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THE EFFECT OF COMPARISON OF POLYPROPYLENE PLASTIC WASTE COMPOSITION AND PAPER SLUDGE ON FIBER REINFORCED COMPOSITE PANELS OF SUGARCANE BAGS ON MECHANICAL PROPERTIES

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ABSTRACT

Indonesia's landfills contain 15% of plastic waste. Of the total plastic waste, some are recycled and stored in the TPA. The remaining unmanaged will be wasted into the environment. Therefore, it is necessary to utilize waste so that it does not damage the environment, for example the use of waste into composite boards. Composite board made from polypropylene plastic wastepaper sludge and bagasse fiber. This study aims to see the effect of the composition of polypropylene plastic waste and the effect of paper sludge composition on the mechanical properties of composite panels. Composites are made using the hand lay-up method. The compositions used varied, namely 60% polypropylene plastic waste: 40% paper sludge, 50% polypropylene plastic waste: 50% paper sludge, 40% polypropylene plastic waste: 60% paper sludge with 2% bagasse fiber. Based on the results of research on the composition of polypropylene plastic waste of 60% and paper sludge composition of 40%, the highest tensile strength, compressive strength and hardness values were 11.86 N/mm^2, 21.54 MPa and 6.33 HV. And the composition of plastic waste polypropylene by 40% and composition of paper sludge by 60% obtained the lowest tensile strength, compressive strength and hardness of 1.23 N/mm^2, 9.77 MPa and 4.53 HV. From this study, it can be concluded that if the composition of polypropylene plastic waste is used more and more and the composition of paper sludge used is less, the value of mechanical properties will be higher. The value of the mechanical properties produced has met SNI.

Keywords : Composite Panel, Polypropylene Waste, Paper Sludge, Sugarcane Bagasse, Mechanical Properties

I. INTRODUCTION

Garbage heaps in Indonesia contain 15% of plastic waste. Of the total plastic waste, only 10-15% is recycled and 60-70% is stored in the landfill. The remaining 15-30% that has not been managed will be wasted into the environment, namely into rivers, lakes, beaches and the sea. Garbage in the ocean has become a major problem in the world, this is because there is no territorial area for marine debris. This increase in plastic waste occurred significantly based on the amount and distribution [1]. Therefore, it is necessary to utilize this waste so that it does not damage the environment, for example the use of waste into composite boards by adding a mixture of other materials.

In simple terms, a composite is a combination of two elements, namely fiber as a filler or reinforcement and a matrix as a binding material for these fibers [2]. The matrix is the phase in the composite which has the largest (dominant) part or volume fraction [3]. Composite boards that are currently developing are composite boards that combine particles and waste paper, composite boards that combine marble, polyester and fiber, composite boards that combine lignocellulosic waste with plastic.

Plastic is a material that is often used in everyday life, for example the use of plastic bags to carry groceries, household appliances, automotive and so on. Plastic consists of several types. One of them is polypropylene (PP). Polypropylene is a type of thermoplastic polymer. Polypropylene is formed from the combination of several small molecules called monomers which will become macro molecules. The manufacturing process uses heat energy and a catalyst as a bond separator of a molecule so that bonds with other similar molecules can occur [4]. Polypropylene is stronger and lighter with low vapor penetration, good resistance to grease, stable to high temperatures and quite shiny, which is flexible, hard and resistant to grease.

Previous research has shown that plastic waste can be made of quality building wall composites. Meanwhile, paper mill waste (sludge) has the main component (95%) organic fiber in the form of cellulose which is almost the same as wood [5]. Paper sludge is residual waste in the form of solids from the pulp and paper industry. This waste is usually gray or black in color with a composition of 90% solids and 10% water. This paper sludge is obtained from the deposition that occurs in the WWTP (Wastewater Treatment Plant). Sludge will continue to increase with the increasing demand for industrial production. So that handling is needed in terms of disposal because the increase in industrial production needs is not proportional to the increase in sludge management.

Several lignocellulosic materials can be modified into composite boards such as corn cobs, empty fruit bunches of oil palm and bagasse. Bagasse produced from sugarcane processing can reach 40% of the weight of sugarcane. So, if 2.5 million tons of sugar cane are produced annually, about 1 million tons of bagasse is produced which must be optimized [6]. With this huge potential, bagasse must be utilized as optimally as possible. One of them is like being a filler material for making composite boards.

