Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan
(Kapal: Journal of Marine Science and Technology)
journal homepage : http://ejournal.undip.ac.id/index.php/kapal
2301-9069 (e)
1829-8370 (p)

Mechanical Strength Properties of Resin-Coated Cardboard as a Viable Alternative to Glass Fiber in the Construction of Fiberglass Vessels

Dwi Putra Yuwandana[1)*)], Yesnina Budiarti[1)], Yopi Novita[1)], Didin Komarudin[1)]

[1)] Fisheries Resources Utilization Department, Faculty of Fisheries and Marine Sciences, IPB University, Bogor-West Java 16680, Indonesia
[*)] Corresponding Author : dwiputra@apps.ipb.ac.id

Article Info

Keywords:
Bending;
Fiberglass;
Modulus of Elasticity;
Vessel;
Tensile.

Article history:
Received: 10/01/2025
Last revised: 02/07/2025
Accepted: 11/08/2025
Available online: 20/08/2025
Published: 31/10/2025

DOI:
https://doi.org/10.14710/kapal.v22i3.70143

Abstract

Fiberglass vessels produce considerable environmental waste due to the non-biodegradable nature of glass fiber materials, necessitating the exploration of biodegradable alternatives. Given the abundance of cardboard waste in Indonesia, this study investigates its potential as a substitute for glass fiber in fiberglass boat construction. In the process of producing cardboard sheets, during the pulping stage using a blender, the 716 grams of cardboard are mixed with 10 to 15 liters of water. The research aims to evaluate resin-coated cardboard's physical properties and mechanical strength, comparing them to the mechanical strength standards set by the Indonesian Classification Bureau (BKI). Utilizing an experimental methodology with descriptive and comparative analysis, the results indicate that resin-coated cardboard possesses robust, lightweight, and water-resistant characteristics. The four-layer treatment achieved the highest tensile strength and bending strength values of 37.61 MPa and 62.23 MPa, respectively. In comparison, the three-layer treatment yielded a maximum modulus of elasticity of 145.80 MPa. Although the mechanical properties did not meet the minimum standards established by BKI, the resin-coated cardboard demonstrates potential as an alternative material for plywood coatings in the superstructures of vessels.

1. Introduction

Fiber Reinforced Plastics (FRP) is a category of structural composite materials that utilize fiberglass or carbon fibers as reinforcement [1]. The use of fiberglass in ship construction has become a substitute for traditional wood, which has been in declining supply. This reduction in wood availability for shipbuilding has increased costs for wooden vessels. As a result, there is a growing trend toward using fiberglass in shipbuilding applications, as it offers a more sustainable and economically viable alternative.

Fiberglass boats effectively increase the productivity of fishermen's catches and reduce fishing costs [2]. These boats have a longer service life, high strength, corrosion resistance, and are lightweight. Additionally, fiberglass boats' production and maintenance costs are significantly lower than those of wooden boats, and they do not require repeated painting. Furthermore, fiberglass materials are more economical than wood or metal for constructing small boats [3]. However, despite these advantages, fiberglass boats have certain disadvantages. One primary concern is the waste generated, which poses a significant environmental threat due to the difficulty of decomposing fiberglass materials. The incineration of fiberglass boat waste is never complete and invariably releases harmful gases, such as nitrogen oxide (NOx) [4]. Efforts to dispose of fiberglass ship waste through incineration produce hazardous gases and leave behind a significant amount of residue, specifically ash. The ash content obtained from burning fiberglass ship waste was 15.97% per gram of material [4].

The issue of glass fiber waste generated from ship production processes may be addressed by minimizing reliance on glass fiber materials. Alternatives with comparable strength to glass fiber while being biodegradable and readily available are essential [19 jd 5]. One promising candidate for such an alternative is cardboard waste, specifically corrugated cardboard, which shows potential as a substitute material due to its favorable mechanical properties and environmental degradability. This exploration into the use of corrugated cardboard aims to mitigate the environmental impact of glass fiber waste while providing a sustainable solution for shipbuilding applications.

Cardboard is derived from sawdust or wood pulp containing a significant amount of cellulose. The chemical composition of cardboard consists of approximately 45% cellulose, 35% hemicellulose, 4% lignin, and 10% extractive substances. This composition contributes to both the strength and biodegradability of cardboard. When sheets of cardboard are combined, they exhibit increased solidity and strength, although they do have specific load limitations. In the process of producing cardboard sheets, approximately 716 grams of cardboard waste, equivalent to two whole pieces of corrugated cardboard, are required. During the pulping stage using a blender, the 716 grams of cardboard are mixed with 10 to 15 liters of water.

