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Experimental & Investigation of Human Leg Bone Behavior Coir Fiber and Palm Fiber with Epoxy Composite

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ABSTRACT

This study investigates the mechanical behavior of composite materials composed of coir fiber, palm fiber, and epoxy, aiming to mimic properties akin to human leg bones. Through a systematic experimental approach, various parameters including fiber type, orientation, and volume fraction are explored to understand their influence on mechanical performance. Mechanical tests, including tensile and flexural testing, reveal key properties such as tensile strength, modulus of elasticity, and toughness. Microstructural analysis via scanning electron microscopy offers insights into the distribution of fibers within the matrix and failure mechanisms. The findings are compared with those of natural bone and conventional materials, highlighting the potential of these composites in biomedical applications. Biomechanical simulations further elucidate their performance under loading conditions relevant to bone structures. This research contributes to the development of innovative materials for orthopedic implants, bone tissue engineering, and prosthetics, offering promising avenues for future advancements in the field.

Keywords: Composite materials, Coir fiber, Palm fiber, Epoxy, Mechanical behavior, Biomedical applications

1. Main text

The human skeletal system, particularly the leg bones, serves as a structural framework crucial for locomotion and support. In biomedical engineering, mimicking the mechanical properties of natural bone has been a longstanding challenge, especially for applications such as orthopedic implants and prosthetics. Composite materials offer a promising avenue for addressing this challenge, as they can combine the desirable properties of different constituents to achieve tailored mechanical performance. Coir fiber and palm fiber, both natural and abundant resources, possess inherent strength and stiffness, making them attractive candidates for reinforcing matrices in composites. When combined with epoxy resin, these fibers can form composite materials with enhanced mechanical properties suitable for biomedical applications.

This study aims to investigate the mechanical behavior of composite materials comprising coir fiber, palm fiber, and epoxy, with a specific focus on replicating the properties of human leg bones. Through systematic experimentation, various parameters such as fiber type, orientation, and volume fraction will be explored to understand their influence on mechanical performance. The findings of this research hold significant potential for advancing the development of innovative materials for orthopedic implants, bone tissue engineering, and prosthetics, ultimately contributing to improved clinical outcomesand quality of life for patients.

2. OBJECTIVES

- Investigate the mechanical behavior of composite materials composed of coir fiber, palm fiber, and epoxy.
- Explore the influence of various parameters including fiber type, orientation, and volume fraction on the mechanical properties of the composites.
- Conduct mechanical tests such as tensile testing and flexural testing to evaluate key properties including tensile strength, modulus of elasticity, and toughness.
- Perform microstructural analysis using scanning electron microscopy to understand the distribution of fibers within the matrix and identify failure mechanisms.
- Compare the mechanical properties of the composite materials with those of natural bone and conventional materials used in biomedical applications.

- Utilize biomechanical simulations to elucidate the performance of the composites under loading conditions relevant to bone structures.
- Provide insights into the potential applications of these composites in fields such as orthopedic implants, bone tissue engineering, and prosthetics.

3. METHODOLOGY

Material Preparation:

- Obtain coir fiber, palm fiber, and epoxy resin.
- Treat fibers, if necessary, to enhance adhesion with epoxy.
- Prepare composite specimens with varying fiber types, orientations, and volume fractions.

Experimental Setup:

- Design and set up mechanical testing apparatus for tensile and flexural testing.
- Ensure appropriate environmental conditions for testing.

Mechanical Testing:

- Conduct tensile tests to measure tensile strength and modulus of elasticity.
- Perform flexural tests to assess bending properties and toughness.
- Record data for analysis.

Microstructural Analysis:

- Prepare specimens for scanning electron microscopy (SEM).
- Image the microstructure of the composite materials.
- Analyze images to observe fiber distribution and matrixfiber interaction.

Data Analysis:

- Analyze mechanical test data to determine the effect of fiber type, orientation, and volume fraction on mechanical properties.
- Correlate microstructural observations with mechanical behavior.

