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Analysis of Rice Straw and Ijuk Fiber Composite for Lightweight Material Applications

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ABSTRACT

Many lightweight materials are required to improve many advancements such as the travel distance of vehicles. Composites are required to be light, strong and if possible, economical so it may be used to increase the lightweight properties of vehicles and other lightweight applications. Indonesia has a variety of natural fibers such as rice straw and Ijuk palm fibers that are abundant and relatively cheap. This study aims to understand the character of the fibers when utilized in composites. Composites are made from resin with different contents of carbon fibers, rice straw fibers and Ijuk fibers. The products are then tested using load, tensile, impact, density and porosity tests. Samples showed that composites are able to withstand a maximum load of 680.79 kgf and tensile test of 12.90 N/mm² from straw fiber composite and 768.24 kgf and tensile test 14.47 N/mm² from Ijuk composites. Impact tests have also shown a maximum impact of 0.189 J/mm² and 0.132 J/mm² for rice straw and Ijuk fibers respectively. There are different variations in density and porosity due to the size of the fibers. The values indicate that it is possible to manufacture the natural fibers and carbon fibers into composites.

1. INTRODUCTION

Air pollution, where vehicles are one of the main sources, needs to be tackled by making several efforts, one of which is creating vehicles that use electric power [1]. Electric vehicles have many advantages, but there are still drawbacks that need to be considered. It currently is still limited by the distance traveled and the top speed of the vehicles [2]. The mileage and speed of an electric car are greatly influenced by the load of the vehicle. To increase the mileage, it is necessary to reduce the vehicle load or vehicle weight by utilizing more lightweight solutions to the vehicle body, one of which is by using composites.

Composite materials have several advantages, namely light, rigid, strong, resistant to corrosion, resistant to high temperature and can be used as damping material [3]. Composite materials are a combination of two or more materials, generally composed of some binding material (matrix) and reinforcing material (fiber). The matrix in the composite serves to distribute the load throughout the composite reinforcing material. The reinforcing material in the composite acts to withstand the load received by the composite material. The properties of reinforcing materials are usually ductile, rigid and tough. Reinforcing materials commonly used so far are carbon fiber, glass fiber, ceramics [3]. The fiber in the composite material acts as the main part that supports the load, so the size of the strength of the composite material is very dependent on the strength of the fiber that forms it. Smaller fiber materials can generally make the material stronger, but it also depends on other factors. Factors that greatly affect the composite material are fiber factor, fiber layout, fiber length, fiber shape, matrix factor, fiber and matrix bonding factor. In addition, fiber composites must also have the ability to withstand high stresses, because fiber and matrix interact where stress distribution occurs [4].

There are some composite materials used for the car bodies such as carbon fiber and glass fiber. Carbon fiber has light properties, the weight of carbon fiber is only 2% of the weight of steel. It has high tensile strength, good insulating properties, and is resistant to chemicals, but this material is very brittle when compressed [5]. It must be covered by the addition of other composite materials that can make the material more ductile. Glass fiber as a composite material is also used for the vehicle bodies. Glass fiber is a synthetic fiber that has many weaknesses, especially its high density and health hazards. The glass fibers that are released and inhaled can cause irritation of the nose, throat, difficulty of breathing, and coughing. Glass fiber can also cause skin and eye irritation [6]. In addition to glass fiber, natural fiber can also be used as a composite material.

Natural fiber has been applied as reinforcing materials in polymer composites [7]. It has several advantages, namely easy to obtain, abundant in number and is renewable. Natural fiber is around us and the price is usually cheaper and many are considered as waste. There are studies that show that these fibers can compete with artificially made fiber (such as glass *fiber*) [7], [8]. These fibers include banana, sisal, hemp and others. In Indonesia especially there are materials such as rice straw fiber and *ijuk* fibers that can be utilized.

