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Investigation of Mechanical Properties of Short Sisal Fiber Reinforced Phenol Formaldehyde and Vinyl Ester Composites

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Abstract
Composite materials are replacing standard Engineering metals and alloys for many applications. Here in this work, Sisal fiber is used as reinforcement. Since it is abundantly available in nature and majority of it is getting wasted without being used as reinforcement in engineering applications. Short Sisal fiber reinforced Phenol Formaldehyde and Vinyl Ester resin composites are prepared with varied fiber lengths (5 mm and 10 mm) and for varied weight fraction (20%, 25% and 30%) of the fibers. The short Sisal fibers are treated with 5% of Sodium Hydroxide (NaOH) solution. In the present work, the effect of the fiber treatment, fiber length and fiber loading on the mechanical properties are investigated. The results show that the Alkali Treated Sisal fiber reinforced composites have better mechanical properties than untreated composites. The 10 mm fiber length reinforced composite shown improved mechanical properties than 5 mm fiber length reinforced composite. Increase in mechanical properties is seen when the fiber content in the composite is increased from 20% to 25% and 25% to 30%. The 30% weight of the Sisal fiber reinforced composite has shown higher values of mechanical properties.

Keywords: *Composite Materials; Phenol Formaldehyde; Short Sisal Fiber and Vinyl Ester Resin.*

1. Introduction

A composite is a structural substance made up of two or more mixed constituents that are insoluble in one another and are blended at a macroscopic level. The matrix is the one in which the reinforcing phase is embedded, and the reinforcing phase itself is one member. The material used in the reinforcing phase can take the shape of flakes, particles, or fibres. In general, the materials of the matrix phase are continuous [1]. Scientists and technologists are interested in using natural fibres such as jute, cotton, banana, coir, sisal, and others in consumer items, affordable housing, and other civic structures. These natural fibre composites have been shown to have greater fracture resistance, superior electrical resistance, and good thermal and acoustic insulating qualities [2]. Natural fibres have several benefits over synthetic fibres, such as low density, high specific strength, and cost effectiveness. They are also renewable resources, which makes them a viable option for reinforcing polymer composites instead of glass. The hydrophilicity of plant fibres causes poor wettability and absorbability towards polymers; hence, there is typically insufficient adhesion between the fibres and polymer matrix. Either surface modification or plasticization of the fibres can be done to enhance the interfacial bonding. It is important to remember that natural fibres have a highly complex cell structure and chemical makeup. Every fibre is basically a composite made of soft lignin and hemicelluloses embedded in stiff cellulose microfibrils. In addition, the micro fibrils are helically coiled along the fiber axis to form ultimate hollow cells. One of the main failure modes is the uncoiling of these spirally orientated fibrils, which requires a significant energy expenditure. Therefore, processing of the fibres would cause different cells as well as the fibre surface to undergo chemical and structural changes, which would then affect the properties of the fibres and composites [3]. There are several natural fibres found in nature, including jute, flax, hemp, remi, sisal, coconut fibre (coir), and banana fibre (abaca). All of these fibres are widely used to make ropes, carpet backing, bags, and other items. They are cultivated as agricultural plants across the world. Natural fibres are made up of cellulose microfibrils scattered over an amorphous lignin and hemicellulose matrix. The percentages of cellulose and lignin in natural fibres vary from 60 to 80 weight percent, depending on the type of fibre. Additionally, natural fibres can have up to 20 weight percent of moisture content [4].

2. Method

The initial composite plates are labelled with the necessary dimensions. With a wire saw, they are cut to the markings for the necessary proportions [5]. To get the specimens to the precise size, they are scraped against emery paper on their edges. The American Society for Testing of Materials (ASTM) guidelines were followed in the preparation of the specimens. In the present work sisal fiber is used as reinforcement and phenol formaldehyde as matrix material. The sisal fibers are chopped into lengths of 5mm and 10mm and also the specimens were prepared for 5mm and 10mm separately. In the proposed work specimens were prepared as shown in Table 1 for three different compositions. The tensile test specimens are prepared according to ASTM D638 standard [6]. The dimensional view of specimen is shown in Figure 1 Table 2 shows the standard dimensions of the tensile test specimen and figure 2 shows the specimens used for testing [7].