Biomechanical Simulation:

- Set up finite element models to simulate loading conditions relevant to bone structures.
- Perform simulations to predict the behavior of composite materials under different loading scenarios.

Comparison and Interpretation:

- Compare experimental results with simulated data and existing literature.
- Interpret findings to draw conclusions regarding the suitability of composite materials for biomedical applications.

Discussion and Future Directions:

- Discuss implications of findings for orthopedic implants, bone tissue engineering, and prosthetics.
- Identify limitations of the study and suggest areas for further research.

4. MAKING PROCEDURE

- Obtain coir fiber, palm fiber, and epoxy resin.
- Cut fibers into specified lengths and treat them, if necessary, for improved adhesion.
- Weigh and mix epoxy resin according to manufacturer's instructions.
- Combine fibers with epoxy resin in appropriate ratios and thoroughly mix to ensure uniform dispersion.
- Select appropriate molds or molds according to the desired shape and dimensions of specimens.

- Apply release agent to molds to prevent sticking.
- Pour epoxy-fiber mixture into molds and compact using a roller or press to remove air bubbles and ensure even distribution.
- Cure specimens according to epoxy manufacturer's curing schedule.
- Set up the testing machine with appropriate grips or fixtures for tensile and flexural testing.
- Calibrate the machine according to standard procedures.
- Ensure environmental conditions such as temperature and humidity are controlled.
- Prepare specimens with standardized dimensions for tensile testing.
- Secure the specimen in the grips of the testing machine.
- Apply tension at a constant rate until failure occurs.
- Record load and displacement data throughout the test.
- Prepare specimens with standardized dimensions for flexural testing, such as ASTM D790.
- Place the specimen on supports with specified span length.
- Apply load at the center of the specimen at a constant rate until failure occurs.
- Record load and displacement data throughout the test.
- Prepare specimens for microstructural analysis by cutting sections or mounting them on suitable substrates.
- Coat specimens with a conductive layer if necessary.
- Examine specimens using a scanning electron microscope (SEM) to observe fiber distribution and matrix-fiber interactions.
- Analyze mechanical test data to determine key properties such as tensile strength, modulus of elasticity, and flexural strength.
- Correlate microstructural observations with mechanical behavior to gain insights into failure mechanisms.
- Interpret results in the context of the experimental objectives and hypotheses.
- Compile all experimental data, analyses, and interpretations into a comprehensive report.
- Include photographs or micrographs of specimens and SEM images for documentation.
- Clearly present findings, conclusions, and recommendations for future research or applications.

5. RESULT AND OBSERVATION

This Section Deals With the results and observation of testing result on the bamboo fibers and coir composite specimen. The test is carried out on each 3 different specimens with same volume fraction ratio. The following table 1 describes the composition use for each specimen with volume faction ratio.

Specimen size : L X b X t = 150x 150 x 15 mm

Sr.No	**COMPOSITES**	**COMPOSITION**
1	Specimen 1	E-poxy + coir fiber + Bamboo fibres (80:10:10) % volume fraction
2	Specimen 2	E-poxy + coir fiber + Bamboo fibres (80:15:5) % volume fraction
3	Specimen 3	E-poxy + coir fiber + Bamboo fibres (80:5:15) % volume fraction
4	Specimen 4	E-poxy + coir fiber + Bamboo fibres (80:10:10) % volume fraction

Table 1: composition of specimen

WEIGHT CALCULATION

Weight of each specimen

- Weight of specimen A= 200gm
- Weight of specimen B = 210gm
- Weight of specimen C = 200gm

The weight of specimen varies because of variation in volume fraction ratio. As volume fraction ratio increases weight of specimen increases, similarly density of specimen also increase. The table 2 shows density of specimen increases the volume fraction ratio increases.

