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An Examination of Natural Fiber Reinforced Hybrid Polymer Composites' Mechanical Properties

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Research Article

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Abstract

The growing "green" economy, which is built on energy efficiency, the use of renewable resources in polymer goods, industrial methods that lower carbon emissions, and recyclable materials that limit waste, will heavily rely on natural fibers. Natural fibers are a kind of renewable resource that has been replenished for thousands of years by both human creativity and the natural world. Additionally, they absorb the same quantity of carbon dioxide that they emit, making them carbon neutral. These fibers have a high specific strength, are inexpensive, non-abrasive, entirely renewable, and biodegradable. These qualities have lately made natural fibers appealing to scientists and researchers as a substitute for fiber-reinforced composites. The history of natural fibers and their uses were outlined in this review study. Additionally, the various qualities of natural fibers (such hemp, jute, bamboo, and sisal) and their uses as glass fiber substitutes were covered in this study.

Keywords

Carbon, Natural Fiber, Polymer, Biodegradability, and Human

Introduction

When two or more physically distinct phases are combined to create aggregate characteristics that vary from those of their constituents, the result is a composite material system. The strength to weight and stiffness to weight ratios of composites are several times higher than those of steel or aluminum, and it is also possible to achieve combinations of properties that are not possible with metals, ceramics, or polymers alone [1]. Due to its appealing qualities, natural fiber reinforced composites have been regarded as the most promising material in many applications in recent years (Table 1). Due to their better mechanical qualities, natural fibers today dominate the construction, sports, and automobile sectors. Flax, hemp, jute, sisal, kenaf, coir, and several more natural fibers are among them [2]. cheap density, cheap cost, low energy inputs, equivalent mechanical characteristics, and improved elasticity of polymer composites reinforced with natural fibers—particularly when modified with crushed, embroidered, and three-dimensional braided threads—are among the many benefits of natural fibers. Glass Fiber Reinforced Polymer (GFRP) is a kind of fiber-reinforced polymer composed of thin glass fibers embedded in a plastic matrix. Because of its superior qualities, fiber glass is a lightweight, sturdy, and strong material utilized in many different sectors. The material is usually significantly less brittle and the raw ingredients are far less costly, although having slightly lower strength and less stiffness than carbon fiber. When compared to metals, its bulk strength and weight characteristics are very advantageous, and molding techniques make it simple to shape. Due to their affordability and ease of availability, natural fibers like sisal and jute fiber composite materials are now taking the place of glass and carbon fibers. Because the area of application is constantly improving, particularly in the automotive sectors, the usage of natural fibers has significantly improved. Natural fiber composites are becoming more and more popular these days because of their environmentally beneficial qualities. Based on these natural fibers, researchers have done a great deal of study. Jute, sisal, silk, and coir are examples of natural fibers that are cheap, plentiful, renewable, lightweight, low density, very durable, and biodegradable. For applications requiring a high strength to weight ratio and further weight reduction, natural fibers like jute

have the potential to substitute conventional reinforcing elements in composites. An overview of previous studies on the relevant topics is included in this chapter. The study on hybrid composites and the impact of different factors on the performance of composites examined by different researchers are presented. The following principles serve as the foundation for the literature review.

Influence of Filler on Mechanical Properties

The mechanical and physical characteristics of Al2O3-filled jute fiber reinforced epoxy composites were investigated by Priyadarshini Tapas et al. [4]. They conducted an experiment to determine how filler affected the characteristics of composites. They have shown that filler significantly alters several characteristics of composites when jute and Al2O3 are used as reinforcement and epoxy is used as the matrix. Additionally, they found that interlaminar shear strength only rose with an increase in fiber and declined with the addition of filler on composites, but hardness, strength, flexural, and tensile modulus all increased with an increase in fiber and filler.

The mechanical characteristics of woven banana fiber, kenaf fiber, and banana/kenaf hybrid fiber composites were investigated by A. Alavudeen et al. [5]. The hybridization of kenaf and banana fibers increases the mechanical strength of woven banana/kenaf fiber hybrid composites. The woven hybrid composite of banana and kenaf fibers has better tensile, flexural, and impact strengths than the separate fibers. Through improved interfacial bonding, sodium lauryl sulfate (SLS) treatments seem to provide an extra boost in mechanical strength. To comprehend the de-bonding of fiber/matrix adhesion, morphological investigations of cracked mechanical testing samples were carried out using scanning electron microscopy (SEM).

Table 1. Provides information about natural fibers available in the nature in different form [3].

