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The Flexural Strength of Artificial Laminate Composite Boards made from Banana Stems

Achmad Jusuf Zulfikar
Department of Mechanical Engineering, Faculty of Engineering, Universitas Medan Area, Indonesia
zulfikar@staff.uma.ac.id

Abstract: *Wood is a forest product that is used as raw material for building construction. The increase in demand for wood causes damage to the environment and the ecosystem. Therefore, investigation is needed to find alternative materials that can replace the old wood. On the other hand, Indonesia is a banana tree producing country which in every harvest produces abundant waste of banana stems. In this study, an investigation will be made of artificial wood from banana stems. The purpose of this investigation is to obtain the flexural strength of artificial wood produced from banana tree trunks. Banana stems will be treated first in 1M NaOH solution. Making artificial wood using special printing tools and adhesives of acetate type. Flexural testing uses the ASTM D790 test standard. The results obtained that the average flexural strength of artificial wood is 3.14 MPa. This value is still much smaller when compared to the flexural strength of commercial wood, which is 87.21. However, artificial wood has the ability to absorb the load provided is better than commercial wood.*
Keywords: *flexural strength; artificial board; banana stems; laminate composite*

I. Introduction

Wood is a forest product that has been used for a long time as a construction material or household equipment. Along with the increasing demand for this material, the impact caused by the felling of trees has resulted in forest destruction and ecosystems which is quite alarming at this time. Based on research data published in the journal Natural Climate Change in June 2014, between 2000-2012, Indonesia lost 6.02 million hectares of forest annually (Margono, Potapov, Turubanova, Stolle, & Hansen, 2017).

Banana trees are plants that flourish and are spread evenly in almost all regions of Indonesia. Based on data from the Department of Agriculture survey in 2014, the number of banana trees in Indonesia is estimated to reach 100 million trees with banana production of 6.9 million tons/year (Susanti, 2014). Based on these data the banana tree is the second largest plant in Indonesia so it has the potential to be developed as a raw material for technology products. The portion of banana plants studied in this article is banana stems (see Figure 1).

Figure 1. *Banana Stems*

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On the other hand, the condition of a comfortable work space with a low noise level has become an important requirement in an industry or office. The normal noise level that can be well received by the human ear is a maximum of 45 dBA (Lin, 2014). Noise levels above this value can interfere with human hearing, can even cause permanent damage to human hearing aids.

Utilization of natural organic materials that are environmentally friendly, strong, and sufficient durability at this time has become a major priority in determining the raw materials for the manufacturing process of technology products (Groover, 2010). This is due to the impact of environmental damage that occurs due to the use of hazardous chemicals in the process of making these technology products. The use of some natural materials such as wood has also been very limited at this time due to extensive forest destruction in Indonesian territory (Namvar et al., 2014). Therefore, an attempt to reduce the use of hazardous chemicals and switch to natural organic materials with abundant availability must be done as an effort to meet the needs of raw materials and maintain the sustainability of the ecosystem (Tao et al., 2018).

Composite material is defined as a material which is a combination of two or more materials that have different properties and phases that are not chemically insoluble with a recognized interface so that it has better properties than the constituent materials (Kalpakjian, Schmid, & Musa, 2009). The strength of this material is strongly influenced by the type of reinforcing material, while the matrix only acts as a protective amplifier and load spreader that is applied to the composite material (Barbero, 2018).

The mechanical strength of a composite material is a combination of the strength of its constituent materials (Abramovich, 2017). The strength of this material can be estimated using equation 1.

$$E_{||} = E_f . V_f + E_m(1 - V_f) \quad (1)$$

Ef is the modulus of elasticity of the reinforcement material, Em is the modulus of elasticity of the matrix, and Vf is the number of volume fractions of the fiber in the matrix in a composite material. Vf values that are too large in a composite material will cause the matrix to be difficult to cover the fiber. Conversely the strength of the composite will become brittle and brittle if the Vf value is too small. Therefore the amount of Vf in the composite material must be adjusted to the conditions of the material formed.