Rice straw fiber can be considered as an alternative in this sense as it is one of the agricultural wastes which are quite large in number. The availability and use have not been much utilized, so the use of rice straw fiber as a raw material for making composites is very promising [9]. Rice straw fiber as a substitute for fiber can increase tensile strength and impact strength in composite materials. Every year, these straw fibers in Indonesia have increased [10]. So far, the utilization of rice straw has not been optimal in the region. It is usually used for animal feed and the rest is left to rot or be burned. This can increase air pollution which can damage the environment. Rice straw can be used as a filler material in inexpensive and environmentally friendly composite materials as a substitute for fiber [7].

Another fiber that could be utilized is *ijuk* fiber or black palm fiber produced by *Arenga pinnata* palm trees. The term "*ijuk*" will be used in this paper. The palm trees grow throughout mainland Indonesia especially at an altitude of 400 to 1000 meters above sea level. Indonesia is rich with these palm trees, however the fibers produced from these palm trees have not been fully utilized by the farmers, usually they are left unused. *Ijuk* is a natural fiber that has good attributes compared to other natural fibers. This black fiber has many features including: durable, resistant to acids and seawater salts, and is a good prevention of subterranean termites [11].

Developing composites with these two fibers which are very common in the Indonesian islands may prove to be cheaper alternatives to other composites in this area. Including the mentioned characteristics, it would be beneficial to understand the mechanical properties of fiber composites of rice straw and *ijuk* fibers. This study aims to find these properties and find an optimal composition of manufacturing the fiber material into composites of rice straw and *ijuk* palm fiber.

Studies have shown that there are several factors of the fiber that can affect the mechanical results of the materials. One such factor is fiber orientation where it can influence the strength of a composite material [7], [11], [12]. In general, the shape of natural fibers is not homogeneous. This is because the growth and formation of these fibers depends on the natural environment and the season in which the fibers grow. The arrangements are based in many ways. Such as unidirectional fibers which are arranged in a parallel direction to each other. The optimal stiffness and strength are obtained in the direction of the fiber, while the smallest strength occurs in the direction perpendicular to the fiber. For bidirectional orientation, the fibers are arranged perpendicular to each other (orthogonal). In this arrangement the highest strength is found in the direction of fiber installation. Pseudo-Isotropic arrangement of the fibers is done randomly, but the nature of this arrangement is isotropic. The strength at one test point must have the same strength from another. The mechanical ability of multi-way fiber installation is the most proportional in many cases because in this installation, fiber can contribute the most from its properties and if it is more random. If the fiber function is small, it can cause the strength of the composite to decrease [12]. This leads to the volume fraction where there are also variables that affect the result.

[13] stated that there was an effect of fiber volume fraction on the strength of carbon fiber reinforced polyester composites. The results of testing the tensile strength of carbon fiber reinforced polyester composites at fiber volume fractions of 25%, 35%, 45%, 55%, and 65% yielded tensile strengths of 415.46 MPa, 509.20 MPa, 548.97 MPa, 604.57 MPa, and 482.72 MPa, respectively. The highest tensile strength was obtained at the fiber volume fraction of 55%, which was 604.57 MPa, while the lowest tensile strength was at the 25% volume fraction of 415.46 MPa.

[14] mentioned that the greater the percentage of natural fibers in the composite, the higher the tensile strength of the composite. The tensile strength of the composites from the study was obtained between 2.26 and 75 kg/mm^2 for composites with 5% *ijuk* palm fiber, and 4.21 kg/mm^2 for composites with 9% *ijuk* fiber. From the *Ijuk* fiber with the composition of the mass fraction of fiber and resin 50:50, it produced the highest impact energy value of 198.75 Joule/cm^2. Tensile test shows the composition of mass fraction 50%:50% produces a tensile strength value of 27.09 MPa, and can produce value of more than 4.02%. This tensile strength value is closest to the value of the comparison material of 30.24 MPa [15].

Another factor to consider when manufacturing the composites is alkali treatments [16]. Both rice straw and *ijuk* composites have used this treatment in manufacturing. [11] showed that the *ijuk* palm fiber soaked in 5% NaOH solution for 2 hours, after which it was dried for 15 minutes resulted in strength value of 36.37 MPa and a strain of 9.34%. Rice straw fiber material has also been soaked in alkali for 60 minutes where it increased the tensile strength by 18.6 MPa of the composite [9]. This is an increase from the normal 20 mm fiber which has a tensile strength value of 14.25 MPa.