Bagasse is a by-product of the extraction process. Most of them contain ligno-cellulose. The length of the bagasse fiber ranges from 1.7 to 2 mm with a diameter of about 20 microns, so that this bagasse can meet the requirements to be processed into artificial boards. Bagasse contains water by 48% to 52%, sugar an average of 47.7%. Bagasse fiber is insoluble in water and consists of 37.65% cellulose, 27.93% pentosan, 22.09% lignin and 3.01% SiO^2 which serves to increase the compressive strength of the composite board [7].

A lot of research on this composite board has been done. One of them states that the optimal composition of raw materials to obtain the highest mechanical strength is the composition of 60% sludge, 40% plastic waste and 2% coconut fiber. In this study, it was also stated that the heavier the paper mill sludge, the lower the flexural strength of the composite [8]. So, a research was made to make a composite with PP plastic waste (Polypropylene) which will be mixed with paper sludge and bagasse fiber by varying the composition between plastic waste and paper sludge which is smaller than before.

II. METHOD

This research is an experimental research, which is making a composite with polypropylene plastic waste as a matrix and paper sludge and bagasse fibber as a filler. The purpose of this study is to find out how the effect of increasing the amount of polypropylene plastic waste and the effect of increasing the amount of paper sludge on the tensile strength, compressive strength and hardness of composite panels.

Testing of mechanical properties in the form of tensile test, compressive test and hardness test. The sample consisted of 3 variations of material composition, namely 60% polypropylene plastic waste: 40% paper sludge: 2% bagasse fibber, 50% polypropylene plastic waste: 50% paper sludge: 2% bagasse fibber and 40% polypropylene plastic waste: 60% paper sludge: 2% bagasse fibber. The tools used in the research are digital scales, spatulas, beakers, stoves, pans, molds, cold presses, infrared thermometers, wire combs, ovens, sieves, jigsaws, universal testing machine, ELE compression testing machine and micro vickers hardness tester. The research materials used were polypropylene plastic waste, paper sludge, bagasse fibber, NaOH and aquadest.

Composite manufacture using the hand lay-up method, through several stages. The first stage is the preparation stage for making samples. At this stage there are three preparations. The first preparation is fibber preparation. Bagasse was obtained from sugarcane ice traders along Tabing Street, Padang City. The bagasse is then soaked in water for 1 day to remove the sugar content that is still in the sugar cane and then dried by drying in the sun for 1 day. After drying, the sugar cane is brushed using a wire brush to separate the fibbers from the cork contained in the sugar cane. The fibbers that have been separated by cork are then cut along 3 cm [9]. Subsequently, the fibber alkalization process was carried out using a chemical substance in the form of 5% NaOH within 2 hours [10]. After the fibber is alkalized then the fibber is washed using clean water, then the fibber is dried by drying in the sun for 1 day [11]. The second preparation is the preparation of paper sludge filler. Sludge obtained from PT. Indah Kiat Perawang is a semi-dry solid. The sludge is then dried in the sun to dry for about 7 days [12]. Then to maximize the drying of the sludge, oven at 110ºC for 3 hours was carried out. After being baked, the sludge is ground using a mortar and pestle. Then sieved using a 100 µm mesh. The third preparation is matrix preparation. Plastic PP is obtained from plastic collectors located in Tabing, Padang City. Plastic is chopped and then dried in the sun.

The second stage is sample making. Melting of polypropylene plastic waste is carried out. Plastic PP requires a temperature of 160ºC to melt [13]. During melting, the plastic waste is stirred continuously until it melts. After the plastic waste melts, it is mixed with paper sludge and then the bagasse fibber which has been cut 3 cm long, is stirred until homogeneous. After the dough becomes homogeneous, then put into a mold measuring 20 cm x 10 cm x 4 cm and 16 cm x 6 cm x 7 cm. The sample was placed in a cold press and then pressed using a pressure of 2,040 kgf/cm^2 which is equivalent to 2 x 108 N/m^2 [9] for 20 minutes. After pressing, the sample was allowed to stand for 10 minutes, then the sample was ready to be removed from the mould.

The third stage is cutting the sample. The finished sample is then cut using a jigsaw according to the standard size of the test. The shape of the sample can be seen in Figure 1.