Banana fiber obtained from the banana tree kepok (m. Paradisiaca) is a fiber that has good mechanical properties. The mechanical properties of banana fronds have a density of 1.35 gr / cm3, cellulose content is 63-64%, hemicellulose 20%, lignin content of 5%, average tensile strength of 600 MPa, average tensile modulus of 17.85 GPa and accretion 3.36% long. The diameter of banana midrib fiber is 5.8 μm, while the fiber length is around 30.92-40.92 cm (Venkateshwaran & Elyanaperumal, 2014).

Mejia et al (Mejía, Rodríguez, & Olaya, 2015) have investigated the compressive strength of banana frond composites. The result is an increase in strength after being given the addition of the fiber. In each thickness of banana fiber 0.55 mm, 0.60 mm, 0.65 mm, and 0.70 mm, the compressive strength of each composite material was 8.08 N / mm2, 12.44 N / mm2, 9.40 N / mm2, and 12.92 N / mm2. Thus the thicker the fiber used, the value of the compressive strength will increase.

Sapuan et al (Sapuan, 2016) have investigated the flexural strength of the composite material of aren-polyester frond sandwiches reinforced with banana stems with the amount of lamina 1 layer, 2 layers and 3 layers at the top and 1 layer at the bottom respectively are 1,106 N / mm2, 1,181 N / mm2, and 1,367 N / mm2, while the bending strength of the 1 layer, 2 layer and 3 layers of palm fiber are respectively 0.730 N / mm2, 0.738 N / mm2, and 0.762 N / mm2. These results indicate that the more lamina (layer) the greater the bending strength of the sandwich composite. Failure on the palm fiber layer will have an impact on the reduced bending strength of the composite.

Some products made from banana stems from the investigation have been done and reported. Banana Abaca has been used as an automotive component and has been produced commercially (Begum & Islam, 2013). Kepok banana stems have been investigated and formed into skateboard boards (Zulfikar, Umroh, & Siahaan, 2019). Banana stem fibers have been investigated and used as raw materials for making car dashboards (Ghosh, Narasimham, & Kalyan, 2019).

This study aims to obtain the flexural strength value of artificial boards made from laminate composites reinforced with banana stems. The value obtained will be compared with the strength of commercial wood so that the characteristics of the artificial board are obtained.

II. Research Methods

The activities of the research and flexural testing are carried out at the Research and Material Development Center, Department of Mechanical Engineering, Faculty of Engineering, Universitas Medan Area. The material used in this study was Kepok banana stem (m. Parasidiaca) obtained from the Banana Farmers' Cooperative, Kecamatan Sunggal, Deli Serdang, Sumatra Utara, Indonesia. 1M NaOH solution and Acetate (PVAC) were obtained from PT. Justus Kimiaraya, Kodya Medan, Sumatra Utara, Indonesia.

Banana stems are chopped into 20 cm size and soaked in 1M NaOH solution for 24 hours. Furthermore, the banana stem is dried in the sun for 3 days until the water content is low. The dried banana stems are then pressed using a pressure plate for 24 hours.

Making an artificial board is done by using a special tool as shown in Figure 2. The process begins by placing a sheet of dried banana stems into a mold and smearing the surface with PVAC. Next place the sheet of dried banana stems back and coat the outer surface with PVAC. The coating process is carried out in the same way until it reaches a thickness of 20 mm. The next process is pressing with a pressure plate and left for 24 hours.

Figure 2. *Molding Tool of Artificial Board*

Next, the artificial board that has been formed is cut into pieces with a width of 20 mm into a flexible test specimen. As comparative data, commercial wood with a size of 200 x 20 x 20 mm is prepared to be tested flexibly as well.

III. Results and Discussion

The shape of the artificial board that has been made is shown in Figure 3. The flexural test conditions of the artificial board specimen are shown in Figure 4. The graph of the flexural test results is shown in Figure 5 and 6. As a comparison of data, plywood is also used to test commercial wood. The graph of the test results is shown in Figure 6. Comparative data from the results of the two types of wood are tabulated and shown in the table 1.

