.92 gr/cm^2, respectively. Lime wood powder has a much higher specific gravity compared to Bangkirai after an alkalization process.

In Fig. 5, it can be seen visually for the results of tensile testing on Bangkirai and Lime wood. After tensile testing for Bangkirai wood (Fig. 5 (b)), the fibers look like still want to retain the fibers on the deformed surface thus the Bangkirai wood fiber visibly tends to be rough. It has a common characteristic that is the color of wood yellow-brown, fine wood texture until somewhat rough [1]. While Lime wood (Fig. 5 (d)) is deformed on the fibers but the shape still looks neat and tends to be finer than Bangkirai. In addition, Lime's fractured smells like camphor. The tensile strengths that obtained the perpendicular on the fiber of Bangkirai and Lime wood is 2.98 MPa and 2.69 MPa, respectively (Fig. 5(e)). The tensile strength of Bangkirai wood can be seen in the fractured surface (Fig. 5 (b)) where the pattern of surface results were rough and the fiber breaks.

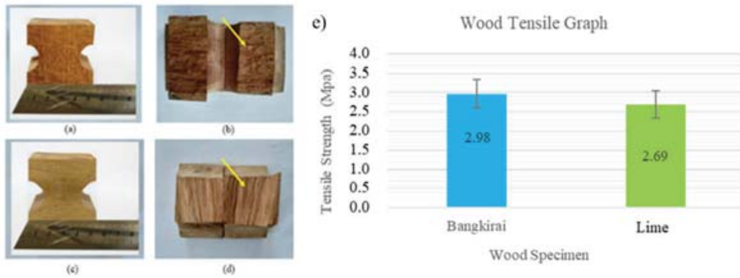

FIGURE 5. (a) Bangkirai wood before the tensile test, (b) Bangkirai wood after the tensile test, (c) Lime wood before the tensile test, (d) Lime wood after the tensile test, (e) Graph of Bangkirai and Lime wood tensile strength values.

The bending strength value of Bangkirai wood can be seen in Fig. 6(a) of 102.13 MPa and lime wood of 54.17 MPa. The standard deviation values for the bending strength of Bangkirai and Lime wood are 3.90 and 7.86, respectively. The value of the strength of Bangkirai wood and Lime wood has a difference of 47.96 MPa. In Fig. 6(b), the modulus of elasticity for Bangkirai wood is 967.65 MPa and Lime wood 681.41 MPa. The modulus of elasticity between Bangkirai and Lime has a difference of 286.24 MPa. Bangkirai wood has greater bending strength and elastic modulus than Lime wood.

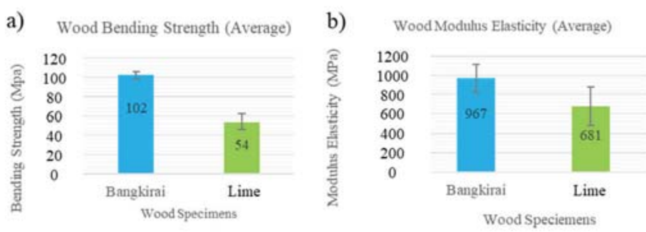

FIGURE 6. (a) Graph of bending strength of Bangkirai wood and Lime wood, (b) graph of modulus of elasticity of Bangkirai wood and Lime wood.

The hardness value of Bangkirai wood in three directions can be seen in Fig. 7(a) of radial 13.74 Kgf/mm^2, tangential 13.21 Kgf /mm^2, and transversal 13.6 7 Kgf /mm^2. The hardness value of Lime wood can be seen in Fig. 6(b) of radial 5.67 Kgf/mm^2, tangential 6.12 Kgf /mm^2, and transverse 7.45 Kgf/mm^2. The hardness of the radial direction on Bangkirai wood has the highest value compared to the direction of tangential and transverse fibers. The hardness of transverse direction in Lime wood has the highest value compared to radial and tangential fiber direction. Hardness value comparison of Bangkirai and Lime wood in the three directions shows Bangkirai wood has a greater hardness value compared to Lime wood.