(a) (b) (c)

Fig. 1. Test Sample (a) Compression (b) Tensile (c) Hardness

Figure 1a is a compression test sample with a sample size of 5 cm x 5 cm x 5 cm. Figure 1b is a tensile test sample with a sample length of 115 mm, width 19 mm, thickness 3 mm, width 6 mm and length 33 mm. Figure 1c is a hardness test sample with a sample size of 2 cm x 2 cm x 3.1 mm.

The last stage is sample testing. The first test is tensile test. The test is carried out by clamping the two ends of the test sample with one end connected to a tension device. Strive for the test sample to be completely vertical, then tighten the two clamps. The bottom of the machine is fixed while the top moves up at a low (constant) speed. The sample is attracted and experiences an increase in length. From the test, data obtained from the initial length, final length, cross-sectional area and tensile strength. The strain value of the test object can be calculated using the following equation 1 [14]:

$$\varepsilon = \frac{\Delta l}{l} \times 100\% \qquad (1)$$

The tensile strength value can be calculated using the equation 2:

$$\sigma max = \frac{Fmax}{A0} \qquad (2)$$

The elasticity value can be calculated using the equation 3:

$$E = \frac{\sigma}{\varepsilon} \qquad (3)$$

The second test is the pressure test. The test is carried out by turning the lever towards the left and installing a pressure device to crush the sample, placing the test sample just below the pressure tool, turning the lever towards the right until the test sample breaks/cracks. From the test, the compressive strength value can be calculated using equation 4 [15]:

$$\sigma = \frac{F}{A} \qquad (4)$$

The last test is hardness test. The test is carried out by applying a load to the material using an indenter with a pyramid shape, so that a stamping pattern will be formed, from this pattern the diameter of the stamping can be measured which can determine the level of hardness of a material. The test was carried out using the Micro Vickers Hardness Tester. The hardness value of the sample can be calculated by the equation 5 [16]:

$$VHN = \frac{1.854\,P}{d^2} \qquad (5)$$

III. RESULTS AND DISCUSSION

The results of this study consist of tensile test data, compressive testing and hardness testing. To find the best composition, several variations of the composition were carried out. Where the test equipment has been given direct data from the specimen being tested and there is some data obtained from processing using equations.

Tensile Strength, based on the measurement data that has been obtained, then the data is processed using equation (1) to obtain the value of the strain that occurs in the test sample, equation (2) to obtain the tensile stress of the sample and equation (3) to obtain the modulus of elasticity of the sample. The average value obtained for each variation in the sample can be seen in table 1.

Table 1. Average value of stress, strain and modulus of elasticity

Material Composition			Tensile Stress (N/mm^2)	Strain (%)	Modulus of Elasticity (N/mm^2)
PP Plastic Waste	Paper Sludge	Sugarcane Bagasse Fiber			
60%	40%	2%	11.86	2	8.7
50%	50%	2%	1.26	0.5	2.51
40%	60%	2%	1.23	0.25	4.87

Testing is done repeatedly in order to get a more accurate value. In table 1 it can be seen the average of each test in each variation. The highest tensile stress value was found in the composition of 60% PP plastic waste: 40% paper sludge: 2% bagasse fiber with a strain value of 2% and a modulus of elasticity of 8.7 N/mm^2.

If plotted in a line graph, the relationship between tensile stress and the composition of polypropylene plastic waste is obtained in the composition of the material as shown in Figure 2 below:

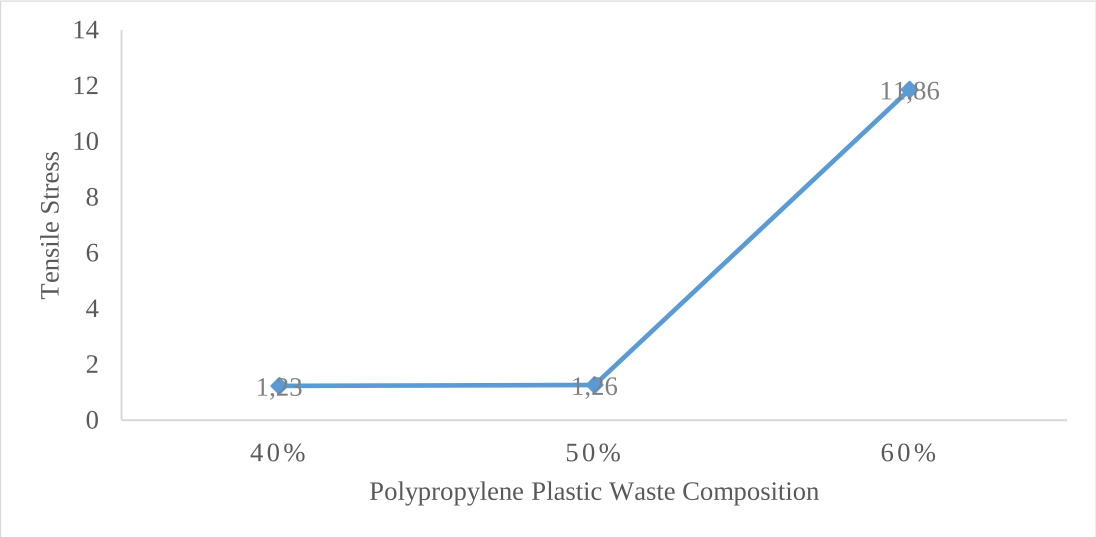

Fig. 2. The relationship between tensile stress and the composition of polypropylene plastic waste

In the figure 2, it can be seen that the composition of 60% plastic waste produces the highest tensile strength of 11.86 N/mm^2, at the composition of 50% plastic waste which is less than before produces a low tensile strength of 1.26 N/mm^2. and at a composition of 40% less plastic waste, it produces a very low tensile strength of 1.23 N/mm^2. It can be concluded that if the composition of polypropylene plastic waste is less in the composition of the material, the value of the resulting tensile strength decreases.

If plotted in a line graph, it is found that the relationship between tensile stress and paper sludge composition on the composition of the material is as shown in Figure 3 below:

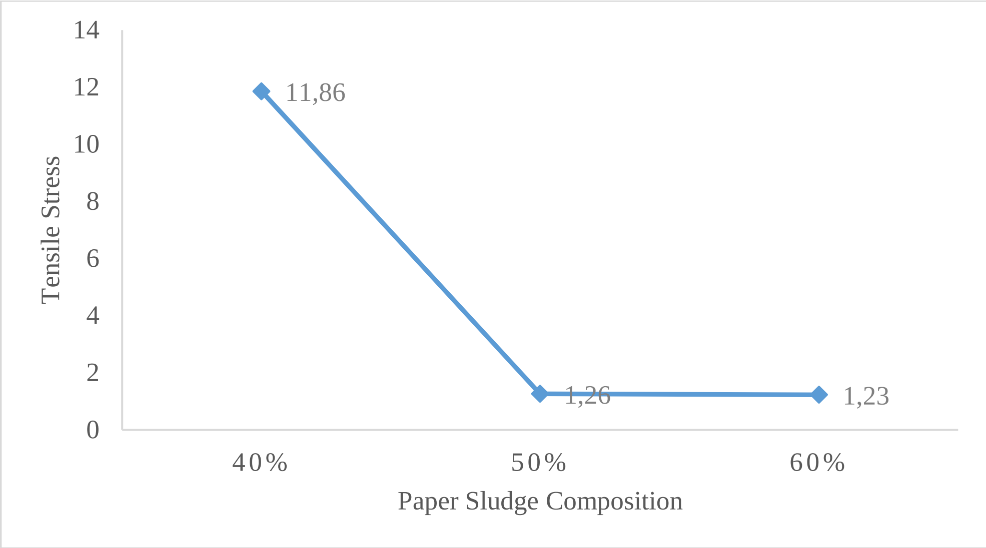

Fig. 3. Relationship between tensile stress and paper sludge composition

In the figure 3, it can be seen that the composition of 40% paper sludge produces the highest tensile strength of 11.86 N/mm^2, at the composition of 50% paper sludge which is higher than the previous one, it produces the lowest tensile strength of 1.26 N/mm^2. and at a composition of 60% more paper sludge, it produces a very low tensile strength of 1.23 N/mm^2. It can be concluded that the greater the composition of the paper sludge in the material composition, the lower the tensile strength value of the composite board.

