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Tensile and flexural properties of sisal fibre reinforced epoxy composite: A comparison between unidirectional and mat form of fibres

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Abstract

Natural fibres offer several benefits such as low density, low cost, environmental friendly and high specific mechanical performance. This work investigates the tensile and flexural properties of sisal fibre reinforced epoxy composite. This composite is prepared by using Hand lay-up method with 15, 20, 25 and 30 wt % of sisal fibres into epoxy matrix. Fibres are oriented in unidirectional as well as in the mat form. The tensile and flexural properties of sisal fibre epoxy composite both in unidirectional and in the mat form are found to be maximum at 30 wt %. It is found that the composite in unidirectional orientation of fibres gives better tensile and flexural properties in comparison to the mat form.

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Keyword: Sisal; Epoxy; Tensile properties; Flexural properties; SEM

1. Introduction

Natural fibres like sisal, jute, banana, hemp, coconut coir, palm, cotton, bamboo and wood has been used as reinforced in polymer composite in recent years (Hu et al., 2010). The property of natural fibre composite depends upon fibres, matrix and interaction between them. The interaction between fibre and matrix play an important role in the mechanical properties (Alawar et al., 2009). Natural fibre mainly consists of cellulose, hemicelluloses and lignin. Rigid cellulose microfibrils play the role of reinforcements in soft hemicelluloses and lignin matrix (Lu et al., 2003). Natural fibre reinforced polymer composite are getting more and more attention in the area of industries and technology due to their better mechanical properties, easy fabrication and easy availability. Natural fibre reinforced polymer composite are replacing synthetic composite in following applications, side panel of Audi A3 replaced by hemp fibre epoxy resin composite with Acrylonitrile-Butadiene-Styrene (Shalwan and Yousif, 2013). Glass fibres are widely used due to their low cost and better mechanical properties compared to other synthetic fibres. Glass fibres reinforced polymer composite has been widely used in automotive and aerospace industries for their excellent properties like high strength and low weight (AlMaadeed et al., 2013). Natural fibres have been used in strings, cords, cables, ropes, mats, brushes, hats, baskets and fancy articles like bags (Rao and Rao, 2007). Use of the glass fibre as reinforcement with wood floor in recycled polypropylene is less costly as compared to glass fibre reinforced polypropylene composite. Glass with wood polypropylene composite shows acceptable mechanical properties as compare to glass polypropylene composite (AlMaadeed et al., 2012).

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Nomenclature

S15	15 wt % sisal fibre reinforced epoxy composite
S20	20 wt % sisal fibre reinforced epoxy composite
S25	25wt % sisal fibre reinforced epoxy composite
S30	30 wt % sisal fibre reinforced epoxy composite
S30 (M)	30 wt % sisal fibre reinforced epoxy composite in the mat form

2. Materials and Experimental Procedure

2.1. Materials

The Epoxy resin Araldite AY-105 and Hardener HY-951 were purchased from Universal Enterprises (Polymer Division) Latouche road, Kanpur and sisal fibre is purchased from Women Development Organization, Dehradun, India.

Table 1. Mechanical and chemical properties of sisal fibre (Venkateshwaran et al., 2011)

Properties	Sisal fibre
Cellulose %	65
Hemicelluloses %	12
Lignin %	9.9
Moisture content %	10
Density (kg/m^3)	1450
Flexural modulus (GPa)	12.5-17.5
Microfibrillar angle	20
Lumen size (mm)	11
Tensile strength (MPa)	68
Young's modulus (GPa)	3.774

2.2. Preparation of composite

The epoxy resin AY-105 and hardener HY-951 was mixed in ratio of 10:1 by weight as recommended. A stainless steel mould having dimensions 500 mm × 300 mm× 50 mm. Composite was made of dimensions 400 mm × 200 mm × 3 mm. A releasing agent was used to facilitate easy removal of composite from the mould after curing. Each composite was cured under a load of 30 kg for 24 hours before removing from mould. This cast was post cured in the air for 24 hours after removal from mould. Specimens of suitable dimensions were cut using diamond cutter for flexural and tensile test.

2.3. Mechanical Testing

Flexure test and tensile test of the specimens were carried out. For each test and composition five specimens were tested and average value is calculated. The flexure properties were measured using a three point bending test method on Universal Testing Machine. The flexure tests were carried out at room temperature at a crosshead speed 2 mm/min as per ASTM D 790. Rectangular composite sample of 80 mm × 13 mm × 3 mm were tested with span length 48 mm. Calculation of flexural strength and flexural modulus were performed by using following formula:

$$\text{Flexural strength} = \frac{3FL}{2bd^2}$$

$$\text{Flexural modulus} = \frac{m\,L^3}{4bd^3}$$

Where; P is ultimate failure load (N), L is span between centre of supports (mm), b and d are width and thickness respectively, m is slope of tangent to the initial straight- line portion of the load- deflection curve.

Tensile test was carried out using Universal Testing Machine as per ASTM D 638, 165mm × 20mm × 3mm with 53mm gage length, at crosshead speed 3 mm/min.

