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Relationship of Physical Properties and Wettability of Jabon Wood (*Anthocephalus chinensis* (Lamk.) A. Rich. Ex. Walp. Syn.) Towards Resistance of Adhesive

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ABSTRACT

The objective of the study was to determine the relationship between physical properties (specific gravity, moisture content, and shrinkage) and bonding strength of Jabon wood; and between wettability and bonding strength. The results showed that the variable of bonding strength and physical properties had a close relationship, it was shown by R^2 = 87.5% and r = 0.93, especially on tangential shrinkage. In addition to physical properties, the wetting property of Jabon sawdust can be used to estimate bonding strength.

Keywords: Jabon Wood, Physical Properties, Specific Gravity, Moisture Content, Radial and Tangential Shrinkage, Adhesive Firmness.

INTRODUCTION

Wood is the main product of forests which support human life for quite a long time. It helps humans to survive and develop their civilization. For humans, wood is used to meet their needs, starting from the use for firewood, building materials, household furniture, particle board, and plywood to paper pulp. Even now, wood is used for petroleum plants to answer the world's oil crisis, Soenardi (1984) suggests that the largest and oldest human debt was debt on wood.

Forest conditions may not support the development of the timber industry at this time and even in the future, an appropriate processing technique for wood is required. According to Syafii (1999) to deal with the biggest problem, it is necessary to make efforts to increase the efficiency in using raw materials by applying gluing technology. This technology was chosen because it can increase the yield in the wood processing process by utilizing wastes from the wood processing process (sawdust, wood chips) into a new product (composite board) that is more useful and has a selling value.

Jabon wood as one of the lesser-known types of wood is currently starting to be in great demand as a substitute raw material for the wood processing industry. Although as a lesser-known species, these species already have a position in the trade and have begun to be empowered. However, the utilization of Jabon wood is still not optimal due to a lack of knowledge about the basic properties of the wood.

This study aims to determine the relationship between physical properties, especially specific gravity, moisture content, and shrinkage with the bonding strength of Jabon wood and also to determine the relationship between wetting properties (wettability) and the bonding strength of Jabon wood. The results of the study are expected to be able to complement and provide information about Jabon wood to related parties, especially HPH PT. Sumpol is hoped the research result may take into account utilizing Jabon as a substitute raw material for the wood processing industry.

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METHODOLOGY

The research was carried out at the Laboratory of Forest Product Technology, Faculty of Forestry, Lambung Mangkurat University, Banjarbaru, while testing the bonding properties of Jabon wood were carried out at the Laboratory of the Research and Standardization Center for Industry and Trade (Baristand) Banjarbaru City, South Kalimantan. The time to conduct the research was three months (March-June 2004).

Sampling and Test Sampling

The raw material is Jabon trees which are felled above the buttresses to the last part of the steam without branches. Then a 150 cm long log is made from the base of each Jabon stem. The logs are then processed into sawn blocks with a size of 150x15x15 cm (coded).

Then, the sawn block is used for making test samples chosen randomly, one piece from every sawn block. The test samples are then air-dried for several weeks. The total number of test samples for testing the physical properties, wettability properties, and bond firmness of the three sawn beams each amounted to 12 pieces so the total test samples were 90 pieces. The way to take the test sample is shown in Figure 1.

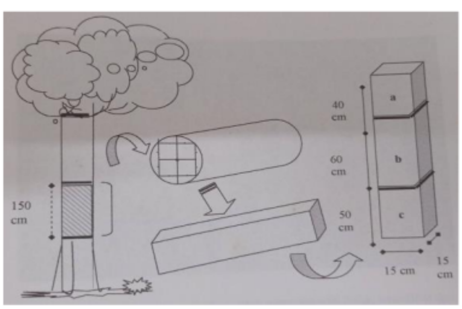

Figure 1. How to take test samples on stems

The shape of the test sample for physical properties, wettability, and adhesive strength is shown in Figure 2

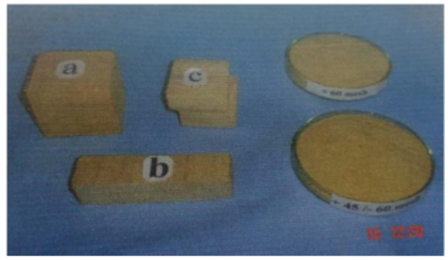

Figure 2. The shape of the test sample pieces for testing. (a). Specific gravity and moisture content (5x5x5 cm), (b). Shrinkage (2.5x2.5x10 cm), (c). Bonding Strength (5.08x3.8x5.08 cm and 0.63 cm notch), (d). +45/-60 mesh of sawdust and +60 mesh of sawdust

