

Fabrication And Mechanical Testing of Abaca, Flax and Ramie Fiber Hybrid Composites Reinforced with Fish Scale Powder

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ABSTRACT: This study explores the fabrication and testing of hybrid composites made from abaca, flax, and ramie fibers reinforced with fish scale powder and epoxy resin. Using a layering technique, the composites were evaluated for strength, durability, and suitability in engineering applications. Results showed that fish scale powder enhanced stiffness and hardness, while hybrid fiber composites outperformed single-fiber ones due to better load sharing and fiber-matrix bonding. The abaca-flax-ramie hybrid composite exhibited the best mechanical performance, confirming that natural fiber composites with bio-waste fillers are sustainable, lightweight, and cost-effective alternatives for engineering use.

KEYWORDS: Hybrid Composites, Abaca, Flax, Ramie, Fish Scale Powder, Epoxy Resin, Mechanical Properties, Bio-Waste Fillers, Sustainability, Engineering Applications.

I. INTRODUCTION

To date, global industries have considered the application of natural fibers as an alternative to synthetic materials as one of the constituents in the composites due to their advantages of being renewable and possessing marketing appeal in composites manufacturing industries. The unique properties of natural fibers—for instance, low cost, low density, recyclability, biodegradability, and sustainable in terms of resources as well as abundant availability—make them considered as the materials of choice. In addition, in terms of natural fibers preparation, it is a facile process with little equipment needed, plus, the preparation approaches utilized do not generate harmful gases, which mitigates the environmental pollution. The utilization of the natural fibers derived from agricultural crops residue as the main source of the composite's product can help reduce the open burning that can lead to air pollution; thus, it can

help protect the environment. The development of natural fibers-based composites has been considered to replace the applications of glass-fiber-based composites especially in many major industries related to structural applications including the civil construction industries, aerospace and automotive industries, etc. These composites-based products can be cost-effective materials for the production of automobile body panels, interiors, storage devices, building and industrial panels, etc. Composite materials are engineered materials formed by combining two or more distinct constituents with significantly different physical or chemical properties to achieve enhanced performance characteristics. The individual components typically consist of a reinforcement phase, such as fibers or particles, and a continuous matrix phase, such as polymers, metals, or ceramics. When combined, these constituents produce a material with superior properties compared to those of the individual components alone. Composites are widely used due to their high strength-to-weight ratio, improved stiffness, corrosion resistance, and design flexibility. By selecting appropriate reinforcements and matrices, composite materials can be tailored to meet specific mechanical, thermal, and environmental requirements. Common applications include aerospace, automotive, marine, construction, and biomedical fields. In recent years, increasing environmental concerns have driven the development of natural fiber-reinforced composites, which offer advantages such as biodegradability, renewability, and reduced environmental impact. These sustainable composites represent a promising direction for future material development while maintaining satisfactory mechanical performance.

Natural fibers are increasingly replacing synthetic fibers like glass and carbon due to their low density, biodegradability, and high specific strength. The interaction between the leaf fiber (Abaca) and bast fibers (Flax and Ramie) provides a

unique mechanical profile suitable for structural applications.

II. MATERIAL OVERVIEW

This chapter describes the materials used, fabrication process, and testing methods adopted for the development of hybrid composite materials. The composite is prepared using abaca, flax, and ramie fibers as reinforcement, fish scale powder as filler, and epoxy resin as the matrix material. The fabrication is carried out using the sandwich (layering/hand lay-up) technique, followed by mechanical testing to evaluate the performance of the composite.

ABACA FIBER: Abaca fiber is widely used for making ropes, marine cordage, and fishing nets due to its high tensile strength. It is also used in specialty papers such as tea bags, currency paper, and filter papers. In textiles, abaca is applied in bags, carpets, furniture, and handicrafts. An important advantage of abaca fiber is its durability combined with flexibility.



ABACA FIBER

FLAX FIBER

RAMIE FIBER

FISH SCALE POWDER: Fish scale powder is prepared from waste fish scales. It contains calcium compounds (mainly hydroxyapatite) which improve the hardness and bonding strength of the composite. Fish scale powder is derived from waste fish scales which are rich in collagen and minerals



FISH SCALE POWDER

FLAX FIBER: Flax fiber is widely used in composites due to its lightweight nature, good stiffness, and biodegradability. It enhances the mechanical strength of the composite. Flax fiber is widely used in the production of linen fabrics for clothing, table linens, and household textiles. Flax fibers exhibit good thermal and acoustic insulation properties.

