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Fabrication and Mechanical Testing of Hemp-Bamboo-Flax Reinforced with Orange Peel Powder Natural Fibre Composites Using Hand Layup Technique

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Abstract- Natural Fiber Reinforced Polymeric Composites (NFRPCs) are increasingly used as sustainable and economical alternatives to synthetic fiber composites, driven by their biodegradability, low cost, and high mechanical strength[3]. This project investigates the mechanical behavior of novel hybrid natural fiber composites. Seven different composite laminates were fabricated using the hand lay-up technique, with Epoxy Resin (LY556) as the matrix and various combinations of Hemp, Bamboo, and Flax fibers, reinforced with 5% Orange Peel Powder (OPP)[44]. Mechanical properties, including tensile, flexural, impact, and hardness, were evaluated in accordance with ASTM standards[5]. The results indicate that the developed composites possess promising mechanical properties for potential application in structural components[6]. Specifically, the Hemp + Flax + 5% OPP hybrid composite exhibited superior tensile and flexural strength, while the Bamboo + Flax + 5% OPP composite showed the highest impact strength and hardness

Keywords: Natural Fiber Composites, Hemp, Bamboo, Flax, Orange Peel Powder, Hand Layup, Mechanical Testing, Epoxy Resin

I. INTRODUCTION

Composite materials utilizing natural fibers are gaining prominence across diverse industries, including naval, automotive, and aerospace, owing to their environmental and economic advantages. Natural fibers offer a combination of low density, suitable stiffness, and high disposability/renewability, addressing sustainability concerns associated with synthetic materials. Common lignocellulosic fibers like bamboo, jute, and coir serve as primary reinforcements in polymeric matrices.

This study focuses on developing hybrid composites of Hemp, Bamboo, and Flax fibers, incorporating Orange Peel Powder (OPP) as an additive. Hemp, Bamboo, and Flax are known for their distinct properties: Hemp for its durability, Bamboo for its high strength-to-weight ratio, and Flax for its tensile properties. The objective is to fabricate and mechanically characterize seven different fiber combinations with 5% OPP to identify the optimal composite for structural applications.

II. MATERIALS AND METHODS

Materials
The composite materials used were:

- Fibers: Hemp, Bamboo, and Flax fibers (300 GSM mats)
- Filler: Orange Peel Powder (OPP) (5% by weight of fiber composition)
- Matrix: Epoxy Resin (LY556)
- Hardener: Hardener (HY951).

Composite Formulations
Seven distinct composite plates were fabricated. In each laminate, 100 grams of Epoxy (LY556) was mixed with 10 grams of Hardener (HY951)[18]. The fiber reinforcement typically constituted approximately 40% of the total composite weight (fiber/resin/hardener), with 5% of the fiber weight replaced by OPP

The composite compositions were (with 5% OPP in each):

1. Hemp Fiber
2. Bamboo Fiber
3. Flax Fiber
4. Hemp + Bamboo Fiber (3 sheets Hemp / 3 sheets Bamboo)
5. Bamboo + Flax Fiber (3 sheets Bamboo / 3 sheets Flax)
6. Hemp + Flax Fiber (3 sheets Hemp / 3 sheets

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Flax)
7. Hemp + Bamboo + Flax Fiber (2 sheets each)

Fabrication Technique
The composites were fabricated using the Hand Lay-Up Process, which is noted for its simplicity and low cost The process involved cutting the long fiber mats to the mold size and placing them on a thin plastic sheet. The resin and hardener mixture was poured and spread uniformly. Subsequent layers of fiber and resin were added (six sheets in total for a 4mm thickness specimen). Pressure was applied to remove air voids, and the laminate was cured for 24 hours at room temperature.

Mechanical Testing
The cured composites were cut into specimens according to ASTM standards

- Tensile Test: ASTM D638 standard specimens (165mm x 12.5mm x 4mm)
- Flexural Test (Three-Point Bending): ASTM D790M-86 standard specimens (100mm x 25mm x 4mm)
- Impact Test: Specimens of 63.5mm x 12.36mm x 6mm thick
- Hardness Test: Performed using ASTM D785 guidelines

III. RESULTS AND DISCUSSION

The mechanical testing results are summarized in Table 1, presenting the calculated tensile strength, flexural strength, impact energy absorbed, and hardness number for the seven composite compositions.

Composite Composition (+ 5% OPP)	Max Tensile Stress (N/mm2)	Max Flexural Stress (N/mm2)	Impact Strength (Joules)	Hardness (Number)
Hemp	2.85 [3333]	89.25 [3434]	3.2 [3535]	92 [3636]
Bamboo	2.43 [3737]	99.75 [3838]	2.6 [3939]	87 [4040]
Flax	3.09 [4141]	91.87 [4242]	5.8 [4343]	110 [4444]
Hemp + Bamboo	2.76 [4545]	81.37 [4646]	4.2 [4747]	99 [4848]
Hemp + Flax	3.81 [4949]	118.12 [5050]	5.2 [5151]	108 [5252]
Bamboo + Flax	2.28 [5353]	99.75 [54]	6.9 [5555]	115 [5656]
Hemp + Bamboo + Flax	3.15 [5757]	84.00 [58]	4.6 [5959]	105 [6060]

Table 1: Summary of Calculated Mechanical Properties for Composites (Values from Tables 4, 5, 6, 7 of the report)

Tensile Strength

The Hemp + Flax hybrid composite demonstrated the highest tensile strength at $3.81 \text{ N/mm}^2 suggesting a strong synergistic effect between these two fibers when combined in the epoxy matrix. Hemp and Flax mono-composites also performed well, ranking third and second respectively

Flexural Strength

The highest flexural stress (modulus of rupture) of 118.12 N/mm^2 was achieved by the Hemp + Flax hybrid composite. This result aligns with the tensile test, reinforcing the superior load-bearing capacity of this specific hybrid combination. The Hemp + Flax and Bamboo + Flax composites both outperformed the triple-hybrid (Hemp + Bamboo + Flax).

Impact Strength

The Bamboo + Flax composite absorbed the maximum energy during the impact test, achieving a result of 6.9 Joules. This high value indicates a superior toughness and resistance to sudden shock and fracture for this hybrid combination, making it suitable for applications requiring impact durability.

Hardness

The Brinell hardness test results showed that the Bamboo + Flax composite possessed the highest hardness number of 115, signifying greater resistance to localized plastic deformation (indentation). The Flax mono-composite also showed high hardness at 110, while the Bamboo mono-composite had the lowest hardness at 87

IV. CONCLUSION

The fabrication and testing of Hemp-Bamboo-Flax hybrid and mono-fiber composites reinforced with 5% Orange Peel Powder were successfully completed. The incorporation of OPP and the use of hybrid reinforcement proved effective in enhancing the mechanical performance of the epoxy-based natural fiber composites[707070].

The main conclusions are:

- The Hemp + Flax + 5% OPP composite exhibited the best overall performance in terms of strength, achieving the maximum tensile stress ($\mathbf{3.81 \text{ N/mm}^2}$) and flexural stress ($\mathbf{118.12 \text{ N/mm}^2}$)
- The Bamboo + Flax + 5% OPP composite showed the highest impact strength ($\mathbf{6.9 \text{ Joules}}$) and greatest hardness ($\mathbf{115}$)
- The mechanical characteristics of the developed materials suggest a strong dependence on the specific fiber combinations and demonstrate potential for use in various structural applications[73].

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