Testing Procedure

a. Testing of Physical Properties (according to Panshin and De Zeew, 1980; Haygreen and Bowyer, 1989)

1) Specific gravity

$$\text{Specific gravity} = \frac{\text{furnace dry weight/dry volume of air}}{\text{water density}}$$

2) Moisture Content

$$\text{Moisture Content} = \frac{\text{initial weight-furnace dry weight}}{\text{furnace dry weight}} \times 100\%$$

3) Shrinkage (cm)

$$\text{Radial shrinkage} = \frac{ro - rkt}{ro} \times 100\%$$

$$\text{Tangential shrinkage} = \frac{to - tkt}{to} \times 100\%$$

Where :

ro = the radial direction

rkt = the final dimensions of the radial direction

to = the tangential direction

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tkt = the final dimensions of tangential direction

a. Wettability Testing (cm) (according to Bodig, 1962)

$$C.W.A.H = h_1 \times \frac{d^2 \pi h_2}{4\, ws}$$

Where:

C.W.A.H = corrected water absorption high
h_1 = absorption high (cm)
h_2 = the height of sawdust in the pipe (cm)
W = powder weight (grams)
s = water type volume (cm^3/grams)
d = inside diameter of the pipe (1,234 cm)
π = 3.1415

b. Wood Bonding Strength Test (according to Scharai dan Rad, 1983)

$$\text{Adhesive firmness} = \frac{P}{A} \ (kg\ cm^{-2})$$

Where:

P = max load (kg)
A = shear area (cm^2)

c. The percentage of wood damage is calculated using the formula:

$$\text{Percentage of wood damage} = \frac{A'}{A} x100$$

Where:

A' = area of damage to the bonded area after testing (cm^2)
A' = the total area of the glued area (cm^2)

Data Analysis

The data obtained were analyzed by simple linear regression analysis to find the relationship between the independent variables (physical properties and wetting properties) and the dependent variable (adhesive firmness values). The general model of regression according to Steel & Torrie (1995) is Y = a + bx

Where:

Y = predicted value
X = independent variable
a = constant
b = regression coefficient

RESULTS AND DISCUSSION

The research result shows a different average value of Jabon's physical properties and toughness. The average value of Jabon's physical properties and toughness is shown in Table 1.

Specific Gravity

The test results showed that the range of the average specific gravity of Jabon wood was between 0.35 – 0.45, this is in line with what was stated by Tjahjono (1980) that the average value of the specific gravity of Jabon wood was in the range of 0.35 – 0.53. Therefore, wood can be classified in the wood group with strong class III and IV, and heavy class IV (light wood). So, Jabon wood is very suitable to use for light construction, plywood, molding furniture, carpentry, crafts, children's toys, pulp, crates, matches, pencils, and particle board.

Based on the value of the freshwater content, Jabon wood in this study had a fresh specific gravity of 0.31 with a range of 0.26 to 0.36. The value of this fresh specific gravity does not vary within one tree. However, for air-dry specific gravity, there are variations in the radial position. In the radial position, variation increases from near the heart to near the bark.

The results of research by Ridho and Marsoem (2015) also yielded a fresh specific gravity value of 0.31 with a range of 0.26 to 0.36. The value of this fresh specific gravity does not vary within one tree. Except for air-dry specific gravity showed variation in radial position from the heart to near the bark.

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Table 1. The average value of Jabon's physical properties and toughness

Wood Properties	Unit	Tree			Average
		A	B	C	
Specific gravity at air dry conditions	-	0.43	0.35	0.45	0.41
The moisture content at air dry condition	%	19.67	18.84	19.00	19.17
Wood shrinkage on the radial plane	%	3.35	2.31	2.36	2.67
Wood shrinkage on the tangential plane	%	4.97	2.68	3.62	3.76
Stick Firmness	kg cm^{-3}	46.25	41.28	44.90	44.14

Moisture Content

The average value of the water content of the three Jabon trees from the measurement results ranges from 18.84% - 19.67%. The variation in the amount of wood moisture content of the three Jabon kinds of wood is suggested due to differences in the anatomical structure and content of the wood constituent compounds. Soenardi (1984) explained that one of the factors that determined the amount of water in wood was the size of the volume of the wood cell cavities that were not filled by cell wall substances and extractives which precipitated in several places on the wood cell walls which replaced the position of water with wood with cellulose and hemicellulose molecules.

The value of the water content in this study is still higher if compared to the results of research on Jabon wood conducted by Rahmayanti, *et.al*, (2016) where the water content value of the dry air of Jabon wood from the base, and middle and end parts are 14.847; 13.965 and 12.374 percents, respectively.