Sr.no	COMPOSITES	DENSITY (g/cm^3)
1	E-poxy + coir fiber + Bamboo fibres (80:10:10) % volume fraction	1.08
2	E-poxy + coir fiber + Bamboo fibres (80:15:5) % volume fraction	1.14
3	E-poxy + coir fiber + Bamboo fibres (80:5:15) % volume fraction	1.19
4	E-poxy + coir fiber + Bamboo fibres (80:10:10) % volume fraction	1.21

Table 2: Density of specimen

The result of tensile test of specimen B having volume fraction ratio is 50% as

	Specimen 1	specimen 2	specimen 3	specimen 4	average
Load at yield (KN)	1.55	1.95	1.35	1.45	1.61
Yield stress (N/mm^2)	20.85	31.20	24.80	25.61	25.61
Load at peak (KN)	3.75	3.00	3.30	3.30	3.70
Tensile strength (N/mm^2)	60.00	69.60	48.50	58.20	59.36

Table 3: tensile testing results

5.1 TENSILE STRESS

Tensile stress measures the internal forces a material undergoes when stretched. It's calculated by dividing the applied force by the cross-sectional area of the specimen. In a tensile test, a specimen elongates under axial loading. The resulting stress-strain curve reveals important material properties like ultimate tensile strength and modulus of elasticity. Tensile stress is crucial for understanding a material's behavior under tension, aiding in material selection and structural design across engineering disciplines.

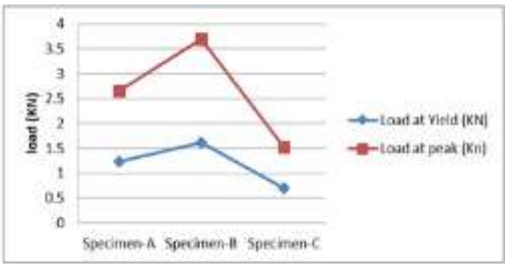


Fig 1: Load at yield and load at yield of specimen

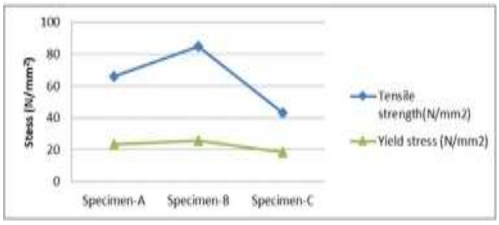
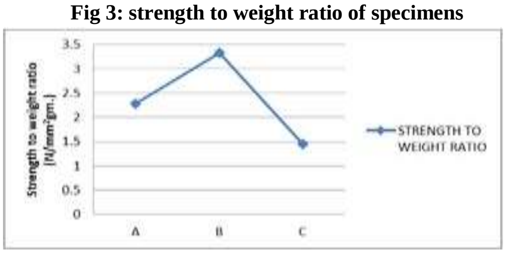


Fig 2: yield stress and tensile strength of specimen

Fig 3: strength to weight ratio of specimens



6. CONCLUSION

Many industries rely on developing composites to obtain novel, environmentally friendly materials with tunable properties for the target application. Natural fibers, mainly made of cellulose, have been widely studied as a critical component of composites. These fibers provide the composite with unique properties, such as enhanced mechanical resilience, flexibility, biocompatibility, and antimicrobial effects. In addition, they are highly hydrophilic, biocompatible, and biodegradable, and exhibit low immunogenicity. Most often, they should be combined or hybridized with other natural or glass/synthetic fibers to achieve good mechanical properties. In biomedicine, bio composites have received particular attention since natural fibers can enhance the composite immune acceptance and improve the cell viability, as evidenced by in vitro studies for various potential biomedical applications, including prostheses, drug delivery technologies, wound healing, and scaffolds for tissue engineering. Additionally, the preparation method should be carefully chosen depending on the desired definitive characteristics. Manufacturing processes can damage the bio composites if humidity, pressure, and synthesis temperature are not meticulously controlled. Consequently, investigating manufacturing techniques is a crucial step in the development of composites to enhance or decrease their tensile, flexural, and impact strength towards, ultimately, their translation from the lab bench to commercial products. Finally, nanomaterials. carbon-based materials and bioactive compounds should be considered for future investigations to face the encountered challenges and limitations of hybrid composites based on natural fibers.

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