From the graphs shown in Figure 2 and Figure 3, it can be concluded that the composition of PP plastic waste is 60% and the composition of paper sludge is 40%, a high tensile strength value is obtained, while the composition of PP plastic waste is 50% and 40% and the composition of paper sludge is by 50% and 60% there is a decrease in the value of the tensile strength. This shows that the tensile strength of the composite board decreases with the increase in the composition of the paper sludge in the material composition and increases with the increase in the composition of PP plastic waste in the material composition. This can be caused by too much filler material used so that the bond between PP plastic waste and paper sludge particles is not good. This is supported by previous research where it is known that the decrease in tensile strength is caused by an uneven distribution of filler material in the matrix which will reduce the interaction between the matrix and the filler material. Another cause is that the higher the viscosity of the mixture at a high concentration of filler material causes an imperfect mixing process [17].

In previous studies, it was also explained that the value of the tensile strength of composite boards decreased with a decrease in the number of matrices. The low matrix composition causes weak interactions between materials, reduced board adhesion, low transfer between phases, resulting in lower cohesiveness between materials in composite boards. This causes the ability of the material to withstand higher maximum loads will be lower [18].

Based on the reference used, namely the standard SNI 03-2105-2006, the minimum recommended tensile strength for composite types in the form of ordinary and decorative composite materials is 3.1 kgf/cm^2 or equal to 0.304 N/mm^2 [19]. Thus, the tensile strength values obtained in this study for each variation of the composition of PP plastic waste with paper sludge and bagasse fiber have met the particle board standard.

Compressive Strength, based on the test data that has been obtained, further processing is carried out using equation (4) to obtain the compressive strength value of the test sample. The average value obtained for each variation in the sample can be seen in table 2.

Table 2. The average value of the compressive force and the value of the compressive strength

Material Composition			Compressive Force(kgf)	Cross-sectional Area (cm^2)	Compressive Strength	
PP Plastic Waste	Paper Sludge	Sugarcane Bagasse Fiber			(kgf/cm^2)	MPa
60%	40%	2%	5493.33	25	219.63	21.54
50%	50%	2%	4516.67	25	180.67	17.72
40%	60%	2%	2490	25	99.66	9.77

Testing is done repeatedly in order to get a more accurate value. In the test, the mass of each sample was also weighed. The sample mass obtained varies because the sample after being printed must be cut according to the test standard. This causes the mass in each sample is different. The data obtained in table 2 can be seen that the highest compressive strength was found in the composition of 60% PP plastic waste: 40% paper sludge: 2% bagasse fiber.

If plotted in a line graph, the relationship between compressive strength and the composition of polypropylene plastic waste is obtained in the composition of the material as shown in Figure 4 below:

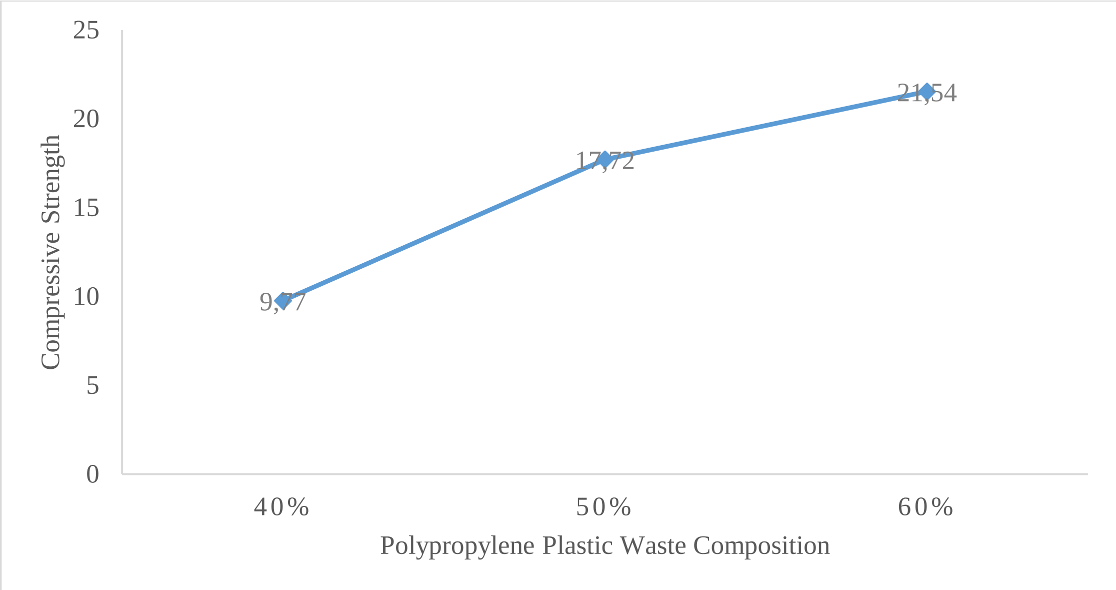

Fig. 4. The relationship between compressive strength and the composition of polypropylene plastic waste

In the figure 4, it can be seen that the composition of 60% plastic waste produces the highest compressive strength of 21.54 MPa, at the composition of 50% plastic waste which is less than before produces a low compressive strength of 17.72 MPa and at a composition of 40. The smaller % of plastic waste results in a very low compressive strength of 9.77 MPa. It can be concluded that if the composition of polypropylene plastic waste decreases in the composition of the material, the compressive strength value of the composite board decreases.

If plotted in a line graph, the relationship between compressive strength and paper sludge composition is found in the composition of the material as shown in Figure 5 below:

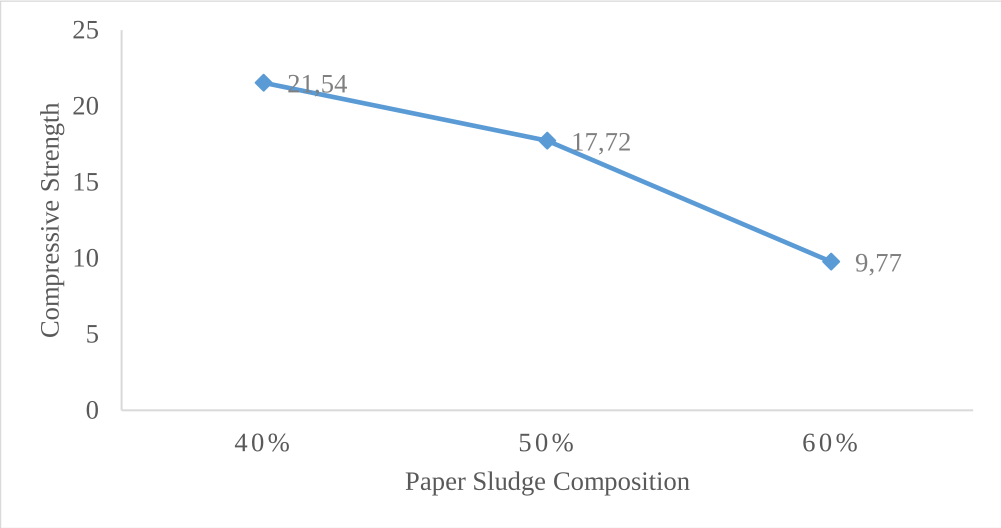

Fig. 5. Relationship between compressive strength and paper sludge composition

In the figure 5, it can be seen that the composition of 40% paper sludge produces the highest compressive strength of 21.54 MPa, at the composition of 50% paper sludge which is more than the previous one produces the lowest compressive strength of 17.72 MPa and at the composition of 60 % more paper sludge, resulted in a very low compressive strength of 9.77 MPa. It can be concluded that if the composition of the paper sludge is greater in the composition of the material, the compressive strength value of the composite board decreases.

From the graphs shown in Figure 4 and Figure 5, it can be seen that there is a low compressive strength value in the plastic waste composition of 40% and the composition of paper sludge by 60%. This is because too much paper sludge composition is used so that the bond between PP plastic waste and paper sludge particles is not good. The cavities in the composite will be filled with filler material which causes the composite to be less strong against loading.

While the composition of plastic waste is 60% and the composition of paper sludge is 40%, there is an increase in the value of the compressive strength of the composite, which is 21.54 MPa. The composition of 60% PP plastic waste: 40% paper sludge: 2% bagasse fiber shows the composition of PP plastic waste is more than paper sludge, so that the polypropylene plastic waste acts as an adhesive on the composite board. This is supported by the theory which states that the matrix is the phase in the composite which has the largest (dominant) part or volume fraction [3].

