FABRICATION AND TESTING OF BAMBOO/RAMIE AND RAMIE/BANANA HYBRID COMPOSITES

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Abstract

The increasing demand for sustainable and eco-friendly materials has led to a growing interest in natural fiber-reinforced composites. This study evaluates the mechanical properties of epoxy resin composites reinforced with bamboo/ramie and ramie/banana hybrid fibers. The composites were fabricated using a hand layup method, where different layers of composite materials were stacked on top of each other to form a total of four layers. The effects of varying fiber combinations and layering sequences on the mechanical performance of the composites were investigated. The flexural strength and hardness of the composites were measured and compared. The results show that the ramie-banana hybrid composite exhibited higher flexural strength compared to the bamboo-ramie hybrid composite and also showed improved hardness. The study demonstrates the potential of using natural fiber-reinforced composites as sustainable alternatives to traditional materials. The findings of this research can be used to optimize the design and fabrication of natural fiber-reinforced composites for various industrial applications.

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1 Introduction

Composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties. When combined, these materials produce a material with characteristics different from the individual components. [1] The resulting composite material often exhibits improved strength, stiffness, toughness, and resistance to fatigue, corrosion, and wear. Composite materials have been increasingly used in various industries, including aerospace, automotive, construction, and sports equipment, due to their exceptional properties and versatility.[2,3] The use of composite materials has enabled the development of lightweight, high-performance structures that cannot be achieved with traditional materials. The concept of composite materials dates back to ancient civilizations, where people used a combination of materials to create stronger and more durable structures. For example, the ancient Egyptians used a mixture of mud and straw to build stronger bricks, while the ancient Greeks used a combination of wood and metal to build ships. However, it wasn't until the mid-20th century that composite materials began to be developed and used extensively in various industries.[4,5]

1.1 Literature Review

In their research, Zulkifli Djafar et al.[6] have focused on evaluating the mechanical properties of ramie fibers and woven ramie-reinforced epoxy composites, which are increasingly recognized for their potential in sustainable materials engineering. The study aims to understand how the structure of ramie fibers influences the tensile and bending strengths of the resulting composites, Standardized testing methods are employed to measure tensile and bending strengths. Tensile tests assess the maximum load a material can withstand while being stretched, while bending tests evaluate the material's resistance to deformation under load. This dual approach allows for a comprehensive analysis of the mechanical performance of the composites. The results indicate that woven ramie-reinforced epoxy

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composites exhibit significantly enhanced tensile and bending strengths compared to non-woven composites. The study by Ain U. Md Shah et al.[7] investigates the tensile properties of bamboo fiber reinforced polymer composites. Given bamboo's high strength-to-weight ratio and rapid growth, it serves as an attractive alternative to conventional synthetic fibers in composite materials. Samples were prepared using different percentages of bamboo fibers mixed with thermosetting and thermoplastic resins. Standard tensile testing methods are employed to evaluate the mechanical properties, focusing on maximum stress, strain at break, and elastic modulus. Findings reveal that the addition of bamboo fibers significantly enhances the tensile strength of the composites, with optimal reinforcement observed at specific fiber loadings. The study identifies the importance of fiber orientation and treatment methods in maximizing the interfacial bonding between the fibers and the polymer matrix, which directly affects mechanical performance. This study by Angel Pozo Morales et al.[8] investigates the development and application of bamboo-polylactic acid (PLA) composite materials for structural purposes. Bamboo, a renewable natural resource, is combined with PLA, a biodegradable polymer, to enhance mechanical properties and sustainability in construction materials. The research begins with the characterization of both bamboo and PLA, focusing on their mechanical and thermal properties. Various composite formulations are created, integrating different bamboo fiber contents and processing methods. The goal is to optimize the composite's strength, stiffness, and durability for structural applications. The findings suggest that bamboo-PLA composites present a promising alternative to traditional materials in construction, offering benefits such as reduced environmental impact, lightweight characteristics, and enhanced mechanical performance. This study by K. Aruna Santhi et al.[9] investigates the mechanical properties of hybrid composites made from jute and ramie fibers reinforced with epoxy resin. Jute and ramie fibers are chosen for their high strength, lightweight nature, and biodegradability, making them ideal for sustainable material applications. The primary objective is to analyze how varying fiber ratios and treatments affect the tensile strength, flexural strength, and impact resistance of the

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composites. The experimental process involves preparing different composite samples with varying proportions of jute and ramie fibers. These samples undergo rigorous mechanical testing to evaluate their performance. Results indicate that hybrid composites exhibit superior mechanical properties compared to those reinforced with only one type of fiber.

