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Review of Mechanical Properties of Coconut Fiber Reinforced Composites

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Abstract

Composite materials have emerged as one of the most significant classes of engineering materials over the past few decades, finding applications in sectors ranging from household products to advanced engineering systems. Among various reinforcement materials, natural fibers have gained considerable attention due to their low cost, biodegradability, renewability, and favorable mechanical properties. Coconut fiber (coir) is one of the most widely available natural fibers and has shown promising potential as a reinforcement material in polymer composites. This review paper presents an overview of coconut fiber-reinforced composites, their applications, and the factors influencing their mechanical performance. Special emphasis is placed on the tensile, flexural, impact, and other mechanical properties of coir fiber composites.

Keywords: Coconut Fiber; Coir Fiber; Composite Materials; Natural Fibers; Mechanical Properties.

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Introduction

Composite materials have been utilized for centuries, with natural fibers serving as some of the earliest reinforcing materials. In recent years, natural fibers have gained substantial importance owing to increasing environmental concerns and the demand for sustainable materials. Natural fibers contribute significantly to the economy of developing nations and provide employment opportunities in rural sectors. Their renewable nature, biodegradability, low density, and environmental friendliness make them attractive alternatives to synthetic fibers.Natural fibers such as sisal, jute, coir, and oil palm fibers have been successfully employed as reinforcements in thermosetting and thermoplastic matrices. The growing demand for environmentally sustainable materials in automotive, construction, packaging, and consumer product industries has accelerated research on natural fiber-reinforced composites [1].

Coir fiber, obtained from the husk of coconuts, is characterized by its high toughness, durability, resistance to moisture, and resistance to microbial degradation. These properties make coir an attractive reinforcement material for composite applications [2]. This review focuses on coconut fiber-reinforced polymer composites and discusses the influence of various parameters on their mechanical properties.

Literature Review

Naveen and Yasaswi [2] investigated the mechanical properties of coir fiber-reinforced polymer composites. Composite specimens were fabricated using a steel mold and tested using a universal testing machine. The study revealed that the tensile strength and Young's modulus decreased with increasing fiber volume fraction, whereas the failure strain increased from 3.4% to 5.8% as the fiber volume fraction increased from 5% to 12.5%. Furthermore, increasing fiber length enhanced both tensile and flexural strength.

Stephano and Thurbius Galdius [3] studied the effect of alkaline treatment on coconut fiber-reinforced epoxy composites. The fibers were treated with sodium hydroxide prior to composite fabrication. Experimental results showed improvements of approximately 33% in tensile strength, 35% in flexural strength, and nearly 100% in impact strength. The enhancement was attributed to improved interfacial bonding between the treated fibers and the epoxy matrix.

Mulinari et al. [4] examined the influence of alkaline treatment on coconut fiber-reinforced polyester composites. Surface morphology was characterized using scanning electron microscopy (SEM), while chemical changes were analyzed through Fourier Transform Infrared Spectroscopy (FTIR). SEM observations revealed the removal of waxes, lignin, pectin, and hemicellulose after treatment, resulting in increased surface roughness and improved fiber-matrix adhesion. Consequently, enhanced mechanical properties were achieved.

Rajeesh and Saju [5] reviewed coir fiber-based composite boards and their flammability characteristics. Various fire retardants, including phosphorus-based, nitrogen-based, halogen-based, and inorganic compounds, were investigated. The study reported that combinations of phosphorus and nitrogen-based retardants effectively improved fire resistance and reduced flammability in coir composite boards.

Shrivastava et al. [6] investigated the influence of alkaline treatment on coir and glass fiber hybrid epoxy composites. Surface modification treatments removed impurities and increased fiber roughness, thereby improving adhesion with the matrix. The study reported that tensile strength and flexural stiffness increased under dry conditions, while moisture exposure adversely affected mechanical performance. Additionally, shorter coir fibers (10 mm) exhibited higher tensile strength (40.7 MPa) compared to longer fibers (15 mm), which exhibited a tensile strength of 32.52 MPa due to fiber waviness and misalignment.

Sathishkumar et al. [7] reviewed the characterization and mechanical behavior of various natural fibers, including coir, sisal, bamboo, agave, and roselle fibers. The authors reported that alkaline treatment reduced moisture content and enhanced thermal stability. Mechanical testing demonstrated superior properties for treated fiber composites compared to untreated composites. X-ray diffraction analysis indicated the presence of crystalline cellulose structures contributing to mechanical strength.