From studies above, it can be recognized that manufacturing rice straw and *ijuk* fiber composites have potential for cheap, lightweight and relatively good strength materials. This study seeks to understand the rice straw and *ijuk* fiber material in tandem with carbon fiber material when applied in a composite. It seeks to understand characteristics of the material, how it would break and its strength to withstand tension and impact so that it may be used for reference for construction of various lightweight vehicles.

2. METHODOLOGY

The research was conducted in the Mechanical Engineering laboratory, Faculty of Engineering, University of Muhammadiyah Malang. Tests were conducted, i.e. tensile test, impact test, density test and porosity test. The equipment used for tensile tests was TN20MD by Controlab and ESSOM TM 113 30 Kn. Model KBO-90M for the impact test. The specimens used were made from resin (polyester yukalac 157 BQTN-EX), carbon fiber and natural fiber. There were few variations of natural fiber to calculate, namely rice straw fiber (A = Resin+Carbon Fiber+Rice straw) and *Ijuk* fiber (B = Resin+Carbon Fiber+Ijuk fiber), with variations to be compared (1 = 72:21:07; 2 = 72:14:14; 3 = 72:07:21). These specimens were considered for tensile tests listed in table 1 below.

Table 1. Research variable and its specimen mix ratio of tensile test

Specimen	Resin+Carbon Fiber+Natural fiber (%)	Results		
A1	72:21:07	A_1	A_2	A_3
A2	72:14:14	A_1	A_2	A_3
A3	72:07:21	A_1	A_2	A_3
B1	72:21:07	B_1	B_2	B_3
B2	72:14:14	B_1	B_2	B_3
B3	72:07:21	B_1	B_2	B_3

Samples were made with hand lay-up method. The size of the mold is in accordance with the standards of ASTM D 3039 for tensile tests and ASTM D 5942-96 for impact tests. Carbon fiber was cut with a size of 225 mm, straw and fiber 90 mm. The resin was mixed with 100:1 catalyst for solidification of the composite material. Examples of the composite samples are displayed in Figure 1.

Figure 1. Carbon fiber/*ijuk* fiber composite samples of B1, B2 and B3

Analysis of data was obtained from the results of tensile and impact tests on the specimens. The values of tensile strength and impact strength were analyzed to understand the strength, ductility and brittleness of the material when there is a combination of carbon fiber, rice straw fiber and *ijuk* fiber. It was then used to analyze the carbon fiber, rice straw fiber and *ijuk* fiber's low density and mechanical properties that are considered in electric car bodies. Impact test specimen variations used the same percentages of natural fiber content where rice straw fiber (C = Resin+Carbon Fiber+Rice straw) and *Ijuk* fiber (D = Resin+Carbon Fiber+Ijuk fiber) can be seen in the table below.

Table 2. Research variable and its specimen mix ratio for impact tests

Specimen	Resin+Carbon Fiber+Natural fiber (%)	Result
C1	72:21:07	C_1
C2	72:14:14	C_2
C3	72:07:21	C_3
D1	72:21:07	D_1
D2	72:14:14	D_2
D3	72:07:21	D_3

Tensile test such as shown in Figure 2 was done and then yield strength (σ_y) was obtained by dividing the material yield load with sample cross-section. Similarly, the ultimate tensile strength (σ_u) was by dividing the maximum load with the cross-section. This analysis of material mechanical properties whether they crumble or break can also be understood by exposing the materials to higher pressures to find the porosity and density.

Figure 2. Sample of Resin+Carbon Fiber+Natural fiber on tensile testing machine

Density testing in this study was carried out in two stages, namely the theoretical density and the actual density. All the specimens were made into ASTM D 3800 standard for density testing. In measuring the actual density, the specimen was weighed, then put into a glass filled with water such as implemented by [18]. The increase of the water in the glass was then measured and recorded. The density is equal to the weight to the recorded volume increased. For the theoretical density, the volume was measured mathematically by multiplying the three sides of the specimens and scaled for the weight.

