International Journal of Allied Research in Engineering and Technology (IJARET)
Volume.13, Number 1; January-2022;
ISSN: 2836-5631| Impact Factor: 5.52
https://zapjournals.com/Journals/index.php/ijaret
Published By: Zendo Academic Publishing

WASTE TO VALUE: TRANSFORMING TEAKWOOD SAWDUST INTO ARTIFICIAL COMPOSITE BOARDS

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Article Info

Keywords: machining, composite materials, particle/powder processing, teakwood sawdust, polyester resin

Abstract

The development industry continuously seeks innovative technological advancements in machining to enhance productivity and product quality while ensuring cost-effectiveness for competing in the global market. A significant focus lies on exploring the potential of natural-synthetic material combinations with desirable mechanical and physical properties, particularly in industries dealing with particle/powder food processing, biomass briquettes, paving blocks, and particle boards.

In the Aceh region, where wood processing industries, specifically teakwood, are prevalent, the production of windows, chairs, panels, and accessories generates substantial waste in the form of sawdust and wood particles. This waste, often left unutilized or merely burned as fuel, could be transformed into value-added products, such as artificial composite boards, through appropriate technology utilization. This study aims to explore the possibility of creating artificial composite boards from teakwood sawdust and polyester resin adhesive.

Previous studies have investigated the composition of teakwood sawdust with various materials, including high-density polyethylene (HDPE) and natural fibers like candlenut, teak, and merbau. These studies have revealed the impact of mixing ratios on the mechanical and physical properties of composites, such as strength and impact resistance. Moreover, research has been conducted on the utilization of mixed powder saws from teakwood and sugarcane fiber dregs, demonstrating their potential as environmentally friendly alternatives to styrofoam.

In this context, this research focuses on exploring the effect of particle size on the physical and mechanical properties of teakwood sawdust combined with epoxy resin. Additionally, a study on reinforced epoxy resin composite with powder saws investigates its mechanical and physical properties. Furthermore, the optimization of the mixture of teakwood powder and various resin combinations is explored to achieve

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the most suitable composite with optimal mechanical properties.By employing specific mesh size powder saws combined with SHCP 2668 WNC polyester resin, this research analyzes various physical and mechanical properties of the composites, including density, moisture content, thickness expansion, MOE, and MOR, following SNI 03-2105-2006 standards.

1. Introduction

The development industry demands the need for technology in the field of machining for could increase score productivity [1]. This is very necessary so that the community gets a product of score of the best quality, and achieves low-cost production in order to compete in the international market with quality fast, and reliable service. Many studies have been carried out in search of a combination of natural composite with synthetic material, with both mechanical and physical properties [2]. This thing especially applies to industry processing particles/powder food, briquettes biomass, paving blocks, and board particles [3,4].

In Aceh a lot there is an industry processing wood, especially wood teak. Production results include the development of windows, chairs, panels, and accessories that use wood as an ingredient main, while with development of fast industry results in the accumulation of waste in the form of powder saws and particles [5-8]. Waste powder saws from wood teak often left pile up even if only part only used _ for ingredient burn. With utilize technology appropriate use, the waste powder could process and become a board known as artificial with board composites [9,10]. Potency this made an opportunity for the Public to add product main addition, one of which utilizes waste Becomes board artificially made from powder saw with the use of polyester resin adhesive.

In 2017, Bootkul et al. [11] studied the composition of teakwood sawdust and HDPE. Study this was conducted for knowing the nature of physical and mechanical composite made in the laboratory with pressing hot. Seven level mixtures, i.e. 10, 20, 30, 40, 50, 60, and 70%, based on fraction sawdust weight added to HDPE with oil palm as a coupling agent. Measurement result obtained that strength impact decreased with increased powder saw until with 30% mixing then increase gradually. However, with increased content of flour mixed, panel water resistance is affected negatively. Wood panels of plastic used for construction house Thai Spirit as decor outside the room.

Koilal et al [9] also ever did a study about the influence of variation powder wood on natural composite material mechanics in 2019. Waste powder wood used _ is candlenut (Aleurites moluccana (L.) Wild), Teak (Tectona grandis Lf), and Merbau (Fabaceae) as composite material reinforcement with volume fractions of 5%, 10%, and 15%. Research results obtained that strength impact increase along increase powder volume fraction of wood. The strength impact highest happens to powder wood Spinach with a 15% volume fraction of 0.115 J/mm².