RAMIE FIBER: Ramie fiber is a strong natural fiber with excellent tensile strength and durability. It provides additional reinforcement to the hybrid composite. Ramie fiber is used in making fabrics for clothing, table linens, and upholstery due to its silky appearance. Ramie fibers possess good dimensional stability and retain strength even when wet.

EPOXY RESIN: Epoxy exhibits excellent additive characteristics, along with high mechanical strength, minimal contraction, chemical resilience, high permeation density, low viscosity, and enhanced electrical resistance capacity. Flax fiber, areca flax, kenaf, and hybrid fibers can all serve as reinforcement options for it.



EPOXY RESIN

III. MATERIAL FABRICATION

Step 1: Preparation of fibres

Cleaning and Cutting of fibres: Abaca, Flax And Ramie Fibres were cleaned and prepared for the fabrication process. If they are not pre-cut, cut the fibres to the required length for your composite.

Drying: Ensure that the fibres are properly dried to remove any moisture, as moisture can reduce the adhesion between the fibres and the resin.

Step 2: Preparation of Resin Mixture

Resin Preparation: Mix the polymer resin with the hardener or catalyst as per the manufacturer's instructions. Ensure proper mixing to achieve the desired consistency for lay-up

Step 3: Incorporating fish scale Powder

Preparation of fish scale Powder: Measure the required amount of fish scale powder (5g). The amount will depend on the type of composite you want to create. Mix the fish scale powder thoroughly with the resin. You can use a mixing stick or an electric mixer to ensure an even distribution of the fish scale powder in the resin. This will create a uniform mixture.

Step 4: Layering Process

Take a polyethylene sheet and apply wax on it and next apply the resin. After applying the resin place a abaca fibre and apply resin on the fibre and after that place a flax fibre and then ramie fibre.

Repetition of layers:

- i. Used 3 abaca fibers and 2 ramie fibers
- ii. Used 2 flax fibers and 2 ramie fibers
- iii. Used 3 abaca fibers and 2 flax fibers
- iv. Used 2 abaca fibers and 2 flax and 2 ramie fibers

Step 5: Curing and Hardening:

Curing:After layering, allow the composite to cure at room temperature or according to the resin manufacturer's instructions (usually 24-48 hours).

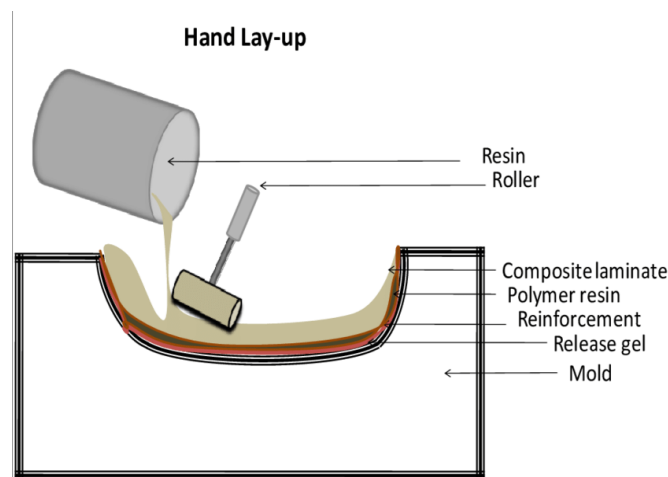
Step 6: Extracting And Cutting

Extracting: Once the composite has cured, it is carefully removed from the polyethylene sheets.

Cutting: Then the composite specimen is trimmed to the desired dimensions using cutting tools.

Step 7: Testing and Evaluation

Mechanical Testing: Performed mechanical tests on the fabricated composite specimen, such as tensile test, flexural test, impact test, compression test, and hardness test.



HAND LAY-UP METHOD

IV. METHODS OF TESTING

TENSILE TESTING: The tensile test is conducted to determine the tensile strength and elongation behaviour of the composite material under axial loading conditions. In this test, the specimen is subjected to a gradually increasing tensile load until failure occurs. It provides essential information about the ability of the material to resist pulling forces and helps in understanding its strength and ductility characteristics.