Determining the porosity is to understand internal voids inside the materials. ASTM D 570-98 was used for standard testing of the materials. Samples are numbered such as Table 3 below where rice straw fiber (E = Resin+Carbon Fiber+Rice straw fiber) and *Ijuk* fiber (F = Resin+Carbon Fiber+*Ijuk* fiber). The porosity was obtained by finding the difference of theoretical and actual densities divided by the theoretical porosity. The result was then converted to the percentage of the porosity of materials.

Table 3. Research variable and its specimen mix ratio for density and porosity tests

Specimen	Resin+Carbon Fiber+Natural Fiber (%)	Result
E1	72:21:07	E_1
E2	72:14:14	E_2
E3	72:07:21	E_3
F1	72:21:07	F_1
F2	72:14:14	F_2
F3	72:07:21	F_3

3. RESULTS AND DISCUSSION

3.1 Load and Tensile Test Results

Based on the content of the mixture of specimens using three independent variables in the load test and tensile test, there are different results. The average results of each variable can be seen in Table 2 and 3 shown the following:

Table 4. Load and tensile test results (carbon fiber + rice straw fiber)

Specimen		P_{min} (kgf)	P_{max} (kgf)	σ_y (N/mm²)	σ_u (N/mm²)
A1	A_1	582.426	583.647	11.42	11.44
	A_2	333.934	746.318	6.30	14.08
	A_3	362.933	712.408	6.72	13.19
	Average	426.431	680.791	8.14	12.90
A2	A_1	690.532	702.625	12.78	13.01
	A_2	592.209	592.239	9.87	9.87
	A_3	329.971	528.430	5.84	9.35
	Average	537.570	607.764	9.49	10.74
A3	A_1	334.347	339.442	5.97	6.06
	A_2	279.602	282.719	4.28	4.87
	A_3	326.261	326.383	5.28	5.82
	Average	313.401	316.181	5.17	5.58

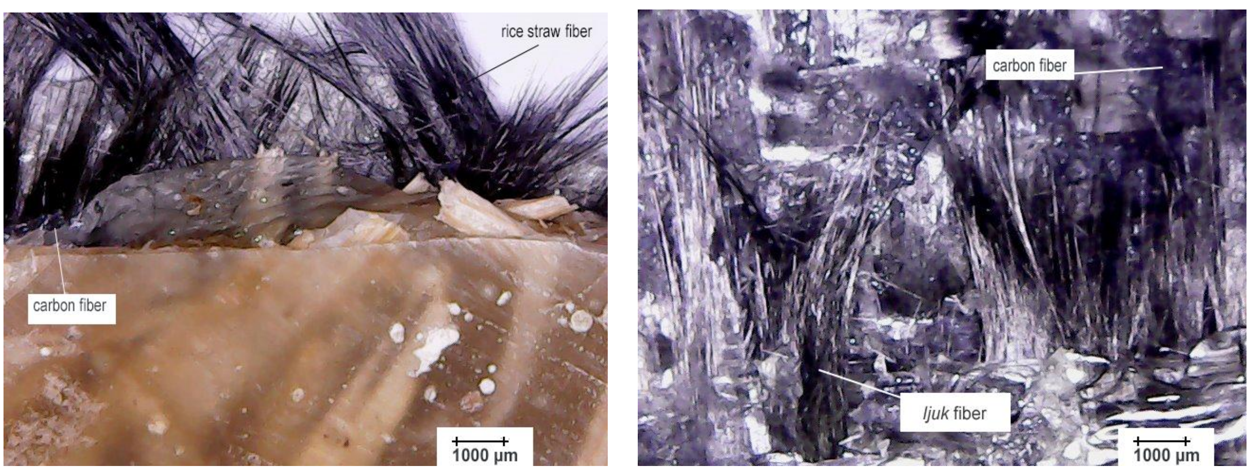
Table 5. Load and tensile test results (carbon fiber + *ijuk* fiber)

