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Analysis Of Tensile Strength Coconut Coir Fiber Composites Using The Vaccum Bagging Method

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Abstract

The utilization of coconut fiber currently is limited to making brooms or for burning, necessitating further applications. One of these applications is its use as a reinforcement in composites, enhancing utility value and environmental friendliness. This study focuses on crafting composites from coconut fiber with variations in fiber orientation: random, 0°, and 45°.Tensile testing results reveal that the random fiber orientation variation exhibits the best performance, with a stress of 27.30 MPa, attributed to higher density. The 45° fiber orientation variation has the lowest stress (24.23 MPa) due to a lower fiber count. In bending tests, the random fiber orientation variation again performs the best, with a bending stress of 120 MPa, attributed to its high density that strengthens the structure. The 0° fiber orientation has the lowest bending stress (88.59 MPa) due to lower fiber density.Overall, utilizing coconut fiber as reinforcement in composites shows promising positive outcomes, with the random fiber orientation variation providing the best mechanical performance. This endeavor holds the potential to enhance the economic and ecological value of coconut fiber.

Keywords: Composite, fiber, coconut, tensile, bending

Introduction

Material is the fundamental building block in the construction of a structure. Material becomes a crucial element in determining the strength of the structure; if the material used meets the criteria for the construction of a structure, it will enable the structure to withstand forces. In the world of transportation, materials play a vital role in creating vehicles that are relatively lightweight yet strong, thus contributing to fuel efficiency. Currently, metals are widely used for vehicles, particularly aluminum. Aluminum is chosen due to its favorable mechanical properties and relatively light weight. An example of aluminum usage is in aircraft skin manufacturing. However, the use of aluminum makes the skin more susceptible to corrosion. As a result, the utilization of aluminum is now being reduced, and composites are being used as a replacement.

A composite is a material composed of a matrix and fibers. In this case, the matrix is used to bind the fibers, and the fibers are the primary constituent of the composite

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(Rahmanto & Palupi, 2019). Composites have better corrosion resistance than aluminum, although the maintenance of composites is more expensive than aluminum. Composites have experienced rapid development nowadays by utilizing various combinations of matrices and fibers. Fibers used can be natural or synthetic. Examples of synthetic fibers are carbon fibers, fiberglass, and nylon. Natural fibers can be obtained from various plant sources like pan& leaves, rattan, bamboo, and others. Natural fibers have the advantage of abun&t availability in the environment, but they exhibit lower mechanical properties compared to synthetic fibers.

However, using natural fibers will make the composite more environmentally friendly. One of the widely available natural fibers throughout Indonesia is coconut coir fiber (Rahmanto & Palupi, 2019).

Indonesia, being a tropical country, allows coconut trees to thrive. Currently, coconut coir fiber is only utilized for making brooms or simply burned. Hence, there is a need for alternative uses to enhance the value of coconut coir fiber.

This research involves the fabrication of a composite using coconut coir fiber. Through this utilization, it is expected to elevate the value of coconut coir fiber and render the composite more environmentally friendly. To determine the mechanical strength of the coconut coir fiber composite to be produced, a tensile testing is conducted.

Based on the aforementioned description, the researcher is intrigued to conduct a study on the topic of analyzing the tensile strength of coconut coir fiber composites using the vacuum bagging composite fabrication method.

Research Methods

This study was conducted by creating a composite of coconut coir fiber using the vacuum bagging method. After the composite fabrication, the next step involved cutting the composite to meet testing standards. The tensile testing standard employed was ASTM D-638, while the bending test used ASTM D790. The specimen configurations are presented in Figure 1. and Figure 2. Subsequently, tensile testing was performed on each variation to determine the tensile strength, and bending tests were conducted to ascertain the flexural strength of the specimens (figure 3).