Based on the results of these tests it was found that the average static strength of artificial wood was 3.14 MPa, while commercial wood averaged 87.21 MPa. The average flexural strength of artificial wood is still smaller than that of commercial wood. On the other hand, based on the shape of the broken during the testing process, it is seen that the artificial wood does not experience breakage up to the tensile limit of the test equipment, whereas commercial wood shows a clear form of breakage. Artificial wood has the ability to reduce the load is quite good compared to commercial wood. This is probably due to the existence of small cavities in artificial wood that can absorb the load given. The cavity of artificial wood is also more flexible than the cavity in commercial wood.

Figure 3. The Artificial Board

Figure 4. Flexural Test Conditions on Artificial Wood

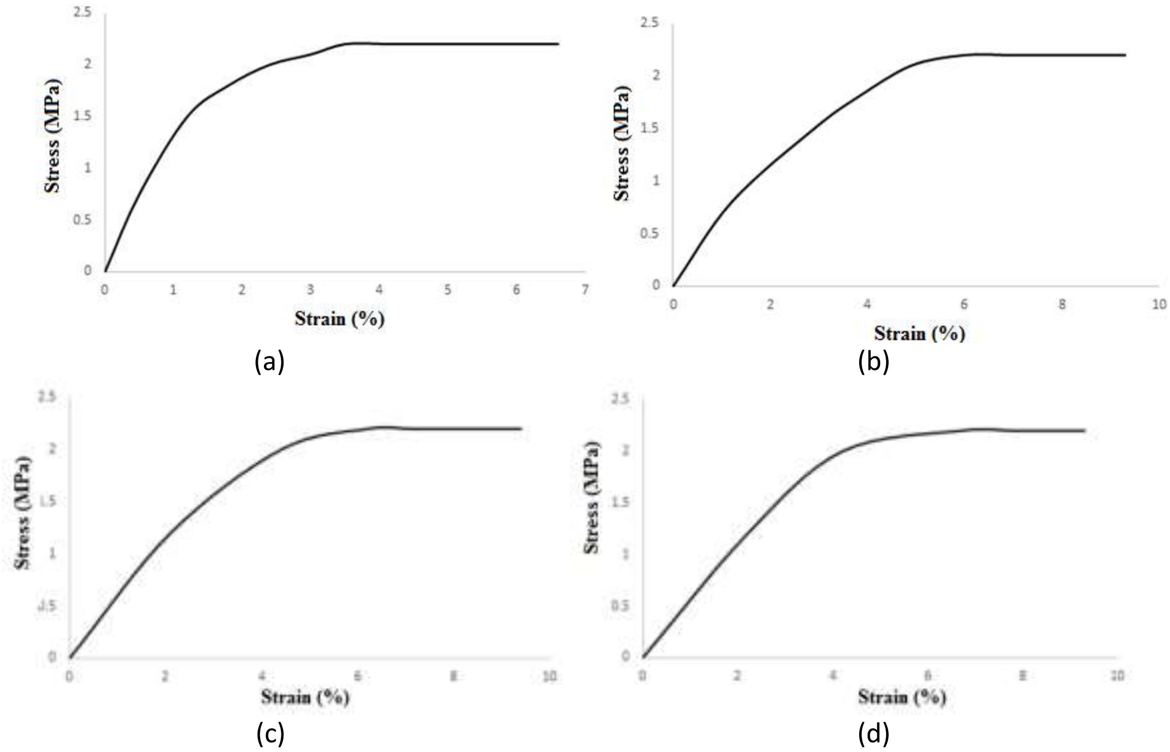

Figure 5. Graphs of Flexural Test Results on Artificial Boards: (A) Specimen 1, (B) Specimen 2, (C) Specimen 3, and (D) Specimen 4