A study about the utilization mixture of powder saw wood teak and fiber dregs sugarcane has also been conducted by Baheramsyah et al[5]. The study was conducted by modifying the isolation ingredient coolbox to increase the nature of the mechanic. The most optimal test results are obtained with alloy 50: 50 which previously has been given the process of immersing 15% NaOH solution. A conductivity value of 0.2907 W/mK and a density of 0.4901 gram/cm^3 were obtained from testing that. Research results conclude coolbox with variation fibers has almost performed the performance same as a coolbox made from styrofoam and potential for replacing styrofoam because of a more friendly environment.

Rita et al, 2022 [13] have to do testing about the influence of size particles on natural physical and mechanical composite waste saw wood teak with the epoxy resin matrix. Density test results are best obtained at size 100 mesh particles with a value of 1.02 g/cm^3. For the thickness test, they get values ranging from 9.3 to 9.8. Whereas results testing qualified mechanic standards namely the MOR test obtained at 100 mesh that is with the value is 341.15 kgf /cm^2, while in the MOE test none of which meets the standards of SNI 03-21052006. The highest MOE value was obtained at a mesh size of 100, which was 8072.49 kgf/cm^2.

Ali et al. in 2022 [2] have also been researching about influence nature of mechanical and physical reinforced epoxy resin composite powder saws. Composite this compressed for produce environmental materials Among ingredient natural and synthetic. Collected data analyzed using analysis statistics. Research results show that because of the effect synergistic from reinforcement, composite with 80% powder saw have to nature more mechanics good than composite ratio-friendly environment other. Roughness test results surface show speed parameter significance spindle CNC router machine for ratio friendly environment SRER composite.

Mercy [12] has done a study about board-reinforced composite wood teak with a vertical drilling technique. Test conducted with various level speed spindle and speed feed and optimized use Taguchi optimization. Observed that power thrust and temperature Become tall moment drill composite wood teak. because strength mechanic wood high teak, when speed increases, style push decreases, and temperature increase. Percentage mixing powder wood teak could be upgraded with various resin combinations to get the most suitable combination for getting natural optimal mechanics.

Based on research that has been conducted previously, Research this uses powder saw wood teak with a specific mesh size combined with SHCP 2668 WNC polyester resin. with reference to SNI 03-2105-2006, Composites then analyzed nature physics and mechanics like density, moisture content, expansion thickness, MOE, and MOR.

2. Literature Review

Composite (Composite) is an adjective that can be interpreted as an arrangement or combination. Composite originated from the word " to compose " which means to compose or combine. Composite is the structure of a material consisting of from two combinations of one ingredient or more formed on a scale macro to form new materials that are more useful and usable[14] (Figure 1).

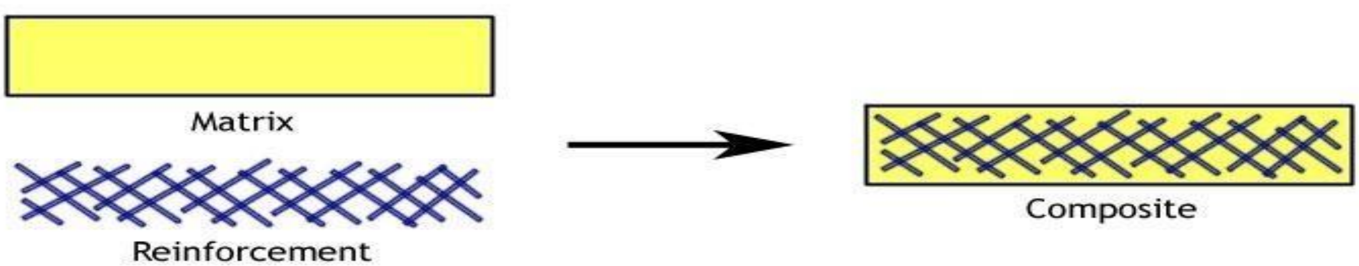

Fig 1. Illustration Composite

According to Gibson[15], composite materials could be interpreted as a combination Of two material arrangements or more, where shapes are different, and also have differences in composition the chemistry, which is not each other dissolve between one material play a role acting as reinforcement and other materials play a role as a fastener. Matrix on structure composite can originate from ingredient polymers, ceramics, and metals. In general, the matrix has the function as follows: a. Binds fibers into a unified structure.

b. Protects fiber from damage caused by environmental conditions.
c. Transferring and distributing the load to the fiber.
d. Contributes several properties such as stiffness, strength, and electrical resistance.