The value of freshwater content depends on the month and season when the tree is felled. In different months the water content will also differ depending on the season, or more clearly in the rainy season the water content will be higher than in the dry season (Manuhuwa, 2007). During logging, there is a transition from the rainy season to the dry season. The value of freshwater content obtained from the results of this study is following Kasmudjo (2010) who stated that in trees that have just been cut, the condition of the moisture content is maximum. The maximum moisture content is generally above 40%.

Wood Shrinkage

The average value of shrinkage on the radial plane of wood ranges from 2.1-3.35% while for the tangential plane, the average value of shrinkage ranges from 2.68-4.97%. The difference in the shrinkage values of the three Jabon kinds of wood in each wood orientation plane (both radial and tangential planes) is caused by differences in bound water content in the wood cell walls. According to Haygreen and Bowyer (1989), the amount of shrinkage that occurs is generally proportional to the amount of bound water that comes out of the cell wall.

The average results of this study are not much different from the results of research by Mahesa, *et al*., (2022). The radial, tangential, and longitudinal shrinkage values of Mahesa, *et al*., (2022) from fresh to dry air conditions were 0.74%, 1.97%, and 0.36%, respectively; while from fresh to dry oven conditions are 2.42%, 5.62%, 0.72%. The T/R ratios of fresh to air-dry and furnace-dry were 2.72 and 2.45, respectively.

The results also show that the shrinkage value of the tangential direction of Jabon wood is greater than the value of the radial shrinkage. This is following what was stated by Schrai and Rad (1983) that in general the largest dimensional

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changes occurred in the tangential direction, where the shrinkage value from the pith outward (radial plane) was smaller than in the tangential plane.

Bonding Strength

The bonding strength value is a parameter of the load capacity that can be carried by an adhesive bond. The adhesive strength value of Jabon wood from this study was higher than the adhesive value of Jabon wood from Sigit's (2002) study which was only 31.01 kg/cm^3.

The reason for the low bond strength of Jabon wood compared to the whole wood bond strength in this study may be due to several factors, namely the type of adhesive and the pressing process. According to Dewi (2008) in Nugraha (2020) adhesive is a substance or material that can bind two objects through a surface bond. Adhesives are usually used in the wood, plastic, paper, and leather industries. In addition, the use of adhesives can be found in building materials, textile packaging and shipping.

Wetting Properties of Wood

Wettability or wetting properties are defined as parameters that describe the ease with which a wood surface can be glued. The average wetting value for Jabon sawdust is presented in Table 2.

Table 2. Average CWAH values of +45/-60 powder mesh and +60 powder mesh.

Wetting Properties	Unit	Tree A	Tree B	Tree C	Average
C.W.A.H. value (+45/-60 powder mesh)	Cm	126.27	123.3	125.4	124.99
C.W.A.H. value (+60 powder mesh)	Cm	104.66	103.34	104.00	104.00

The test results for the wetting properties of +45/-60 mesh powder and +60 mesh powder showed the same trend, and the CWAH values of the three Jabon kinds of wood for each powder size showed different numbers. The variation in the CWAH value is suggested to be caused by differences in the extractive content in the wood which clogs the wood cell walls thereby blocking the absorption of water into the wood cells. Based on the results of research conducted by Violet (1996) it can be concluded that the wetting properties of Kintabeli wood are strongly influenced by the extractive compounds present in the wood. Then Pari (1994) reported that the removal of extractive substances in sawdust (by hot and cold immersion treatment) can increase the wetting value of sawdust.

Factors Determining Bonding Strength

In general, specific gravity has a high positive correlation with the bonding strength of wood. It can be seen from the value of the correlation coefficient (r), which is 0.89. This is in line with the explanation of Freeman (1959) in Prayitno (1996) which states that the specific gravity has a positive correlation with the stickiness where the greater the value of the specific gravity of the wood, the stickiness produced will also be higher. The relationship between specific gravity and bonding strength is shown in Table 3.

Table 3. Relationships between bonding strength (Y) and specific gravity (X_1), water content (X_2), sringkage (X_3), radial sringkage (X_4),

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+45/60 powder size (X_5), and +60 powder size (X_6).

