Research Article

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Investigation of Snake Grass/Casuarina/Cork Filler Reinforced Bio Polymer Hybrid Composite

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ABSTRACT

The environment is continuously affected for various reasons, prompting researchers to seek solutions from different angles. This study explores the potential of mixing polymers with and without agricultural/bio fillers such as Snake Grass / Casuarina / Cork in various volume proportions, analyzing their mechanical properties. The hybrid materials are made with the polymers and bio fillers without any change in the quality of existing polymer products, the quality of hybrid materials is assured by the results of impact, flexural, and tensile tests. The biodegradability tests revealed weight loss in a soil burial test when bio filler was added to the polymer composite.

Keywords: Snake grass; Cork; Casuarina; Bio fillers; Alternative materials.

1. INTRODUCTION

Bio-based plastic goods and biodegradable polymers, crafted from renewable resources, hold promise for creating environmentally friendly and sustainable alternatives that can effectively compete in today's market (Mohanty *et al.* 2002; Satyanarayana *et al.* 2009; Fernandes *et al.* 2013). Parthasarathy *et al.* (2022) fabricated composite specimens using the hand lay-up technique by incorporating varying proportions of *Casuarina* fibers into an epoxy matrix. The mechanical properties of the developed composites were evaluated through tensile, flexural, and impact tests. Based on the performance results, the material was further employed in the fabrication of an environmentally friendly gear. The findings indicate that epoxy-based Casuarina composites are suitable for small- to medium-load applications. The mechanical properties of composites made from natural fibers are affected by parameters such as fiber type, orientation, maturity, chemical treatment, fiber volume / weight percentage, alignment, distribution, processing procedures, and additives utilized (Arrakhiz *et al.* 2013; Pickering *et al.* 2016; Dixit *et al.* 2017). Jenish *et al.* (2022) investigated the mechanical properties of epoxy composites reinforced with snake (Mudar) grass fibers. The composites were further modified by incorporating nano-silica as a filler material. The results demonstrated an improvement in mechanical performance with the addition of nano-silica, indicating the suitability of these composites for structural applications. The composite containing 20-25% natural filler had the best mechanical properties, demonstrating an optimal balance between filler concentration and composite performance (Chandramohan *et al.* 2023; Parthasarathy *et al.* 2024). Recent research into biodegradable and environmentally friendly fillers of composites from polymers has gained traction due to globally environmental movements and recycling challenges (Jagadeesh *et al.* 2013; Shah *et al.* 2014; Prabhakar *et al.* 2015). A major concern with using natural fibers in composites is their tendency to absorb moisture, which can negatively impact their physical and mechanical qualities. The type of fiber and matrix, production method, and relative humidity all influence the amount of moisture absorbed (Dhakal *et al.* 2007). Kalimuthu *et al.* (2019) developed polyester composites reinforced with *Cyperus pangorei* fiber (CPF) using the compression molding technique. The effects of fiber length and fiber content on the mechanical properties were systematically evaluated. The composite with an optimal configuration of 40 mm fiber length and 40 wt% fiber content exhibited significant improvements in tensile, flexural, and impact strengths. These findings indicate that CPF-reinforced polyester composites are a promising alternative for structural applications in the construction and automotive sectors. Parthasarathy *et al.* (2024)fabricated composite specimens using the hand lay-up technique by incorporating varying proportions of cork powder into an epoxy matrix. The mechanical properties were evaluated through tensile, flexural, and impact tests. The study identified the optimum composition corresponding to enhanced mechanical performance. Megahed *et al.* (2017) investigated the effect of carbon/silica hybrid nanofillers on the wear resistance and hardness of glass fiber-reinforced epoxy composites. The results indicated significant improvements in both wear resistance and hardness with the incorporation of hybrid nanofillers. Among the

factors studied, wear time was identified as the most influential parameter, followed by nanoparticle content. Senthilrajan *et al.* (2022) evaluated the influence of fiber length and fiber loading on the flexural and dynamic mechanical properties of jute/polyester composites. The composite containing 5 mm fiber length and 25 wt% fiber loading exhibited the highest flexural strength. In contrast, the composite with 15 mm fiber length and 25 wt% fiber content showed improved fiber–matrix adhesion and a higher storage modulus, indicating enhanced dynamic mechanical performance. Padmanabhan *et al.* (2024) evaluated aluminium-based hybrid fiber metal laminates (HFMLs) reinforced with basalt, hemp, and bamboo fibers. Among the various stacking sequences, the BBbAlBbB configuration exhibited superior mechanical properties. The results highlight the potential of these laminates for eco-friendly, high-performance applications, particularly in micro-mobility vehicle panels.