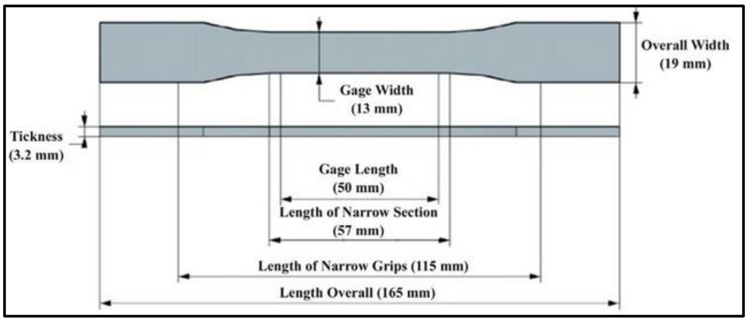

Figure 1. ASTM D-638
Source: (Venkatesan & Bhaskar, 2020)

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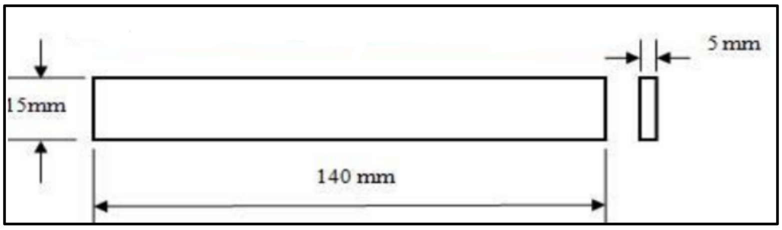

Figure 2. ASTM D790
Source: (Venkatesan & Bhaskar, 2020)

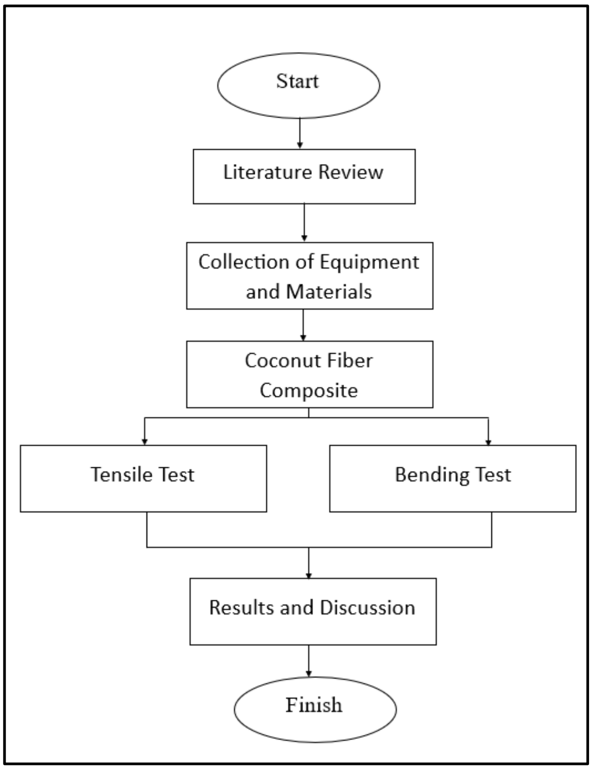

Figure 3. Flow Chart

Result and Discussion

1. Tensile Test Results

The creation of specimen variations was carried out in a single vacuum bagging process. After the castings had thoroughly dried, the specimens were then cut according to the ASTM standards for each tensile test in Figure 4. , Figure 5. And Figure 6,

Figure 4. 0° Variation

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Figure 5. 45° Variation

Figure 6. 45° Random

Tensile testing has been conducted to determine the tensile strength of each fiber orientation variation: 0°, 45°, and random. The testing was carried out at the ITNY material testing laboratory using a tensile testing machine.

Overall, the results of the tensile testing are presented in Table 1. From the comparison of the average values for each variation, it can be observed that the random fiber orientation variation exhibits the highest tensile strength, while the lowest tensile strength is observed in the 45° fiber orientation variation.

Tabel 1. Tensile Test Results

Variation	Speciment	Width	Thick	Area	Max. Force (kgf)	Tensile Strength (kgf/mm^2)
0°	1	13.95	5.39	75.19	307.97	4.10
	2	13.18	5.83	76.84	145.39	1.89
	3	14.49	3.97	57.53	103.14	1.79
Average (MPa)						25.44
45	1	13.95	5.28	73.66	62.55	0.97
	2	14.27	5.28	75.35	183.48	2.72
	3	14.41	6.26	90.21	132.67	2.22
Average (MPa)						24.23
Random	1	13.97	4.62	64.54	176.21	2.39
	2	13.06	5.16	67.39	240.99	3.20
	3	14.77	4.05	59.82	248.59	2.76
Average (MPa)						27.30

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Table 2. presents the density of each variation, showing that the random fiber orientation variation has the highest density, while the 0° and 45° fiber orientation variations have the lowest densities.

