Strength Analysis of Epoxy Resin Composite with Litchi and Jamun Seed Powder

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Abstract
Recent advances in materials science have opened up new methods for developing sustainable and high-performance composite materials. The research focused on combining epoxy resin with natural fillers to create composites with mechanical strength, tensile strength, flexural strength, thermal properties, and environmental characteristics. This research project focuses on the innovative creation of a novel composite material by combining epoxy resin with jamun and litchi seed powder as reinforcing agents. The aim is to explore the feasibility of utilizing agricultural waste as discarded seeds to produce a sustainable and eco-friendly composite material with enhanced mechanical and thermal properties. Furthermore, the project will focus on sustainability by repurposing agricultural waste, reducing environmental impact, and potentially offering a cost-effective alternative to conventional composite materials. The outcomes of this research will contribute to the development of sustainable composite materials and offer insights into the potential applications of agricultural waste in composite material engineering. The findings will pave the way for eco-friendly alternatives in various industries including manufacturing, construction, and packaging, promoting a more sustainable and greener future. The flexural analysis of the composite specimen infers that sample S6 (10% of litchi seed powder) has the highest flexural strength among all other specimens. The impact analysis of the composite specimen infers that sample S1 is higher than the others. The tensile analysis of the composite specimen infers that sample S1 has the highest tensile strength among all other specimens.
Keywords: waste materials, strength, composites, litchi seed powder, jamun seed powder.

1. Introduction

The study examines the behavior of castor oil-based polyurethane resin slabs with coconut and sisal fibers as plain weaves. Results show sisal fibers offer better results than coconut fibers. Increased fiber content increases tensile strength, stiffness, and water absorption but decreases flexural strength. Polymeric laminates of epoxy and castor oil-based polyurethane resins are technically viable for timber wood reinforcement. Mercerisation treatment reduces tensile behavior variability but decreases stiffness and tensile strength[1]. Natural fibers provide high-specific qualities such as impact resistance, stiffness, flexibility, modulus, cheap cost, low density, vibration dampening, and improved recovery. They are abundantly accessible, have minimal health risks, and have little abrasion resistance.Renewable fibers have high potential due to their low cost, high production volume, and advantageous properties in other markets. Natural fiber production consumes 60% less energy compared to glass fibers[2]. The study investigated the impact of rice husk on bio-composite's mechanical and thermal properties. Results showed rice husk increased elasticity and tensile strength while reducing elongation to failure. Polypropylene and Argan's nutshells improved Young's modulus. Coconut shell and palm fruit combinations improved mechanical coconut bio-composite. High hemp amounts made polylactic acid matrix production economically viable. Bio-composites from polylactic acid and bamboo cellulose nano-whiskers were studied for structure and behavior [3]. The study explores the use of various waste and organic materials in friction composites, including cashew dust, walnuts, hazelnut shells, and rice husk dust. These materials are binders, reinforcements, abrasives, friction modifiers, solid lubricants, heat, and space fillers. Phenolic resin is commonly used as a binder in friction composites, while reinforcements include various fiber materials like aramid fiber, rock wool, and ion composites [4]. Mango seed waste is a major issue in Indonesia, accounting for 1 million tons of garbage per year. To solve this, a brake pad made from mango seeds as a natural fiber material is being developed, together with a magnesium oxide and brass combination. The study examines the amount of mango seed powder, brass powder, and magnesium oxide in the brake lining material and employs wear, hardness, and macro picture tests. The composite brake pad material is composed of an epoxy matrix supplemented with mango seed powder, magnesium oxide powder, Indica, and brass powder. It has been evaluated for wear, hardness, microstructure, and mechanical characteristics [5]. Natural fibers are divided into six categories: bast fibers (jute, flax, hemp, ramie, and kenaf), leaf fibers (abaca, sisal, pineapple), seed fibers (coir, cotton, kapok), core fibers (kenaf, hemp, jute), grass and reed fibers (wheat, maize, rice), and all other varieties (wood and roots). The study included oil palm fiber, birch fiber, and eucalyptus fiber, which are byproducts of palm mills and have increased toughness, making them possible reinforcement in polymers. Palm fiber's low density makes it good for weight loss [6].