ROCKWELL HARDNESS TESTING: The hardness test is performed to determine the resistance of the composite material to surface indentation and wear. It provides an indication of the surface strength and durability of the material. In this test, a

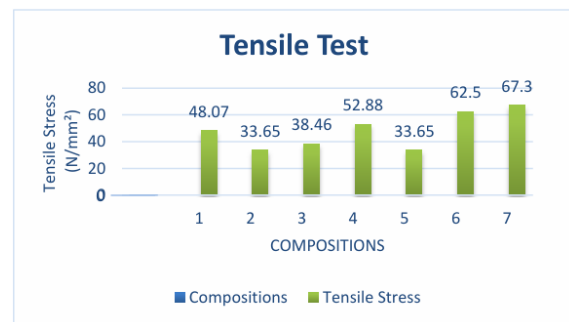
specific load is applied through an indenter, and the hardness value is measured based on the indentation produced.

COMPRESSION TESTING: The compression test is carried out to determine the compressive strength and deformation behaviour of the composite material under compressive loading conditions. In this test, the specimen is subjected to a gradually increasing compressive load until it fails or deforms significantly.

IMPACT TESTING: The impact test is conducted to determine the toughness and energy absorption capacity of the composite material under sudden loading conditions. In this test, the specimen is subjected to a high-speed impact, and the energy absorbed during fracture is measured

V. RESULT TENSILE TEST TABLE

S.NO	Compositions	Load (N)	Tensile Stress (N/mm ²)
1	Abaca + Fish Scale Powder (5 g)	2500	48.07
2	Flax + Fish Scale Powder (5 g)	1750	33.65
3	Ramie + Fish Scale Powder (5 g)	2000	38.46
4	Abaca + Ramie + Fish Scale Powder (5 g)	2750	52.88
5	Flax + Ramie + Fish Scale Powder (5 g)	1750	33.65
6	Abaca + Flax + Fish Scale Powder (5 g)	3250	62.5
7	Abaca + Flax + Ramie + Fish Scale Powder (5 g)	3500	67.30



It is observed from the above graph that the Abaca + Flax + Ramie + 5 grams of Fish Scale Powder produced the highest tensile, indicating that combining all three fibers results in the strongest composite material

Model Calculation :

Abaca + Flax + Ramie with 5 g of Fish Scale Powder:
 $\sigma_t = 3500/52$
 $= 67.30 \text{ N/mm}^2$

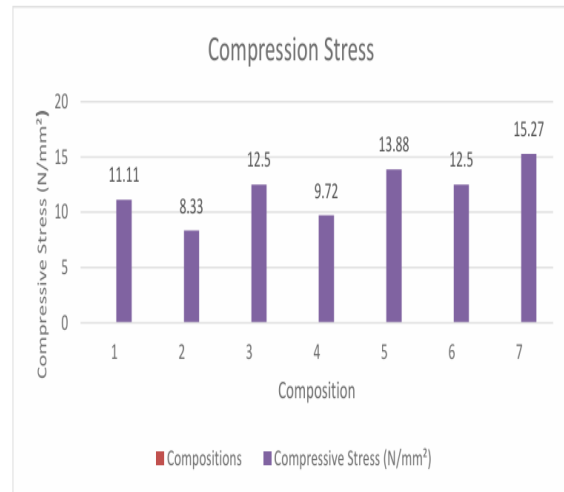
COMPRESSION TEST

S.NO	Compositions	Load (N)	Compressive Stress (N/mm ²)
1	Abaca + Fish Scale Powder (5 g)	10000	11.11
2	Flax + Fish Scale Powder (5 g)	7500	8.33
3	Ramie + Fish Scale Powder (5 g)	11250	12.5
4	Abaca + Ramie + Fish Scale Powder (5 g)	8750	9.72
5	Flax + Ramie + Fish Scale Powder (5 g)	12500	13.88
6	Abaca + Flax + Fish Scale Powder (5 g)	11250	12.5
7	Abaca + Flax + Ramie + Fish Scale Powder (5 g)	13750	15.27

MODEL CALCULATION:

Abaca + Flax + Ramie with 5 g of Fish Scale

Powder: $\sigma_c = 13750/900$
 $= 15.27 \text{ N/mm}^2$



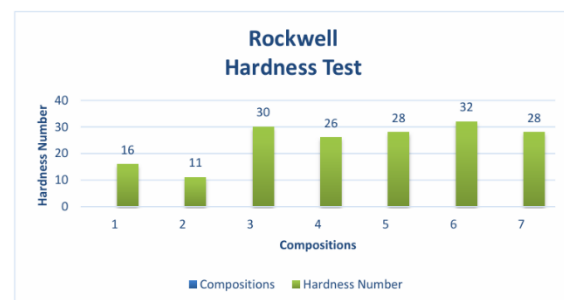
COMMENT: It is observed from the above graph that The Abaca + Flax + Ramie + 5 g fish scale powder composite showed the highest compressive stress, indicating that combining three natural fibers provides better load-bearing capacity and improved mechanical performance.