By the requirements set by the Indonesian Classification Bureau (BKI), the bending properties of cardboard and resin sandwich materials indicate their suitability for specific components in fiberglass ship construction [6]. Therefore, cardboard presents a viable alternative to glass fiber in fiberglass vessels. If the utilization of cardboard waste is validated as a substitute material for glass fiber, it could significantly reduce the environmental impact of both glass fiber and cardboard waste. This study aims to characterize composite materials derived from resin-coated cardboard waste and to evaluate their properties in comparison to the standards for ship construction materials established by the Indonesian Classification Bureau (BKI).

2. Method

This research was conducted from February to May 2024 utilizing an experimental methodology. The preparation of material test samples was performed in the ship laboratory on the 5th floor of the Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Science (FFMS), IPB University. Subsequently, mechanical testing was carried out in the testing facility on the 3rd floor of the same department's laboratory. The tools and materials utilized in the preparation and testing of specimens included scissors, glass, blenders, molds, basins, scrapers, grinders, brushes, universal testing machines (UTM) 10 tons, resins yucalac 157, catalysts, corrugated cardboard, talc, and mirror glaze. Cardboard sheets can be produced using 716 grams of cardboard waste, equivalent to two complete corrugated cardboard boxes. In the process of producing cardboard sheets, approximately 716 grams of cardboard waste, equivalent to two whole pieces of corrugated cardboard, are required. During the pulping stage using a blender, the 716 grams of cardboard are mixed with 10 to 15 liters of water. Corrugated cardboard is a composite material characterized by its board-like structure, which contains internal cavities. The structural integrity of corrugated cardboard is enhanced by the number of layers of cavities; an increase in the number of layers correlates with improved strength and durability of the material [7].

2.1. Research Procedure

This research was conducted in three stages: 1) literature review, 2) fabrication of test samples using resin-coated cardboard material, and 3) mechanical testing, which included tensile and bending tests. The literature review aimed to gather standards for fiberglass boat construction, providing a reference for evaluating the technical capabilities of the resin-coated cardboard composite material. Test samples were produced under three treatment conditions, namely:

1. Treatment 1 (T_1) consisted of a composition of three layers of cardboard coated with resin.
2. Treatment 2 (T_2) involved a composition of four layers of cardboard coated with resin.
3. Treatment 3 (T_3) comprised a composition of six layers of cardboard coated with resin.

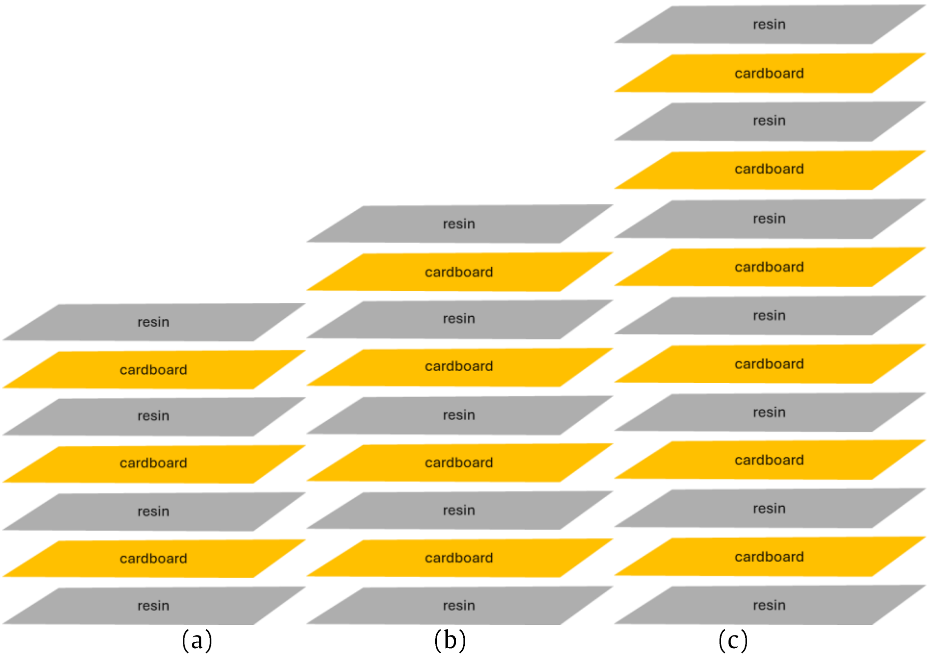


Figure 1. The layer arrangements in the test samples: (a) three layers, (b) four layers, and (c) six layers.

The selection of three, four, and six layers for the test samples corresponds to the different sections of the hull, including the side shell, bottom shell, and upper deck, by SNI [8]. As outlined by [9], specimen testing is conducted for each position within the fiberglass hull lamination.

The cardboard sheet samples coated with resin was fabricated using the hand lay-up method, a fundamental fiber boat construction technique. This method is recognized as the simplest and most straightforward lamination approach [10]. The resin was mixed with a catalyst and talc in a specific ratio during the coating process. Following the recommendations of [11], the optimal resin-to-catalyst ratio was maintained at 100 ml of resin to 0.2 ml of catalyst.