2. Materials used

The composite specimens are prepared by using the following materials:

2.1 Epoxy resin

In this project, epoxy resin is essential since it acts as the composite matrix material. Its adhesive strength and adaptability provide the basis for blending with jamun and litchi seed powder. Epoxy resin serves as a binding agent that improves the composite's durability and structural integrity, while the seed powders serve as reinforcing agents that may improve its mechanical and thermal properties. By encasing and binding these organic reinforcements, the resin provides a sustainable solution that turns agricultural waste into a useful composite material. The protecting, insulating, and adhesive qualities of epoxy resin enable the development of an environmentally friendly composite with enhanced functionality and a smaller environmental footprint.

2.2 Litchi seed powder

The project benefits greatly from the use of litchi seed powder, which is a naturally occurring reinforcing element in the composite material. Sugarcane fiber serves as a reinforcement material, and tamarind seed powder particles are used as filler. Hybrid bio-composite specimens were created using varying reinforcing and filler ingredients, all while maintaining a constant weight proportion of epoxy resin [7]. The fibrous and particulate properties of the litchi seed powder allow it to blend in with the epoxy resin matrix, which may improve the mechanical strength and thermal stability of the composite. Its innate qualities, such as durability and hardness, can strengthen the matrix and increase the material's ability to withstand impact and strain. Furthermore, its sustainable sourcing and natural abundance support the environmentally beneficial goal of recycling agricultural waste, providing an affordable and environmentally responsible option for the production of composite materials that may result in a long-lasting and sustainable final product.

2.3 Jamun seed powder

The powdered jamun seed provides an important natural reinforcement to the composite material, enhancing the epoxy resin matrix. Its distinct granular and fibrous makeup may improve the mechanical qualities of the composite, providing increased stiffness, strength, and possibly even higher heat resistance. By repurposing agricultural by-products, jamun seed powder contributes to the sustainability goal by decreasing waste and providing an environmentally beneficial alternative. This natural reinforcement has built-in qualities that, when paired with the resin, might increase the overall longevity of the composite. This opens up a promising path for the development of durable, sustainable materials that could find use in a range of industries.

2.4 Hardener

The hardener catalyzes the cross-linking reaction when mixed with the resin, turning the liquid into a strong, solid substance. The composite's ultimate mechanical qualities, temperature tolerance, and cure time are all determined by its inclusion. The strength, adhesion, and resistance of the material are ensured by accurately measuring and combining the hardener with the epoxy resin. As the end product's stability and integrity, the hardener's function is essential to the composite material's performance and desired properties.

2.5 Experimental setup and method of testing

The hand layup process is an essential method in the production of composites. It entails the methodical layering of reinforcing fibers, like carbon or fiberglass, inside a mold. Tensile and flexural strengths are maximized by hand layup, vacuum bagging, and sparing filler addition. It is essential to add more filler in order to improve the hardness and wear resistance. Fibres' wear resistance and hardness were impacted by chemical treatment [8].

The preparation of the mold and the subsequent insertion of the dry reinforcing fibers into it are the first steps in this practical procedure. The fibers are then manually impregnated and saturated with epoxy glue to create a uniform distribution and strong binding. This method is useful and economical since it allows for design flexibility and may be used for small- to medium-scale production. To ensure structural integrity, perfect fiber alignment, uniform resin distribution, and air pocket elimination require expert craftsmanship. Tensile, flexural, impact, and moisture absorption tests were performed on five sets of specimens two treated and one untreated in order to fully assess the physical strength of each particular combination. In comparison to the untreated fibers, treated fibers had a greater increase in tensile, flexural, impact, and moisture tests out of all the tests [9].

1. Preparation of mold and materials: The initial step involves cleaning and preparing a mold for shaping the final product, while reinforcing materials like fiberglass or carbon fiber are cut and organized for easy access.
2. Layering of reinforcing material: The next step involves manually arranging reinforcing materials in the mold, ensuring proper alignment and minimal air entrapment for the final composite's strength and integrity.
3. Resin application and curing: Reinforcing materials are laid out, and epoxy resin is applied manually to fully saturate fibers. The composite is left to cure, allowing the resin and hardener to solidify. Control of temperature and curing time is crucial. The composite is then covered with a release film for optimal bonding. The resin undergoes a chemical reaction, forming the final composite structure.
4. Composite tensile specimens were prepared in compliance with ASTM D3039, while resin specimens were prepared in