Tabel 2. Density of Tensile Test Variations

Variation	Speciment	Length (mm)	Width (mm)	Height (mm)	Volume (mm^3)	Mass (gr)	Density (gr/mm^3)
0°	1	156.07	13.95	5.39	12215.16	21	0.0017
	2	158.97	13.18	5.83			
	3	158.65	14.49	3.97			
45°	1	148.41	13.95	5.28	13337.05	23	0.0017
	2	146.69	14.27	5.28			
	3	147.85	14.41	6.26			
acak	1	158.85	13.97	4.62	10613.86	22	0.0021
	2	157.5	13.06	5.16			
	3	148.1	14.77	4.05			

Figure 7. displays the graph of tensile test results for the 0° fiber orientation variation. From the test results, it is evident that Straight 1 specimen has the highest values in terms of stress and strain. Meanwhile, the specimen with the lowest strain is observed in Straight 3.

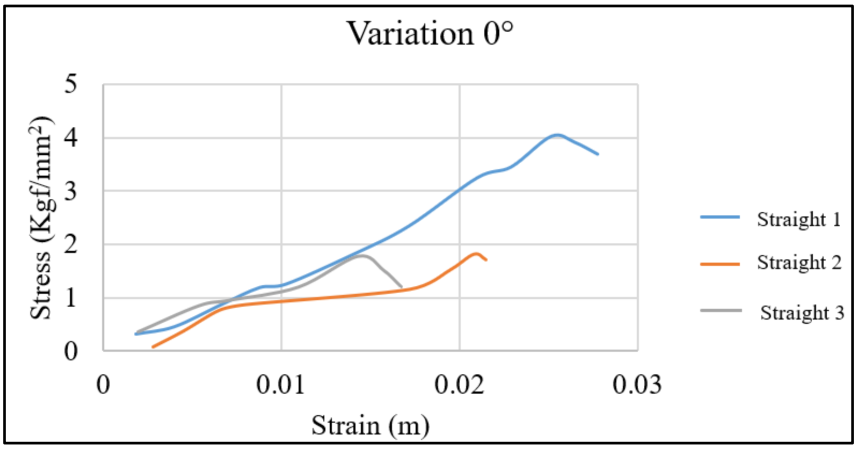

Figure 7. Graph of bending test with 0° variation.

In Figure 8. there is a graph depicting the results of a tensile test for fiber orientation variation at 45° angle. The graph shows that the specimen with the highest stress is Cross 2, while the lowest stress is observed in Cross 1 specimen. Cross 3 specimen exhibits the highest strain value, whereas Cross 2 specimen shows the lowest strain value.

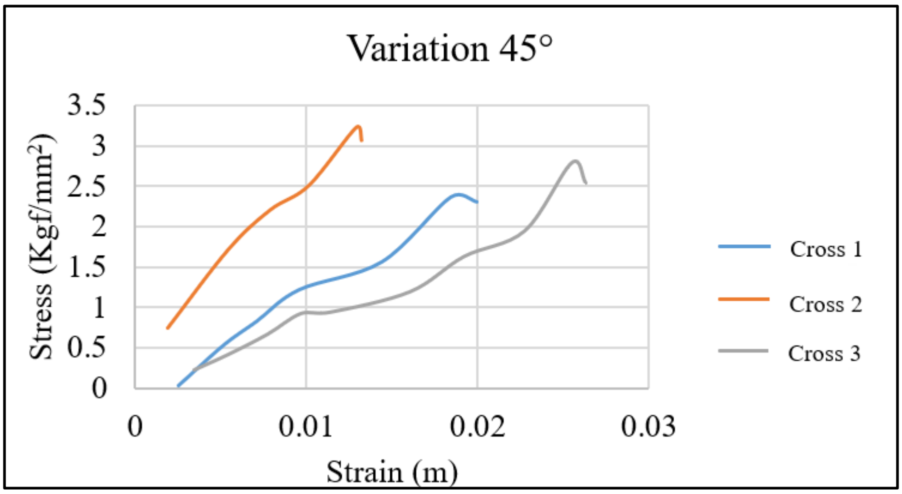

Figure 8. Graph of tensile test with 45° variation

In Figure 9. the results of tensile testing for random fiber orientation variation are displayed. It is evident that Random 2 specimen has the highest stress value, while the lowest stress is observed in Random 1 specimen. The specimen with the highest strain value is Random 3.