One part main of composite is functional reinforcement as a guarantor burden main on composites. Reinforcement can be in the form of fibers, particles, and flakes. Based on the amplifier used composite could be distinguished, Becomes three, namely particle-reinforced composites, fiber-reinforced composites, and structural composites.

According to Sudarsono et al [16], materials composite board particles consist of a number of particles held together by a matrix. A composite material particle is a combined ingredient composite reinforced consisting of particles normally called composite particles (particulate composites). A particle by definition is no fiber because not have a size long. Composite material particles in general have an amount of deficiency that is a little more weak and visible (fracture toughness) more low compared to ingredient board composite fiber long. But from sector other, the material this often said more excel, like have the endurance to worn out.

The composite material consists of two elements, that is working matrix as something fastener fiber and functional fiber as an amplifier. The matrix must have a good match with the fiber. A number of types of matrix very frequent polymers used are matrix thermosets in the form of polyester, epoxy, phenolics, and polyamides and matrices polymer which is also a polyethylene, polypropylene, nylon, polycarbonate, and polyether ether ketone[17]. Based on type filler (matrix), the composite could be distinguished becomes three types, namely Polymers Matrix Composites, Ceramic Matrix Composites, and Metal Matrix Composites.

Polyester not fed up worn as resin laminate or merged with fiber reinforcement as formulation print composite. Polyester not fed up could modify with oils and fatty acids to become resin alkyd or as a modifier nature other adhesives (e.g. polyurethane of isocyanate). In research, this used production polyester matrix from SHCP (Singapore Highpolymer Chemical Product), with code 2668 WNC is a resin which has the color red young, which has a strength of 82.4 MPa bending and a strong pull of 29.4 MPa [18]. In general used to coat tile, coating glass, coating bathtubs, boat hulls, and more.

Certain chemical treatments need to be conducted on fiber natural to increase compatibility with fiber natural as an amplifier in the composite. In this case, chemical modification is very influential and direct to the structured fiber and as a modifier, the chemical composition of the fiber can reduce the value of moisture absorption by the fiber so that it will provide a better bond between the fiber and the matrix[19]. Alkali treatment in the form of NaOH from natural fibers is one of the chemical treatments that have been carried out to increase the value of the cellulose content by removing the hemicellulose and lignin content. The following is the reaction of alkaline NaOH treatment of fiber:

Fibers – OH + NaOH ------ > Fibers – O^- Na^++ H_2O

Studies about the alkaline treatment of fiber mention that the strength sticks Among fiber with matrix could increase by 5%. Compared to other types of alkalis such as KOH and LiOH, the alkaline treatment of NaOH is the best treatment due to Na^+ has a very small particle diameter and can enter to pore the smallest fiber so which could release oil and contaminants more good [20-21].

Teak (Tectona grandis Lf) is a high-quality commercial wood belonging to the Verbenaceae family originating from India, Myanmar, and Thailand [22-23]. Teak was first planted in Indonesia, namely on the island of Java, estimated in the second century AD by Hindus. Teak wood can grow well with an optimum average temperature of 22-27˚C. In the wood processing industry, only about 60-70% of the wood commodity is processed into a product, with wood waste and sawdust reaching an amount of approximately 30 – 40 % or about 3.03 - 4.03 million m^3 for 2015[24]. Usually, this teak waste is not used at all but is disposed of or burned [25].

2.1. Material

The raw materials used in this study consisted of sawn teak waste taken from the rest of the teak wood craftsman industry in the Blang Pulo area, Lhokseumawe City, alkali NaOH solution, and using polyester resin SHCP 2668 WNC. The equipment used includes a sieve, aluminum foil, a balance, a mixing container, a table saw, a mold for the manufacture of boards, a compression machine, and physical and mechanical properties testing equipment.

