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Analysis of Physical and Mechanical Properties of Rice Husk-based Particle Board

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ABSTRACT

This study was conducted to determine the physical and mechanical properties of particleboard. Manufacture of particleboard utilizes raw materials of rice husk with epoxy resin. The composition variations of rice husk : Epoxy are, 82:18, 77:23, 72:28. The rice husk was soaked in 5% NaOH solution for 1.5 hours, then smoothed and filtered with a size of 20 mesh. After preparation, the rice husk and epoxy were mixed with their respective compositions. Then the hot forging process was carried out with a pressure of 25 kg/cm^2 at a temperature of 140° C for 8 minutes. The results of density test was found from 0.703 - 0.712 g/cm^3, the water absorption value from 7.12%-8.75% and the thickness expansion value from 11.5% - 19.4%. The compressive strength (MOR) values range from 56.105 -82.63 kgf/cm^3 and the flexural strength (MOE) values range from 8695 kg/cm^2 - 10470.49 kg/cm^2.

1. Introduction

Rice, the primary agricultural commodity in agrarian nations such as Indonesia, is processed into rice, bran, and husk, with 72%, 5%, and 20-22%, respectively [1]. Rice husk, an abundant by-product of rice milling, has traditionally been employed as a fuel for red brick firing, cooking, or discarded outright. Inadequate treatment of rice husk may lead to environmental pollution. The volatile organic matter contained in rice husk, including lignin, cellulose, and sugar, accounts for 78-80% of its composition. The combustion process of rice husk generates 20% ash [2]. To reduce environmental impact, alternative applications of rice husk are required. One possibility is to employ rice husk as the primary material for creating particleboard. This would enable the substitution of wood, which currently dominates the manufacture of particleboard, with rice husk. The resulting particleboard could serve as a substitute for wood in markets where demand for wood remains high. The

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replacement of wood with particleboard is anticipated to reduce the heavy use of wood for both structural and non-structural purposes.

There are numerous studies being conducted to explore the usage of natural fiber or particle-based panels. This trend has gained popularity due to the abundant availability of natural fibers, low density, high porosity, environmental sustainability, renewability, cost-effectiveness, and good insulation properties [3-5]. Many research efforts have been devoted to exploring the potential of natural fibers as the primary material for manufacturing particleboards, including but not limited to coffee skin [6-9], coconut coir fiber [11], and palm wood [12]. Additionally, previous studies have demonstrated the feasibility of using natural fibers as acoustic panel materials, such as hemp fiber [13], sisal, sugarcane, and banana [14]. Particleboard offers several advantages over natural wood, including the ability to adjust its density according to specific needs, isotropic properties, and controllable quality. However, one major disadvantage of particleboard is its low dimensional stability, with thickness swelling ranging from 10% to 25% under wet conditions, surpassing that of natural wood, and linear expansion up to 0.35% [15]. This significant thickness swelling can greatly impact the utilization of particleboard, particularly in the construction industry and sound absorption panels [16]. In light of this, the present study aimed to investigate the physical and mechanical properties of particleboard made from rice husk and epoxy resin. The study involved various analyses, including density, water absorption, thickness development, and flexural properties.

2. Methodology

In the present study, rice husk (RH) sourced from the Lhoksukon region of North Aceh, Indonesia is used in combination with epoxy resin (E) and hardener in a 1:1 ratio, along with 5% NaOH procured from PT Justus Sakti Raya Corporation, Medan, Indonesia. The experimental setup comprised a hot press, 20 mesh sieve, blender, and 150x100x10 mm mold. The preparation of raw materials involved cleaning the rice husk and soaking it in NaOH solution for 1.5 hours. Following this, the RH is cleaned with running water and dried using an electric oven at a temperature of 103 ± 2°C for 24 hours. The RH is then ground utilizing a blender for 30 seconds and filtered with a 20 mesh sieve. The RH:E weight percent composition ratios employed are 82:18, 77:23, 72:28, and 67:33. The manufacturing process of the particleboard entailed mixing RH and E according to their respective composition ratios. The homogeneous mixture of particles and resin is then placed in a mold measuring 150 x 150 x 1 mm. The mixture is hot forged for 8 minutes at a temperature of 1400C and a pressure of 25 kg/cm^2. Following this, the sample is cooled, released from the mold, and conditioned at 25^o C for 7 days.