1. Treatment 1 (T_1) utilized 400 ml of resin, 200 grams of talc, and 0.8 ml of catalyst.
2. Treatment 2 (T_2) incorporated 500 ml of resin, 250 grams of talc, and 1 ml of catalyst.

3. Treatment 3 (T_3) comprised 700 ml of resin, 350 grams of talc, and 1.4 ml of catalyst.

The dimensions of the resulting samples were 30 cm x 30 cm, with the thickness adjusted according to the number of layers in each treatment. Each layer consisted of a resin-cardboard-resin configuration, as shown in Figure 1. Furthermore, each treatment included six samples to allow for treatment repetitions by SNI [8]. The dimensions of each sample were determined based on the reference standards set by [9], with the size tailored to the specific tests conducted (tensile and bending tests).

1. The tensile test utilized samples with dimensions of 250 mm in length, 25 mm in width, and a thickness (h) that varied according to the treatment. An illustration of the dimensions for the tensile test sample is presented in Figure 2.
2. The bending test employed samples with dimensions of (20 x h) mm in length, 15 mm in width, and a thickness (h) corresponding to the treatment. An illustration of the dimensions for the bending test sample is shown in Figure 3.

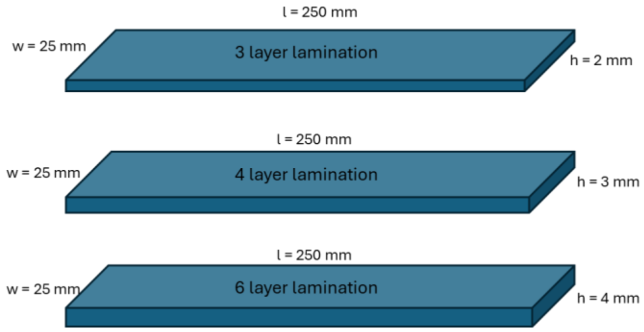


Figure 2. Illustration of the dimensions for the tensile test sample.

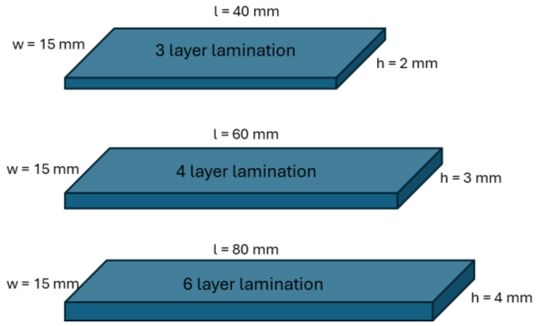


Figure 3. Illustration of the dimensions for the bending test sample.

2.2. Sample Testing

a. Tensile Test

Tensile testing is employed to ascertain the material's tensile strength, which reflects a test sample's ability to withstand tensile forces prior to failure. This tensile test serves as a complementary assessment, providing essential information for the material's fundamental design and strength evaluation [12]. The tensile strength and fracture strain values are calculated using the following formulas [13].

$$\sigma = \frac{P}{b \times h} = \frac{P}{A_0} \tag{1}$$

$$= \frac{l_i - l_0}{l_0} \times 100\% = \frac{\Delta l}{l_0} \times 100\% \tag{2}$$

where:

σ = Tensile strength (N/mm^2, Mpa)	Ao = Initial cross-sectional area (mm)
ε = Maximum strain (%)	li = Measurement length after fracture (mm)
P = Maximum load (N)	lo = Initial measurement length (mm)
b = Specimen width (mm)	Δl = The magnitude of the specimen extension (mm)
h = Specimen thickness (mm)	

b. Bending Test

The bending test is a method used to evaluate the strength of a material under load and to assess the elasticity of the resulting joints. The outcomes of this bending test are reflected in the flexural strength of the tested material. The flexural stress and strain values calculations are conducted using the following formula [14].

$$\sigma f = \frac{3FL}{2bh^2} \tag{3}$$

$$= \frac{600sh}{L^2} \times 100\% \tag{4}$$

where:

σ f = Flexural stress (N/mm², Mpa)
ε = Maximum strain (%)
FL = Maximum Force (N)
b = Specimen width (mm)
h = specimen thickness (mm)
s = Deflection (mm)

c. Modulus of Elasticity

Flexural testing is a method employed to determine the maximum load that a test sample can withstand. Flexural strength typically correlates with the elongation value at break obtained from the tensile strength test [15]. Calculating the modulus of elasticity is performed using the following formula [13].

$$E = \frac{\sigma}{\varepsilon} \tag{5}$$

where:

E = Modulus of elasticity (N/mm², Mpa)
σ = Tensile strength (N/mm², Mpa)
ε = Maximum strain (%)

2.3. Data Analysis

The data analysis employed in this study is descriptive analysis, which provides an overview of the physical properties of the resin-coated cardboard material, including its physical form, specific gravity, and water resistance. This analysis also encompasses the results of mechanical test values, specifically tensile strength, bending strength, and modulus of elasticity. Additionally, a descriptive-comparative analysis is utilized to compare the test results of each sample (tensile strength, bending strength, and modulus of elasticity) against the standards established by BKI in 2022. According to [9]), the test results for glass fiber or fiberglass materials must meet or exceed the values specified in Table 1.