2.2. Equation

Density is a measure of the compactness of a particle in a sheet. Its value is highly dependent on the density of the fiber used and the magnitude of the compression pressure applied during the sheet manufacturing process. Density according to SNI 03-2105-2006 [26] is calculated by the formula:

$$\rho = m/v \tag{1}$$

Where is ρ = density in (gr/cm^3), m = dry mass of air (gr) and v = Dry volume of air in cm^3. The moisture content of particleboard will be lower with the addition of the adhesive used because the distance between the particles will be closed so it will be difficult for water to enter between the wood particles. The level according to SNI 03-2105-2006 is calculated by the formula:

$$KA = \frac{mKU - mKO}{mKO} \times 100\% \tag{2}$$

Where is KA = Moisture content (%), mKU = Dry mass of air (gr), and mKO = Oven dry mass (gr). Thickness expansion is a physical property of particle board that indicates the ability to increase the thickness of the board which is soaked for 2 hours and 24 hours. Determination of the thickness expansion value can be calculated by the formula:

$$PT = \frac{t2 - t1}{t1} \times 100\% \tag{3}$$

Where is PT = Composite thickness expansion (%), t_2 = Thickness after soaking (gr), and t_1 = Thickness before soaking (gr). The modulus of elasticity is a value that indicates the nature of stiffness which is a measure of the ability of beams and piles to withstand changes in shape or bending that occur due to liberation at the proportion limit. The determination of the MOE value can be calculated by the formula:

$$MOE = \frac{\Delta PL^3}{4\Delta Ybd^3} \tag{4}$$

Where is MOE = Elastic Modulus (kgf/cm^2), P = Change in load (kgf), Y = Change in deflection (cm), L = Support distance (cm), b = Width of specimen (cm), and d = Thickness of specimen (cm). The modulus of rupture (MOR) is a continuation of the modulus of elasticity testing, where this test continues loading until fracture toughness is obtained. The determination of the MOE value can be calculated by the formula:

$$MOR = \frac{3PL}{2bh^2} \tag{5}$$

Where is MOR = Modulus of fracture (kgf/cm^2), P = Maximum weight (kgf), L = Span length (cm), b = Width of test sample (cm), and h = Thickness of the test sample (cm).

3. Methods

The raw material in the form of sawn teak waste is sieved using sieves with sizes of 10 and 22 mesh, so that it becomes wood powder and then mixed with polyester resin SHCP 2668 WNC with a ratio of 60: 40. Coupled with various alkaline treatments of NaOH 2,5, 5, and 7 %, repeating the activity for comparison of variations as much as 3 times the test sample. Inserted into a mold measuring 25 cm long, 25 cm wide, 15 cm high, and 1 cm thick. Put into the press machine with a temperature of 150˚C for 20 minutes, and a pressure of 50 kg/cm^2. The resulting particleboard (Figure 2) was naturally dried for ± 7 days and cut according to the requirements of the SNI 032105-2006 standard (Figure 3). Testing of physical and mechanical properties in the form of (density, moisture content, thickness expansion, flexural strength/MOE, and fracture strength/MOR). Following the standard of SNI 03-2105-2006.

