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Mechanical Behavior of Coir Fiber Reinforced Epoxy Composites with Variable Fiber Lengths

V. S. Jagadale, S. N. Padhi

Abstract: ***Most studies on the application of natural fibers as reinforcement in polymer composites are growing as a result of the changes in characteristics that fibers can provide for the product. This can be achieved by manufacturing of composites using Hand Layup process. The 2% NaOH fiber treatment was performed to improve fiber-matrix interfaces making spathe-fibre-reinforced composites better mechanical characteristics. Filler loadings as 5% by volume of coir fiber are selected as reinforcement in composites. The varying lengths of fiber chosen as 5mm, 10mm & 15mm and resin-hardner ratio are maintained as 10:0.8. A total 3 numbers of plates with volume as 300 x 300 x 4 mm^3 were produced and specimens as per the various ASTM standard were tested to determine the ultimate various Mechanical properties for different configuration. The strength of epoxy resin / coir fiber composites was noticed at a maximum 15 mm (15.27 N / mm^2) fiber length. The maximum impact strength of the charpy was also 15 mm fiber length (9.87 kJ / m^2).The Experimental results were validated using a numerical method technique in FEA software. The obtained results by experimentation and Finite Element Analysis are very much closer to each other. The results show good mechanical properties and hint us as a replacement for conventional materials in industrial applications.***

Keywords: ***FEA, Coir Fiber, Mechanical Properties, ASTM.***

I. INTRODUCTION

Compared to traditional plastics like their greater particular strength, rigidity and fatigue features, which make the structural design more flexible, the composites offer many advantages. Composite materials are, by definition, coupled with two or more physically separable stages. However, composite materials are only accepted if the composite stage materials have different physical characteristics. However, it is only recognized as a composite material if the composite phase materials have distinct physical features. The matrix or binder (organic or inorganic) preserves the orientation and position of the reinforcement. Composites retain their individual, physical and chemical properties, yet together they create a combination of qualities that cannot be produced by different elements on their own. The enhancement can also be platelets, particles or fibers and is generally added to improve the matrix material's mechanical characteristics such as rigidity, strength and toughness. The most efficient load transfer is provided by long, stress-oriented fibers. This is because the stress transfer region only extends across a small portion of the interface of the fiber matrix, and fiber end effects can be ignored.

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In other words, the fiber's ineffective length is small. In high-performance composites such as glass, carbon and aramid fibers, popular fibers can be used as constant filaments. The primary advantage of modern composite materials is that they are both strong and light. By choosing a correct matrix mix and reinforcement material, a new material can be generated that meets the precise requirements of a particular implementation. As many can be molded into complex forms, a composite also offers flexibility in design. Often the downside is the price. Although the resulting composite product is more effective, the raw materials are often costly. Compared to other natural fibers, the inclusion of coir as a component in polymer composites is not satisfactory in any sense due to its small cellulose (36–43%), elevated lignin content (41–45%) and its elevated micro-fibrillary angle. A scientist who conducted morphological studies on coir fibers demonstrates that lignin's external sheath avoids the binding of cellulose to polymers. To this end, several commonly accepted treatments, such as alkaline therapy, blanching and graft copolymers, etc., are used to enhance the surface characteristics of natural fibers. The coir sector is well advanced in India. Coir polymer fiber has many applications for building systems, electrical panels, ducting etc. Coir fibers are mainly characterized by their low electrical and thermal conductivity. The coir composites can thus be used in electronic packaging and household applications as low-temperature insulation products.

II. LITERATURE REVIEW

Rozman et al. [1] concluded that coir fibre packed with lignin-filled polypropylene composites perform better flexural characteristics than control composites. This study investigates the use of coir-based natural fiber composites strengthened with polypropylene for the automotive interior application panel. Rout et al. [2] researched the importance of coir strengthened polyester composite surface therapy. Before being added with general purpose polyester resin, the coir fiber was alkaline therapy, bleaching and vinyl grafting. Due to surface treatment, mechanical properties such as tensile strength, bending and impact force have been enhanced. Blended composite fiber (65oC) showed improved flexural strength. The composite NaOH handled fiber / polyester showed better tensile strength. Pothan et al. [3] Maximum tensiles strength of 30 mm fiber length and peak impact strength of 40 mm of composite fiber-long banana polyester fiber. With the quantity of fiber rising to 40%, the power of the tensile enhanced by 20% and the power of the impact reduced by 34%. Monteiro et al.