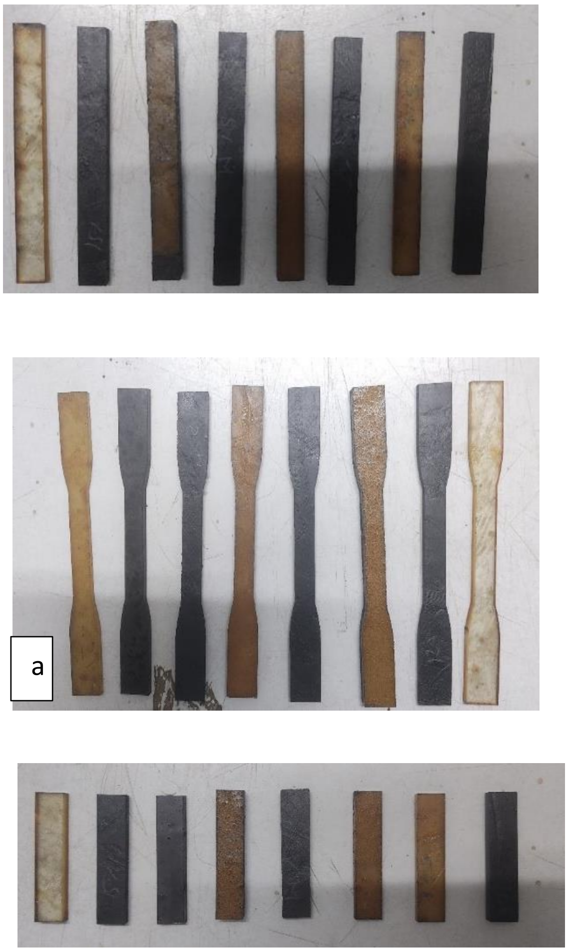


Figure 2 (a) Tensile specimen (b) Flexural specimen (c) Impact specimen

accordance with ASTM D638. Tensile specimens made of sisal and phenolic/PU resin were examined at a speed of 10 mm per minute. Composites made of PU/sisal fibers and phenolic resin were tested at a rate of 0.2 mm/min and, correspondingly, 5 mm/min [10]. The material in the shape of a dog bone shown in figure 2 (a) is ready for tensile testing. Because it is based on the ASTM D638 Type IV standard, which is frequently used for tensile testing of composite materials, this shape was selected.

5. Flexural testing of the epoxy resin composite is carried out per ASTM requirements; the prepared flexural testing measures are 3.2 mm in width, 12.7 mm in height, and 125 mm in length and are shown in the figure2 (b).

6. Based on ASTM standards, which are presented in figure 2 (c), the dimensions of 64 x 12.7 x 3.2 mm enable a sufficient sample size to correctly assess the impact resistance of the epoxy resin composite. As a baseline structure, composite structures with a general quasi-isotropic configuration were created. Shear strength and flexural characteristics of certain materials were assessed using laminated composites theory and relevant ASTM testing [11].

2.6 Weight Fraction Calculation

The weight fraction of Jamun & litchi seed powder in a composite material which is shown in the table 2.1, can vary widely depending on the specific application, requirements, and the desired properties of the composite.

Table 2.1 Weight fraction calculation

Sample	Epoxy resin (g)	Harde-ner(g)	Jamun seed powder (g)	Litchi seed powder (g)
S1	405	45	0	0
S2	384.75	42.75	22.5	0
S3	364.5	40.5	45	0
S4	344.25	33.25	67.5	0
S5	384.75	42.75	0	22.5
S6	364.5	40.5	0	45
S7	344.25	33.25	0	67.5
S8	384.75	42.75	11.25	11.25
S9	364.5	40.5	22.5	22.5

3. Results and Discussion

3.1 Flexural test results

The pure sample without adding any seed powder contains only 405 g of resin and 45 g of hardener has a flexural strength of 29.7 N/mm^2.

The sample with 5% jamun seed powder contains 22.5 g of jamun seed powder, 384.75 g of resin, and 42.75 g of hardener and has a flexural strength of 18.45 N/mm^2 which is 37.8

% less than the pure sample's flexural strength. The sample with 10% jamun seed powder contains 45 g of jamun seed powder, 364.5 g of resin, and 40.5 g of hardener and has a flexural strength of 23.15 N/mm^2 which is 22 % less than the pure sample's flexural strength. The sample with 15% jamun seed powder contains 67.5 g of jamun seed powder, 344.25 g of resin, and 33.25 g of hardener and has a flexural strength of 12.97 N/mm^2 which is 56.32% less than the pure sample's flexural strength.