Fig 2. Particleboard Results

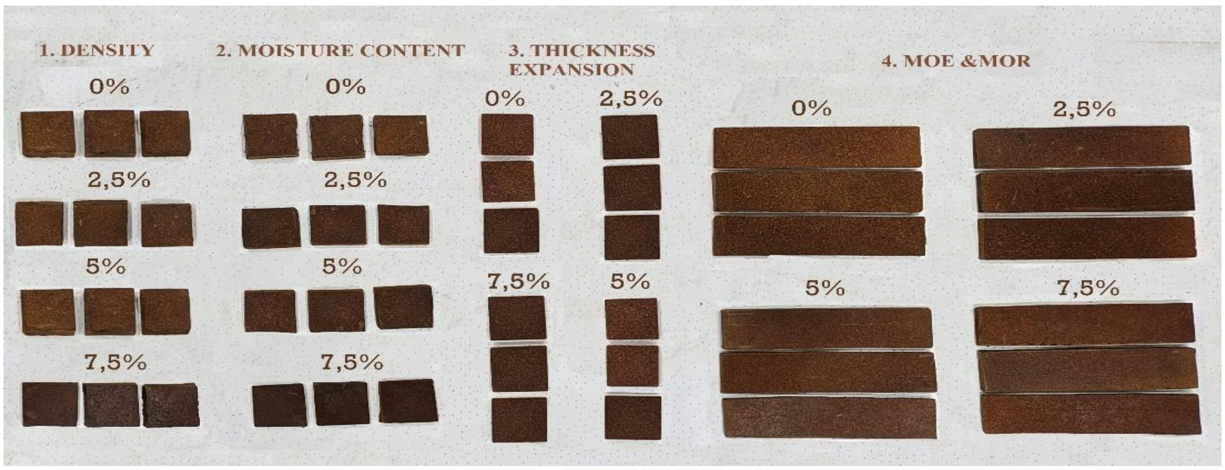

Fig 3. Specimen After Cutting

4. Results and Discussion

4.1. Density

The results of the particle board density test show values ranging from 0.65 gr/cm^3 to 0.85 gr/cm^3. The results of this test show that 5% NaOH concentration has the highest density value, compared to 0% NaOH concentration with the lowest density value. As shown in (Figure 4). That at 5 % NaOH concentration has the highest density value with a value of 0.854 gram/cm^3 while the lowest density is at 0% NaOH concentration with a value of 0.650 gram/cm^3. The density of particleboard resulting from repeated testing is close to the target density value according to the standard, although at a concentration of 0 % NaOH the density value is far from the test value with NaOH concentration treatment, this value still meets the standard. The density value of particleboard is very influential on the raw materials, including the percentage of combined sawdust and resin. The presence of NaOH treatment showed that the density value of the particle board was different from the density value without treatment. However, from the test data, the density value for each test sample meets the standards required by SNI 03-2105-2006 with a density value of 0.4 gram/cm^3 - 0.9 gram/cm^3.

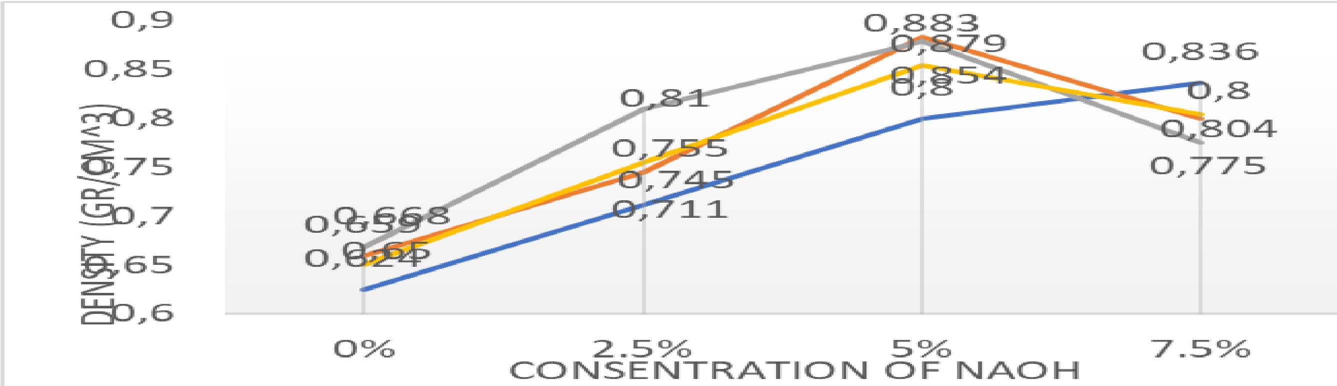

Fig 4. Graph of Density Test Results

4.2. Water Level

Based on the test results data shown in (Figure 5), the water content can be interpreted as the amount of water still contained in the particle board. The water content data values ranged from 4.5 % to 6.0 %, it was known that the highest water content was 6.018% without NaOH treatment and the lowest water content was 4.563% indicated by 2.5% NaOH treatment. The test data showed that each test sample met the standards required by SNI 03-2105-2006. Where the SNI 03-2105-2006 standard states that the water content value is at a value of 14%, this particle board is included in the category of medium-density fiberboard (MDF). This can happen because the treatment with the concentration of NaOH can increase the water-repellent properties so that the test sample that gets the treatment can reduce the moisture content of the particle board.

