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Performance Testing of Jute Fiber-Reinforced Composite Resin as a Crewboat Building Material

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Abstract: The maritime industry requires lightweight, strong, corrosion-resistant, and environmentally friendly materials, particularly for crewboat construction. Conventional metallic materials often suffer from corrosion, high weight, and elevated maintenance costs. This study investigates the mechanical performance of epoxy–jute fiber composite materials as a sustainable alternative for crewboat hull applications. Experimental laboratory testing was conducted using a quantitative approach to evaluate the tensile strength, flexural strength, impact resistance, and environmental durability of the composites. Specimens were fabricated using epoxy resin reinforced with jute fibers arranged in four different orientations (0°, 45°, 90°, and random) and tested according to ASTM standards. The results indicate that fiber orientation significantly influences mechanical properties. The 0° fiber orientation exhibited the highest tensile strength (89.04 MPa) and elongation (1.287%), indicating efficient load transfer and good ductility. The 45° orientation produced the highest flexural strength (39.14 MPa), while the random fiber orientation demonstrated the greatest elastic modulus (25.81 GPa) and impact resistance (6.409 kJ/m), providing superior stiffness and energy absorption. Seawater immersion tests showed no visible degradation in the composite structure. These findings suggest that epoxy–jute fiber composites have strong potential as eco-friendly crewboat construction materials, especially when applied using hybrid laminate configurations (0°/±45°/random) to optimize strength, stiffness, and impact resistance.

Keywords: Crewboat; Epoxy resin; Fiber; Jute fiber composite; Mechanical properties

Introduction

The maritime industry continues to face challenges in creating ship materials that are lightweight, strong, corrosion-resistant, and environmentally friendly (Odunlami et al., 2025; Okuma et al., 2023). Crew boats, which are often used to support shipping industry operations, require high-performance materials that can withstand aggressive marine environmental conditions (Rubino et al., 2020; Wijewickrama et al., 2025). Conventional materials such as metal often face problems such as corrosion, heavy weight, and high maintenance costs.

In an effort to find alternative solutions, natural fiber-based composite resins such as jute fibers have emerged as potential candidates (Ashraf et al., 2019; Kumar et al., 2021; Sonali et al., 2023). Jute fiber has the advantages of high tensile strength, biodegradability, light weight, and abundant availability (Haryanti, 2017; Hidayah et al., 2023). However, although it has been widely used in non-structural applications, the full potential of jute fiber as a composite reinforcement in shipbuilding has not been thoroughly explored (Kustiwansa, 2025; Simatupang et al., 2024). This research focuses on testing the performance of yute fiber-based composite resins to determine their suitability as the main material in the manufacture of crew boats.

The purpose of this study is to test the tensile strength of yute and hemp fiber-based composites using epoxy resin, test the compressive strength of yute fiber-based composites and hemp using epoxy resin, and test the resistance of yute fiber-based composites to impact. This research supports the strategic agenda of the

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Makassar Shipping Science Polytechnic which focuses on the development of environmentally friendly technology and maritime material innovation. The urgency of this research includes several important aspects.

This research is in line with the vision of the Makassar Shipping Science Polytechnic to become a center of excellence in the development of sustainable maritime technology. By researching alternative materials that are environmentally friendly, this research supports a research roadmap in the field of composite materials and maritime technology innovation. This research makes a real contribution to the shipping industry by offering lighter, more durable, and economical material solutions for crew boat manufacturing (Chauhan et al., 2022; Setyawan & Marasabessy, 2022).

This research expands insights in the field of natural fiber-based composites, particularly in maritime applications. Research findings can be a reference for the development of new materials and open up opportunities for further research. This research is expected to produce scientific data on the mechanical properties and durability of jute fiber-based composite resins, prototypes of materials that are ready to be tested at the laboratory scale and marine environment simulations, relevant scientific publications in national and international accredited journals, and technical recommendations that can be adopted by the shipping industry for environmentally friendly alternative materials.