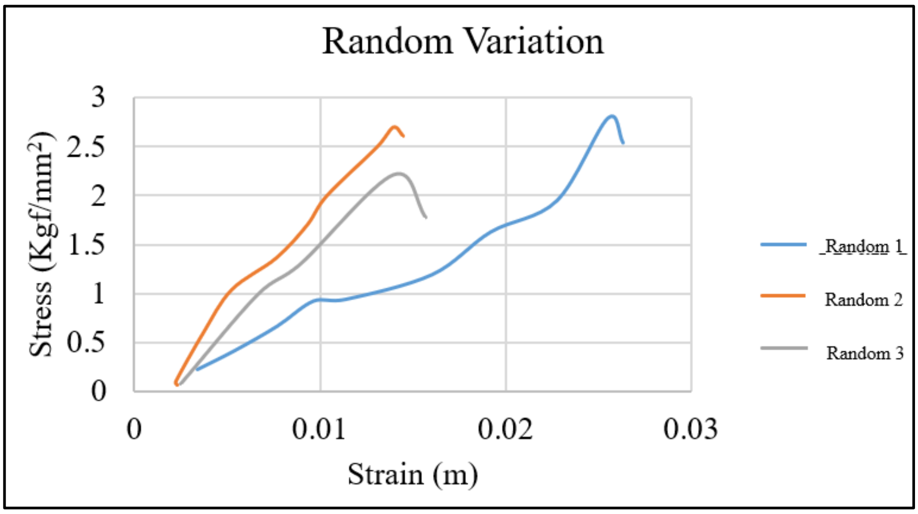

Figure 9. Graph of tensile test with 45° fiber orientation variation

Figure 10 presents photographs of the fracture surfaces of each specimen before and after testing. From the tensile testing results, the best fiber orientation variation is found in the random orientation with a tensile strength of 27.3 MPa (Figure 11.). Furthermore, the results for the 0° fiber orientation are higher than those for the 45° fiber orientation, aligning with theoretical expectations. When fibers are aligned parallel to the applied force, they tend to have higher stress values compared to orientations where the fibers are not aligned parallel to the force. However, in this study, the results deviate from

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the theory, similar to the findings of the research conducted by Fajarudin & Widodo (2021).

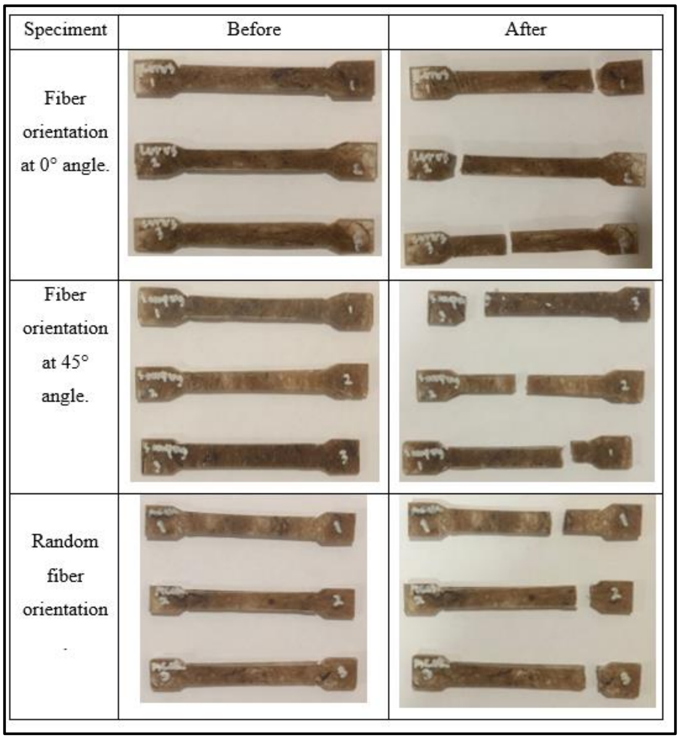

Figure 10. Fracture results of the tensile test variations.