Based on the reference used, namely the SNI standard 03-2105-2006, the value of the compressive strength of particleboard is set at a minimum of 6 kg/cm^2 or equal to 0.588 MPa [20]. Thus, the compressive strength values obtained from this study for the three variations of the composition of PP plastic waste with paper sludge and bagasse fiber met the particle board standard.

Hardness, based on the test data that has been obtained, further processing is carried out using equation (5) to obtain the hardness value of the test sample. The average value obtained for each variation in the sample can be seen in table 3.

Table 3. The average value of the square of the footing diameter and the Hardness Value

Material Composition			Burden (kgf)	d² average (mm)	Hardness (VHN)
PP Plastic Waste	Paper Sludge	Sugarcane Bagasse Fiber			
60%	40%	2%	0.025	0.00732857	6.33
50%	50%	2%	0.025	0.0093367	4.97
40%	60%	2%	0.025	0.01032594	4.53

Testing is done repeatedly in order to get a more accurate value. The value of diameter 1 and diameter 2 on the indenter footing ideally is the same as the error value of 5%. In table 3 it can be seen that the highest hardness value is found in the composition of 60% PP plastic waste: 40% paper sludge: 2% bagasse fiber.

If it is plotted in a line graph, it is found that there is a relationship between the hardness value and the composition of polypropylene plastic waste in the composition of the material as shown in Figure 6 below:

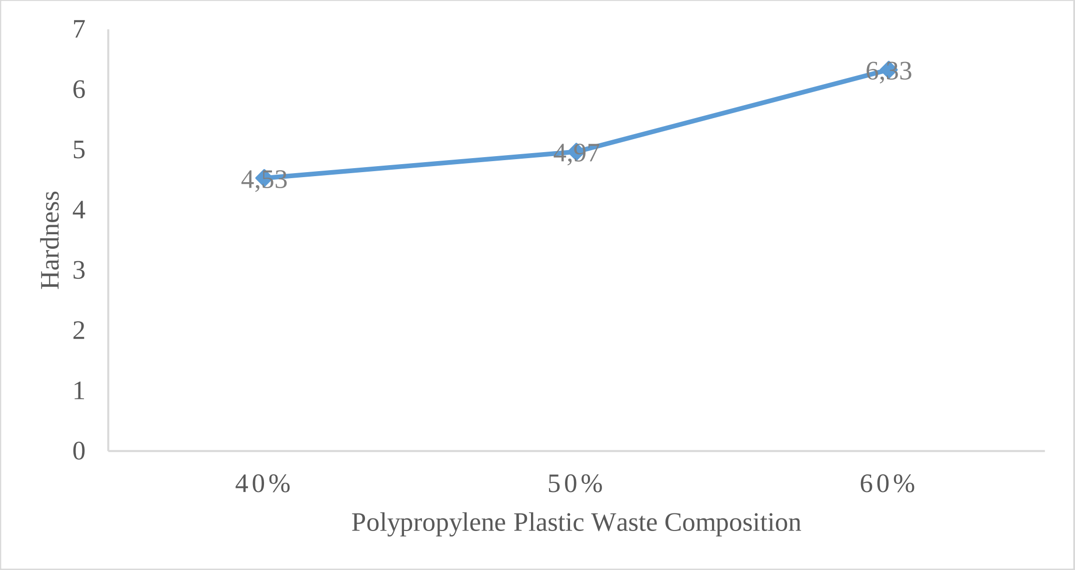

Fig. 6. The relationship between hardness and the composition of polypropylene plastic waste

In the figure 6, it can be seen that the composition of 60% plastic waste produces the highest hardness value of 6.33 HV, at the composition of 50% plastic waste which is less than before produces a low hardness value of 4.97 HV and at a composition of 40 The smaller % of plastic waste results in a very low hardness value of 4.53 HV. It can be concluded that if the composition of polypropylene plastic waste decreases in the composition of the material, the hardness value of the composite board decreases.

