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Enhancing The Flexural Strength of Hybrid Coconut Fiber Polyester Composite Board Through the Addition of Fiberglass

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Abstract

The research study aims to develop and characterize a hybrid coconut fiber-polyester composite board with the addition of fiberglass as a reinforcement. The study's main objective was to investigate the composite board flexural strength and evaluate the fiberglass's effects on its mechanical properties. The research methodology involved the fabrication of the composite board using a hand-lay-up technique. Coconut fibers were manually extracted from the trunk and processed into small powder-like pieces. Flexural tests were conducted using a Universal Testing Machine by ASTM D790 standards. The results showed the highest performance of flexural strength for the composites with 10% coconut fiber with addition of 10% fiberglass with the value of 509.05 N/mm^2. The composites with 10% coconut fibers with no addition of fiberglass exhibited the lowest flexural strength with the value of 173.61 N/mm^2. This indicates that fiberglass plays a crucial role in enhancing the bending strength of the composite material. The study concludes that the hybrid coconut fiber-polyester composite board with the addition of fiberglass exhibits promising mechanical properties, particularly in terms of flexural strength. The study recommends further exploration of fiber treatment methods to improve the adhesion between the coconut fibers and the polyester matrix. Additionally, the evaluation of the composite's environmental impact and the investigation of advanced fabrication techniques, such as resin infusion or compression molding, are suggested to optimize the production process and enhance the quality of the composite. Overall, the study contributes to the understanding of the mechanical properties of the hybrid coconut fiber-polyester composite board and its potential applications in various industries.

Keywords: - Hybrid composite, flexural strength, fiberglass reinforcement

1. Introduction

Composite materials have been in use for centuries, with their origins rooted in natural fibers. These natural fibers have become integral to the global economy, serving as a significant source of employment, particularly in developing countries. Their environmental benefits, including biodegradability and renewability, have positioned natural fibers as a preferred material in various industries. Fibers such as jute and coconut coir have been proven effective as reinforcements in both thermoset and thermoplastic matrices (Singh et al., 2020).

The increasing interest in applications within the automotive, cosmetics, and other sectors has amplified the demand for composites reinforced with natural fibers. This shift is driven by the economic and environmental advantages these materials offer over traditional inorganic reinforcements. Consequently, numerous industrial companies are actively seeking new composite materials that exhibit specific desirable properties, including mechanical, chemical, and residential building applications (Lertwattanaruk & Suntijitto, 2015).

In the quest for such innovative materials, a study was conducted focusing on the integration of coconut fiber (coir) into composite materials in Fig. 1. Coir, extracted from the coconut husk, is a thick, coarse, yet durable natural fiber. It is notably water-resistant and exhibits resilience against saltwater and microbial degradation. These properties make coir an excellent candidate for composite (Asasutjarit et al., 2007).

Fig. 1. Coconut fiber

This paper reviews the use of coconut fiber in composites with various epoxy resins, emphasizing the mechanical properties of coir fibers. Fig. 2 shows the polyester resin that was used in this research. Coconut fiber composites have shown promise due to their unique combination of strength, durability, and environmental compatibility. The review explores the potential of coir-based composites in enhancing the performance and sustainability of composite materials (Manik et al., 2019).

Fig. 2. Polyester resin

The study highlights that coconut fiber composites not only meet the growing demand for eco-friendly materials but also offer a viable alternative to synthetic fibers (Rahman et al., 2023). The use of coir in composites could lead to reduced environmental impact and lower production costs, aligning with the broader goals of sustainable development.

Furthermore, the paper delves into the mechanical properties of coconut fibers, providing insights into their performance in different resin matrices. This includes an analysis of their tensile strength, flexibility, and overall durability. The findings suggest that coir fibers can significantly enhance the mechanical properties of composite materials, making them suitable for a wide range of industrial applications.

2. Methodology

The experiments were carried out in the lab using materials that varied in the proportion of glass and coconut fibers. To guarantee that the hybrid composite composition used in the construction of drain covers is appropriate, these tests are essential. To evaluate the flexural strength characteristics of such a hybrid composite, a three-point flexural test was conducted using the ASTM D790 Standard (Kai et al., 2019). In Fig. 3, the process of making Hybrid Coconut Fiber-Polyester composite against polyester resin for sample preparation and fiberboard.