Wood fiber	Stalk fiber	Fruit fiber	Seed fiber	Leaf fiber	Bast fiber
Hard wood	Bamboo	Coconut	Cotton	Sisal	Rattan
Soft wood	Wheat	Betel nut	Oil palm seed	Manila	Hemp
Saw dust	Rice		Kapok	Banana	Jute
	Grass		Alfalfa	Palm	Ramic
	Barley			Mengkuang	Bananna
	Corn			Date palm	Flax
				Pinappile	Suger cane
				Abaka	Kenaf
					Roselle

The mechanical characteristics of sisal, jute, and glass fiber reinforced polyester composites were examined by M. Ramesh et al. [6]. They found that the highest tensile strength was achieved when glass fiber was added to the jute fiber composite. Similarly, they found that samples of jute and sisal mixed composites had the highest flexural strength and that the sisal fiber composite had the highest impact strength. An example of a composite material is shown in Figure 1.

H. Ranganna et al. [5] examined the variation in tensile strength, flexural strength, and compressive strength of epoxy-based sisal-glass hybrid composites and found that 2 cm fiber length hybrid composites demonstrated maximum optimal tensile, flexural, and compressive strength compared to 1 and 3 cm. Additionally, the impact of alkali treatment on the compressive and tensile flexural characteristics has been investigated. The strength of treated hybrid composites was found to be greater than that of untreated composites. The mechanical behavior of jute fiber in polyester and epoxy matrices was experimentally studied by Gopinath et al. [7]. The findings shown that the processing time for jute-polyester laminate is much less than that of jute-epoxy laminate.

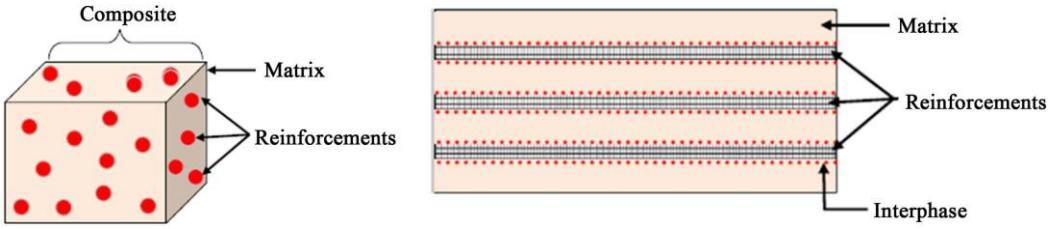
A. Gowthami et al. [8] used 100% biodegradable sisal fibers as reinforcement in the polyester matrix to create sisal natural fiber composites with and without silica. According to the findings, composites containing silica have tensile strength and tensile modulus that are 1.5 and 1.08 times higher than those without silica, respectively. Compared to composites without silica and plain polyester, the impact strength of the composite including sand was 1.36 and 1.8 times higher, respectively.

The three-body abrasive wear and mechanical characteristics of particulate-filled glass epoxy composites were investigated by Amar Patnai et al. [9]. The purpose of their work was to investigate the abrasive wear behavior of randomly oriented glass fiber (RGF) reinforced with epoxy resin containing dust from pine bark, SiC, and Al2O3. Rubber wheel abrasion tests (RWAT) with dry sand were performed at a test speed of 100 rpm. The abrading distance was varied from 200 to 600 m in order to conduct the experiments at 50 and 75 N loads. According to experimental findings from abrasive wear testing, composite wear was less susceptible to sliding velocity and more sensitive to changes in abrading distance.

The impact of a bamboo fiber composite packed with cenosphere was investigated by Hemalata Jena et al. [10]. They have reported that the use of cenosphere as filler and lamina significantly affects the impact property of bio-fiber reinforced composites. Filler increases the impact strength of a certain laminated composite up to a certain point, beyond which it decreases with more filler. The findings show how sensitive the impact characteristics are to the filler concentration. The impact strength increases as the lamina is raised from 3 to 7, and it decreases when the lamina is increased to 9. The composite with 1.5 weight percent cenosphere has the highest impact strength of 18.132 KJ/m2 out of all seven layers. Additionally, a drop in the density of the composites is seen, which is also significantly influenced by the fiber and filler quantity.

Girisha, C. et al. [11] investigated the mechanical characteristics of composites made from chemically treated arecanut husk and tamarind fruit fibers. When compared to untreated fibers, they found that treated fibers performed better. Additionally, they observed that when the volume proportion of fiber in the hybrid composites grows, so does their strength. In the study, arecanut fruit husk fibers and tamarind fruit fibers were strengthened using an epoxy matrix, and composites were created using a manual hand layup technique. The investigation revealed that for 40% to 50% of the fiber reinforcements, all hybrid natural fiber composites had the best mechanical qualities.

The physical and mechanical properties of composites may be altered by including a filler phase into the matrix body during the composite fabrication process, according to research on fillers from [4] to [11]. Filler is added to composites to enhance their tribological and mechanical qualities.