This research contributes to strengthening the capacity of the Makassar Shipping Science Polytechnic as a higher education institution oriented towards maritime technology innovation. By creating more sustainable and efficient materials, this research provides direct benefits to students, lecturers, and industry, and encourages the application of locally-based technologies on a global scale

Method

This type of research includes experimental research with a quantitative approach. This research involved laboratory testing to test the mechanical performance of jute fiber-based composite resin materials (Islam et al., 2024; Pramanik et al., 2024). This research involves laboratory testing to test the mechanical performance of yute fiber-based composite resin materials which were carried out on: mechanical Laboratory and Mechanical Workshop of Ujung Pandang State Polytechnic, used for the process of making composites and making tensile test specimens, bending tests, and impact tests in accordance with ASTM standards as well as mechanical testing, including tensile strength, flexural strength, and impact strength on composite specimens that were made from July to August 2025; and the Geopolymer Laboratory of the State University of Makassar to test seawater immersion from May to August 2025.

A precision digital balance (*Electronic Balance* capacity of 1000 g) is used to measure sample mass with an accuracy of 0.01–0.1 g. This tool is equipped with *a tare* function and a digital screen, making it easier to weigh the process quickly and accurately in research.

The composite panels are made using 200 mm × 200 mm × 4 mm molds pressed with hydraulic jacks as the pressing system. This mold is used to produce five test specimens, each of which is intended for tensile testing, flexure testing, and impact testing according to research needs.

Testing of the mechanical properties of epoxy/jute composites was carried out using a Galdabini PM 100 type Universal Testing Machine (UTM) with a load capacity of 20 kN and a test speed of 0.5 mm/min. This tool is used to obtain data on tensile strength and bending strength of composite materials.

Toughness testing was carried out using the Charpy impact test instrument with a pendulum specification of 0.8 kg, pendulum arm length of 0.45 m, and a maximum swing angle of 140°. The working principle of this tool is to drop the pendulum from a certain height to pound the specimen, so that the absorption energy due to the fault can be calculated. The energy absorbed indicates the resistance of the material to shock loads.

Figure 1. Jute Fiber

The main material used in this study is jute fiber as a composite reinforcing material. Jute fiber comes from *the Corchorus sp.* which is widely used because it is environmentally friendly, lightweight, easy to obtain, and has quite good tensile strength (Ramesh & Deepa, 2024; Zhang et al., 2019). In this study, jute fibers were used as reinforcement in epoxy matrices to improve the mechanical properties of composites. The jute fibers used are shown in Figure 1.

Figure 2. EPR *174 type A epoxy resin*

Figure 2 shows EPR 174 type Epoxy A Resin, which is used as a matrix material in the manufacture of epoxy/jute composites (Iqbal et al., 2024). Epoxy resin was chosen because it has good mechanical properties, high adhesion, and the ability to form strong bonds with reinforcing fibers (Dilfi KF et al., 2018; Mohanty & Misra, 1995). In this study, epoxy resin acts as a matrix phase that binds jute fibers so that composites with better mechanical properties are formed.

Figure 3. Hardener B type EPH 555

Figure 3 shows Hardener B type EPH 555, which is used as a catalyst in the epoxy resin bonding process (Nugraha et al., 2024; Nugroho et al., 2025). This hardener functions to trigger a polymerization reaction in epoxy resin, so that the resin can harden and form a strong bond with the jute fiber. With the presence of hardeners, the resulting epoxy/jute composite has better and stable mechanical strength.

Composite Manufacturing

The composite manufacturing process begins with the preparation of jute fibers as shown in Figure 4. The fibers are cut and trimmed, then weighed according to a predetermined composition before being placed into the mold. Weighing is carried out so that the number of fibers is according to the volume fraction planned in the manufacture of composites.

Figure 4. Jute Fiber Preparation

The next stage is the preparation of the epoxy resin and hardener as shown in Figure 4, the resin and hardener are weighed according to a predetermined ratio, then mixed until homogeneous. Next, half of the mixture is poured first into the blank mold, then the jute fiber is inserted, and the rest of the mixture is poured back over the surface of the fiber. In this way, an epoxy/jute composite is obtained with an even distribution of matrix and fibers.