[4] The research showed that the coir fiber proportion could be increased to 80% and discovered that the composites became rigid up to 50% of the fiber loading and are composites such as agglomerates. Samal et al. [5] The mechanical, thermal and morphological features of polypropylene hybrid bamboo and glass fiber composites were prepared and examined. In order to enhance the fiber matrix interface bonding, the malefic anhydride grafted polypropylene (MAPP) has also been added to the composite. Compared to virgin polypropylene, the hybrid composite displays enhanced mechanical characteristics such as tensile, effect and bending strength. The fiber interface gap in the SEM composite micrograph was reduced. To regulate composite resistivity, the composites of hybrid polyester processed with other chemicals such as sodium carbonates, sodium hydroxide, acetic acid, benzene, carbon tetrachloride, ammonium hydroxide, toluene and water have been tested Reddy et al.[5]. The hybrid composites demonstrated outstanding chemical resistance and enhanced the tensile strength of the alkalized hybrid composite. Biswas et al. [7] conducted a survey on the meaning of fiber length on coir / epoxy composite mechanical personality. He has found that the composite hardness decreases by increasing the fiber length to 20 mm and then rises afterwards. They found that fiber length has a significant effect on improving mechanical characteristics such as tensile strength, bending strength and impact strength.

Ayrilmis et al.[8] have demonstrated that coir fiber is an essential element in thermoplastic composite manufacturing, in particular for efficient replacement of relatively high-cost, thick glass fibers. If the amount of coir fiber risen to 60 wt. The flexural and tensile characteristics of the composites respectively enhanced by 26% and 35%. Romli et al. [9] conducted a factorial research on coir strengthened epoxy composite tensile strength. During the solidification of the composites, volume fraction, curing time and compression load were taken as parameters. According to the outcomes, the volume fraction affects the composite tensile strength. Sreenivasan et al. [10] confronted untreated and handled surface composite mechanical features of Sansevieria cylindrical fibers (SCFs). Surface treatments such as potassium permanganate, alkali, benzoyl peroxide, and stearic acid were performed to change the fiber soil. They observed that the treated surface fiber had enhanced mechanical properties compared with the untreated fiber.

Lu et.al. Tingju. 11] Before being added to epoxy composites, Bamboo cellulose fibers were handled with the aqueous NaOH solution and silane coupling agent respectively. The effect of surface modification on mechanical characteristics was assessed under monitored circumstances by tensile and impact tests. The NaOH solution therapy improved tensile strength by 34 percent, and break elongation by 32 percent, compared to the untreated cellulose-filled epoxy composites. While the therapy of silane coupling agents generated an improvement of 71% in tensile strength and of 53% in break elongation. The current work, Mishra, V. [12], discusses the creation and characterization of a fresh collection of natural fiber composites composed of bidirectional fiber matt jute as reinforcement and epoxy resin as a matrix material. The result demonstrates that fiber loads have an important impact on the mechanical characteristics of composites. Samia Sultana Mir [13], the manufacture of composite materials with fiber load variations at 0, 5, 10, 15 and 20 wt%. Tensile, bending, effect and hardness tests were applied to evaluate mechanical features of the composites.

The mechanical and thermal conduct of natural fiber-intensified polymer composites is described in several literature studies. The impacts of the fiber length shift on the mechanical and thermal behavior of coir fiber-reinforced epoxy composites were also very limited. Against this background, the present research was performed to examine the ability of coir fiber as a polymer composite refurbishing material and the effect of the resulting fiber length change composites on the mechanical and thermal behavior.