1.2 Materials Selection

This project focuses on the development of sustainable composite materials using natural fibres. The selected natural fibres are bamboo, ramie, and banana. Bamboo: Bamboo is a highly renewable and sustainable natural fibre, with a high growth rate and low environmental impact. Bamboo fibres exhibit excellent mechanical properties, including high tensile strength, stiffness, and toughness. Bamboo is also biodegradable, non-toxic, and resistant to pests and decay. Ramie: Ramie is a natural fibre obtained from the ramie plant, which is native to Asia. Ramie fibres are known for their exceptional strength, stiffness, and resistance to shrinkage. Ramie is also biodegradable, non-toxic, and has natural antibacterial properties. Banana: Banana is a widely available and renewable natural fibre, with a low environmental impact. Banana fibres exhibit good mechanical properties, including high tensile strength and stiffness. Banana is also biodegradable, non-toxic, and has natural antibacterial properties.

2 Methodology

1. Started up by layering the fibre mats one above the other (both in case of bamboo/ramie and ramie/banana composite) by spreading the epoxy resin mixed with hardener on calculated proportions.

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3 Four layers of fibre mats were stacked up total in both the cases

3. After the completion of these processes the material was kept for drying for 24 hours and a weight was kept above the material.

4 After drying the material was cut using jig-saw cutting into required proportions

5. To check for the mechanical properties the composite material were set for testing at Konkan Speciality Poly Products Private Limited, Mangaluru, Karnataka. The tests included flexural test, and hardness test was done in the testing lab of mechanical department of P.A College of Engineering, Mangaluru.

4.1 Fabrication Procedure

Figure 1 below represents the fabrication procedure for the composite material.

5 Experimental Tests Performed

5.1 Flexural Test (ASTM D7264

In the flexural test the specimen was freely supported by a beam and the maximum stress was applied in the center of the specimen until it fractured and broke. Three specimens were tested, and the average was determined for the given samples of 140×12.7 mm in length and width respectively. Figure 2 below represents the dimensions of the flexural specimen. respectively.

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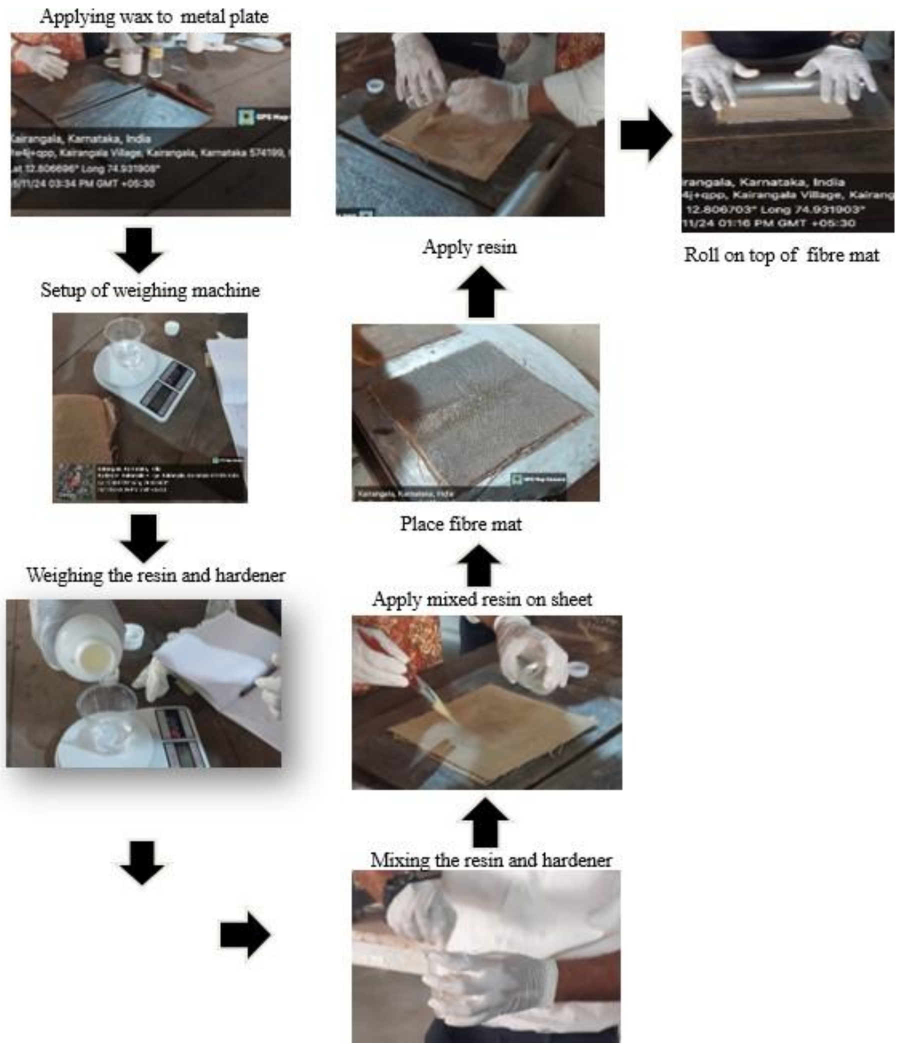