The sample with 5% litchi seed powder contains 22.5 g of jamun seed powder, 384.75 g of resin, and 42.75 g of hardener and has a flexural strength of 11.3 N/mm^2 which is 61.9% less than the pure sample's flexural strength. The sample with 10% litchi seed powder contains 45 g of jamun seed powder, 364.5 g of resin, and 40.5 g of hardener and has a flexural strength of 38.45 N/mm^2 which is 29.46% higher than the pure sample's flexural strength. The sample with 15% jamun seed powder contains 67.5 g of jamun seed powder, 344.25 g of resin, and 33.25 g of hardener and has a flexural strength of 12.97 N/mm^2 which is 56.3% less than the pure sample's flexural strength.

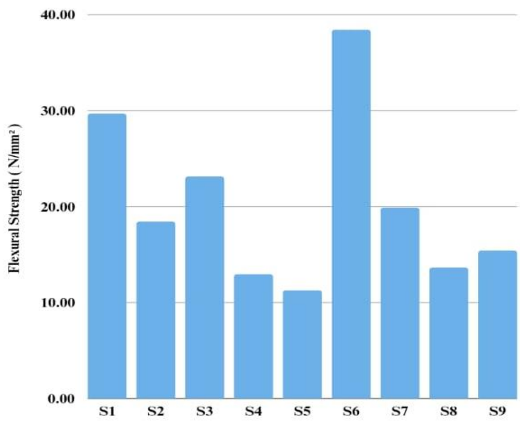
The sample with a 5% mixture of two seed powder contains 11.25 g of jamun seed powder, 11.25 g of litchi seed powder, 384.75 g of resin, and 42.75 g of hardener has a flexural strength of 13.66 N/mm^2 which is 54% less than the pure sample's flexural strength. The sample with a 10% mixture of two seed powder contains 22.5 g of jamun seed powder, 22.5 g of litchi seed powder, 384.75 g of resin, and 42.75 g of hardener has a flexural strength of 15.42 N/mm^2 which is 48% less than the pure sample's flexural strength. The flexural test results are shown in the figure 3.1.

Figure 3.1 Flexural Strength

3.2 Impact test results

The pure sample without adding any seed powder contains only 405 g of resin and 45 g of hardener and has the work done of 0.726 joule. The sample with 5% jamun seed powder contains 22.5 g of jamun seed powder, 384.75 g of resin, and 42.75 g of hardener has the work done of 0.167 joule which is 76% less than the pure sample's work done. The sample with 10% jamun seed powder contains 45 g of jamun seed powder, 364.5 g of resin, and 40.5 g of hardener has a work done of 0.252 joule which is 65.2% less than the pure sample's work done. The sample with 15% jamun seed powder contains 67.5 g of jamun seed powder, 344.25 g of resin, and 33.25 g of hardener and has the work done of 0.209 joule which is 71.2% less than the pure sample's work done.

The sample with 5% litchi seed powder contains 22.5 g of jamun seed powder, 384.75 g of resin, and 42.75 g of hardener has the work done of 0.167 joule which is 76.9% less than the pure sample's work done. The sample with 10% of litchi seed powder contains 45 g of jamun seed powder, 364.5 g of resin, and 40.5 g of hardener has the work done of 0.337 joule which is 53.5% less than the pure sample's work done. The sample with 15% of jamun seed powder contains 67.5 g of jamun seed powder, 344.25 g of resin, and 33.25 g of hardener has the work done of 0.379 joule which is 47.7% less than the pure sample's work done.



The sample with 5% of mixture of two seed powder contains 11.25 g of jamun seed powder, 11.25 g of litchi seed powder, 384.75 g of resin and 42.75 g of hardener has the work done of 0.167 joule which is 40.5% less than the pure sample's work done. The sample with 10% of mixture of two seed powder contains 22.5 g of jamun seed powder, 22.5 g of litchi seed powder, 384.75 g of resin and 42.75 g of hardener has the work done of 0.252 joule which is 34.4% less than the pure sample's work done. The impact test results are shown in the figure 3.2.