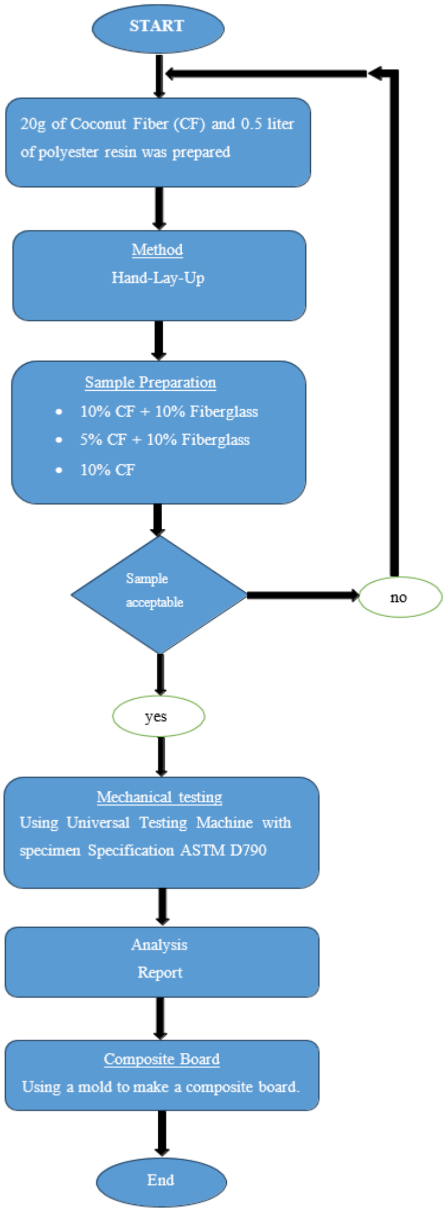

Fig. 3. Flowchart of experiment

The composites were fabricated using a manual lay-up method. The coconut fiber (CF) was physically removed from the trunk and then chopped into tiny bits to resemble a powder. The 127 x 12.7 x 3.2 mm samples were used to mix oil palm fronds with polyester resin according to ASTM D790 guidelines. This natural composite was divided into three different ratios: 10% CF + 10% Fiberglass (FG), 5% CF + 10% Fiberglass, and 10%. Following completion of the flexural test, the obtained data will be used, particularly those that appropriately depict future applications, such as drain covers. These findings are anticipated to influence and guide future practical uses of composite materials.

2.1 Hand Lay-Up Method

Hand lay-up is an open molding technique used to make small composite goods. It is one of the most basic ways of composite molding, with multiple advantages including low-cost equipment, easy processing, and the flexibility to make parts in a variety of sizes (Kai et al., 2019). It is very flexible to design modifications, and the initial equipment investment is low when compared to other composite production processes.

2.2 Composite Preparation

This study used externally procured coconut fiber and fiberglass. Table 1 contains a description of the mixing ratios used in this investigation to measure the mechanical strength of the composite polymer made from coconut fiber and fiberglass. Several combinations of coconut fiber and fiberglass were created, including 10% CF (no fiberglass), 5% CF with 10% FG, and 10% CF with 10% FG inside the polyester matrix. The composite composition is based on previous study that discover the maximum content of coconut fiber is up to 15wt.% to get the value of flexural strength. From the study, the researcher observed that the value of flexural strength of the composite contain more than 15wt.% will decrease (Das & Biswas, 2016). Thus, in this study the content of coconut fiber range 5wt.% and 10wt.% was chosen to fabricate the composite.

Table 1. Composite composition

Coconut Fiber (CF) Wt. %	Fiberglass (FG) Wt.%
10%	0%
10%	10%
5%	10%

2.3 Mechanical Testing

The Mechanical testing is a Universal Test Machines (UTMs) to evaluate the strength of each specimen by ASTM D790 requirements is an excellent technique. This approach provides for exact the measurement of the specimen's mechanical characteristics, notably its flexural strength and modulus. Choosing the strongest specimen from these tests assures that the material used in the subsequent process of manufacturing a drain cover has the required strength and structural integrity. Adherence to ASTM standards is critical for quality control and ensuring the final product fulfills the specifications. Fig. 4 shows the specimen sample. Each composition of composite has samples for us to test or analyse.