III. MATERIAL & METHODOLOGY

Manufacturing of Laminates by Compression molding Technique:

Local sources collect the coconut fiber (Figure 1) that was taken as reinforcement in this research. The coir fibers were treated with alkaline treatment using 2 % NaOH. This was to remove wax, lignin, oils and other fiber elements that could reduce matrix and fiber adhesion and thus form a fragile border layer. The molds were made with dimensions of 300×300×4 mm^3. The coconut fiber of different lengths chosen as 5mm, 10mm and 15mm has been mixed with epoxy resins of their respective weights by simple mechanical stirring and mixture are poured in the mould, keeping the view on testing condition and characterization standards. The composites were prepared in three different compositions. The air trapped is removed by sliding roller and the mould has been closed at temperature 30° C for 24 hour and at a constant load of 50 kg.

Fig. 1: Chemical Treatment of Coconut coir fibers with 2% NaOH

Fig. 2: Coir fibers with different configuration

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Fig.3: Manufactured Composite Laminates

IV. EXPERIMENTAL ANALYSIS

Mechanical Testing:

a. Tensile Testing

The experiment was conducted using an ASTM D-3039 universal testing machine. The specimen size was 200 x 20 x 4mm.

Fig.4: Specimens of Tensile Test before fracture

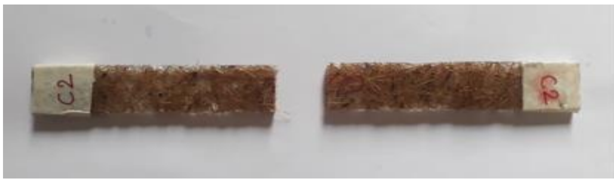

Fig.5: Specimens of Tensile Test After fracture

Results of Tensile Test:

Table 1: Tensile Test Results

Composites	Tensile strength (MPa)	
	Trial 1	Trial 2
C1	12.34	11.846
C2	13.02	12.86
C3	15.27	14.81

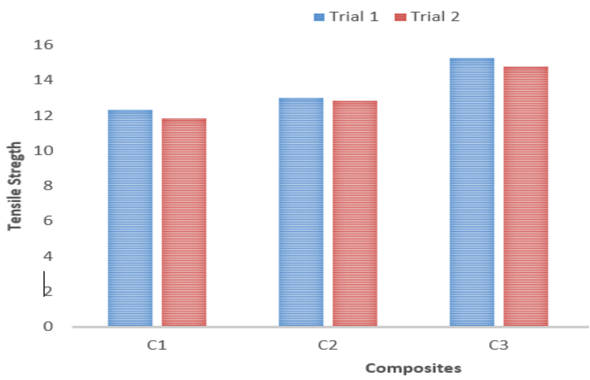

Fig. 6: Comparison of Tensile Test Results

b. Flexural Testing

Flexural testing for the samples was performed using a universal testing machine (Fig. 4). The ASTM D-790 conducted the three-point flexural test and the size of the specimen was 100x 13x 4 mm.

Fig. 7: Flexural Test Specimens Before Fracture

Fig. 8: Flexural Test Specimens After Fracture

Results of Flexural Test:

Table 2. Flexural Test Results

Composites	Flexural strength (N/mm2)	
	Trial 1	Trial 2
C1	25.11	25.59
C2	28.58	27.45
C3	29.47	28.98

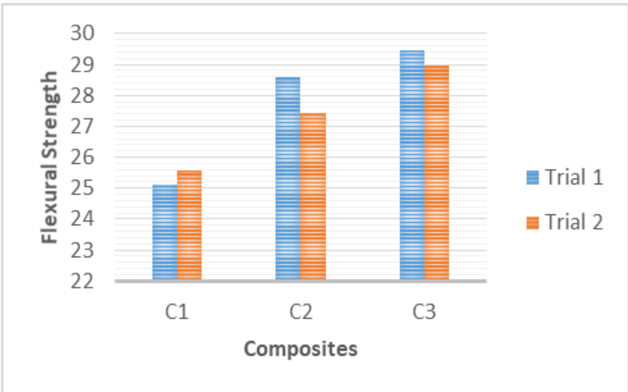

Fig. 9: Comparison of Flexural Test Results

c. Impact Testing (Charpy)

Charpy Impact Test was performed to determine the toughness of ASTM D-256 composite samples using Charpy principle and the size of the specimen was 65 x 12.7 x 4 mm.