Figure 5. Preparation of Epoxy Resin and Hardener for composite printing

In Figure 5, the process of making epoxy/jute composites begins by pouring half of the matrix (resin and hardener) into an empty mold and heating it to reduce pores, then the jute fibers are inserted and leveled. The rest of the matrix is poured over the fibers and reheated, after which the mold is closed and mounted on the frame. The final stage is carried out through a pressing process with a hydraulic jack so that a solid and homogeneous composite panel is formed.

Manufacture of Test Specimens

As a continuation of the composite panel molding process in Figure 6, the test specimen manufacturing stage is carried out by cutting/fabricating the epoxy/jute composite panel into tensile test specimens, flexure tests, and impact tests according to the ASTM standards set.

Figure 6. Prepared tensile, bending, and impact test specimens of epoxy/yute composite panels with variations in fiber direction

Each specimen is shaped and coded based on the type of test, with standard references: ASTM D638 for tensile test, ASTM D790 for flexure test, and ASTM D5942 for the impact test (Hestiawan et al., 2025; Suyuti et al., 2025). Specimens of each fiber orientation are made with the same procedure and quantity so that the results of the mechanical properties evaluation can be compared consistently.

Mechanical Properties Testing

After all specimens are ready, mechanical properties are tested to obtain tensile strength, flexural strength, and impact toughness. Tensile and flexural tests were performed on UTM PM 100 Galdabini (capacity 20 kN, speed 0.5 mm/min) referring to ASTM D638 and ASTM D790, while impact testing was performed using the Charpy tool (pendulum 0.8 kg; arm 0.45 m; maximum angle 140°) in accordance with ASTM D5942. The order in which each test was carried out is shown in Figure 7 (tensile test).

Figure 7. Tensile Test Proces

Result and Discussion

Tensile Test Results

Based on the average value of the tensile test analysis results in Table 1, a summary of the mechanical performance of jute fiber composites is presented in Figure 8. Figure 9 shows the elongation limit (σy) and tensile strength (σu), Figure 10 shows the elongation (ε), while Figure 4.3 shows the elastic modulus (E) for each fiber orientation (0°, 45°, 90°, and random).

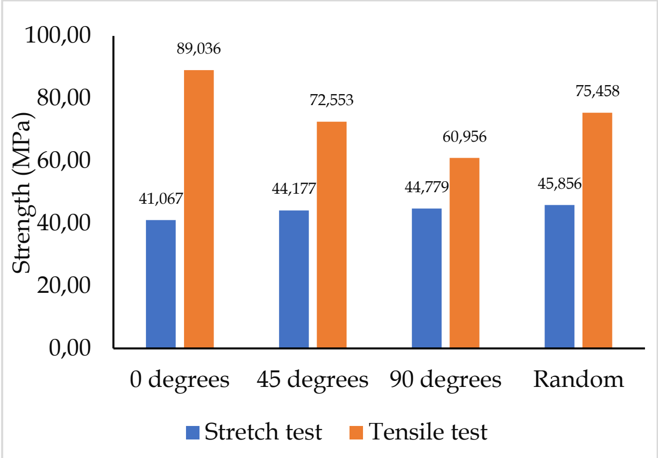

Figure 8. Stretch Limit & Tensile Strength of Jute Fiber Composite

Figure 8 shows that the orientation of the fibers strongly determines the tensile strength (σu) of the epoxy/jute composite. The highest value was obtained at an orientation of 0° = 89.04 MPa, followed by random = 75.46 MPa, 45° = 72.55 MPa, and the lowest at 90° = 60.96 MPa; thus, 0° is about 46% stronger than 90°, 23% stronger than 45°, and 18% stronger than random. This pattern is consistent with the load transfer mechanism: at 0° the fibers are aligned in the direction of load so that the load is effectively transferred along the fiber, while at 45° and above 90° the interface sliding and the dominance of matrix deformation decreases the tensile capacity. In contrast, the elongated limit (σy) is relatively less affected by orientation, being in the range of 41.07 – 45.86 MPa (difference ≈ 12%), which indicates that the early stages of deformation are still controlled by an epoxy matrix in line with the material composition (±90% matrix: 10% fiber). Thus, for tensile-dominant working components, 0° fiber alignment is recommended, while random orientation provides a more uniform directional strength compromise but remains below 0° performance.