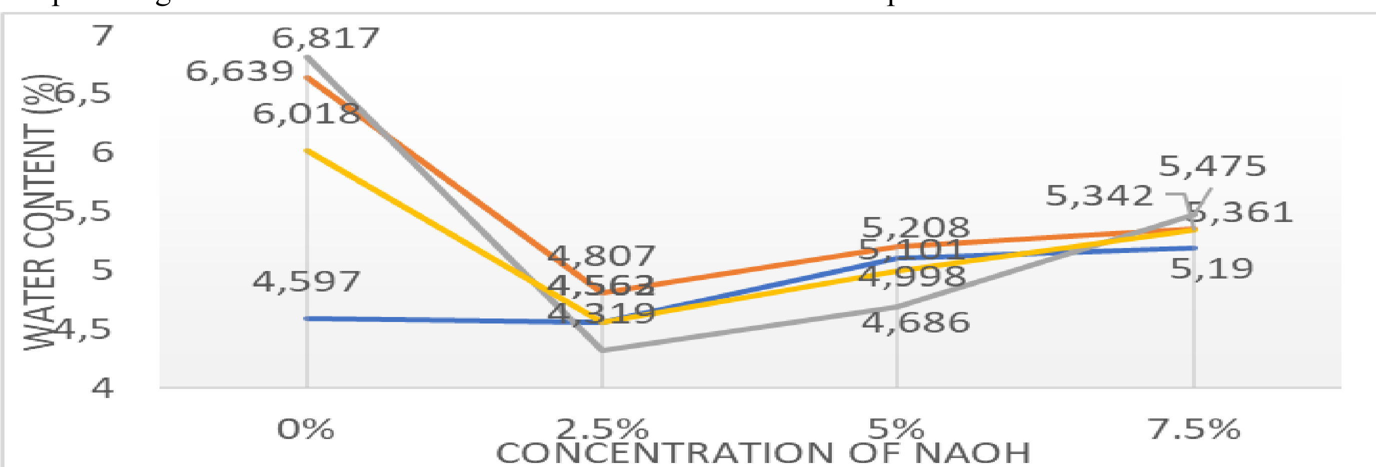

Fig 5. Graph Of The Results Of The Water Level

4.3. Thick Development

In the thickness expansion test, it can be defined that the thickness expansion is a property of the particle board which determines whether a particle board is suitable for use for interior or exterior purposes. If the thickness expansion value on a particle board is high, it can be said that the dimensional stability of the particle board cannot be used for interior or exterior use for a long period because the mechanical properties of the particle board will immediately decrease. Based on the data from the thickness expansion test on the particle board as shown in (Figure 5), the thickness expansion value ranges from 7.5 % - 11 %, where the highest thickness expansion value is 9.852 % without NaOH concentration treatment, and the lowest value is 7.573 % at 5 % NaOH treatment. In the standard SNI 03-21052006, the value of determining the maximum thickness expansion is 12%, the test data shows that each test sample meets the standards required by SNI 03-2105-2006. Can be interpreted based on the graph shown (Figure 6). That the greater the value of NaOH concentration in the particle board thickness expansion test, the lower the thickness expansion value due to the nature of the NaOH, namely water repellent/water rejection properties so that the test sample experienced a decrease in the thickness value.