The present work examines the effects of incorporating bio fillers into a matrix made from epoxy as a fiber material, with the goal of determining how it influences the mechanical properties and biodegradability of epoxy composites. While previous studies frequently utilized both bio and non-bio fibers/fillers in the epoxy composites, this research stands out by focusing on optimizing the formulation of composites using epoxy and bio fillers at different volume percentages. Bio composites provide an eco-friendly alternative to traditional plastics by utilizing renewable resources such as plant fibers. These materials lead to a more environmentally friendly future by reducing emission of carbon and reliance on fossil fuels. Furthermore, bio composites typically biodegrade more readily than conventional plastics, helping to mitigate environmental pollution.

Table 1. Bio filler and epoxy percentages in the specimen

Sample ID	Materials			
	Epoxy (%)	Casuarina (%)	Cork (%)	Snake Grass (%)
Type-1	80	0	10	10
Type-2	80	10	0	10
Type-3	80	5	5	10

2. EXPERIMENTAL PROCEDURE

2.1 Materials

To achieve uniform dispersion, a mechanical mixer was used to continually stir both the natural and synthetic resins for 45 minutes. The compression molding method was used to create cork filler with epoxy hybrid polymer material laminates (Ganesamoorthy *et al.* 2021). The laminates were sliced for various testing in conformity with the criteria of the ASTM standards after they had cured. Table 1 shows the ratios of bio fillers and epoxy used in specimen production.

3.TESTING METHODS

3.1 Mechanical Properties

The Instron universal testing machine was used to perform tensile and flexural testing. The ASTM D-3039 was followed in the performance of the tensile test. To determine flexural vigor, a three-point bending experiment was executed by ensuing the guidelines of ASTMD-790 (Altaee *et al.* 2023) In compliance with ASTM D-4812, the impact strength was determined using the Izod method. Five samples were used in each test, and the median value was calculated. Table 2 gives details about the specifications and dimensions for the test specimens.

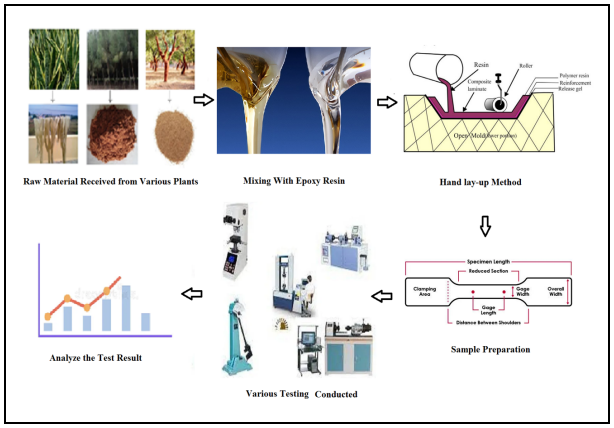


Fig. 1: Work flow of bio filler epoxy composite study

Table 2. Test specimens standards

Testing Methodology	Specification	Dimension (mm)
Tensile Testing	ASTM D 3039	250 x 25 x 2.5
Impact Testing (Izod)	ASTM D 4812	64 x 12.7 x 3.2
Flexural Testing	ASTM D 790	154 x 13 x 3

3.2 Biodegradability Test

The most traditional and widely used technique for evaluating deterioration is soil burial, which takes advantage of the rich microbial community in soil that arises from actual waste disposal circumstances (Guo *et al.* 2013). By tracking weight loss in soil over time, the biodegradability of the samples was evaluated. Samples were first weighed, buried in soil, excavated after intervals of 30, 60, 90, and 120 days, rinsed, and then reweighed.