Physical testing of particleboard is carried out on 3 samples cut with dimensions of 50 mmx50 mmx 10mm. For testing the thickness development (TS) and water absorption (WA) of each sample, measurements are taken before and after soaking in water for 24 hours. In measuring these physical properties, the SNI 03-2105-2006 standard is applied [17].

The test of mechanical properties consists of flexural firmness or modulus of elasticity (MOE) and fracture firmness or modulus of rupture (MOR). This test uses 3 points using the MTS EXCEED E43 universal testing machine with a speed of 2 mm/min. The dimensions of the samples are 150 mmx 30 mmx 10 mm, with a support distance of 100 mm based on the ASTM D790 standard [18].

3. Results

Based on the research conducted, the results are obtained for density, water absorption, thickness development, and flexural strength properties. Particleboard density values are ranged from 0.703 - 0.712 g/cm^3. Water absorption values ranged from 7.12 - 8.75% and thickness development values ranged from 11.5 - 19.4%. Figure 1 illustrates the average density values of particleboard made from rice husk and epoxy resin. The lowest density value is at composition sample of 82:18 and has value of 0.703 g/cm^3 and the highest at 67:33 with value of 0.712 g/cm^3. It can be seen that the trend of the density graph increases along with the addition of the amount of adhesive. The addition of adhesive to rice husk particle board has been reported in previous studies and the addition of rice husk to particle board can cover the voids in wood-based particle board [19]. It can be seen that reducing the amount of rice husk particles and increasing the proportion of epoxy resin can increase the density of the board. On the other hand, increasing the amount of rice husk particles and decreasing the amount of epoxy resin makes the density value decrease. This is due to the minimal particle composition and the large number of voids or gaps in this sample, causing the particle board to have a small weight compared to the volume of the panel itself. The higher the epoxy resin composition, the higher the total weight produced at the same volume. In the composition of 82: 18 there is an increase in compactness between particles, because the empty space contained in the board will get smaller because it is covered by resin, so the density will increase and this is in accordance with the investigation of Ismail, 2020 [20].

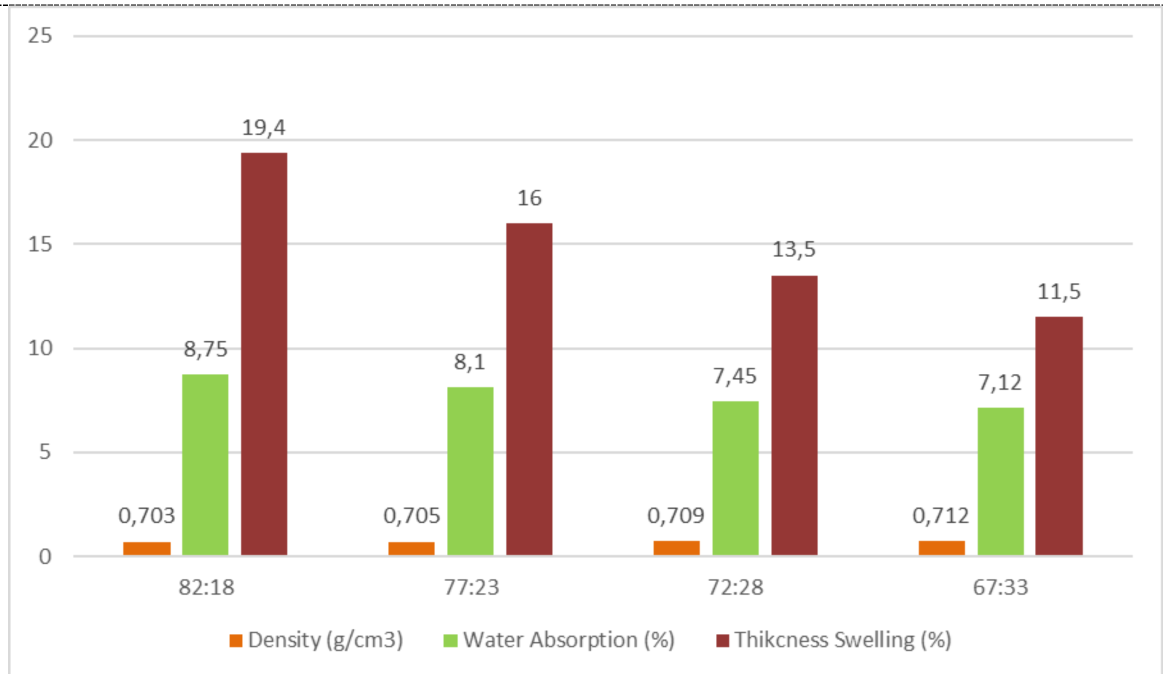

Fig. 1. Effect of particle board value composition on density, water absorption and thickness swelling