If it is plotted in a line graph, it is found that there is a relationship between the hardness value and the composition of the paper sludge on the composition of the material as shown in Figure 7 below:

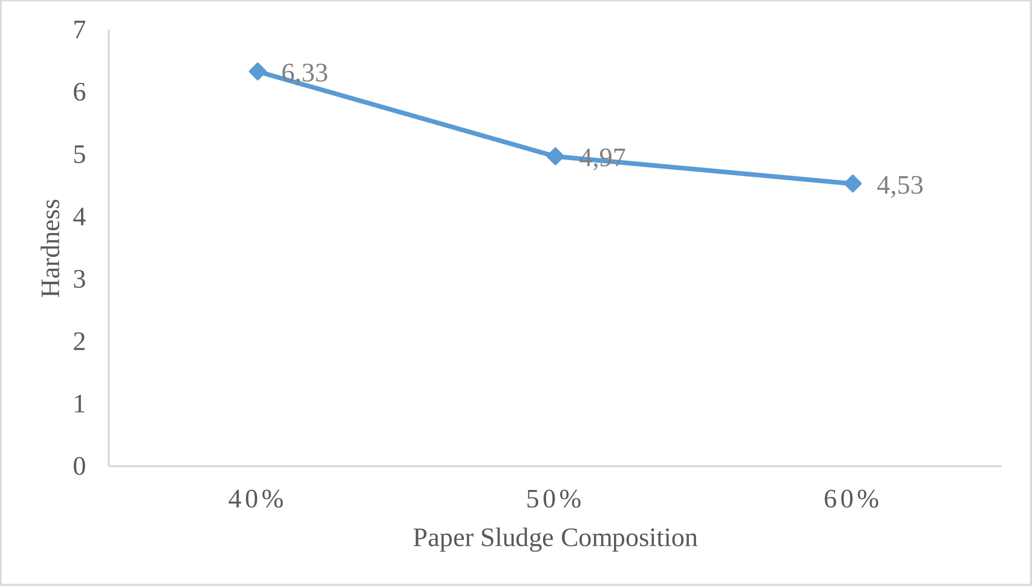

Fig. 7. Relationship between hardness and paper sludge composition

In the figure 7, it can be seen that the composition of 40% paper sludge produces the highest hardness value of 6.33 HV, at the composition of 50% paper sludge which is more than the previous one, it produces a low hardness value of 4.97 HV and at a composition of 60 % more paper sludge, resulted in a very low hardness value of 4.53 HV. It can be concluded that if the composition of the paper sludge in the composition of the material is greater, the value of the hardness of the composite board decreases.

The graphs in Figure 6 and Figure 7 show that the lowest hardness value is in the composition of plastic waste at 40% and the composition of paper sludge by 60%, where this composition contains a large composition of paper sludge so that the board becomes brittle. While the composition of plastic waste is 60% and the composition of paper sludge is 40%, the higher hardness value is 6.33 HV.

Based on previous research, it was stated that the higher the adhesive concentration, the higher the particle board hardness, as was the density value [21]. This is also supported by previous research which states that a large amount of adhesive will increase the bond between particles, with increasing particle bonding, the properties of the board will be harder, so that the resulting particle board is more resistant to water and more stable [22].

In reviewing the traces of the indenter on the test sample, samples with deeper traces have lower hardness values. Meanwhile, samples with shallower indenter traces have higher hardness values. This happens because the harder a material is, the more difficult it is to damage, so the traces of the indenter are shallower.

In this study, the results obtained were not in accordance with previous studies which concluded that the optimal composition of raw materials to obtain the highest mechanical strength was produced at the composition of 60% paper sludge: 40% plastic waste: 2% coconut fiber [9].

IV. CONCLUSION

Based on the results and analysis obtained from this study, it can be concluded that the effect of the composition of the polypropylene plastic waste used on the composition of the material on the tensile strength, compressive strength and hardness of the composite panel is that the greater the composition of the polypropylene plastic waste in the material composition, the higher the mechanical properties. on composite panels. And the smaller the composition of polypropylene plastic waste in the composition of the material, the lower the mechanical properties of the composite panel. As for the effect of paper sludge composition on the tensile strength, compressive strength and hardness of the composite panel, the greater the composition of the paper sludge in the material composition, the lower the mechanical properties of the composite panel. And if the smaller the composition of the paper sludge in the material composition, the higher the mechanical properties of the composite panel. The optimal material composition to obtain the highest mechanical value was obtained at the composition of 60% polypropylene plastic waste, 40% paper sludge and 2% bagasse fiber. The mechanical values produced in this study all meet SNI 03-2105-2006 and can be used as an alternative to the board.

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