Specimen		P_{min} (kgf)	P_{max} (kgf)	σ_y (N/mm²)	σ_u (N/mm²)
B1	B_1	390.075	398.259	7.35	7.51
	B_2	353.758	438.675	6.43	7.97
	B_3	454.195	462.282	8.90	9.06
	Average	399.342	433.072	7.56	8.15
B2	B_1	437.809	452.221	7.81	8.07
	B_2	573.494	573.494	10.08	10.80
	B_3	536.997	538.845	9.42	9.45
	Average	521.100	551.520	9.10	9.44

B3	B_1	738.105	741.708	14.19	14.26
	B_2	894.927	895.258	17.54	17.55
	B_3	666.273	667.761	11.58	11.61
	Average	766.435	768.242	14.44	14.47

The load test is analyzed by comparing specimens A1 and B1 where it can be seen high carbon fiber content greatly affects the P_{min} and P_{max} values. P_{min} on carbon fiber and rice straw fiber obtained a value of 426.431 kgf and P_{max} 680.791 kgf. The carbon fiber and *ijuk* fiber obtained P_{min} 399.342 kgf and P_{max} 433.072 kgf. At the mixture of carbon fiber and rice straw fiber, the value is greater than the value of a mixture of carbon fiber and *Ijuk* fiber. The difference in P_{min} and P_{max} values was caused by combining the rice straw into smaller fibers than the fibers, even though the ratio was similar.

Analysis of the data A1 and B1 is based on the yield point and maximum tensile strength, the results show that high carbon fiber content and low straw fiber content are very influential. The addition of a mixture of rice straw and carbon fibers with a content of (7%) shows that the tensile strength of rice straw is greater than that of *ijuk* fiber. This is because the combined rice straw is made of fibers that are smaller than the *ijuk* fibers, and have caused tensile strength differences due to their fiber composition. This can be seen in the microscope picture of the samples seen in Figure 3.

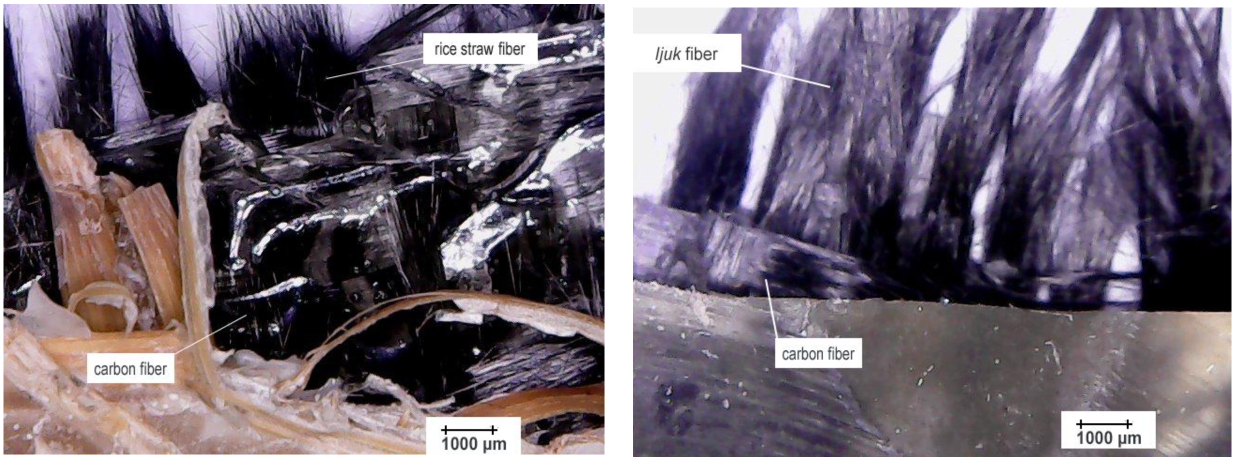


(a) (b)

Figure 3. Microstructure of fracture samples (a) A1 rice straw fiber composite and (b) B1 *ijuk* fiber composite

The minimum load and maximum load on the specimens of A2 and B2, rice straw fiber saw a greater value than that of the *ijuk* fibers. This is due to the reduced carbon fiber. The carbon fiber-*ijuk* mix maximum load value is still far from that of a mixture of rice straw fibers. This is because the fibers of the *ijuk* are stiffer and more brittle than the fiber of rice straw, while the maximum load of carbon fiber and rice straw fiber is able to withstand a maximum load of 607.76 kgf.