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Fig. 10: Impact Test Specimens Before Fracture

Fig. 11: Impact Test Specimens after Fracture

Results of Impact Test:

Table 3. Impact Test Results

Composites	Impact Energy (kJ/m^2)	
	Trial 1	Trial 2
C1	7.2	7.1
C2	8.3	8.1
C3	9.7	9.87

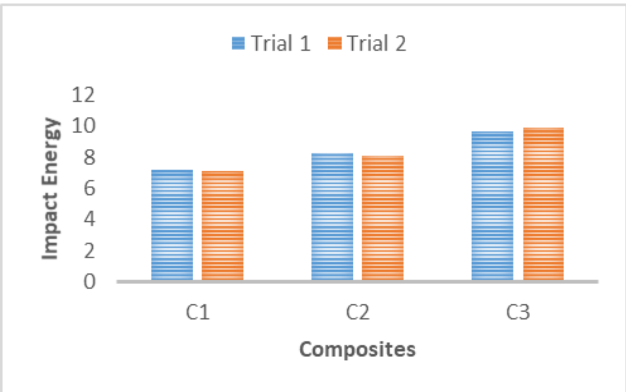

Fig. 12: Comparison of Test Results

V. FINITE ELEMENT ANALYSIS

Finite component assessment is a pc mainly based analysis method for determining the strength and comfortability of FEM constructions. The structure is shown as finite components. These components are joined at certain points known as nodes. The FEA is used to calculate the deflection, stress, strain, temperature and buckling comfortability of the member. FEA is implemented by a beam in our project to determine the secure load. The Analysis of Finite Components may be a simulation technique that evaluates the compliance of parts, devices and structures in different load conditions, as well as the force, pressure and temperature applied. Thus, a fashionable engineering drawback with non-standard shape and sheer mathematical properties can be solved when there is a closed type resolution. Finite element analysis can be solved. Finite component analysis methods provide outcomes from stress distribution, shifts and response masses at models etc.

The charging types that can be used for static analysis include forces, moments and pressures applied externally. The steady state mechanical phenomenon forces gravity and mandatory non-zero displacement. If the strain values acquired during this assessment cross the allowed values, the structure failure within the static situation itself will lead. This assessment is critical in order to prevent such a failure. Finite assessment of components was effectively developed for the assessment of the durability of epoxy fiber composites.