3. Results and Discussions

3.1. Scanning electron microscope (SEM)

Fig. 1. shows the micrograph of fractured specimen of flexural and tensile test of sisal fibre reinforced epoxy composite. The SEM images show that there was large breakage of fibres and few voids presents due to pull out test. This indicates the interaction between the sisal fibre as a reinforced and epoxy as a matrix.

a b

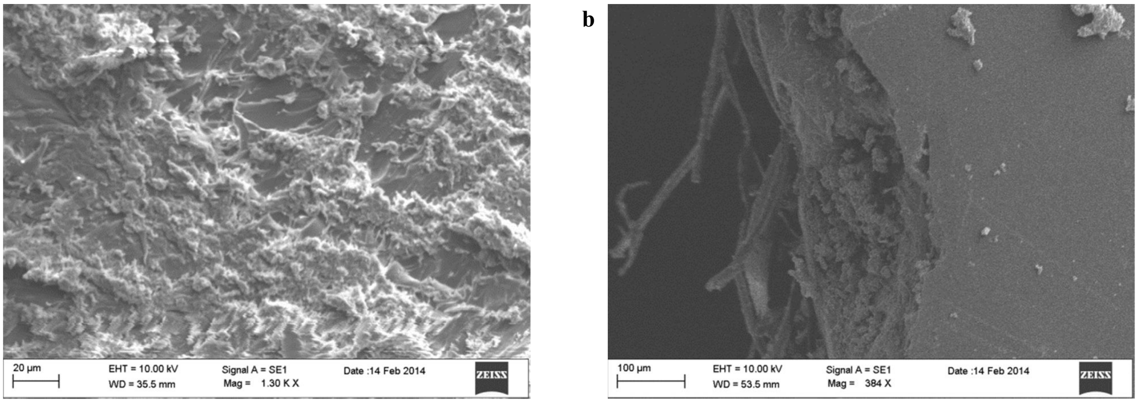


Fig. 1. SEM image of fractured specimen of for S30 (a) tensile test (b) flexural test

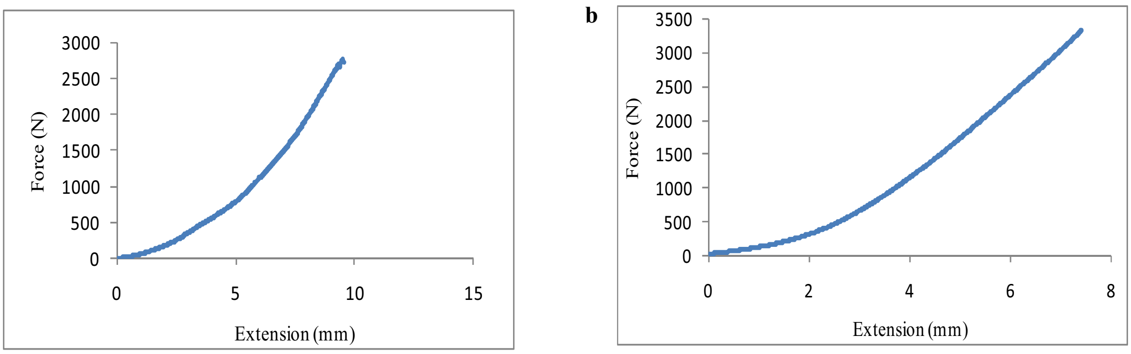
3.2 Tensile test

A typical force-extension graph for S15, S20, S25, S30 and S30 (M) are shown in Fig.2. It is observed that all the curves first increases exponentially and then linearly up to the maximum force. The tensile strength and modulus of sisal fibre reinforced epoxy composite are plotted in Fig. 3 whose data values can be seen in Table 2. The tensile modulus is obtained by taking the corresponding value of stress and strain from the linear portion of graph. It may be noted that increasing the sisal fibre content in composite resulted in increase in tensile strength and tensile modulus. The tensile strength and tensile modulus of S30 was found 89.3 MPa and 395 MPa in the mat form. The tensile strength and tensile modulus of S30 are found improved by 48.6 and 70.3% respectively as compare to S30 in the mat form. S30 (M) has low tensile strength and tensile modulus due to poor adhesion between sisal fibre in the mat form and epoxy matrix.

Table 2. Tensile and flexural properties of sisal fibre reinforced epoxy composite.