Table 1. Minimum Values of Mechanical Properties of Fiberglass Based on BKI Standards

Property	Minimum Value (MPa)
Tensile Strength	85
Modulus of Elasticity	6350
Bending Strength	152

3. Results and Discussion

3.1. Physical Condition of Resin-Coated Cardboard Composite Material

The resulting resin-coated cardboard test specimens exhibit a slightly flexible and rigid texture; however, each treatment shows some differences (Figure 4). The mechanical properties of fiberglass laminates, including their strength, are influenced by multiple variables [16]. These factors encompass the parameters of the lamination process, the specifications and calibration of the processing equipment, the proficiency of the operators, and the environmental conditions at the site of fabrication. In general, fiberglass boats possess hard yet slightly flexible properties. This is attributed to the material used, specifically talc, which acts as a mixture in the fiberglass dough to enhance hardness and flexibility [17]. Furthermore, observations were made regarding the effect of the number of layers on the physical condition of the material samples. Table 2 presents the physical properties of the test material with varying numbers of layers.

Table 2 indicates that each treatment exhibits distinct physical characteristics, with a minimum specimen thickness of 2 mm; specimens thinner than this threshold are unsuitable for bending tests due to their excessive elasticity. The average weights for Treatments 1, 2, and 3 are 18.5 grams, 19.5 grams, and 23.3 grams, respectively, based on the mean weight of six test specimens for each treatment. Notably, Treatment 2 demonstrates properties like conventional glass fibers, characterized by rigidity combined with slight elasticity, enhancing its fracture resistance. The coloration across treatments ranges from light transparent to dark opaque, facilitating the assessment of thickness and layering. Additionally, all treatments exhibited uniform water resistance, as none of the specimens absorbed water after being submerged for 72 hours in a sealed container.

Figure 4. Example of resin-coated cardboard test specimen

Table 2. Comparison of Physical Conditions of Test Samples for Each Treatment

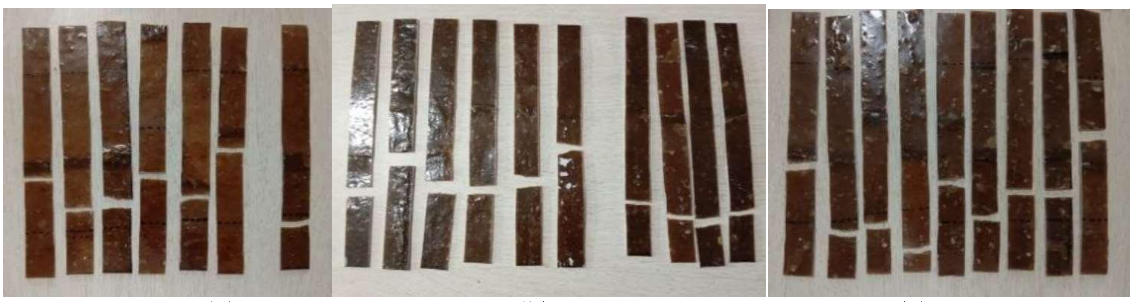
Physical properties	Treatment 1 (T1)	Treatment 2 (T2)	Treatment 3 (T3)
Thickness	2 mm	3 mm	4 mm
Weight	18.5 gr	19.5 gr	23.3 gr
Stiffness	flexible	stiff and slightly flexible	very stiff and easy to break
Color	transparent golden yellow	transparent brown	dark brown
Water resistance	water resistant	water resistant	water resistant

3.2. Mechanical Strength Value of Resin Coated Cardboard Combination Material

a. Tensile strength

Tensile testing was conducted for each treatment, with six repetitions performed to determine the average maximum load the test samples could withstand before failure. This testing method is classified as destructive, involving applying a continuous load to the test samples until they fracture. The results from the tensile tests indicate that the samples undergo significant deformation from their initial state prior to failure. The outcomes of the tensile testing are illustrated in Figure 5, providing a visual representation of the deformation and ultimate failure characteristics of the materials tested.

The data presented pertain to test samples that fractured at the midpoint, aligning with the criteria established by [9], which stipulates that acceptable test results occur when the sample breaks centrally. Conversely, fractures occurring at the clamp regions are deemed unacceptable, as they may result from improper installation or excessive gripping force rather than the applied load. The tensile strength of a material serves as an indicator of the laminate construction's capacity to withstand tensile forces. The results of the tensile tests for each treatment are summarized in Table 3, providing a comprehensive overview of the material's performance under tensile loading conditions.