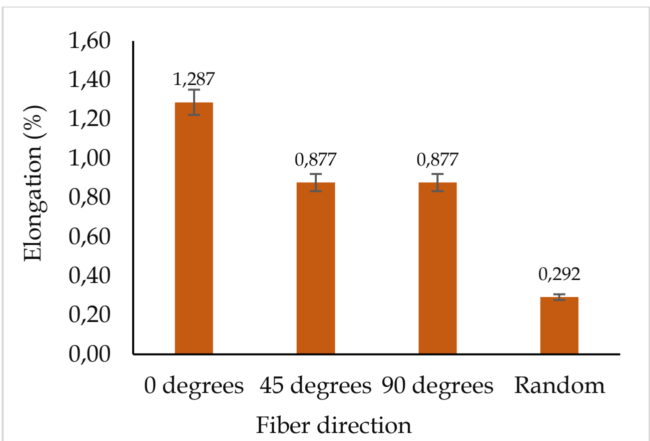

Figure 9. Jute Fiber Composite Elongation

Figure 9 shows that the elongation of epoxy/jute composites is strongly influenced by the orientation of the fibers. The highest values occurred at 0° = 1.287%, while 45° = 0.877% and 90° = 0.877% were at the intermediate level, and the lowest occurred at random = 0.292%. Thus, the 0° orientation has a fracture strain about 47% greater than 45°/90° and more than four times greater than random orientation. Mechanistically, the fibers aligned with the load (0°) transfer the load along the fibers so that the initiation and propagation of cracks in the matrix are delayed; at 45°–90°, component sliding and upright fiber orientation accelerate fiber–matrix debonding, lowering the fracture strain. Random orientation results in a non-uniform stress distribution and local stress concentration, so the ductility is the lowest. This finding is consistent with the trade-off against rigidity (see Figure 4.3): the random panel has the highest modulus, but the elongation is the least (more brittle behavior). Therefore, for applications that prioritize toughness/tenacity, fiber orientation at 0°—or moderate off-axis orientation—is more recommended than random orientation.

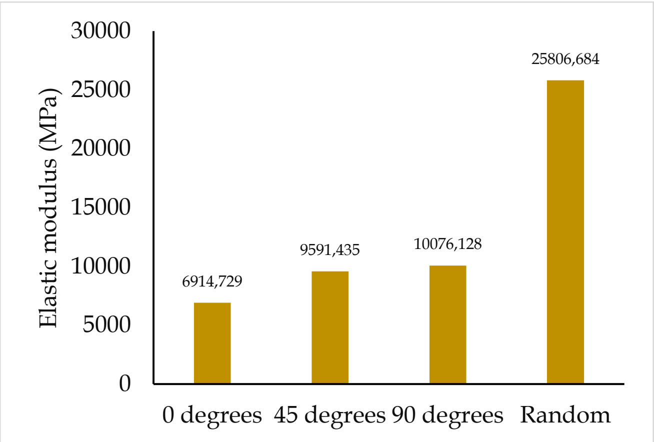

Figure 10. Jute Fiber Composite Elastic Modulus

Figure 10 shows the tendency that the elastic modulus (E) of epoxy/jute composites increases from 0° to 90° and reaches the highest value at random orientation. Quantitatively, the mean E values were 6.91 GPa (0°), 9.59 GPa (45°), 10.08 GPa (90°), and 25.81 GPa (random), respectively. Thus, the random orientation stiffness is approximately 3.7 times higher than 0° (+273%), approximately 2.7 times higher than 45° (+169%), and approximately 2.6 times higher than 90° (+156%); while 90° is only slightly stiffer than 45° (+5%) but higher than 0° (+46%). Mechanistically, the increased stiffness at random orientation can be explained by a multidirectional fiber network that provides deformation-holding pathways from various directions (quasi-isotropic response), so that axial strain is more limited and E is effectively increased. In contrast, at 0° the stiffness is lowest because axial deformation is more likely to occur when the fibers are load-aligned—plus the possible effects of fiber waviness/misalignment and resin-rich domains that degrade the load transfer efficiency. These results are also consistent with the findings in Figure 11, where the random panel exhibits high E but has the least elongation, indicating more brittle behavior, while the 0° orientation is more tenacious but less rigid. For rigidity-prioritizing designs, multidirectional/random fiber orientation is preferred, while tenacity needs are better fulfilled by inline orientation (0°).