This discrepancy could be attributed to several factors that led to a decrease in stress values, including: Uneven fiber distribution, due to equipment limitations, has resulted in areas that are not adequately filled with fibers. Inconsistent fiber orientation is observed due to the delicate nature of the fibers, making it challenging to control. Considering mass density, the random fiber orientation variation exhibits the highest stress

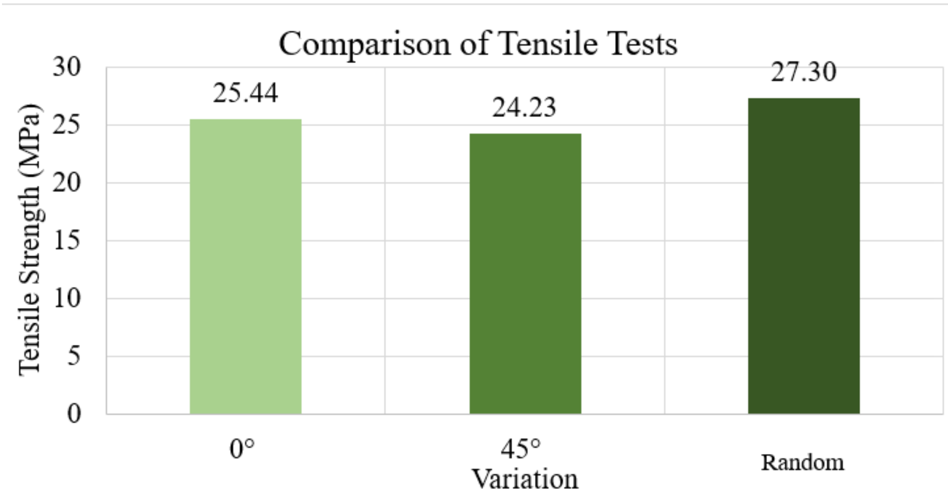

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Figure 11. Comparison of tensile tests among different variations

2. Bending Test Results

Bending testing was conducted to assess the bending strength of each composite fiber orientation variation. The three-point bending method was employed for this purpose, involving 2 supports and 1 loading point. The details of the specimen fabrication are outlined in Figure 12.

Variation	Figure	Weight (gram)	Fiber (gram)
0°		57	2
45°		58	2
Random		56	2

Figure 12. Results of Bending Test Specimens

Table 3. displays the average bending test results for each fiber orientation variation. The highest bending strength is observed in the random fiber orientation variation with a value of 120 MPa, while the lowest variation is found in the 0° fiber orientation variation with a value of 89.6 MPa.

Table 3. Results of Bending Test

Variation	Speciment	l (mm)	t (mm)	Moment (kgf.m)	Bending Strength (kgf/mm^2)	Rata-rata (MPa)
0°	1	16.9	9.44	2.08	8.28	89.6

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	2	16.81	8.96	2.05	9.09	
	3	17.62	9.57	2.62	9.75	
45°	1	17.19	8.84	2.05	12.28	114.0
	2	17.69	9.19	1.81	10.60	
	3	17.95	9.14	2.82	11.68	
Random	1	15.73	9.41	3.08	13.77	120.0
	2	17.32	7.69	1.97	7.94	
	3	18.69	8.81	3.63	14.54	

In Figure 13, Figure 14, and Figure 15 , graphs depicting the bending test results are presented. To assess the performance of each specimen, one can observe the highest peaks of stress that occur. Figure 4.5 illustrates the bending test graph for the 0° fiber orientation variation. The specimen with the highest stress is identified as Straight 3, while the lowest stress is observed in Straight 1 specimen.