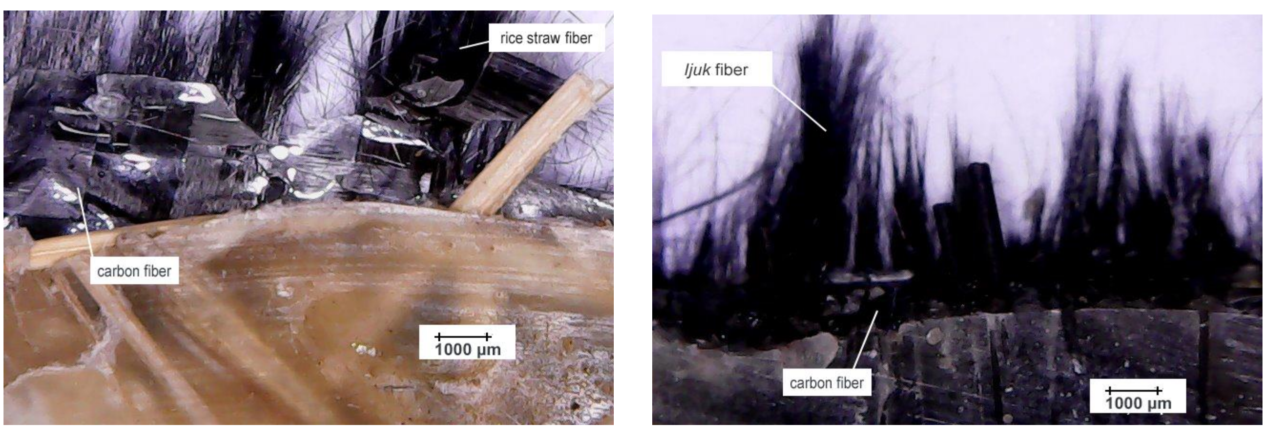
For maximum tensile strength of sample A2 and B2, the mixture of carbon fiber and rice straw fiber is greater than that of *ijuk* fiber. The difference in the maximum tensile strength is because the smaller the diameter of the straw fiber increases the value of the tensile stress [17]. Rice straw fibers can help maintain maximum tensile strength values, even though carbon fiber decreases. This is due to the bonds between the fiber molecules and the matrix being perfectly formed and reducing voids that will produce voids in the material [19]. The microstructure of fracture of the composite can be seen in Figure 4 below.



(a) (b)

Figure 4. Microstructure of fracture samples (a) A2 rice straw fiber composite and (b) B2 *ijuk* fiber composite

The result shows that the maximum tensile strength is still far below that of rice straw fiber mix. This is because the fibers of the *ijuk* are stiffer and have less fiber than that of rice straw. The diameter and length of the fiber also greatly affects the tensile strength [9]. We can also see that *ijuk* fiber is less fused with the matrix compared to the rice fibers as seen in Figure 4. Although the ratio of natural composite specimens is the same, the size, number and diameter of the fibers can affect the bond between the matrices. According to [20], the sample with the addition of 5 mm straw fiber showed the most optimum value, which was 12.17 MPa, this was due to the matrix bond with the filler being well connected.



(a) (b)

Figure 5. Microstructure of fracture samples (a) A3 rice straw fiber composite and (b) B3 *Ijuk* fiber composite

There is a decrease in the value of the maximum load of rice straw for the comparison of A3 and B3. This occurs due to the decrease in carbon fiber content and the larger diameter of the fibers. The decrease in maximum tensile strength in rice straw was also due to reduced carbon fiber content. There is also the factor of arrangement of rice straw fibers not being comparable to the fiber layer even though the levels were the same such as shown in the microscopy picture of Figure 5 above. According to [19], the drawback of rice straw fiber is that it usually has a non-uniform fiber size, thus affecting the tensile test value. The diameter and length of the fiber are not uniforms, this causes imperfect filler and matrix bonds to occur. The molecular bonds in the filler and matrix are not perfectly interwoven, resulting in voids which will reduce the tensile stress of the composite.