Romli et al. [8] investigated factors affecting the tensile strength of coir fiber-reinforced epoxy composites. The effects of curing time, fiber volume fraction, and compression load were studied. Results indicated that tensile strength increased with increasing fiber content and compression load for a curing period of 24 hours. However, prolonged curing beyond 48 hours resulted in a reduction in tensile strength.

Araújo Junior et al. [9] developed binderless fiberboards from unripe coconut husks. The chemical composition of the fibers was analyzed, and fiberboards were fabricated under different temperatures and pressures. The study found that boards produced at approximately 210°C exhibited the highest modulus of elasticity. Excessive processing temperatures caused degradation of lignin and cellulose, thereby reducing mechanical performance.

Mohammed et al. [10] reviewed natural fiber-reinforced polymer composites and highlighted factors affecting their performance, including fiber orientation, fiber strength, volume fraction, and interfacial adhesion. The study emphasized that chemical treatment is essential to reduce the hydrophilic nature of natural fibers and improve compatibility with polymer matrices. Tribological performance under different loading conditions was also discussed.

Rajini et al. [11] investigated naturally woven coconut sheath composites reinforced with nanoclay and polyester resin. Alkali-treated fibers exhibited superior mechanical properties compared to untreated fibers. The incorporation of nanoclay improved both flexural strength and vibration damping characteristics. The treated hybrid composite demonstrated approximately 40% higher flexural strength than neat polyester.

Girisha et al. [12] studied moisture absorption and mechanical properties of sisal/coir-epoxy composites. Coir fibers were treated with sodium hydroxide and incorporated into epoxy resin. Experimental results indicated that moisture absorption reduced tensile strength due to deterioration of the fiber-matrix interface. However, flexural strength increased with fiber content under wet conditions.

Verma et al. [13] reviewed coir fiber-reinforced polymer composites and discussed their applications. The authors highlighted that coir fibers are economical, readily available, and environmentally friendly. However, the hydrophilic nature of natural fibers often results in poor interfacial bonding. The study reported that increasing fiber content altered tensile modulus, while excessive fiber loading reduced tensile strength due to inefficient stress transfer.

Venkateshwaran et al. [14] examined the effects of fiber length and fiber content on the mechanical properties of banana fiber/epoxy composites. Results demonstrated that tensile strength and modulus increased with fiber length and fiber weight fraction up to an optimum value of 15 mm fiber length and 12 wt.% fiber content. Beyond these levels, mechanical properties deteriorated due to poor adhesion and fiber agglomeration.

Majid Ali [15] reviewed the versatility of coconut fibers in civil engineering applications. The study highlighted the use of coconut fibers in cementitious composites, mortars, and concrete. Coir-reinforced composites were found to provide economical and durable solutions for non-structural construction applications.

Mechanical Properties Of Coconut Fiber Composites

The mechanical performance of coconut fiber-reinforced composites depends on several factors, including fiber volume fraction, fiber aspect ratio, fiber orientation, fiber length, interfacial bonding, and stress transfer efficiency between the fiber and matrix.Fiber content plays a critical role in determining composite strength and stiffness. An increase in fiber content generally enhances load-bearing capacity up to an optimum level. Beyond this limit, poor wetting and fiber agglomeration may reduce mechanical properties.

Fiber length is another important parameter. Short fibers below the critical fiber length fail primarily through interfacial debonding, whereas fibers longer than the critical length can effectively transfer stress and contribute to higher composite strength. Studies have shown that fiber lengths around 15 mm and fiber contents around 12–16 wt.% provide optimal tensile properties [14].

Chemical treatments such as alkali treatment improve fiber surface roughness and remove impurities, thereby enhancing interfacial adhesion and mechanical performance. Improvements in tensile strength, flexural strength, impact resistance, and modulus have been widely reported for treated coir composites [3], [4], [6].

The tensile strength of composites is highly sensitive to fiber orientation and interfacial bonding, whereas the elastic modulus is strongly influenced by fiber properties. Therefore, achieving a strong fiber-matrix interface and proper fiber alignment is essential for maximizing composite performance.