The highest tensile strength is achieved at the 0° (89.04 MPa) fiber orientation, well beyond 45, 90°, and random orientations. This indicates optimal load transfer efficiency when the fibers are aligned with the direction of the tensile load. At 0° orientation, the fibers are able to withstand stress along their axis directly. In contrast, the 45° and 90° orientations tend to trigger shear stresses as well as premature cracking in the matrix, thereby lowering the tensile strength.

The yield limit value (σy) at all orientations is in a narrow range (41–46 MPa), reflecting the dominant role of the epoxy matrix in the early stages of deformation. This is consistent with a low fiber volume fraction, where the contribution of the fiber is significant after passing the yield limit.

The highest break strain (ε) was also found at the 0° orientation (1.287%), and a significant decrease was observed at the random orientation (0.292%). This suggests that the orientation of the fibers affects the ductility of the material. Fibers aligned with the load direction slow down the initiation and propagation of cracks, while at random orientations, uneven stress distribution accelerates material failure.

In contrast, the highest elastic modulus (E) was found at random orientation (25.81 GPa), far exceeding the 0° orientation (6.91 GPa). This indicates that the multidirectional fiber structure at random orientation produces quasi-isotropic rigidity, with the ability to limit deformation from various directions. However, the consequence is that the behavior of the material becomes more viscous, characterized by low break elongation.

Thus, the orientation of the fibers strongly determines the dominant character of the mechanical properties of the composite: the 0° orientation excels in strength and ductility, while the random orientation offers high rigidity but is more brittle.

Bending Test Results

To determine the effect of fiber orientation on the bending strength of composites, bending tests were performed on specimens with variations in fiber direction of 0°, 45°, 90°, and random. The test results are shown in Figure 11, which were then averaged for each orientation. This average value is used to compile Figure 4.4, which shows the comparison of the bending strength of jute fiber composites in each direction of fiber orientation.

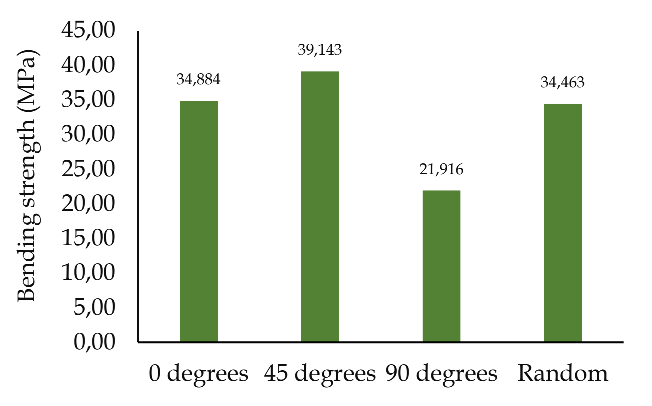

Figure 11. Bending Strength of Jute Fiber Composite

Figure 11, shows the effect of fiber orientation on the bending strength of jute fiber composites. The highest bending strength value was obtained at a 45° orientation of 39.14 MPa, followed by an orientation of 0° (34.88 MPa), random (34.46 MPa), and the lowest at a 90° orientation of 21.92 MPa. The high bending strength at an orientation of 45° indicates that in this direction, the fibers can contribute optimally to the resistance of bending loads. The fibers that form an angle relative to the direction of the bending force can withstand the combination of tensile and compressive stress in the bending zone, thereby increasing the total bending strength. This suggests that the orientation of the fiber is slanted (off axis) and can provide a synergistic effect in the stress distribution.