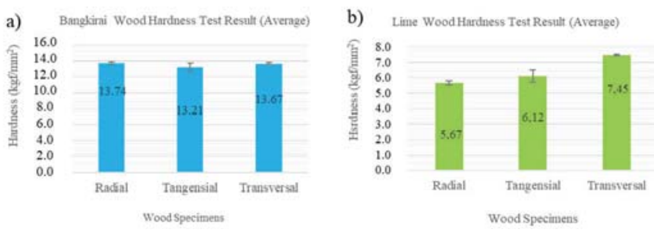

FIGURE 7. (a) Hardness test Graph of Bangkirai wood, (b) hardness test graph of Lime wood.

Composite Mechanical Test and SEM Result

In Fig. 8(a), the graph obtained from the average tensile strength of Bangkirai wood powder composite is 20.98 MPa while Lime wood composite is 27.52 MPa. The tensile strength of both wood composites compared to Fig. 5 (e) has increased significantly. It means making composite with compression molding method with 40% powder volume fraction and 60% resin can improve the mechanical properties of the tensile strength both Bangkirai and Lime wood. Another mechanical test results (Fig. 8(b)), the bending strength, show Bangkirai wood composite of 407.88 MPa, with a standard deviation of 29.41. This bending strength increases when made into a composite. As well as for Lime wood composites bending strength also increased to 412.68, with a standard deviation of 30.68. Fig. 8(c) shows the increase of the modulus elasticity of Bangkirai and Lime wood composite compared with Fig. 6(b). A significant increase from raw material wood was seen in Lime wood composites where the increase in bending strength reached 358.51 MPa and the modulus of elasticity increased to 5,348.46 MPa greater than that of Bangkirai wood powder composites.

In Fig. 8(d), the hardness value of Bangkirai wood composite is 22.81 kgf/mm^2 and the hardness value of Lime wood composite is 18.33 kgf/mm^2. The two wood composites experienced an increase after the composite was made by making wood powder combined with polyester matrix. The combination of two or more different materials will develop and improve the mechanical properties of the constituent materials including strength, stiffness, corrosion resistance, thermal conductivity, and fatigue resistance [10].

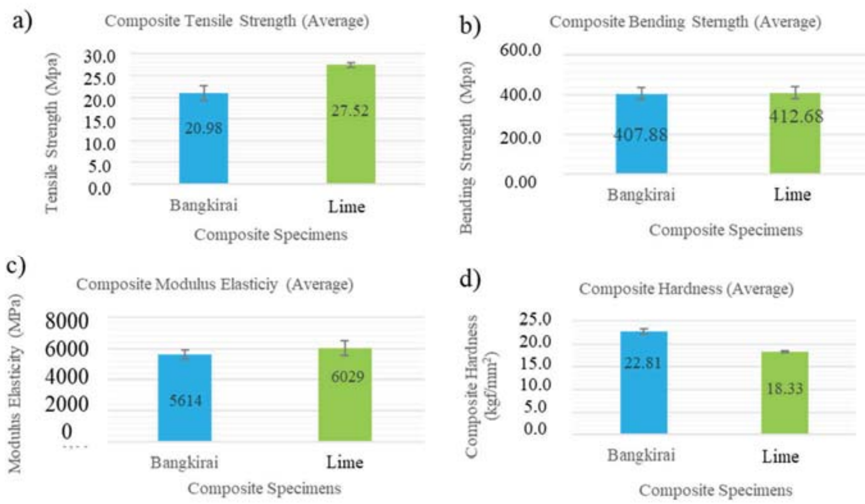

FIGURE 8. (a) Graph of tensile strength of wood composites, (b) graph of bending strength of wood composites, (c) graph of modulus of elasticity of wood composites, (d) . Graph of Composite hardness test result.

SEM testing was performed to determine the fracture of the tensile test results. SEM testing was conducted at Labq.id Private Laboratory, Puspitek Business Zone, Bogor City. SEM test of 500x magnification was performed using SEM FEI QUANTA 650 FEG with Back-scattered Electron Composition (BEC) signal type with a voltage of 20 kV. In Fig. 9(a) it can be seen from the SEM results of the tensile fracture test portion of the Bangkirai wood powder composite that describe the distribution of Bangkirai wood powder after experiencing a fracture due to a tensile test which results in a powder (filler) and a matrix. The matrix serves to transfer the stress to the reinforcement so that the strength of the composite can be affected by the presence of voids on the composite, while one of the advantages of making composites with the compression molding method can minimize the presence of voids formed on composite materials made. Visually, the shape of the Bangkirai powder (filler) looks flat and almost evenly distributed on the composite part, surrounded by a polyester matrix around the Bangkirai powder. Uneven distribution of wood particles causes the matrix to not be able to bind the reinforcement properly, so the interface bond between the filler and the matrix becomes weak [11].