Table 1 Weight Fraction Composition of the Sisal Fiber Composites Used

S.No	Weight Fraction Compositions of Sisal Fiber Composite
1	Short sisal fiber 30% + phenol formaldehyde 70%
2	Short sisal fiber 25% + phenol formaldehyde 75%
3	Short sisal fiber 20% + phenol formaldehyde 80%

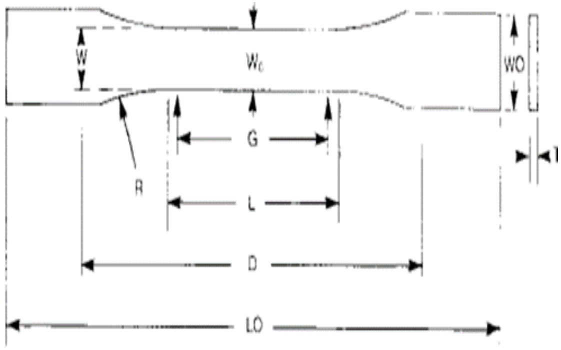

Figure 1 The Dimensional View of Specimen

Table 2 Standard Dimensions of the Tensile Test Specimen

w-width of the Narrow Section	19mm
L—Length of narrow section	57mm
WO—OverallWidth,	29mm
LO—OverallLength,	246mm
G—Gage length	50mm
D—Distance between grips	135mm
R—Radius of fillet	76mm

Figure 2 Specimens Used for Testing

3. Experimentation

Figure 3 Computerized Universal Testing Machine

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In this work Tensile test of Sisal/Phenol Formaldehyde and Sisal/Vinyl Ester composites were conducted. Tensile tests were conducted using computerized universal testing machine. The Figure 3 shows the universal testing machine used in this work to obtain the Tensile Mechanical properties. The Figure 4 shows the tested Tensile specimens of the Sisal Fiber-Phenol Formaldehyde composites.

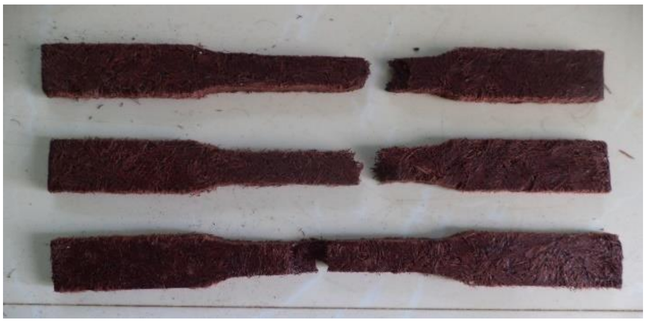

Figure 4 Tested Tensile Specimens

4. Results and Discussion

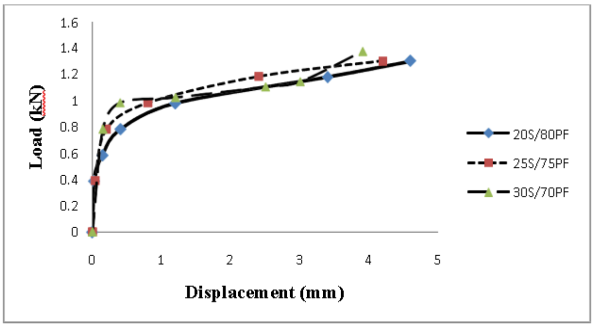

Figure 5 Load V/S Displacement Curve for Sisal Fiber with 5 Mm Fiber Length Reinforced Phenol Formaldehyde Composite