An orientation of 0° also indicates a high bending strength. In this direction, the fibers are aligned with the long axis of the specimen and also resist the tensile stress on the underside of the specimen during bending loading. However, the contribution of fibers on the compressive side is limited, so the flexural strength is slightly lower than the 45° orientation. Random orientation indicates a bending strength close to the value at 0°, indicating the contribution of fibers in both parallel and oblique directions to the bending direction. Despite the wide spread of the fiber directions, this distribution still contributes to rigidity in various loading directions, resulting in a fairly good flexural response. In contrast, a 90° orientation provides the lowest bending strength because the fibers are perpendicular to the direction of the bending stress and are unable to contribute effectively to resisting tensile or compressive forces. More load is borne by the matrix, which has lower mechanical properties than fibers, thus lowering the bending performance of composites.

Overall, these results suggest that the orientation of the fibers greatly affects the stress transfer mechanism during bending. The 45° orientation provides the optimal combination of force and load distribution, while the 90° orientation is the least effective. The selection of the fiber direction should be adapted to the dominant load type in structural applications to optimize the flexural strength of the composite.

Impact test results

To evaluate the robustness of composites in absorbing impact energy, impact tests were performed on specimens with variations in fiber direction of 0°, 45°, 90°, and random. The test results data are shown in Table 1, which contains the impact strength values of each sample. The average values of each fiber orientation are then used to compile Figure 4.5, which shows the comparison of the impact strength of jute fibers based on the direction of fiber orientation.

Figure 12, shows that the impact strength of jute fiber composites is greatly influenced by the orientation of the fibers. The highest impact strength value was obtained at a random orientation of 6.409 kJ/m, followed by an orientation of 45° (5.63 kJ/m), 0° (4.406 kJ/m), and the lowest at 90° of 2.473 kJ/m. The high impact strength at random orientation suggests that the spread of fibers in various directions can improve the material's ability to absorb impact energy.

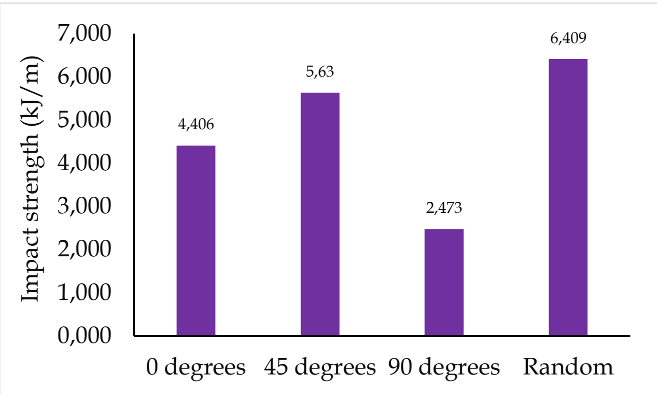

Figure 12. Impact Strength of Jute Fiber Composite

The multidirectional orientation of the fibers allows for a more even distribution of stress during a collision, so that cracking and crack propagation can be delayed or dispersed. This makes composites with random fiber orientation more resistant to impact damage. At an orientation of 45°, the fibers are in an inclined position relative to the direction of impact, which allows them to contribute effectively to resisting the combination of tensile and shear forces. This explains the high impact strength achieved, although it is lower than that of random orientation. In contrast, a 0° orientation results in a lower impact strength because the fibers are aligned with the direction of the impact stress and are more prone to delamination or debonding along the direction of impact.

Although fibers in this direction are strong against tensile forces, their configuration is less effective in absorbing dynamic and multi-directional impact energy (Chaudhary et al., 2024; Venkatesh et al., 2023). A 90° orientation indicates the lowest performance because the fibers are perpendicular to the direction of impact. Under these conditions, the fibers cannot directly contribute to energy absorption, and the load is fully borne by the matrix which has lower toughness (Salman, 2020; Santulli et al., 2013; Shahinur et al., 2022; Singh et al., 2018; Wang et al., 2019). This makes it easier for interlaminar damage such as debonding and matrix cracking to occur.