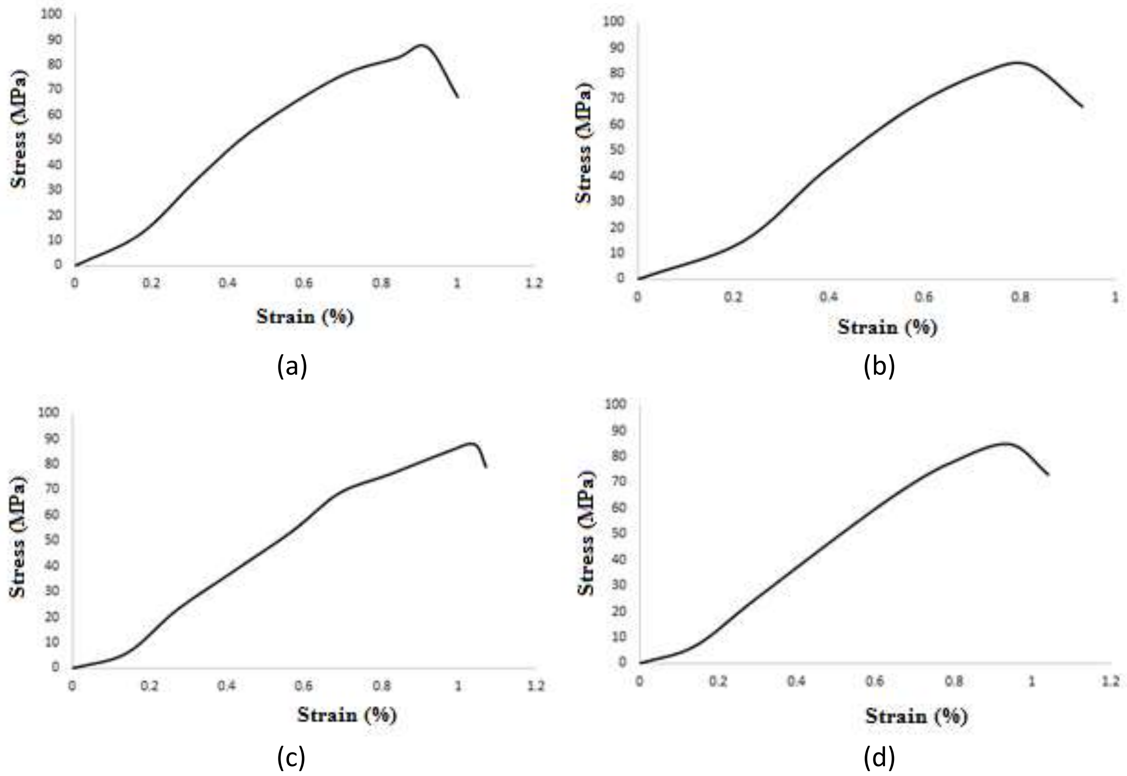

Figure 6. Graphs of Flexural Test Results on Commercial Boards: (A) Specimen 1, (B) Specimen 2, (C) Specimen 3, and (D) Specimen 4

Table 1. Flexural Strength of Artificial Wood and Commercial Wood

No.	Flexure Stress (MPa)	
	Art. Wood	Comm. Wood
1	3.69	89.43
2	2.96	88.69
3	2.96	83.52
4	2.95	87.21
Avr.	3.14	87.21

The artificial wood produced has advantages in terms of good load reduction so that it has the potential to be further developed into advanced materials. One opportunity that can be developed is further investigation in the field of hybrid composite materials. The application of fibers of different materials might produce better artificial wood products. Providing other fibers of other types of composite reinforcing fibers might improve the mechanical behavior of the material produced. Conversely, the form of wood which is still very flexible provides opportunities for further investigation to produce better material properties.

IV. Conclusion

Based on experimental results that have been done, it is obtained that the flexural strength of artificial wood is still smaller than the flexural strength of commercial wood. However, artificial wood has the ability to absorb loads better than commercial wood. This is evidenced from the results of specimen fractures during flexural testing. Not all loads are passed on to the wooden body. Thus, this wood has the potential to be applied as a material to reduce the load on machinery. One potential that might be developed is making this wood as raw material for engine components as load dampers, such as: external walls, engine bearings, and sound absorber. However, for sound absorption must be further investigated.

Artificial wood from this banana trunk also has the potential to be useful for other purposes, such as building materials, partition walls, etc. This is due to the availability of abundant raw materials in the territory of Indonesia. Further investigation is still needed to produce better artificial wood products.

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