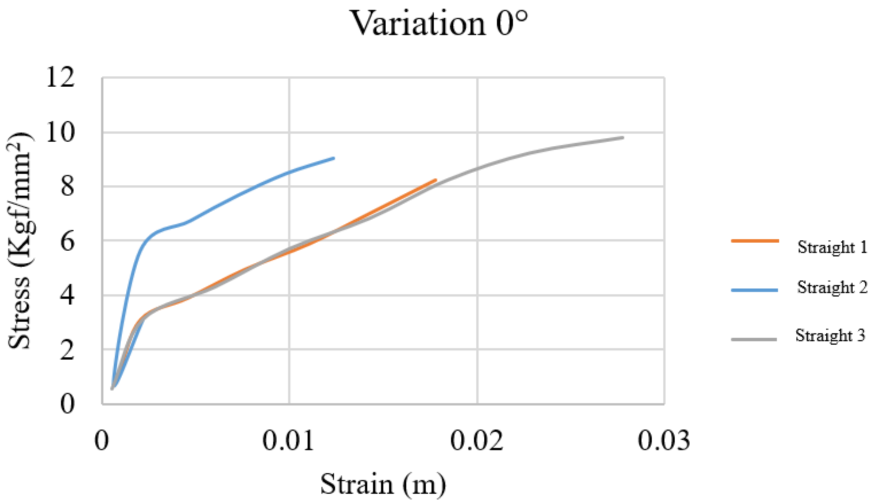

Figure 13. Graph of Bending Test for 0° Fiber Orientation Variation

From Figure 14, which represents the graph of bending test results for the 45° fiber orientation variation, it is evident that the specimen with the highest stress is Cross 3, while the lowest stress is observed in Cross 2 specimen.

In Figure 15, there is a graph depicting the results of the bending test for the random fiber orientation variation. The highest stress is observed in random 3 specimen, while the lowest stress is observed in random 1 specimen.

Similar to the tensile test, the best bending strength is found in the random fiber orientation variation with a value of 120 MPa (Figure 17 and 18.). The factors contributing to this outcome are consistent with those in the tensile test, including the highest mass density compared to the other variations.

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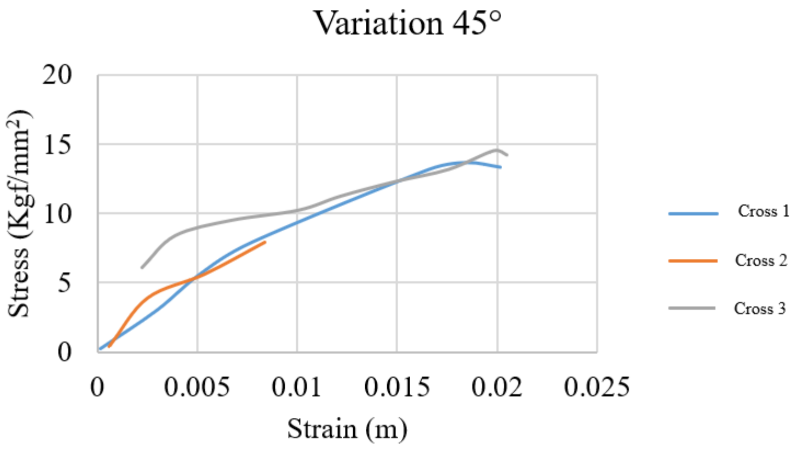

Figure 14. Graph of Bending Test with 45° Fiber Orientation Variation

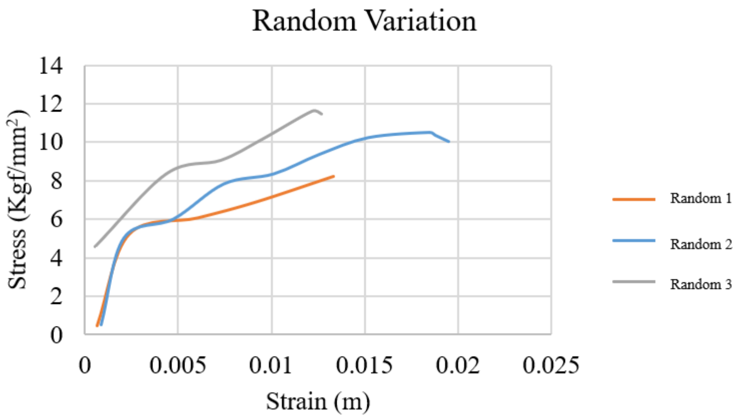

Figure 15. Graph of Bending Test for Random Fiber Orientation Variation

Speciment	Before	After
0° Fiber Orientatio n		
45° Fiber Orientatio n		
Random Fiber Orientatio n		