Fig. 4. The specimen samples

The Universal Testing Machines (UTMs) are adaptable equipment used to evaluate the mechanical characteristics of materials, especially their response to flexural stress. Fig. 5, flexural tests, often known as bending tests, are carried out to assess a material's modulus of elasticity and ultimate bending strength (Saritha et al., 2023).

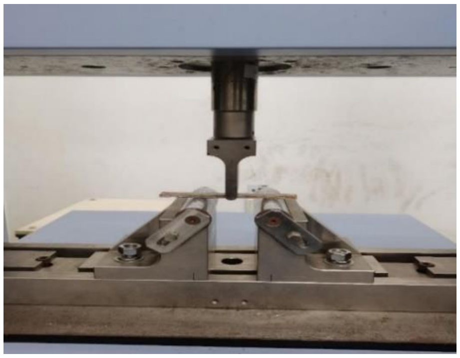

Fig. 5. Mechanical testing using universal testing machine (flexural test)

2.3.1 Three-Point Test Flexural Strength

In Fig. 6, a three-point test for the flexural strength (given the symbol σ) can be used. The material's flexural stress-strain response and modulus of elasticity in bending are measured using the three-point bending flexural test. A three-point bend fixture is used on a universal testing apparatus, also known as a tensile tester or tensile testing machine, to conduct this test (Nikolenko et al., 2021).

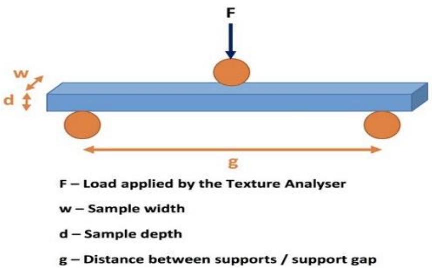

Fig. 6. Three-point bend testing

2.3.1 Flexural Strength Calculation

Equation (1) is used to calculate the flexural stress in a rectangular cross section.

$$\sigma f = \frac{3FL}{2bd^2} \qquad (1)$$

σf = Stress in outer fibers at mid-point, (MPa)
F = Load at given point on the load deflection curve, (N)
L = Support span, (mm)
b = Width of test beam, (mm)
d = Depth or thickness of test beam, (mm)

3. Result and Discussion

The flexural mechanical properties of the hybrid coconut fiber-polyester composite boards reinforced with varying amounts of fiberglass were evaluated through a series of tests on twelve specimens. These tests, conducted using a Universal Testing Machine by ASTM D790 standards, provided valuable insights into the mechanical performance of the composites with different reinforcement ratios.

a) 10% Coconut Fiber (CF) with No Fiberglass

The composite with 10% CF with 0% FG exhibited the lowest flexural strength among the three tested configurations. From Table 2, an average maximum force recorded was 118.52 N, with a corresponding maximum stress of 17,777.6 N/mm². The value of flexural strength calculated are 173.61 N/mm². These results serve as a baseline, highlighting the intrinsic mechanical properties of coconut fiber when used alone without additional reinforcement. These results are aligned with previous research which also record the lowest value of flexural strength when no fiberglass added to the composite (Jenarthanan & Marappan, 2019; Rahul et al., 2023).

Table 2. Flexural strength for variation 10% CF

No.	Max. Force (N)	Max. Stress (N/mm^2)	Break Force (N)	Break Stress (N/mm^2)
Sample 1	107.991	16198.6	0	0
Sample 2	98.8897	14833.5	98.7307	14809.6
Sample 3	148.672	22300.7	148.487	22273.1
Average	**118.5176**	**17777.6**		

b) 5% Coconut Fiber + 10% Fiberglass (FG)

Introducing 10% FG to a composite with 5% CF resulted in a significant enhancement of its mechanical properties. Table 3 shows an average maximum force increased to 233.52 N, and the maximum stress rose to 35,028.325 N/mm². The calculated flexural strength saw a substantial improvement, reaching 342.07 N/mm². This marked improvement indicates that even a modest addition of fiberglass substantially strengthens the composite, enhancing both its durability and load-bearing capacity. The enhancement of the mechanical properties of the composite in line with the previous research that stated that the addition of fiberglass has significantly improved the flexural strength of the composites (Shrivastava et al., 2017).