3.2 Impact Test Results

The impact test analysis is based on the ASTM D 5942 polymer composite material test standard and the results can be seen in the Table 6 below.

Table 6. Load and tensile test results (carbon fiber + *Ijuk* fiber)

Variable	Average Impact Results (J/mm²)
C1	0.0984
C2	0.1894
C3	0.1134
D1	0.1068
D2	0.1269
D3	0.1324

The impact test data for variables C1 and D1 is compared and can be seen that the mixture of resin, carbon fiber and *ijuk* fiber is higher with the value of 0.1068 (J/mm²). High carbon fiber content greatly affects the impact test. Because carbon fiber can withstand or absorb energy during impact testing, the fiber structure can withstand large loads. The fiber content is also very helpful in supporting the load and absorbing energy during the impact test. *Ijuk* fibers have a fiber arrangement unlike rice straw fibers, the diameter of the fibers is larger and harder.

Based on the Table 6 above, it can be seen that the best result is a mixture of resin, carbon fiber and rice straw fiber of around 0.1894 (N/mm²). Differences in impact test results on variables C2 and D2 can be influenced by several factors. First, the reduction in carbon fiber in D2 greatly affects the impact test, because carbon fiber has an elastic fiber compared to straw and fiber fibers. Second, rice straw fibers are smaller than the *ijuk* fibers. Third, the higher the content of rice straw, it will be able to withstand the impact of the impact test, because the arrangement of straw fibers is tighter. But even though the natural fiber content has the same content, the fiber has a value that is not too different.

3.3 Density and Porosity Test Results

The density of the composite depends on the volume fraction of the constituent elements. The density test uses the ASTM D 3800 standard and the porosity test uses the ASTM D 570-98 standard. The results of the density and porosity test are presented in Table 7 below:

Table 7. Research variable and its specimen mix ratio

Specimen	Sample (%)	Result		
		Theoretical Density (g/cm^3)	Actual Density (g/cm^3)	Porosity (%)

(Resin. Carbon Fiber + Rice Straw)	E1	1.08	1.02	0.5
	E2	1.09	1.06	0.3
	E3	1.08	1.04	0.3
(Resin. Carbon Fiber + Ijuk)	F1	1.12	1.04	0.7
	F2	1.12	1.06	0.5
	F3	1.12	1.04	0.7

From the theoretical density analysis, there is a difference of about 0.04 (g/cm³) in the two variables E1 and F1. The highest variable F1 *ijuk* mixture was 1.12 (g/cm³) compared to rice straw fiber. This difference in results is due to the hard shape of the *ijuk* fibers and during the matrix application process, the height of specimens is constant. In the E1 variable, the rice straw fiber mixture decreased in value when the theoretical density test was 1.08 (g/cm³). This is because when a matrix is applied, it decreases or changes shape. This decrease in shape causes differences in the results of the theoretical density test. The actual density test of variables saw different values, due to the low theoretical density values of the two specimens. The difference in the actual density value of the mixture of rice straw and *ijuk* fibers is also different, this is due to differences in the composition of the fibers. *Ijuk* has a fairly dense and hard fiber arrangement, so the actual value is large compared to rice straw fiber. The magnitude of the actual density value is also influenced by one of the components of the composite [18].

The porosity values of the variables E1 and F1 of rice straw and *ijuk* fiber have a difference of 0.2%. The value of the porosity of the *ijuk* is greater than that of straw fiber, this is due to the large and hard diameter of the fibers. According to [20] said that the diameter of these fibers is larger than glass fiber, so that during the preparation of the fiber there are more air voids on the board, so the porosity will be greater.

From the theoretical density analysis there were also differences in the E2 variable. The difference in the results of the theoretical density test on rice straw fiber is smaller than that of the actual fiber mixture. This phenomenon is caused by the addition of the matrix, the rice straw fiber shrinks in diameter and becomes soft. The nature of the fiber is easy to absorb water, so the height of the specimen will decrease.