(a) (b) (c)

Figure 5. Form of tensile strength test results: (a) Treatment 1 (T1); (b) Treatment 2 (T2); (c) Treatment 3 (T3)

Table 3. Average data of tensile test results on test samples for each treatment

Treatment	μ P max (N)	Δl (mm)	μ σ (MPa)	SE	μ ε (%)
T1	827.26	4.73	27.58	0.77	0.19
T2	1692.65	8.84	37.61	2.95	0.35
T3	1500.76	6.65	25.01	0.28	0.27

Note: μ P max = average maximum load; Δl = extension of test sample; μ σ = average tension; SE = standard error; μ ε = average strain

The tensile test results indicate that the test material for Treatment 1 (T1) exhibits a tensile strength of 0.19% and an average fracture strength of 27.58 MPa, corresponding to a load of 827.26 N. This value is notably lower than the tensile strength specified in SNI [8], which states that the tensile strength of 3-layer fiberglass specimens should be 112.85 MPa. Treatment 2 (T2) demonstrates a tensile strength of 0.35% and an average fracture strength of 37.61 MPa under a load of 1692.65 N. The tensile strength of fiberglass with 4-layer lamination is reported to be 3.65%, with a tensile strength of 148.93

Mpa [18]. For Treatment 3 (T3), the tensile strength reaches 0.27%, with an average fracture strength of 25.01 MPa at a load of 1500.76 N. Fiberglass with 6-layer lamination on the bottom plate achieves a tensile strength of 6.05% and a tensile strength value of 186.64 MPa, while the keel plate exhibits a tensile strength of 4.43% with a tensile strength of 136.48 Mpa [18]. The average tensile strength performance across the three treatments is illustrated in Figure 6.

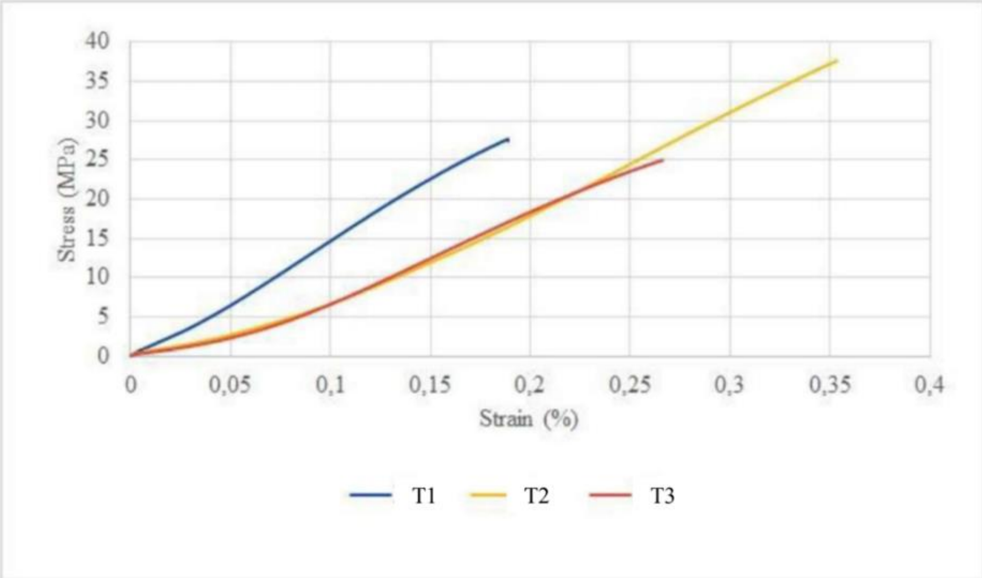


Figure 6. Average tensile strength performance values of the three test samples for the three treatments

Treatment 2 (T2) recorded the highest tensile strength value, which utilized a 4-layer resin-coated cardboard. Treatments 1 and 2 demonstrated an increase in tensile strength. An increase in layers within a material typically correlates with enhanced tensile strength; however, thickness alone does not guarantee superior tensile strength. Instead, the fiber type and lamination configuration play a more critical role in determining tensile strength. In contrast, Treatment 3 (T3) exhibited a decrease in tensile strength, indicative of an anomaly. This reduction can be attributed to the continued use of the hand lay-up method for material fabrication, which may result in inconsistencies among the test samples. A notable limitation of this method is that it often leads to suboptimal bonding between the layers of fiber and resin in the constructed hull [10].

b. Modulus of elasticity

The modulus of elasticity is intrinsically linked to a material's stress and strain characteristics. It can be calculated using the stress and strain values obtained from tensile testing. The modulus of elasticity indicates a material's stiffness; a higher modulus of elasticity signifies greater stiffness [12]. The modulus of elasticity values for each treatment are presented in Table 4, offering a comprehensive overview of the stiffness properties associated with the different material treatments.