Overall, the data trends in Figure 12 indicate that the impact toughness of composites is largely determined by the extent to which the orientation of the fibers can disperse and absorb impact energy. Therefore, for applications requiring high impact resistance, a random or off-axis fiber configuration such as 45° is more recommended than an orientation of the fiber that is parallel or perpendicular to the direction of the impact load.

Table 1. Tensile test results

Composite		Specimen Dimensions			Tensile Test Data			Mechanical Properties			
Direction	Code	L_o (mm)	H (mm)	W (mm)	Li (mm)	Fy (N)	F_u (N)	σ_y (MPa)	σ_u (MPa)	ε %	E (MPa)
0°	A11	57	4.40	13.45	57.7	2280	4840	38.53	81.78	1.23	6659.59
0°	A12	57	4.50	13.30	57.75	2460	5400	41.10	90.23	1.32	6857.14
0°	A13	57	4.30	13.45	57.75	2520	5500	43.57	95.10	1.32	7227.46
Average								41.07	89.04	1.29	6914.73
45°	A21	57	4.00	13.00	57.8	2240	4060	43.08	78.08	1.40	5562.98
45°	A22	57	3.70	13.50	57.4	2300	3480	46.05	69.67	0.70	9927.93
45°	A23	57	3.90	13.35	57.3	2260	3640	43.41	69.91	0.53	13283.40
Average								44.18	72.55	0.88	9591.43
90°	A31	57	3.85	12.90	57.9	2200	2920	44.30	58.79	1.58	3723.61
90°	A32	57	3.75	12.70	57.4	2200	2960	46.19	62.15	0.70	8856.69
90°	A33	57	4.00	13.00	57.2	2280	3220	43.85	61.92	0.35	17648.08
Average								44.78	60.96	0.88	10076.13
Random	A41	57	3.95	13.90	57.2	2320	3780	42.25	68.85	0.35	19621.16
Random	A42	57	3.90	12.60	57.1	2400	4020	48.84	81.81	0.18	46630.04
Random	A43	57	3.90	12.80	57.2	2320	3780	46.47	75.72	0.35	21580.53
Average								45.86	75.46	0.29	25806.68

(a) (b)

Figure 13. Environmental Testing in soaked water: (a) before soaking; and (b) after soaking

Environmental testing

There are no changes in shape that occur before and after being soaked in seawater. Islam et al. (2025) reported that the tensile strength of jute–coconut coir composite was 57.104 MPa at 0° fiber orientation, while this study reached 89 MPa—about 56% higher. Meanwhile, the jute woven composite study reported an impact energy of 8.7–16.6 kJ/m², which is higher than the results of this study (6.41 kJ/m²). The difference is likely due to different fiber fractions.

Conclusion

The orientation of fibers significantly influences the mechanical performance of epoxy–jute composites. When the fibers are aligned at a 0° orientation, the composite exhibits the highest tensile strength of 89.04 MPa and a strain of 1.287%. This configuration indicates efficient load transfer and good ductility, making it ideal for applications that experience longitudinal load paths, such as panels or the hull of a crewboat. Conversely, a random fiber orientation achieves the highest elastic modulus of 25.81 GPa and the greatest impact resistance of 6.409 kJ/m. This type of orientation enhances rigidity and resistance to wave impacts, although the reduced elongation makes the material more brittle. Therefore, it is suitable for hull areas that require high stiffness and impact resistance. Meanwhile, the 45° fiber orientation provides the highest bending strength of 39.14 MPa, along with balanced toughness. The beveled fiber arrangement effectively withstands a combination of tensile and shear stresses during bending loads. Based on these characteristics, the optimal design for a crewboat hull should employ an integrated laminate of 0°/±45°/random orientations to simultaneously maximize strength, rigidity, and toughness.

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Authors contributions
This article was written by four authors, namely M. S., H. P. N., S., and M. A. S. All authors contributed to every stage of the research because this research was carried out together.

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Conflict of Interest
The authors declare that they have no conflict of interest related to this study.

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