For the F2 samples, the value was greater than that of rice straw. This difference in results was due to the hard and dense fibers, so that when the matrix was added, it had no effect on the size of the specimen. In the actual density analysis, there is a similarity of 1.06 (g/cm³) in the E2 and F2 variables. The occurrence of the similarity of the actual density values in the variables E2 and F2 is most likely the diameter and level of hardness of the fibers are not the same. The unequal diameter and hardness of the fibers also affect the water absorption capacity at the time of immersion, so that the actual density value is the same variable.

The E2 and F2 variables have the same value, the effect is water absorption when soaking. Carbon fiber made from non-natural synthetic materials, is not easy to absorb water. According to Sari in Nuryati et al, [19], the decrease in water content is closely related to the watertight nature of the plastic particles themselves, meaning that plastic particles do not have the ability to absorb water from the surrounding environment. The porosity values in the E2 and F2 variables showed a difference in yield of 0.2% for a mixture of rice straw and *Ijuk* fiber fibers. The diameter of the large and hard fibers has an effect on the porosity value. The difference in porosity values also occurs, because the theoretical density value in rice straw fiber is 1.08 (g/cm³).

Variables of rice straw fiber mixture in the theoretical density analysis shows values that are not the same. The mixture of rice straw fibers is very influential on the theoretical density, because the addition of the matrix can reduce its diameter. Decreased diameter of rice straw fiber, affected by large water absorption, resulting in a decrease in specimens. The theoretical density of the value is not the same, as during the addition of the matrix the diameter of the *ijuk* affects water absorption. The actual density values in the variables E3 and F3 are the same, due to the difference in the diameter of the *ijuk* that is not the same. The difference in the diameter of the *ijuk* is not the same, it is possible that at the time of immersion of the specimen the water absorption capacity is the same as the rice straw fiber. This is the similarity of the actual density value in the mixed specimens of resin (72%), carbon fiber (07%), rice straw and *ijuk* (21%). The porosity value of the mixture of resin (72%), carbon fiber (07%), *Ijuk* (21%) obtained a value of 0.4%compared to rice straw. The difference in porosity values is also due to the theoretical density values. The mixture of rice straw fiber in these 3 variables is affected by the height of the specimen when resin coating is performed, because rice straw fiber changes in diameter and tends to shrink.

4. CONCLUSION

Experimental data from load and tensile test shows that the largest values are from A1 rice straw fiber and B3 *ijuk*. The sample A1, namely resin (72%), carbon fiber (21%), rice straw fiber (7%), has a maximum load value of 680.79 kgf and tensile test of 12.90 N/mm². While B3 is resin (72%), carbon fiber (7%), and *ijuk* 21%) has a maximum load value of 768.24 kgf and tensile test 14.47 N/mm². It is greater than the value of A1. Here, it shows that carbon fiber is very influential on the load and tensile test, because rice straw has a small fiber size and is easily broken. However, on variable B3, the reduction of carbon fiber and the increase in the amount of *ijuk* fiber can increase the value of load test and tensile test. It may because *ijuk* fiber has a hard and strong fiber.

Based on data and analysis of impact test variable, C2 with resin (72%), carbon fiber (14%), the rice straw fiber (14%) has the highest value among the rice straw fibers of 0.189 J/mm². For variable D3, the resin (72%), carbon fiber (7%), *ijuk* (21%) has a smaller highest value for *ijuk* by 0.132 J/mm². This result is due to rice straw fiber being smaller than that of *ijuk* and it will be able to withstand the impact of the impact test, because the arrangement of straw fibers is closer.

In the analysis of theoretical and actual density test, three variables of *ijuk* mixture have a fairly large average value of about 1.12 g/cm^3 and 1.04 g/cm³. It demonstrates that *ijuk* fiber can affect the theoretical and actual density values. This is due to *ijuk* fiber having strong fiber properties where the addition of matrix and water immersion does not affect the fiber.

The average value of variable porosity of *ijuk* mixture has a greater value of about 0.7% compared to rice straw fiber. This is due to *ijuk* fiber when the process of addition and immersion does not absorb the matrix and water. *Ijuk* has a strong fibrous structure and is not easily absorbed and shrinks during the process of matrix addition and water immersion.

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