Figure 16. Bending Test Fracture Results

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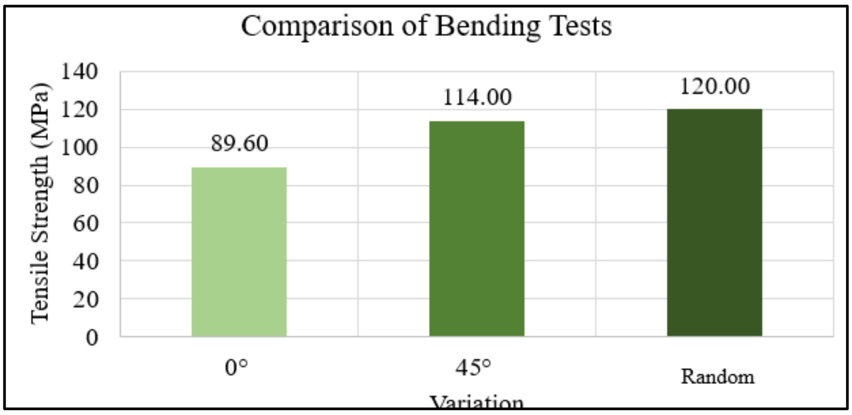

Figure 17. Comparison of Bending Tests among Variations

In Table 4, the mass density of specimens in each variation is presented. It is noticeable that the random fiber orientation variation has the highest mass density, while the lowest mass density is found in the 0° fiber orientation variation.

Table 4. Mass density of bending test specimens for each variation

Variation	Spesimen	Length (mm)	Width (mm)	Height (mm)	Volume (mm^3)	Mass (gr)	Density (gr/mm^3)
0°	1	158.98	16.9	9.44	25952.83	26	0.0010
	2	159.11	16.81	8.96			
	3	153.91	17.62	9.57			
45	1	153.51	17.19	8.84	26151.64	29	0.0011
	2	158.63	17.69	9.19			
	3	159.4	17.95	9.14			
Random	1	154.12	15.73	9.41	22812.73	27	0.0012
	2	159.37	17.32	7.69			
	3	159.33	18.69	8.81			

3. Macroscopic Photo Analysis

From both the tensile and bending test results, the best-performing specimens are those with a 45° fiber orientation variation. This outcome can be attributed to the fewer voids, defects, and cracks present compared to the 0° and random variations. Additionally, the highest fiber density is found in the specimens with a 45° variation. This assertion is supported by the photographic evidence of the specimens provided below.

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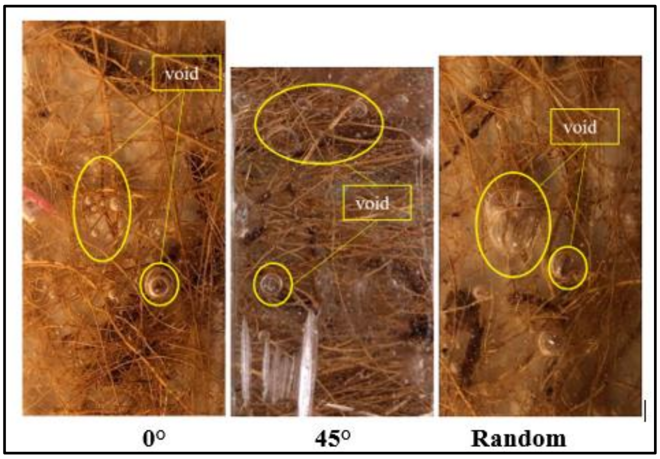

Figure 18. Macroscopic Photo Analysis of Specimens

Conclusion

1. Based on the tensile test results, the best fiber orientation variation is found in the random orientation with a stress value of 27.30 MPa, while the lowest stress value is observed in the 45° fiber orientation variation with a value of 24.23 MPa. This is due to the higher fiber density in the random fiber orientation variation, resulting in a relatively higher fiber content compared to other variations. As a result, the structure of the random fiber orientation variation is relatively stronger than the 0° and 45° orientations.
2. From the bending test results, the best fiber orientation variation is also found in the random orientation with a bending stress value of 120 MPa, while the lowest bending stress value is observed in the 0° fiber orientation variation with a value of 88.59 MPa. This phenomenon is attributed to the denser fiber arrangement compared to other variations, which reinforces the composite structure, similar to the tensile test results.

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