Table 4. Elastic modulus value of test samples for each treatment

Treatment	$\mu\ \sigma$ (MPa)	$\mu\ \varepsilon$ (%)	μ E (MPa)	SE
T1	27.58	0.19	145.16	4.10
T2	37.61	0.35	107.46	8.34
T3	25.01	0.27	92.63	1.07

The average modulus of elasticity for each treatment is as follows: Treatment 1 (T1) exhibits an average of 145.16 MPa, the highest among the evaluated treatments. Treatment 2 (T2) has an average modulus of 107.46 MPa, while Treatment 3 (T3) shows an average of 92.63 MPa. These results indicate that Treatment 1 (T1) possesses greater stiffness compared to Treatments 2 (T2) and 3 (T3). Consequently, Treatment 1 (T1) demonstrates the highest resistance to deformation, whereas Treatment 3 (T3) exhibits the lowest resistance. Therefore, Treatment 1 (T1), utilizing 3-layer resin-coated cardboard, offers the best material quality regarding flexural strength compared to the other treatments.

c. Bending Strength

Bending testing shares similarities with tensile testing, as both are destructive methods where the test sample is subjected to continuous loading until it undergoes deformation and ultimately fractures. All test samples in the bending tests exhibited deformation from their initial condition until failure occurred, with fractures consistently occurring in the middle of the specimens. This observation aligns with the guidelines set forth [9], which state that acceptable test results are those in which the specimen breaks within the middle third; fractures occurring outside this region render the results invalid. The bending strength of a material reflects the laminate construction's ability to withstand applied loads. The post-bending test condition of the samples is depicted in Figure 7. The bending test results for each treatment are detailed in Table 5, while the average tensile strength performance across the three treatments is illustrated in Figure 8.

(a) (b)

Figure 7. The shape of the test specimen after testing: (a) broken test specimen, (b) bent test specimen

Table 5. Average data of bending test results on test samples for each treatment

Treatment	µ P max (N)	Δl (mm)	µ σ (MPa)	SE	µ ε (%)
T1	37.15	8.91	37.13	2.59	6.68
T2	93.35	3.94	62.23	10.08	1.86
T3	40.29	16.67	20.12	2.54	6.21

Note: µ P max = average maximum load; Δl = extension of test sample; µ σ = average tension; SE = standard error; µ ε = average strain

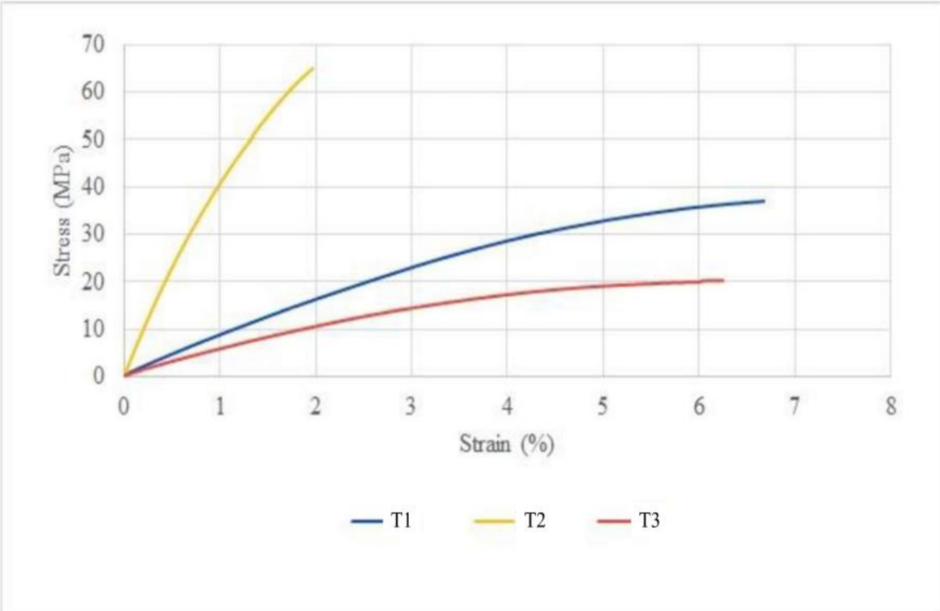


Figure 8. Average bending strength performance values of the three test samples for the three treatments

Each treatment exhibited distinct average bending strength values. Treatment 2 (T2) recorded the highest average bending strength at 62.23 MPa, with a strain of 1.86%, and could withstand a load of 93.35 N. Following T2, Treatment 1 (T1) showed an average bending strength of 37.13 MPa and a strain of 6.68%, enabling it to withstand a load of 37.15 N. In contrast, Treatment 3 (T3) displayed the lowest average bending strength, measuring 20.12 MPa, with a strain of 6.21%, and could withstand a load of 40.29 N. The variation in bending strength values can be attributed to the uneven distribution of resin across each layer, which resulted in cavities within the laminate. These cavities act as stress concentrators, making the test specimens more susceptible to fracture when subjected to loading.