ROCKWELL HARDNESS TEST:

S.NO	Compositions	Rockwell Hardness Number
1	Abaca + Fish Scale Powder (5 g)	16
2	Flax + Fish Scale Powder (5 g)	11
3	Ramie + Fish Scale Powder (5 g)	30
4	Abaca + Ramie + Fish Scale Powder (5 g)	26
5	Flax + Ramie + Fish Scale Powder (5 g)	28
6	Abaca + Flax + Fish Scale Powder (5 g)	32
7	Abaca + Flax + Ramie + Fish Scale Powder (5 g)	28

MODEL CALCULATIONS :

Abaca + Flax + Ramie with 5 g of Fish Scale Powder = 28



COMMENT: It is observed from the table that Among all the samples, the Abaca + Flax + 5 g fish scale powder composite exhibited the highest hardness value

IMPACT TEST:

S.NO	Compositions	Energy (J)	Impact stress (J/mm ²)
1	Abaca + Fish Scale Powder (5 g)	135	3.37
2	Flax + Fish Scale Powder (5 g)	130	3.25
3	Ramie + Fish Scale Powder (5 g)	151	3.77
4	Abaca + Ramie + Fish Scale Powder (5 g)	144	3.6
5	Flax + Ramie + Fish Scale Powder (5 g)	139	3.47
6	Abaca + Flax + Fish Scale Powder (5 g)	153	3.82
7	Abaca + Flax + Ramie + Fish Scale Powder (5 g)	148	3.7

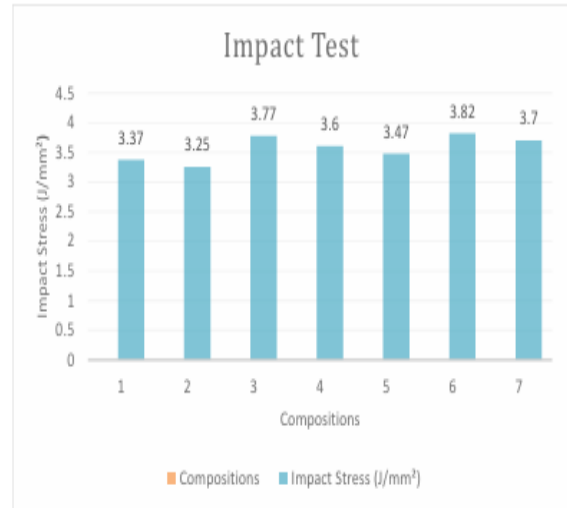
CONCLUSION

- Hybrid composite with Abaca, flax, ramie and fish scale powder has been successfully fabricated by hand lay-up technique.
- The mechanical testing like tensile, compression, impact, and Rockwell hardness tests were conducted.
- Among all the fabricated specimens, the tensile test is maximum in Abaca + flax+ ramie + 5gm of fish scale powder and minimum in flax + 5gm of fish scale powder.
- The impact stress Is maximum at abaca + flax + 5gm of fish scale powder and minimum at 5 gms of fish scale powder
- The rock well hardness for fabricated specimen is maximum at abaca + flax + 5gm of fish scale powder and minimum at

REFERENCES

MODEL CALCULATION:

Abaca + Flax + Ramie with 5 g of Fish Scale Powder:
 $\sigma_i = 148/40$
 $= 3.7 \text{ J/mm}^2$



COMMENT: It is observed from the above graph that the Abaca + Flax + 5 g fish scale powder composite showed the highest impact strength indicating that this combination can absorb more energy before fracture and has better resistance to sudden loads.

5gm of fish scale powder.

- Compressive stress for fabricated specimen is maximum at abaca + flax + 5gm of fish scale powder and minimum at flax+ 5gm of fish scale powder.

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