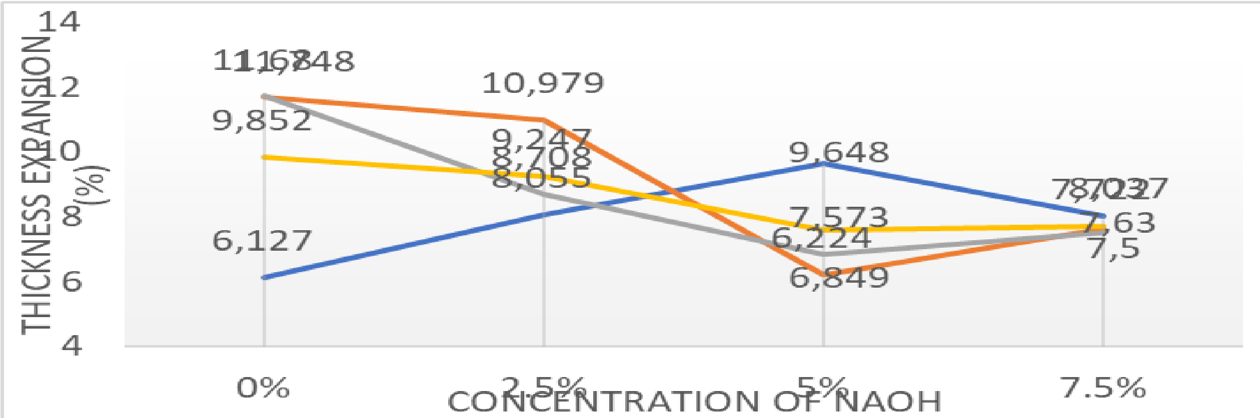

Fig 6. Graph of Thick Development Results

4.4. Modulus Of Elasticity

Based on (Figure 7) the data value of the lowest MOE test results is 2.470 kgf/cm^2 at 2.5% NaOH variation, while the highest MOE is 10.722 kgf/cm^2 at 7.5 % NaOH concentration, which means that the lower the NaOH treatment concentration in this test. the lower and smaller the value of the elastic modulus, because the NaOH treatment on the test sample has water-repellent properties so in this test some test samples do not meet the requirements according to the SNI 03-2105-2006 where the minimum value is 2.55 kgf/cm^2.

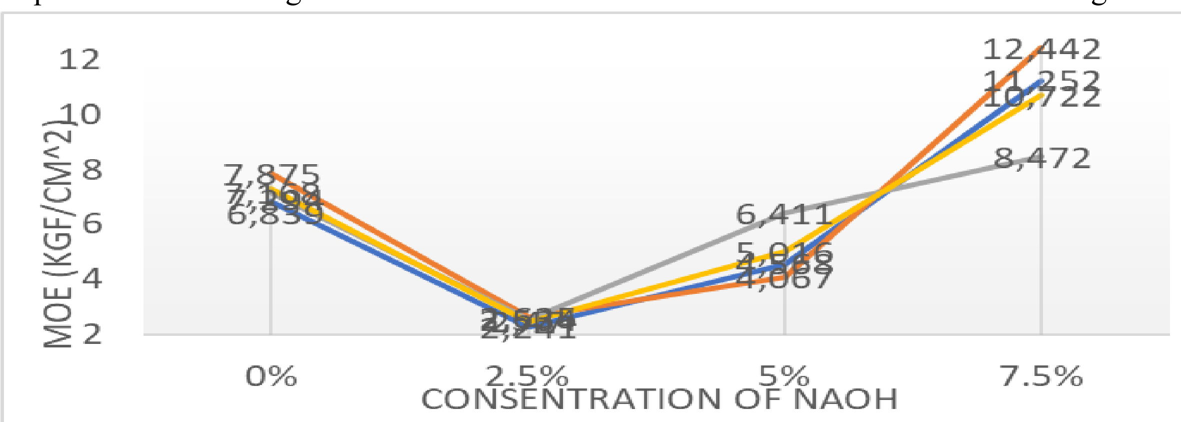

Fig 7. Graph of MOE Test Results **4.5.**

Modulus Of Rupture

The process of testing the fracture modulus is carried out by continuing the testing of the elastic modulus, with the same method and test sample, where testing on the fracture modulus of the test sample is continued until it breaks. Similarly, in the MOE test based on (Figure 8) the value of the data from the particle board test, namely the MOR test shows that the value ranges from 20 kgf/cm^2 - 48 kgf/cm^2, where the highest MOR value of 48.611 kgf/cm^2 is found at a NaOH concentration of 7.5 % and the lowest was 20.837 kgf/cm^2 at 2.5 % NaOH concentration. It can be concluded that the greater the concentration of NaOH in this MOR test, the greater the fracture value of the particleboard test sample.