3.3. Comparison of Mechanical Strength of Resin Coated Cardboard Combination Material with BKI Mechanical Strength Standard

The mechanical strength of the resin-coated cardboard composite material was evaluated and compared with the BKI standard to assess its compliance with established criteria. The results of this comparison are presented in Table 6.

Table 6. Comparison of mechanical strength of resin-coated cardboard material with BKI standards

Mechanical Properties	Minimum BKI Value for FRP (MPa)	Treatment 1 (MPa)	Treatment 2 (MPa)	Treatment 3 (MPa)
Tensile Strength	85	27.58	37.61	25.01
Modulus of Elasticity	6350	145.16	107.46	92.63
Bending Strength	152	37.13	62.23	20.12

The BKI standard referenced pertains to the mechanical properties required for marine vessels' side shell, bottom shell, and upper deck. Based on key mechanical properties such as tensile strength, modulus of elasticity, and bending strength, all test samples failed to meet the minimum standards set forth by BKI. However, considering the material thickness and water-resistant properties, the 4-layer laminated cardboard (Treatment 2, T2) still exhibits potential as a viable material for plywood coatings in ship superstructures. The construction of ship superstructures typically involves 12 mm multiplex material reinforced with wood to enhance durability [19]. The structure is then laminated with a 2-3 mm layer of fiberglass to improve resilience and resistance to damage [20].

4. Conclusion

The resin-coated cardboard composite in Treatment 1 (T1) has a mass of 18.5 grams, a thickness of 2 mm, a transparent golden-yellow color, and exhibits flexibility. Treatment 2 (T2) weighs 19.5 grams, has a thickness of 3 mm, is a transparent brown color, and is stiff yet retains slight flexibility. Treatment 3 (T3) weighs 23.3 grams, has a thickness of 4 mm, is dark brown and opaque, and is highly stiff, with a tendency to break easily. Despite these differences in physical properties, all three treatments share a common characteristic of water resistance. The mechanical properties, including tensile strength, bending strength, and modulus of elasticity, vary across the three treatments. The average tensile strength for Treatments 1, 2, and 3 is 27.58 MPa, 37.61 MPa, and 25.01 MPa, respectively. The average bending strength values for the same treatments are 37.13 MPa, 62.23 MPa, and 20.12 MPa, respectively. The average modulus of elasticity for Treatments 1, 2, and 3 is 145.80 MPa, 106.39 MPa, and 94.00 MPa, respectively. 3). The tensile strength, bending strength, and modulus of elasticity values measured for all treatments fall below the minimum requirements for the hull sections of the ship as stipulated by the BKI standards.

Acknowledgment

The authors would like to thank the Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences (FFMS), IPB University, for providing the material testing facilities utilized in this study.