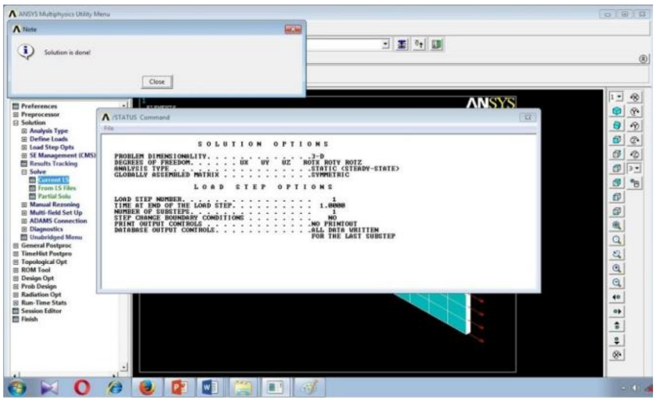

Fig. 13: Final ANSYS Result

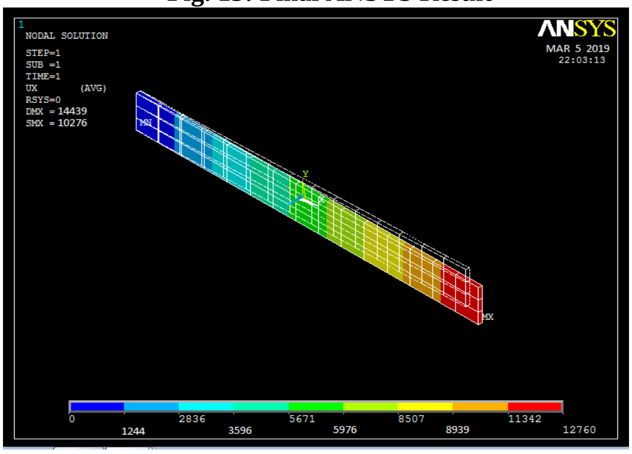

Fig. 14: Deviation Of Specimen With Respect To Applied Load

VI. RESULT & DISCUSSION

1. Comparison of Experimental & ANSYS results of Tensile Testing

Table 4. Tensile Test Result comparison

Composite	Experimental Results	ANSYS Results
C1	12.093	14.439

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C2	14.94	18.174
C3	15.04	21.27

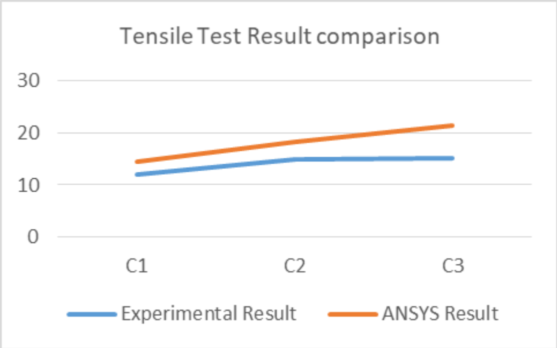

Fig. 15: Comparison of Experimental and ANSYS Results

The variation in result is due to the manufacturing defects. The better manufacturing technique can reduce the error.

2. Mechanical Properties of Coir composite laminates.

Table 5. Mechanical Properties

Composites		C1	C2	C3
Tensile Strength	Trial 1	12.34	13.02	15.27
	Trial 2	11.846	12.86	14.81
Flexural Strength	Trial 1	25.11	28.58	29.47
	Trial 2	25.59	27.45	28.98
Impact Strength	Trial 1	7.2	8.3	9.7
	Trial 2	7.1	8.1	9.87

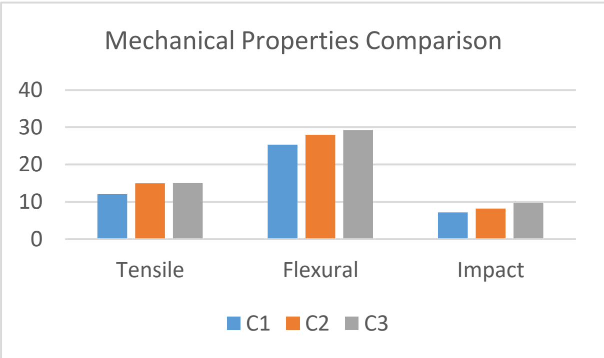

Fig. 16: Comparison Mechanical Properties

The above results shows that mechanical properties of coir composites are gradually increasing as we increase the fiber lengths but the increment is not sudden so an further detailed analysis is needed to know the change in effect.

VII. CONCLUSION

A thorough survey of the mechanical conduct of the coir / epoxy composite was performed based on various fiber lengths. Alkali coir fiber therapy has also been performed. The research resulted to the following findings.

1. Epoxy resin can be produced with alkaline-treated fiber by hand-laying method.
2. In tensile testing, tensile resistance with growing fiber length gradually improves. It also has been discovered that alkaline-treated composites with fiber load show outstanding tensile strength. With a fiber length of 15 mm, the highest tensile strength is thus acquired.
3. With the increasing fiber length in flexural testing, flexural resistance is gradually improved. High flexural strength at 15 mm fiber length.
4. With the increase in fiber length, impact resistance improves gradually in impact testing. It also demonstrates the broken surface's fragility.
5. The findings of the FEA also validate the test outcomes with a variation of +-10%. The change is due to production defects in terms of vacuums or cavities.

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