(a) (b)

Figure 1. (a) Explains composition of laminate which include resin as a matrix and fiber as reinforcement and (b) shows inter-phase of matrix and reinforcement.

Effect of Process Parameters on Mechanical Characteristics

Berhanu *et al.* [12] studies the effect of weight percentage of jute fiber reinforced in polypropylene based com-posites and found out that mechanical properties enhanced as the jute weight percentage increased up to 40%.

D. dash *et al.* [13] concluded that the mechanical properties of composites such as tensile strength and com-pressive strength of natural fiber composite was reported and compare with the data for glass/epoxy composites. It has been seen form tensile test that bamboo composite laminates having higher tensile strength and stiffness than jute composite laminates, but not at par the glass fibre reinforced composite. Compressive test shows that compressive strength and modulus of jute composite is higher than bamboo composite, but less than glass com-posite the fibre orientation angle of 0/90, 15/−75, 30/−60, and 45/−45 as shown in **Figure 2**, on tensile beha-viour were analyzed and showed that the fiber orientation of 0 provides higher strength and modulus than 45 di-rection of fiber orientation. The mechanical property also depends upon individual material property. The glass fiber was manufactured artificially in an industrial plant with special tool while the bamboo and jute fiber was available from nature & manufactured by simple tool and/or manually that may result inconsistency during manufacturing of product. Due to this reason the strength of natural fibers does not come up to the level of tradi-tional e-glass fiber. But the natural fiber reinforced composite can be used in places where light load application is important and the economics of natural fiber composite materials is more beneficial as compared to e-glass fiber composites.

S. Raghuraman *et al.* [14] concluded that the composite with 50% sisal-glass fiber and 50% resin combination has maximum tensile strength of 97.71 MPa. The breaking load of sisal-glass fiber reinforced composite is found as high (10.285 KN). It is found that breaking load of sisal-glass fiber reinforced composite is 1.10 times higher than sisal-coir-glass fiber reinforced composite and 1.33 times higher than coir-glass fiber reinforced composite. The percentage elongation of coir-glass fiber reinforced composite is found as higher than the other composites and hence it may have more ductile property in nature. The hybrid with composite with 40% sisal-coir-glass fibers and 60% resin combination has high flexural strength (138.87 MPa) and high impact strength (1.429 KJ/m^2).

Zamri *et al.* [15] studied the mechanical properties of jute/glass reinforced polyester with water absorption condition. Composites are subjected to various water conditions and test were performed by immersing compo-site specimen in to three different water conditions, distilled water, sea water and acidic water, and water was in room temperature for a period of three weeks and also effect of the various water environments on the flexural and compression characteristics were investigated in this study. It found out that the jute composite is not suita-ble for underwater applications.

Onal *et al.* [16] studies the properties such as tensile and flexural strength of glass/carbon hybrid specimen

with layer by layer sequence before impact and after impact. It is found out that carbon fire on the end surfaces in-creases flexural strength and also the tensile property of hybrid is better. Gujjala *et al.* [17] reviewed the me-chanical properties of jute/glass reinforced epoxy hybrid laminate with varying hybrid sequences and pure glass, jute and epoxy composite and they were compared. Composites prepared bu using hand layup technique and

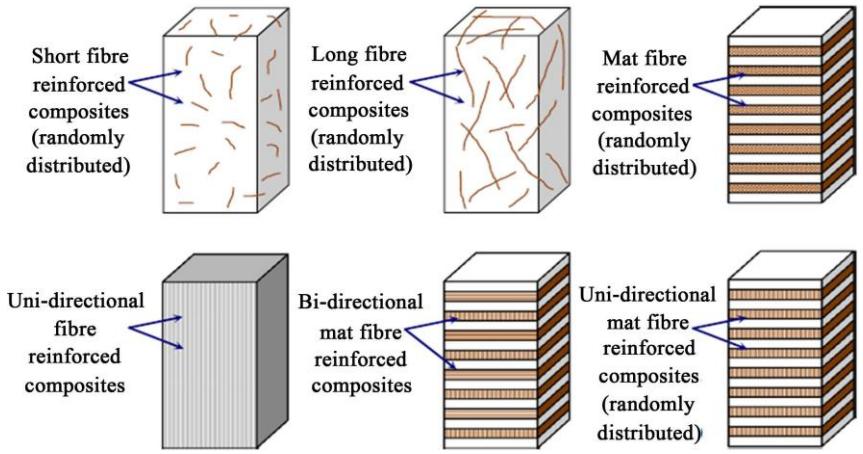


Figure 2. Different type of fiber orientation used for the laminate manufacturing.