3.3 RESULTS AND DISCUSSION

The hybrid bio composite was made using different fiber and filler material compositions in accordance with ASTM standards, and a mechanical evaluation was performed on it. Pure epoxy was used as

the reference material and compared with three types of epoxy-based composites. Type 1 composites were prepared by incorporating 10% snake grass fiber and 10% cork filler into the epoxy matrix. Type 2 composites consisted of 10% snake grass fiber and 10% Casuarina filler. Type 3 composites were developed using a hybrid combination of 10% snake grass fiber, 5% cork filler, and 5% Casuarina filler. The results are presented in Fig. 2 to Fig. 4. Fig. 2 illustrates the tensile performance of the various composite compositions, including tensile strength and tensile modulus. The preparation of tensile specimens was carried out in compliance with ASTM D3039 [ASTM D3039, 2014]. All three epoxy composite types (Type 1, Type 2, and Type 3) exhibited improved tensile performance compared to pure epoxy. Type-3 composition (5% Casuarina/ 5% cork/ 10% snake grass fiber/ 80% epoxy resin) exhibited optimal outcomes, with overall tensile strength at 37 MPa and tensile modulus at 1398 MPa. These findings demonstrate how significantly the fiber volume ratio affects the tensile characteristics of composites.

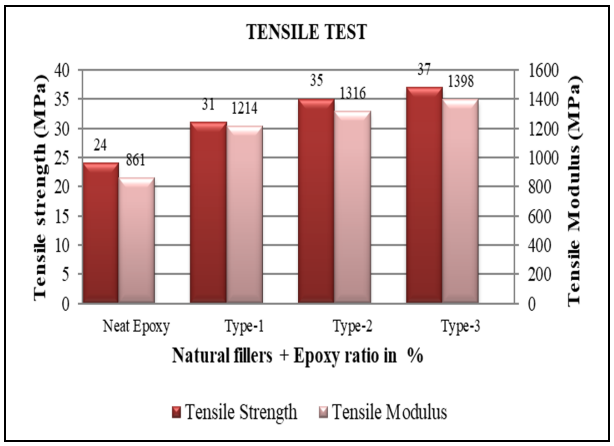


Fig. 2: Hybrid composite material - tensile properties

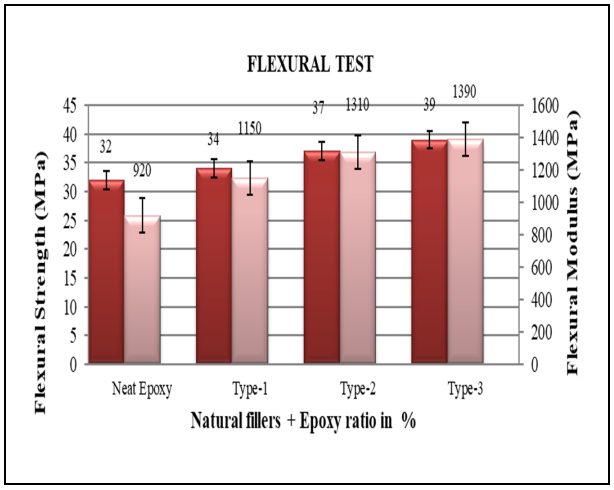


Fig. 3: Hybrid composite material - flexural properties

Fig. 3 illustrates the changes in flexural strength and flexural modulus in different mixtures. The preparation of tensile specimens was carried out in compliance with ASTM D790 [ASTM D790, 2014]. The flexural test results of epoxy composites Types 1, 2, and 3 were superior to those of pure epoxy. Type-3 composition (5% Casuarina / 5% cork / 10% snake grass fiber/ 80% epoxy resin) demonstrated superior performance, with overall flexural strength of 39 Mpa and a modulus of 1390 MPa. This pattern will be further explained in terms of how the fiber content affects the composite's flexural qualities. Fig.4 illustrates the changes of impact strength in different mixture. The preparation of impact specimens was carried out in compliance with ASTM D4812 [ASTM D4812, 2019]. The Type-3 composition (5% Casuarina / 5% Cork / 10% Snake grass fiber / 80% epoxy resin) exhibits the maximum impact strength, measuring 1.73 J, as shown in Fig. 4. The impact test results of epoxy composites Types 1, 2, and 3 were higher than those of pure epoxy, indicating improved impact resistance. Impact strength measures a material's capacity to endure abrupt, heavy load for a brief period of time (Venkateshwaran *et al.* 2011). Impact tests are designed to produce large strain in a short amount of time, hence no discernible variation in impact strength results should be expected across all compositions tested.