Figure 5 shows the load v/s displacement curve for an composite made with untreated short sisal fiber with 5mm length and phenol formaldehyde. It is clear from the figure that the composite made with 30% of the sisal fiber and 70% of the phenol formaldehyde can take the highest load before it breaks thus leading to increased tensile strength. It is also observed from the figure that as the fiber content in the composite increased, the load at which the specimen fails i.e. the failure load is increased. It is evident from Figure 5 that the strength values rise linearly as the fibre volume fraction rises. The main cause of this behaviour is the reinforcing action that the fibres provided, which made it possible for the uniform stress distribution to go from the continuous polymer matrix to the scattered fibre phase. Any composite's tensile strength is influenced by a number of variables, the most important of which are the bonding strength between the fibre and matrix, the volume percentage of fibre, and the strengths of the fibres and matrix. When a fiber-reinforced composite is loaded, the fibres carry the load, and the stress is distributed uniformly and effectively along the fibres from the matrix, giving the composite its good mechanical properties. The population of fibres determines the uniform distribution of stress. Low fibre loading prevents fibres from passing load to one another, which causes stress to build up at certain composite locations and reduces tensile strength.

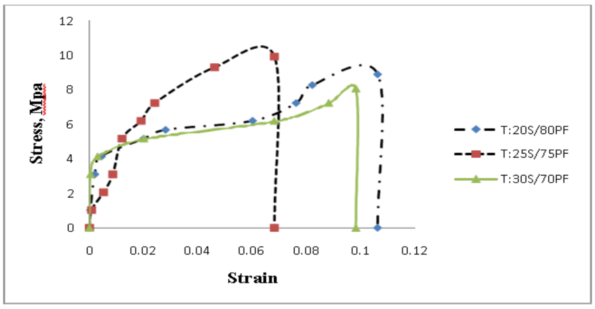

Figure 6 Stress v/s Strain Graph for Composites with Sisal Fiber with 5mm Length and Phenol Formaldehyde

Figure 6 shows the stress v/s strain graph for composites consisting of untreated 5mm fiber length with 20%, 25% and 30% of fiber volume fractions reinforced with phenol formaldehyde matrix. The stress-strain curve in Figure 6 exhibits a linear behaviour for fibre weight fractions of the composite that are 20%, 25%, and 30%. The material in this area behaves like an elastic body and abides by Hook's law. The tensions and stresses are not proportionate from that point on. Even a slight variation in stress causes the strain to increase quickly if the load is increased more. The data shows that the increase in the reinforcement content produces an increase in the Tensile strength of the composites with no change in Tensile strength has been observed for the composite when the fiber content is increased from 20% to 25%.

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Table 3 Tensile Properties of Untreated Sisal Fiber Reinforced with PF Composites at Three Different Weight Fractions and Two Different Fiber Lengths

Fiber weight (%)	Fiber length(mm)	Tensile strength (MPa)
20	5	6.8
	10	8.26
25	5	6.8
	10	6.81
30	5	7.22
	10	8.46

When the fiber content is increased from 25% to 30%, an increase of 6% in the Tensile strength has been observed. The table 3 also shows that the increase in the fiber length also increases the strength values of the composite. The specimens made with 20% weight of the sisal fiber and 5mm fiber length showed a tensile strength of 6.8Mpa while the same specimen made with 10mm fiber length showed a tensile strength of 8.26Mpa, with an enhancement of about 22% in the tensile strength values. When the fiber content has increased from 20% to 25%, very small improvement of about 1% in the tensile strength is observed for varied fiber length. Again the specimens made with 30% weight of the sisal fiber and 5mm fiber length has a tensile strength of 7.22Mpa while the same specimen made with 10mm fiber length showed a tensile strength of 8.46Mpa, with an enhancement of about 17% in the tensile strength.

Conclusion

In this work, Phenol Formaldehyde composites reinforced with short sisal fibres were created for varying fibre lengths and weight percentages. Composites made of sisal and phenol formaldehyde have their tensile qualities examined. When the fibre percentage was raised from 20% to 30%, the composites' tensile strength values showed an increasing trend. This demonstrates that the mechanical properties increase with increasing fibre content. This could be because fibres carry load and stress is transferred from the matrix along the fibres, resulting in an efficient and uniform distribution of stress and good mechanical properties in the composite. Comparing across the fiber lengths, the composite made with 10mm fiber length showed better results than the 5mm fiber length for most of the composite combinations. This confirms the increase in the fiber length increases the mechanical properties and this is because at the same volume fraction level there are a higher number of shorter fibers correspondingly, there are more fiber ends resulting in more stress concentration regions leading to more damage zone.

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