Table 3. Flexural strength for variation 5% CF + 10 FG

No.	Max. Force (N)	Max. Stress (N/mm^2)	Break Force (N)	Break Stress (N/mm^2)
Sample 1	209.554	31433.1	209.367	31405
Sample 2	185.795	27869.2	163.612	24541.9
Sample 3	279.35	41902.5	269.419	40412.9
Sample 4	259.39	38908.5	230.951	34642.7
Average	**233.5223**	**35028.325**		

c) 10% Coconut Fiber + 10% Fiberglass

The highest performance metrics were observed in the composite with 10% CF and 10% FG. An average maximum force achieved was 312.34 N, with a corresponding maximum stress of 46,851.44 N/mm² as shown in Table 4. The calculated flexural strength peaked at 509.05 N/mm². These results underscore the efficacy of fiberglass as a reinforcement material, significantly boosting the composite's mechanical properties and demonstrating its crucial role in enhancing flexural strength and resistance to bending. The highest value of flexural strength is influenced by the amount of fiberglass added to the composite. These statements are supported by previous study state that increasing the number of layers of fiberglass increases the mechanical properties of the composite such as flexural and tensile strength (Windyandari et al., 2022).

Table 4. Flexural strength for variation 10% CF + 10% FG

No.	Max. Force (N)	Max. Stress (N/mm^2)	Break Force (N)	Break Stress (N/mm^2)
Sample 1	274.359	41153.9	273.209	40981.3
Sample 2	208.213	31231.9	207.268	31090.3
Sample 3	343.952	51592.8	337.178	50576.7
Sample 4	541.627	81244	541.411	81211.6
Sample 5	193.564	29034.6	193.564	29034.6
Average	**312.343**	**46851.44**		

The variation of flexural strength for each ratio has been calculated in equation (1). Based on Fig. 7, the highest ratio is 10% CF + 10% FG, with a total flexural strength test of 509.05 N/mm², while the lowest is 10% CF, with a total flexural strength test of 173.61 N/mm². Fiberglass plays a critical role in increasing the bending strength of this composite. An in-depth analysis of the overall graph reveals that the addition of fiberglass significantly contributes to the increase in bending strength found in the composite material.

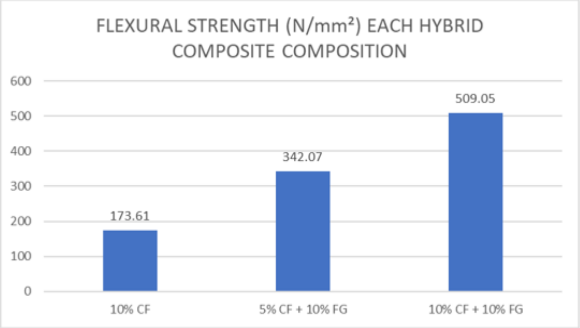

Fig. 7. Average overall flexural strength for all ratio

3.1 Implications for Industrial Applications

The study's findings suggest that hybrid coconut fiber-polyester composites reinforced with fiberglass have considerable potential for various industrial applications. The improved mechanical properties make these composites suitable for use in scenarios requiring enhanced strength and durability, such as in the automotive, construction, and aerospace industries. The lightweight nature of the material, combined with its increased flexural strength, offers both economic and environmental advantages over traditional inorganic reinforcements.

3.2 Recommendations for Future Research

Future research should focus on exploring different fiber treatment methods to improve the adhesion between coconut fibers and the polyester matrix (Jamaluddin & Hashim, 2021; Okpala et al., 2021). Additionally, evaluating the environmental impact of these composites and investigating advanced fabrication techniques, such as resin infusion or compression molding, could optimize production processes and enhance the quality of the composites (Azevedo & Soares, 2023; Sarukasan et al., 2021). Application-specific studies in various industries are recommended to assess the suitability and potential advantages of these composites in different contexts (Ghosh & Bar, 2019).

Overall, this study contributes significantly to the understanding of the mechanical properties of hybrid coconut fiber-polyester composites and their potential applications in various industries. The integration of fiberglass not only enhances the mechanical properties but also paves the way for more sustainable and high-performance composite materials.

4. Conclusion

In conclusion, this study has demonstrated the significant benefits of reinforcing coconut fiber-polyester composites with fiberglass. The enhanced mechanical properties, particularly in terms of flexural strength, make these composites promising candidates for a variety of industrial applications. By addressing the recommendations for future research, the potential of these materials can be further realized, contributing to the development of sustainable and high-performance composites. This study advances the understanding of hybrid coconut fiber-polyester composites and sets the stage for further innovation in composite material science.

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