The relationship between particle board composition and water absorption value is shown in Figure 1. The water absorption value ranges from 8.10 to 7.12%. The lowest water absorption is in the 67:33 composition at 7.12%. While the highest absorption value of 8.75 % is in the 82:18 composition. The value of water absorption (WA) is a key parameter in the dimensional stability of particleboard. As mentioned in the literature, low water absorption can be due to the hygroscopic character of the rice husk, which has many hydroxyl groups in the parenchyma tissue that facilitate more hydrogen bonding. In addition, the parenchyma is sponge-like, making it easier for the rice husk to absorb water [21]. In addition to the raw materials affecting the high water absorption of the board, the use of liquid adhesives can also increase its water content.

Rice husk base material with fine particles can absorb water according to its composition. The number of particles can affect the board's ability to absorb water during the conditioning process. The addition of epoxy concentration can reduce the water absorption value. The higher the epoxy composition, the lower water absorption will be. This is because with the addition of epoxy resin, the water contained in the crevices of the particle board will be pressed and come out during hot pressing and create a strong bond between particles.

The highest thickness swelling value is found in the 82:18 composition of 19.4% and the lowest in the 67:33 composition of 11.5%. The lowest thickness development value is in the 67:33 composition with a value of 11.5% and the highest 19.4% is in the 82:18 composition. The particles used in this research are fine particles so they require more particles. The large number of particles used can affect the thickness development value of the board. The more particle composition, the greater the thickness swelling value. This can be seen in each composition of increasing number of particles, otherwise the decrease in the number of particles and the increase in the amount of epoxy resin can reduce the value of thickness swelling. Milawarni, 2018, reported that increasing the level of polystyrene adhesive on coffee skin particleboard can reduce the value of thick development [6].

Bending or fracture testing or Modulus of Rupture (MOR) is a test that measures the toughness of materials against gradual loads, where loading is carried out slowly. In Figure 2 there is a value of broken toughness (MOR) which ranges from 56.105 -82.63 kgf/cm^3. The highest MOR value is in the 72:28 composition and the lowest in the 82:18 composition. The amount of epoxy resin greatly affects the MOR value of particle board. Particle board in the composition of 72:28 and 67:33 meets the MOR testing standards according to JIS A 5809-2003 requires the MOR value of particle board which is 82 kg/cm2 to 184 kg/cm^2. Maloney (1993) states that the MOR value is influenced by the content and type of adhesive used, the binding power of the adhesive, and the particle size. Due to the composition of the material using coarse rice husk, the coarse rice husk has large voids between the particles so that the strength between the particles is weak.

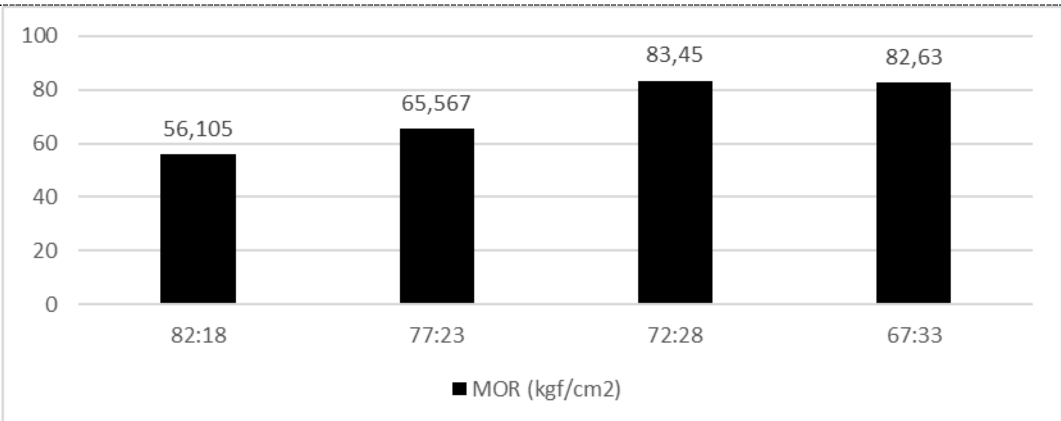

Fig. 2. Effect of particle board value composition on modulus of rupture (MOR)