Parameters	r values	Equation
Specific gravity	0.89	$26.2 + 43.7 X_1$
Water content	0.82	$-48.4 + 4.8 X_2$
Tangential ringkage	0.73	$35.5 + 3.2 X_3$
Radial sringkage	0.93	$36.3 + 2.1 X_4$
+45/60 powder size	0.99	$-171.1 + 1.7 X_5$
+60 powder size	0.82	$-48.4 + 4.8X_6$

The coefficient of determination (R^2) is 80.7%, concluding that the specific gravity of Jabon wood has a very large influence on the value of the sticking firmness of the wood, while the other 19.3% is the influence of external factors such as chemical properties of wood, the anatomical structure of wood, materials adhesives, and the gluing process.

The regression equation of the relationship between moisture content and bonding strength is Y = -48.4 + 4.8X and a high correlation value of r = 0.82 (Table 3)

The results of the analysis show that the water content of wood has a positive correlation with the bonding strength of the wood, where the higher the water content of the wood, the stronger the bonding strength.

Shrinkage is the process of loss of water from the wood cells. The results showed that there was a tendency to increase the bonding strength of wood with increasing shrinkage that occurred both in the radial and tangential planes of the wood (Table 3).

The resulting form of the regression equation is Y = 35.5 + 3.2X with a close relationship of r = 0.73. According to Soenardi (1984) that good wood is wood which has high stability with a low (T/R) value characteristic.

The relationship between tangential shrinkage and bonding strength can be seen in Table 3. The regression equation of the above relation is Y = 36.3 + 2.1X with a very high relationship of r = 0.93. The increase in wood shrinkage will be followed by bonding strength. The magnitude of tangential shrinkage can determine the value of the bonding strength that is shown by the value of the coefficient of determination (R^2) which is 87.5%.

The more water that comes out of the wood cell walls, the wider the place for the contact between the adhesive molecules and the wood surface to form adhesive tendrils. According to Prayitno (1996), the conditions in the substrate in which adhesive tendrils occur are conditions that contribute to increasing the bonding strength.

The relationship between wetting values for powder sizes and bonding strength can be seen in Table 3.

The form of regression equation for the above relationship is Y = -171.1 + 1.7X with a very high relationship of r = 0.99. The bonding strength of wood has a close relationship with the CWAH value for powder size +45/-60 mesh. This is in line with the results of a study conducted by Bodiq (1962) in Pari (1994) that a high wettability value results in a high bonding strength as well.

The form of the regression equation is Y = -348 + 3.8X with a very high relationship of r = 0.96. The relationship between the wetting value for the +60 mesh size powder and the bonding strength can be seen in Table 3.

The wetting value of sawdust can also be used to indicate the content of extractives in wood. Pari (1994) reported that the wetting value of sawdust will increase reducing extractive substances in the sawdust after being treated with hot and cold immersion. Pari (1994) also explained that by reducing the content of extractive substances from sawdust, the bonding strength of the particle board derived from the powder shown increasing.

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CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The conclusions can be stated as follows:

a. The results of the linear regression between the bonding strength and the physical properties variables (specific gravity, moisture content, radial and tangential shrinkage) show a strong relationship (perfectly positive), this is proved by the high value of the coefficient of determination (R^2) and the correlation coefficient (r) on regression results. The largest value of the coefficient of determination and the correlation coefficient was obtained from the regression results between the values of tangential shrinkage and bonding strength (R^2 = 87.5% and r = 0.93) while the smallest was obtained from the regression between radial shrinkage and bonding strength which the value of R^2 = 54. 6% and r = 0.73.
b. The linear regression between the bonding strength and the wetting value of the two sizes of arm powder shows a very high correlation coefficient (perfect positive relationship), but the more closely intertwined wood substance relationship is between the bonding strength and +45/-60 mesh powder with an R^2 value of 98.4% and r correlation of 0.99. Meanwhile, for +60 mesh powder, the coefficient of determination and correlation coefficient were (R^2) 93.7% and (r) 0.96.
c. In addition to physical properties, the wetting properties of Jabon sawdust can also be used to predict the bonding strength of the wood, especially the wetting properties of +45/-60 powder mesh.

Recommendations

The recommendations are as follows:

a. It is necessary to carry out further research on the chemical and anatomical properties of Jabon wood to find out a processing technique that is appropriate and accurate to the condition of the wood so that its utilization becomes better.
b. Jabon wood comes from the HPH area of PT. Sumpol has good prospects for utilization and cultivation because based on research results the wood has properties that meet the requirements for various uses.
c. For the bonding strength value of the resulting better product, Jabon wood should be pretreated in the form of steaming, cold immersion, and hot immersion with the intention that the wood substances which do not support the gluing process can be removed.
d. Other efforts can be made to increase the bonding strength of Jabon wood by selecting the type of adhesive that is suitable for the intended use of the wood, applying glue according to the conditions of the wood, and applying greater pressure and longer pressing time.

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