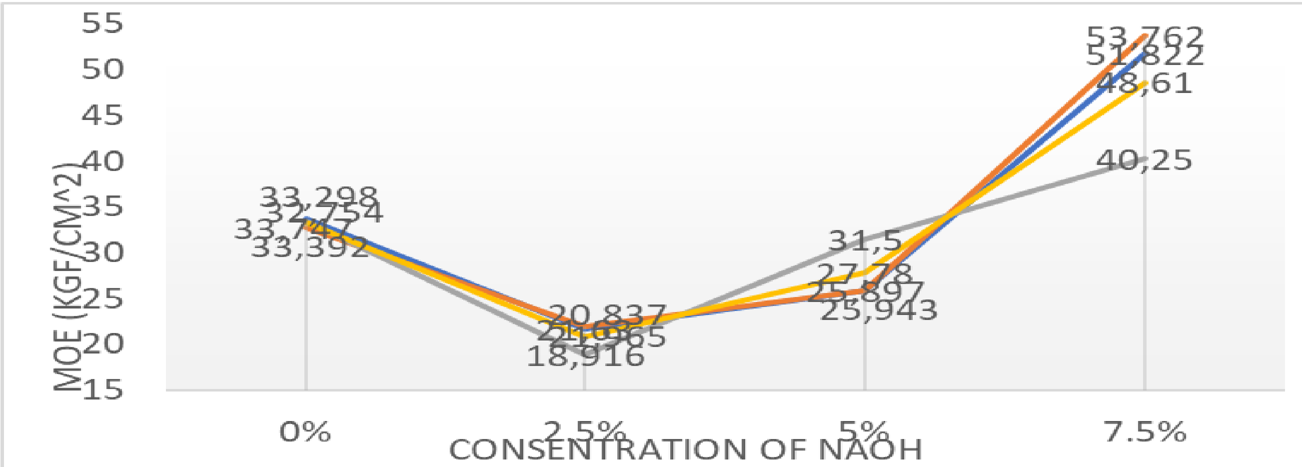

Fig 8. Graph of MOR Test Results

From all research data that has been obtained, it can be made a data comparison in the form of a table which is represented by Table 1.

Table 1. Research Result Data Based on SNI Standard 03-2105-200

Test	Standart Value	Size (cm)	Research Result	Description
Density (gr/cm^3)	0,4 – 0,9	5 × 5	0% = 0,65 gr/cm^3 2,5% = 0,75gr/cm^3 5% = 0,85 gr/cm^3 7,5% = 0,80 gr/cm^3	Fulfill Fulfill Fulfill Fulfill
Water Content (%)	14	5 × 5	0% = 6,01 % 2,5% = 4,56 % 5% = 4,99 % 7,5% = 5,43 %	Fulfill Fulfill Fulfill Fulfill
Thickness Expansion (%)	12	5 × 5	0% = 9,85 % 2,5% = 9,24 % 5% = 7,57 % 7,5% = 7,72 %	Fulfill Fulfill Fulfill Fulfill
Modulus Of Elasticity (kgf/cm^2)	2,55	20 × 5	0% = 7,2 kgf/cm^2 2,5% = 2,4 kgf/cm^2 5% = 5 kgf/cm^2 7,5% = 10 kgf/cm^2	No Fulfill No No
Modulus Of Rupture (kgf/cm^2)	133	20 × 5	0% = 33 kgf/cm^2 2,5% = 20 kgf/cm^2 5% = 27 kgf/cm^2 7,5% = 48 kgf/cm^2	Fulfill No Fulfill Fulfill

5. Conclusion

The highest density was found in the test sample with 5% NaOH concentration treatment with a value of 0.854 gr/cm^3, while the lowest was in the sample without concentration treatment or 0 % NaOH with a value of 0.650 gr/cm^3. The highest water content was obtained in the test sample without concentration treatment or NaOH 0% with a value of 6.018 %, while the lowest was obtained in the test sample with a concentration treatment or NaOH

2.5 % with a value of 4.563 %. The highest thickness development was in the test sample without NaOH treatment with a value of 9.852 %, while the lowest was in the 5% NaOH concentration test sample with a value of 7.573 %. Has met the requirements of the standard SNI 032105-2006.

For the MOE test, only one test sample met the standard of SNI 03-2105-2006, namely the concentration of NaOH treatment of 2.5 % with a value of 2,470 kgf/cm^2. The highest MOR test was obtained at 7.5% NaOH concentration with a value of 48.611 kgf/cm^2 while the lowest was at 2.5% NaOH concentration with a value of 20.837 kgf/cm^2.

Acknowledgment

The authors would like to thank the Rector, Dean of Engineering Faculty and Research institutions, and community service (LPPM) Universitas Malikussaleh, who have funded this research with no. 20/PPK-2/SPK-JL/2022.

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