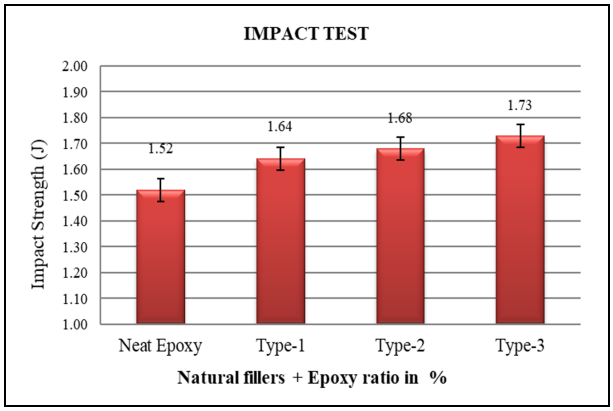


Fig. 4 Hybrid composite material - impact properties

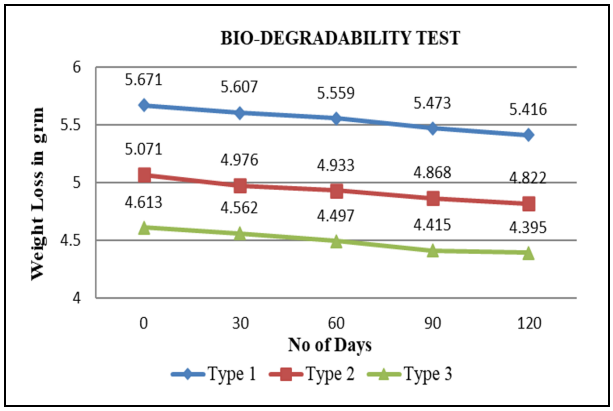


Fig. 5 Bio degradability analysis

Biodegradability testing involved burying a material sample in damp soil, as illustrated in Fig. 5, to

assess the impact on cork-blended epoxy polymer materials. Before burial, the sample's initial weight was recorded, and further measurements were collected at regular intervals to track any changes. After 120 days, the samples exhibited a loss of approximately 4 to 5 percent of their total weight. The interaction with micro and macro-organisms was attributed for the weight loss observed in the composite sample over time. A comparative evaluation of the substance with other bio fiber and filler-reinforced polymer composites showed that its biodegradability was higher. The incorporation of bio filler in the epoxy hybrid material contributes to the production of a more environmentally friendly polymer.

4. CONCLUSION

This study investigated the development of bio-composites hybrid polymer material by incorporating snake grass, Casuarina, and cork fillers into epoxy resin. The research comprehensively analyzed the consequence of these fillers upon mechanical qualities of the epoxy.

- A thorough examination of mechanical qualities revealed that the composite containing Type 3 (10% snake grass, 5% Casuarina, 5% cork, and 80% epoxy) exhibited superior impact, flexural and tensile strengths.
- This optimization was greatly aided by the remarkable fit between the bio fillers and resin, which was especially noticeable at an amount ratio of 5% Casuarina, 5% cork, 10% snake grass, and 80% epoxy.
- In the biodegradability test, a notable weight loss ranging between 4 to 5 percent was observed over a span of 120 days, signifying the most substantial degradation.
- Incorporating agricultural products as fillers not only meets the quality expectations for polymer products but also enhances their performance compared to pure polymers.
- The increased rigidity of the composite material presents significant opportunities for industries emphasizing mechanical robustness, particularly aerospace and automotive sectors. Stiffer epoxy composites facilitate weight reduction and enhance structural performance in aircraft components, thereby improving fuel efficiency.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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