In the SEM test results in Fig. 9(b) of the Lime wood powder composite, it can be seen that the Lime wood filler has a shape like spherical granules which is spread evenly on the matrix. Distribution of filler and matrix that occurs in the Lime wood composites have good distribution on the surface fracture tensile test results, which show at the fairly even spread filler to affect the mechanical properties of the Lime wood powder composite. Composite consists of a matrix as a binder and reinforcement as a composite filler. Advantages and benefits of composite materials are that it can provide the best mechanical properties owned by its constituent components, has a lightweight corrosion-resistant, economical, and not sensitive to chemicals [10].

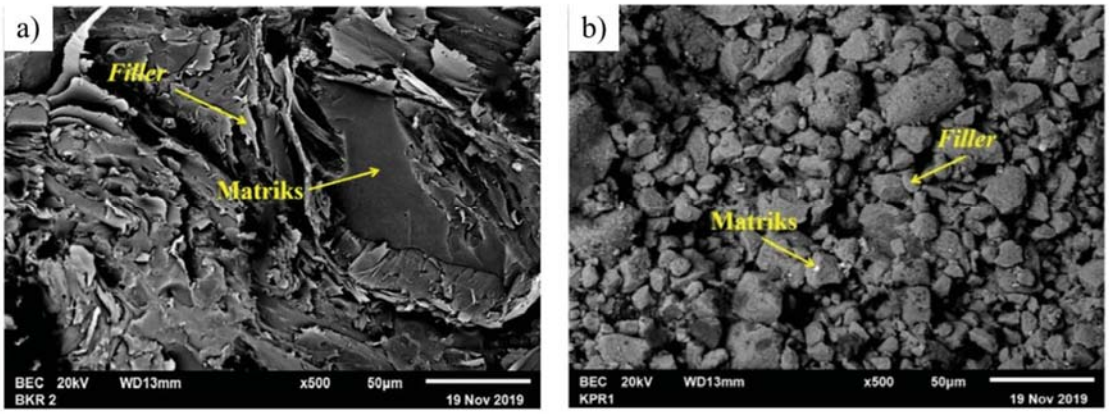

FIGURE 9. (a) SEM results on the Bangkirai wood powder composite fracture pattern, (b) SEM test result of Lime wood powder composite fracture patterns.

CONCLUSION

The conclusions obtained from the results of this study are, as follows:

1. Types of Lime wood and Bangkirai wood after being tested mechanically get an average value, bangkirai wood has a value of 2.98 MPa and 2.69 MPa lime wood. Bangkirai wood bending strength value of 102.13 MPa, modulus of elasticity of 967.65 MPa and Lime wood of 54.17 MPa, modulus of elasticity of 681.41 MPa. The hardness of bangkirai wood in the average tangential, transverse, and radial directions was 13.54 kgf /mm^2, and Lime wood 6.41 kgf /mm^2.

2. Bangkirai wood powder composite after tensile testing has a value of 20.98 MPa and Lime wood powder composite of 27.52 MPa. The bending strength of Bangkirai wood powder composite values was 407.88 MPa, modulus of elasticity was 5.1414.11 MPa, and the composition of Lime wood powder was bending strength of 412.68 MPa, modulus of elasticity was 6,029.87 MPa. The hardness of Bangkirai wood powder composite value of 22.81 kgf /mm^2 and Lime wood composite 18.33 kgf /mm^2.

3. From the results of the tensile test fracture pattern according to SEM observations show that the composite of Bangkirai wood powder and Lime wood with a polyester matrix have different particle shapes. In the Bangkirai wood powder composite filler, the resulting particles tend to be flat while the composite Lime wood powder composite fillers tend to be round grains which spread evenly on the matrix.

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