Figure 1: 1. Fabrication process

5.2 Hardness test (ASTM-E384

The hardness test was carried out using the Brinell hardness tester for the given samples of 30×10 mm in length and width respectively. The below figure 3 represents the dimensions for the hardness testing of the sample.

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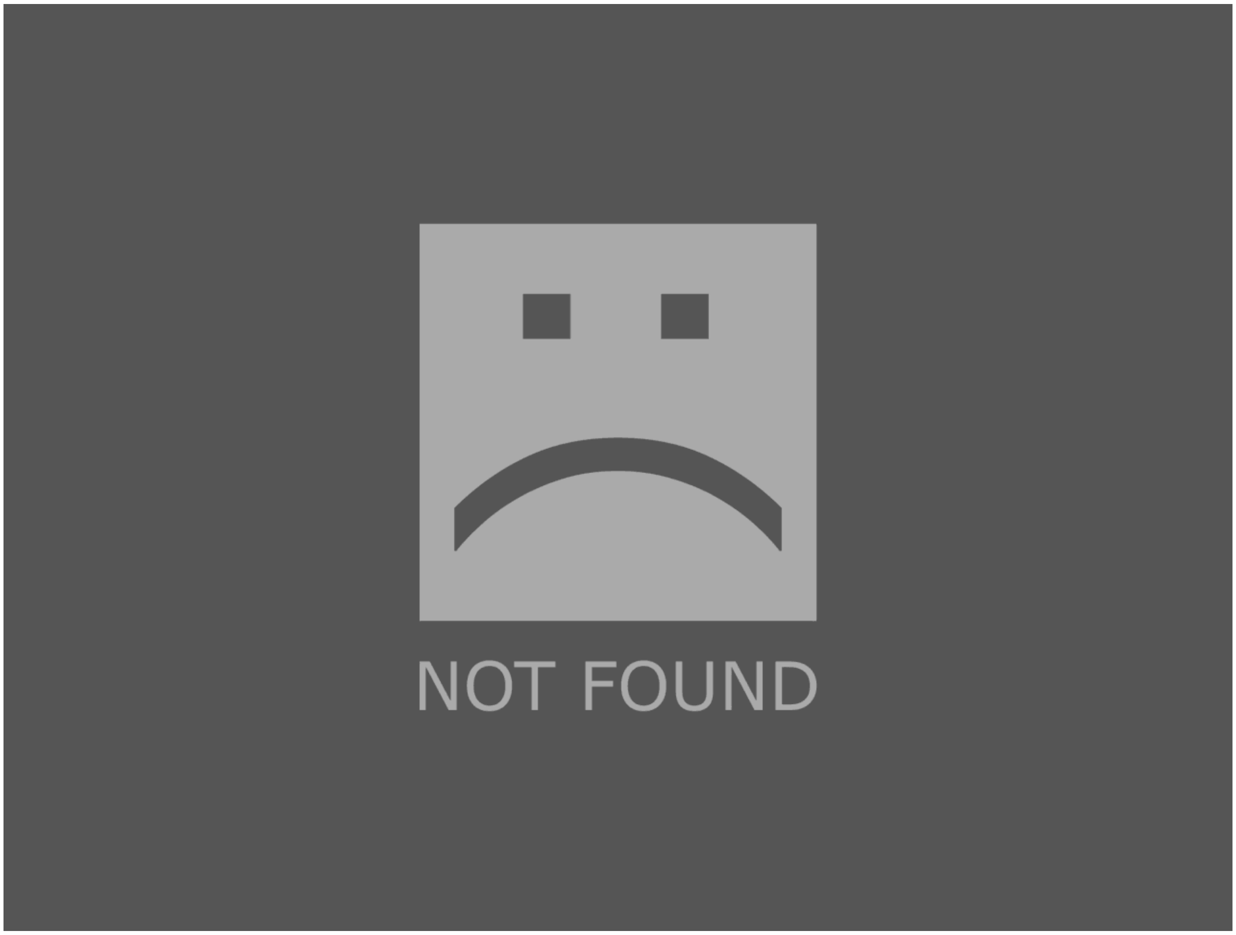