Conclusion

Based on the reviewed literature, coconut fiber-reinforced composites exhibit considerable potential as sustainable and cost-effective engineering materials. The mechanical properties of coir composites are significantly influenced by fiber length, fiber content, fiber orientation, and fiber surface treatment. Alkaline treatment has been identified as one of the most effective methods for improving fiber-matrix adhesion by removing surface impurities and reducing the hydrophilic nature of the fibers. Such treatments result in significant improvements in tensile, flexural, and impact properties.The literature further indicates that the selection of appropriate fiber dimensions, matrix systems, curing conditions, and processing parameters plays a crucial role in determining composite performance. Coconut fibers possess excellent toughness, energy absorption capability, and environmental advantages, making them suitable for a wide range of structural and non-structural applications. Future research may focus on optimizing fiber architecture, hybridization with other natural or synthetic fibers, and numerical validation using finite element tools such as ANSYS to further enhance the mechanical performance and application potential of coconut fiber composites.

References

1. K. M. M. Rao and K. M. Rao, "Extraction and tensile properties of natural fibers: Vakka, date and bamboo," *Composite Structures*, vol. 77, pp. 288–295.

2. P. N. E. Naveen and M. Yasaswi, “Experimental analysis of coir-fiber reinforced polymer composite materials,” *International Journal of Mechanical Engineering and Robotics Research*, vol. 2, pp. 10–18, 2013.
3. S. Stephano and V. G. Thurbius Galdius, “Fabrication of hybrid coconut fibre with epoxy composite,” *International Journal of Innovative Works in Engineering and Technology*, vol. 3, no. 4, pp. 370–377, 2017.
4. D. R. Mulinari, C. A. R. P. Baptista, J. V. C. Souza, and H. J. C. Voorwald, “Mechanical properties of coconut fibers reinforced polyester composites,” *Procedia Engineering*, pp. 2074–2079, 2011.
5. C. R. Rajeesh and K. K. Saju, “Methods and materials for reducing flammability behaviour of coir fibre based composite boards: A review,” *Materials Today: Proceedings*, pp. 9399–9407, 2017.
6. R. Shrivastava, A. Telang, R. S. Rana, and R. Purohit, “Mechanical properties of coir/glass fiber epoxy resin hybrid composite,” in *Proceedings of the 5th International Conference on Materials Processing and Characterization (ICMPC 2016)*, 2017.
7. T. P. Sathishkumar, P. Navaneethakrishnan, S. Shankar, R. Rajasekar, and N. Rajini, “Characterization of natural fiber and composites – A review,” *Journal of Reinforced Plastics and Composites*, pp. 1457–1476, 2013.
8. F. I. Romli, A. N. Alias, A. S. M. Rafie, and D. L. A. A. Majid, “Factorial study on the tensile strength of a coir fiber reinforced epoxy composite,” in *AASRI Conference on Modelling, Identification and Control*, 2012.
9. C. P. Araújo Junior, C. A. C. Coaquira, A. L. A. Mattos, M. S. M. S. Filho, J. P. A. Feitosa, J. P. S. Morais, and M. F. Rosa, “Binderless fiberboards made from unripe coconut husks,” *Waste and Biomass Valorization*, 2017.
10. L. Mohammed, M. N. M. Ansari, G. Pua, M. Jawaid, and M. S. Islam, “A review on natural fiber reinforced polymer composite and its applications,” *The Scientific World Journal*, Hindawi Publishing Corporation.
11. N. Rajini, J. T. Winowlin Jappes, S. Rajakarunakaran, and P. Jeyaraj, “Mechanical and free vibration properties of montmorillonite clay dispersed with naturally woven coconut sheath composite,” *Journal of Reinforced Plastics and Composites*, vol. 30, no. 20, pp. 1364–1376, 2012.
12. C. Girisha, Sanjeevamurthy, and G. R. Srinivas, “Sisal/coconut coir natural fibers–epoxy composites: Water absorption and mechanical properties,” *International Journal of Engineering and Innovative Technology (IJEIT)*, vol. 2, no. 3, pp. 166–170, 2012.
13. D. Verma, P. C. Gope, A. Shandilya, A. Gupta, and M. K. Maheshwari, “Coir fibre reinforcement and application in polymer composites: A review,” *Journal of Materials and Environmental Science*, vol. 4, pp. 263–276, 2013.
14. N. Venkateshwaran, A. ElayaPerumal, and M. S. Jagatheeshwaran, “Effect of fiber length and fiber content on mechanical properties of banana fiber/epoxy composite,” *Journal of Reinforced Plastics and Composites*, pp. 1621–1627, 2011.
15. M. Ali, “Coconut fibre: A versatile material and its applications in engineering,” *Journal of Civil Engineering and Construction Technology*, pp. 189–197, 2011.