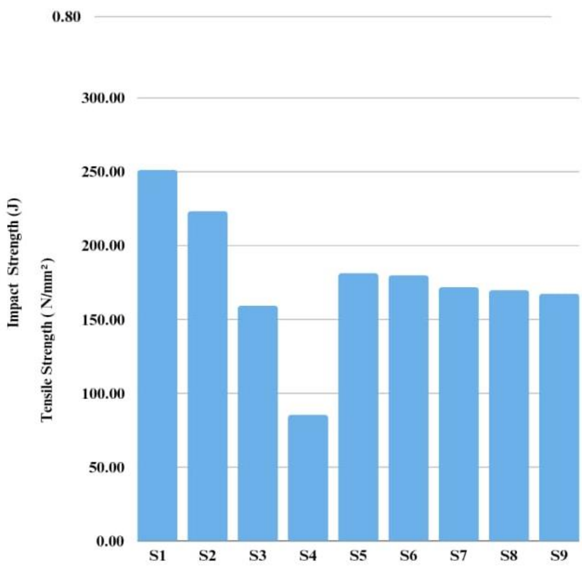


Figure 3.2 Impact strength

3.3 Tensile test results

The pure sample without adding any seed powder contains 405 g of resin and 45 g of hardener and has a tensile strength of 104.987 N/mm^2.

The sample with 5% jamun seed powder contains 22.5 g of jamun seed powder, 384.75 g of resin, and 42.75 g of hardener and has a tensile strength of 132.975 N/mm^2 which is 26.6% higher than the pure sample's tensile strength. The sample with 10% jamun seed powder contains 45 g of jamun seed powder, 364.5 g of resin, and 40.5 g of hardener and has a tensile strength of 136.800 N/mm^2 which is 30.2% higher than the pure sample's tensile strength. The sample with 15% jamun seed powder contains 67.5 g of jamun seed powder, 344.25 g of resin, and 33.25 g of hardener and has a tensile strength of 121.654 N/mm^2 which is 15.5% higher than the pure sample's tensile strength.

The sample with 5% litchi seed powder contains 22.5 g of jamun seed powder, 384.75 g of resin, and 42.75 g of hardener and has a tensile strength of 114.765 N/mm^2 which is 9.3% higher than the pure sample's tensile strength. The sample with 10% litchi seed powder contains 45 g of jamun seed powder, 364.5 g of resin, and 40.5 g of hardener and has a tensile strength of 126.986 N/mm^2 which is 20.9% higher than the pure sample's tensile strength. The sample with 15% jamun seed powder contains 67.5 g of jamun seed powder, 344.25 g of resin, and 33.25 g of hardener and has a tensile strength of 131.345 N/mm^2 which is 25% higher than the pure sample's tensile strength. This sample has the highest tensile strength among all the samples.

The sample with 5% of a mixture of two seed powders contains 11.25 g of jamun seed powder, 11.25 g of litchi seed powder, 384.75 g of resin, and 42.75 g of hardener has a tensile strength of 136.334 N/mm^2 which is 29.8% higher than the pure sample's tensile strength. The sample with a 10% mixture of two seed powders contains 22.5 g of jamun seed powder, 22.5 g of litchi seed powder, 384.75 g of resin and 42.75 g of hardener has a tensile strength of 133.897 N/mm^2, which is 30.3% higher than the pure sample's tensile strength. The tensile test results are shown in the figure 3.3.

Figure 3.3 Tensile strength

4. Conclusion

The composite material with epoxy resin, Jamun and Litchi seed powder is fabricated with the help of a hand layup process. The mechanical properties of impact and flexural tests were demonstrated. The flexural analysis of the composite specimen infers that sample S6 (10% of litchi seed powder) has the highest flexural strength of 38.45 N/mm^2 among all other specimens. The sample(S5) 5% litchi seed powder has a flexural strength of 11.3 N/mm^2 which is the lowest flexural strength among all. The impact analysis of the composite specimen infers that sample S1 (pure) has an impact energy of 0.726 joule which is higher than the others. The samples (S2, S5, S8) has the lowest impact energy of 0.167 joule among all other samples. The tensile analysis of the composite specimen infers that sample S1 (pure sample) has the highest tensile strength of 251.254 N/mm^2 among all other specimens. The sample(S4) has lowest tensile strength of 84.416 N/mm^2 among all specimens.

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