References

[1] E. Widyaningsih, B. Herbudiman, and S. Hardono, "Kajian Eksperimental Kapasitas Sambungan Material Fiber Reinforced Polymer," *RekaRacana: Jurnal Teknik Sipil*, vol. 2, no. 3, pp. 29–38, 2016, doi: https://doi.org/10.26760/rekaracana.v2i3.29
[2] M. Imron, D. A. Soeboer, and R. Ramadhoni, "Analisis Tekno-Ekonomi Laminasi Kapal PSP 01 di Palabuhanratu, Jawa Barat," *ALBACORE Jurnal Penelitian Perikanan Laut*, vol. 2, no. 3, pp. 315–332, Oct. 2018, doi: https://doi.org/10.29244/core.2.3.315-332.
[3] S. Pambudi, M. Asrofi, A. Triono, M. Z. Bin Tsabit, and N. A. Murtadho, "Perahu Fiberglass Untuk Penunjang Alat Penangkap Ikan dan Sektor Parawisata Desa Sumberasri Kecamatan Purwoharjo Banyuwangi," *SELAPARANG Jurnal Pengabdian Masyarakat Berkemajuan*, vol. 4, no. 3, p. 723, Oct. 2021, doi: https://doi.org/10.31764/jpmb.v4i3.4843.
[4] N. Rahmawati, Y. Novita, D. Komarudin, and M. D. Iskandar, "Study of FRP Ship Waste Composite Materials and Its Combustion Residue," *International Journal of Marine Engineering Innovation and Research*, vol. 9, no. 1, pp. 146–152, Mar. 2024, doi: https://doi.org/10.12962/j25481479.v9i1.19913.
[5] Oni. Ramadhoni and Pardi, "The Use of Composit Materials Alternative Fiberglass (Coco Fibers & Rags) on Fiberglass Ship in Traditional Shipyards Bengkalis Regency", *Kapal*, vol. 12, no. 3, pp. 121-132, Aug. 2015, doi: https://doi.org/10.14710/kpl.v12i3.8362
[6] Suzdayan and Romadhoni, "Pengaruh Kekuatan Struktur Material Komposit Sandwich Plate Fiberglass Terhadap Biro Klasifikasi," *Inovtek Polbeng*, vol. 8, no. 1, pp. 31–39, 2018, doi: https://doi.org/10.35314/ip.v8i1.266.
[7] D. P. Santoso and M. Wibowo, "Perancangan Mebel untuk Desain Interior Rumah Susun dengan Material Cardboard (studi kasus: Rusun Wonorejo Surabaya)," *Intra*, vol. 6, no. 2, pp. 10–17, 2018.
[8] B. S. N. [BSN], *SNI 8793:2019 Tentang Kapal Perikanan Kapal Ukuran 3 GT Berbahan Fibreglass Reinforced Plastic (FRP)*. Jakarta: Badan Standardisasi Nasional, 2019.
[9] Biro Klasifikasi Indonesia, *Guidance for FRP and Wooden Fishing Vessel up to 24 M Consolidated Edition 2022*. Jakarta: Biro Klasifikasi Indonesia, 2022.
[10] S. Ardhy, M. E. E. Putra, and I. I. Islahuddin, "Pembuatan Kapal Nelayan Fiberglass Kota Padang dengan Metode Hand Lay Up," *Rang Teknik Journal*, vol. 2, no. 1, pp. 143–147, Apr. 2019, doi: https://doi.org/10.31869/rtj.v2i1.1103.
[11] S. Suryana and R. E. Putra, "Optimasi formulasi resin-katalis dalam pembuatan media pembelajaran bioplastik tumbuhan thallus," *Kandaga*, vol. 1, no. 2, pp. 46–55, 2019, [Online]. Available: https://jurnal.unpad.ac.id/kandaga/article/view/24081/12829
[12] P. Tambunan, H. Yudo, and P. Manik, "Analisa Teknis Papan Laminasi Serat Bambu Petung Dengan Serat Fiberglass Woven Roving Untuk Material Kulit Kapal," *Jurnal Teknik Perkapalan*, vol. 10, no. 2, pp. 21–28, 2022.
[13] M. T. Marantika, I. Sujana, and M. Ivanto, "Analisa uji tarik komposit berpenguat serat daun nanas dengan variasi susunan menggunakan perlakuan alkali," *Jurnal Teknologi Rekayasa Teknik Mesin*, vol. 3, no. 1, pp. 62–68, 2022.
[14] H. Yunasdi, "Uji Bending," *Jurnal Praktikum Material Teknik*, vol. 67, pp. 1–7, 2020.

[15] Silvia, Castiqliana, and Halimatuddahliana, "Pengujian Kekuatan Tarik dan Kekuatan Lentur Komposit Hibrid Plastik Bekas Kemasan Gelas Jenis Polipropilena/Serbuk Kayu Kelapa Termodifikasi/Serbuk Serat Kaca Tipe E," *Jurnal Teknik Kimia USU*, vol. 4, no. 3, pp. 1–5, Sep. 2015, doi: https://doi.org/10.32734/jtk.v4i3.1473.

[16] I. Marzuki, A. Zubaydi, and B. Ma'ruf, "Kajian Penerapan Aturan Klasifikasi Pada Laminasi Struktur Konstruksi Lambung Kapal Ikan Fiberglass 3 GT," *Wave: Jurnal Ilmiah Teknologi Maritim*, vol. 11, no. 1, pp. 15–22, 2017, doi: https://doi.org/10.29122/jurnalwave.v11i1.2055.

[17] A. H. Siregar, B. A. Setyawan, and A. Marasabessy, "Komposit Fiber Reinforced Plastic sebagai Material Bodi Kapal Berbasis Fiberglass Tahan Api," *Bina Teknika*, vol. 12, no. 2, pp. 261–266, Aug. 2017, doi: https://doi.org/10.54378/bt.v12i2.82.

[18] F. Atthoriq, "Kekuatan konstruksi lambung kapal FRP galangan kapal rakyat UD Wahyu Asih Fiberglass, Kebumen-Jawa Tengah," IPB University, 2023.

[19] P. Pardi and A. Afriantoni, "Fabrikasi Kapal Fiberglass Sebagai Bahan Alternatif Pengganti Kapal Kayu Untuk Meningkatkan Produktifitas Nelayan Di Perairan Bengkalis," *Kapal*, vol. 14, no. 2, p. 53, Aug. 2017, doi: https://doi.org/10.14710/kpl.v14i2.12670.

[20] D. P. Yuwandana, F. Purwangka, B. H. Iskandar, "Desain dan konstruksi perahu katamaran fiberglass untuk wisata pancing", *Buletin PSP*, vol. 21, no. 1, pp. 119-136, Oct. 2013.