laminates were prepared with a total of four piles by varying the position of glass and jute. It is found out that hybrids have better properties than pure jute and epoxy alone but less than pure glass.
Sathish Pujari *et al.* [18] reviewed the comparison and potentiality of jute & banana fiber composites empha-sizes both mechanical and physical properties and their chemical composition. The utilization and application of the cheaper goods in high performance appliance is possible with the help of this composite technology. Com-bining the useful properties of two different materials, cheaper manufacturing cost, versatility etc., makes them useful in various fields of engineering, high performance applications such as leisure and sporting goods, ship-ping industries, aerospace etc. Hence, with this back ground, it is concluded that, the composite stands the most wanted technology in the fast growing current trend.
Tara Sen *et al.* [19] reviewed that the application of composites in structural facilities is mostly concentrated on increasing the strength of the structure with the help of artificial fibres and does not address the issue of sus-tainability of these raw materials used for strengthening purposes. In an expanding world population and with the increase of the purchasing potentials, the need for raw materials required for structural strengthening, that would satisfy the demand on world market is rapidly growing. In the **Table 2** provide information about the properties of various natural fibers.
Samivel *et al.* [20] studied the experimentally the effect of hybridization of banana and kenaf fiber reinforced hybrid composites and found out that hybrid composites offered better resistance to water absorption as com-pared to un-hybrid composites. Jayabal *et al.* [21] investigated the effect of hybridization on mechanical proper-ties of coir-glass hybrid laminate and found out that coir fibre (natural) fails quicker than glass fibre and incor-poration of glass fibers at extreme plies enhances the mechanical properties of coir laminates.
Hind Abdellaoui *et al.* [22] examined the effects of number of layers and fibre directions on the mechanical behaviour of composites. The results illustrate that the mechanical behaviour of laminated has improved by in-creasing the number of layers. The maximal properties were obtained in case of composite at 5 layers. The composites at 0 degree fibre direction and 0 degree cutting direction have high mechanical properties than the other cases. The results show a certain difference between the measured and predicted

modulus (Young modulus, shear modulus, Poisson coefficient). This difference is probably due to the perfect bonding between fibres and matrix as considered in assumptions. Yoshihiko Arao *et al.* [23] developed an effective process to improve the mechanical properties of jute/poly lactic acid composites. From results they noted that note that the suppression of hydrolysis is necessary to improve the overall performance. When PLA without modification against hydro-lysis was used, addition of jute fiber increased the modulus but lowered the absolute tensile strength.

Ahmed and Mohammad *et al.* [24] revealed the theoretical dynamic analysis of Reinforced Concrete slab un-der free-free and simply supported condition. They showed that there is an influence of the support on the modal properties as the values are high in simply supported condition than other. Hence for experimental analysis free-free condition gives the accurate modal properties. Ratnaparkhi *et al.* [25] studied the dynamic properties by experimental and FEA simulation of glass/epoxy reinforced hybrid composite under free-free condition with different aspect ratio and the ply orientation. Here the result show that the increase in aspect ratio leads to in-crease of natural frequency and increase of ply orientation about [45/−45] and [30/60] leads to decrease of natu-ral frequency. From [11]-[25] literature concluded that fabrication of composites mainly influenced on the prop-erties of the composites. The mechanical properties such as tensile, flexural and impact strength can be modified by fabricating the composites using different techniques. **Figure 3** shows varieties of natural fibers which are produced by plants.

Table 2. Properties of various natural fibers.

Fibre type	Density Kg/m^3	Water absorption %	Modulus of elasticity E (GPa)	Tensile strength (MPa)
Sisal	800 - 700	56	15	268
Roselle	800 - 750	40 - 50	17	170 - 350
Banana	950 - 750	60	23	180 - 430
Date palm	463	60 - 65	70	125 - 200
cocounut	145 - 380	130 - 180	19 - 26	120 - 200
Reed	490	100	37	70 - 140



JUTE COIR BAMBOO




HEMP SISAL

Figure 3. Varieties of Natural Fiber which are produced by plants.

Conclusions

The use of natural fiber as reinforcement in polymer composites was examined from the perspectives of natural fiber position and expectations, natural fiber fabrication and characterization, fiber surface refitting using various fillers, and changes in the properties of the natural fiber-based polymer composite. Natural fibers were proven to be better in industrial applications when compared to glass fiber reinforced composites. Furthermore, the use of natural fibers in many technical applications and building sectors makes it possible for rural communities to flourish economically.
The investigation's findings suggest that jute fiber reinforced polyester composites may be able to improve their qualities. However, relatively little research has been done on the characteristics of epoxy composites reinforced with jute or glass fiber. The literature revealed a lack of knowledge on the modal test technique for determining the dynamic characteristics of the composites. The automotive industry will benefit from the development of a suitable hybrid with a known stacking sequence for weight and cost reduction. This opens the door for research into the mechanical and dynamic properties of jute/glass fiber reinforced epoxy hybrid composites using both static and dynamic test methods, with the results validated through FE simulation.

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