Figure 2: 2. Dimensions for flexural specimen

6 Results and Discussion

6.1 Flexural Test Results

A flexural test was conducted on a universal testing machine with a load limit of 0.1 MPa and a 1.7 mm/min speed. Figure 4 shows the experimental setup of flexural tests performed on the specimen.

6.1.1 Flexural test of Bamboo-Ramie hybrid composite

The flexural test was done on the bamboo-ramie specimen below. Table 1 represents the flexural strength result of the test conducted.

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Figure 3: 3. Dimensions for Hardness testing specimen

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Figure 4: 4. Flexural test of bamboo-ramie hybrid composite

Table 1: 1. Flexural test of Bamboo-Ramie hybrid composite

Material	Specimen	F_{max}	Flexural strength (MPa)	Average Strength (MPa)	Flexural modulus (MPa)	Average modulus (MPa)
	1	63.58	61.6		4600	
Bamboo-Ramie hybrid composite	2	53.08	51.8	63	3900	4274.66
	3	72.53	63.6		4330	

6.1.2 Flexural test of Ramie-Banana hybrid composite

The flexural test was done on the ramie-banana specimen below. Table 2 represents the flexural strength result of the test.

Table 2: Flexural test of Ramie-Banana hybrid composite

Material	Specimen	F_{max}	Flexural strength (MPa)	Average Strength (MPa)	Flexural modulus (MPa)	Average modulus (MPa)
	1	109.68	71.7		4221	
Ramie-Banana hybrid composite	2	101.12	82.1	72.96	4160	4316.66
	3	92.31	73.7		4130	

6.2 Hardness test results

The hardness test is performed in the Brinell hardness tester as shown in below Figure 5.

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Figure 5: 5. Brinell hardness tester for testing of hardness of the composite

6.2.1 Hardness test of Bamboo-Ramie hybrid composite

The hardness test was done on the bamboo-ramie specimen below. Table 3 represents the hardness results of the tests conducted.

Table 3: Hardness test ofBamboo-Ramie hybrid composite

Trial No.	Hardness Number	Avg. Hardness
1	4.3	
2	5.2	5.1
3	5.2	

6.2.2 Hardness test of Ramie-Banana hybrid composite

The hardness test was done on the ramie-banana specimen, below Table 4 represents the hardness results of the tests conducted.

Table 4: 4. Hardness test of ramie-banana hybrid composite

Trial No.	Hardness Number	Avg. Hardness
1	20.1	
2	22.3	23.2
3	24.2	

7 Conclusion

1. The ramie-banana hybrid composite exhibited higher average flexural strength (71.7 MPa) and flexural modulus (4316.66 MPa) compared to the bamboo-ramie hybrid composite (61.6

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MPa and 4274.66 MPa respectively), indicating better load-bearing capacity under bending.

2. The ramie-banana hybrid composite showed a significantly higher average Brinell hardness number (23.2) than the bamboo-ramie hybrid composite (5.1), suggesting superior surface resistance to indentation.

3. The results clearly demonstrate that the incorporation of banana fiber in combination with ramie enhances both the mechanical (flexural) and surface (hardness) properties of the hybrid composite.

4. Based on the mechanical performance, the ramie-banana hybrid composite is more suitable for applications requiring higher structural strength and surface durability compared to the bamboo-ramie counterpart.

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