Figure 2 illustrates a positive correlation between the MOR value and the increment in epoxy resin and the decrement in the composition of rice husk particles. Notably, the composition of 72:28 yields the highest MOR value. This is attributable to the commendable physical value of the particle board in this composition, which engenders an excellent bond between the particles. According to a study conducted by Grzegorz Kowaluk in 2013, biocomposites obtained from willow trees can increase the MOR value of the material by providing it with enhanced strength due to the presence of fibers [22].

The flexibility of this particle board can be seen from the Modulus of Elasticity (MOE) value. The MOE values obtained ranged from 8695 kg/ cm^2 - 10470.49 kg/ cm^2. The highest MOE value is found in particle board with a composition of 77:23 and the lowest of 8695 kg/cm^2 is found in the composition of 82:18.

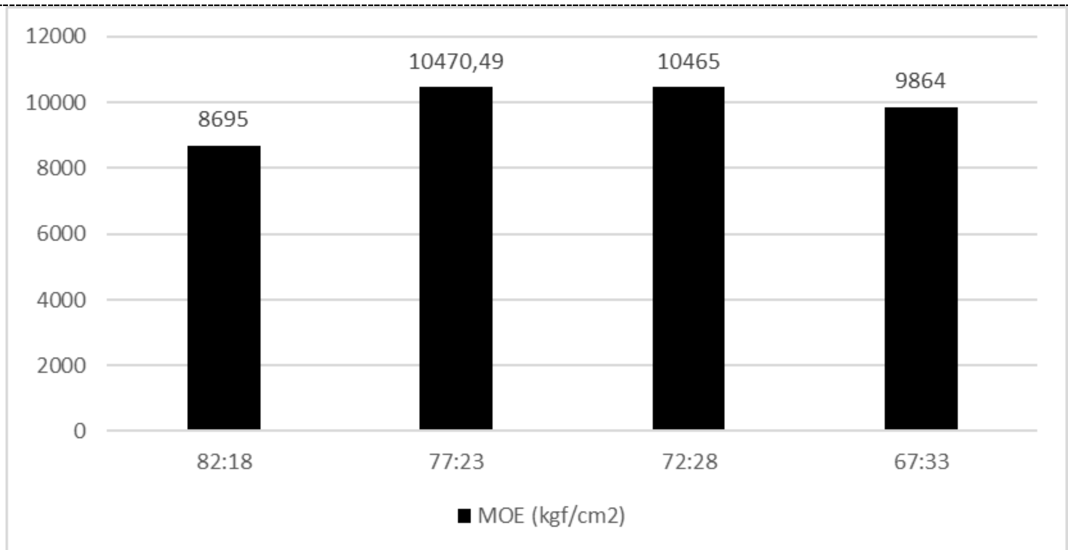

Fig. 3. Effect of particle board value composition on modulus of elasticity (MOE)

Figure 3 shows that the particle board with a composition of 77:23 exhibits the highest MOE value, whereas the lowest is found in the composition of 82:18. The MOE value can be augmented by increasing the concentration of epoxy, as a result of the stronger bond between particles caused by the adhesive. Notably, the MOE value in this investigation falls short of meeting the SNI 03-2105-2006 standard of 20,000 kg/cm^2.

4. Conclusions

The research has been conducted on the manufacture of particle board which is made from rice husks and epoxy resin. In general, the results show that variations in the composition of rice husk and epoxy resin have a significant effect on particle board characteristics. The highest density value is 0.712 g/cm^3, the lowest water absorption is 7.12% and the lowest thickness expansion is 11.5% in the composition of rice husk: epoxy, 67:33. Meanwhile, the highest fracture strength (MOR) value of 83.45 kgf/cm is in the 67:33 composition and the flexural strength (MOE) of 10470.49 kgf/cm^2 is in the 77:23 composition.

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