Composite	Tensile strength (MPa)	Tensile modulus (MPa)	Flexural strength (MPa)	Flexural modulus (GPa)
S15	66.74	251.8	204.3	12.08
S20	87.54	492	167.7	9.31
S25	74.89	228	235.3	11.75
S30	132.73	673	288.6	18.21
S30 (M)	89.3	395	152.12	14.80

a b



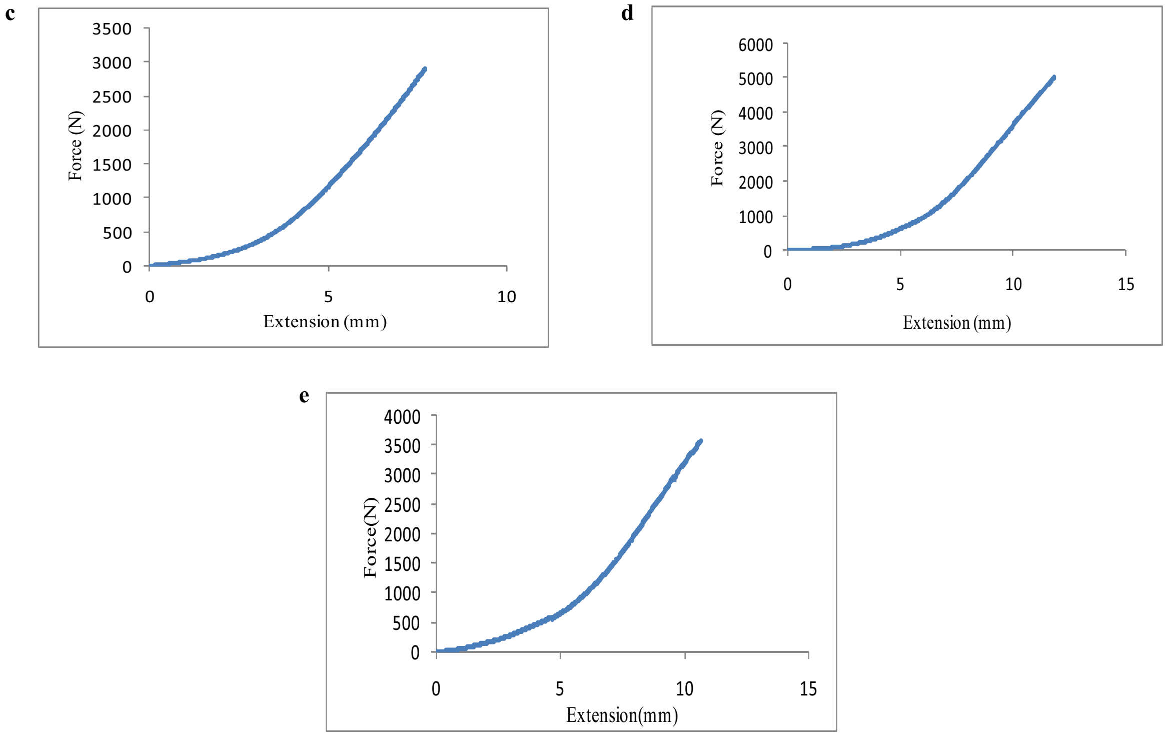


Fig. 2. Force-Extension diagrams (Tensile), (a) S15; (b) S20; (c) S25; (d) S30; (e) S30 (M).

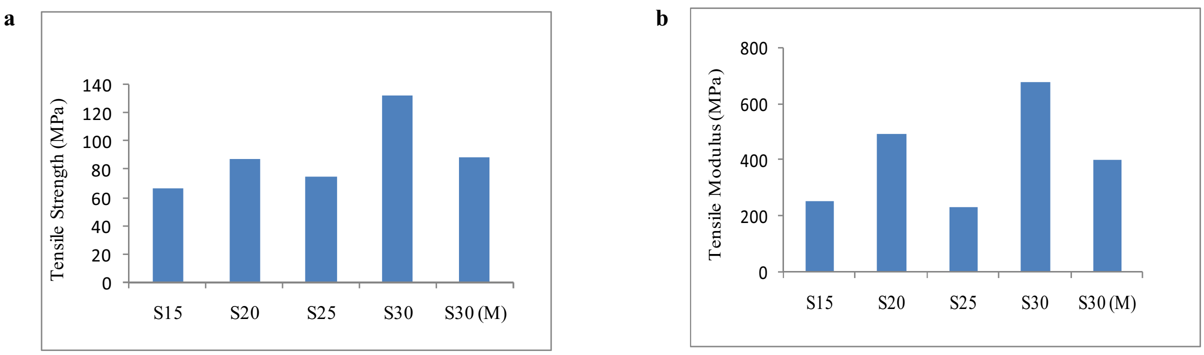


Fig. 3. (a) Effect on increasing sisal fibre content on (a) Tensile Strength; (b) Tensile Modulus.

3.2. Flexural Test

A typical force-displacement graph for S15, S20, S25, S30 and S30 (M) are shown in Fig.4. It is observed that all the curves increase linearly with respect to displacement up to the maximum force. The flexural strength and modulus of sisal fibre reinforced epoxy composite is plotted in Fig. 5 whose data values can be seen in Table 2. It may be noted that increasing the sisal fibre content in composite resulted in increase in flexural strength and flexural modulus. Flexural strength and flexural modulus of composite was found 152.12 MPa and 14.8 GPa respectively with S30 in the mat form. The tensile strength and tensile modulus of S30 are found improved by 89.7 and 23 % respectively as compare to S30 in the mat form. The adhesion between the sisal fibre and epoxy (unidirectional) is better than sisal fibre composite in the mat form.

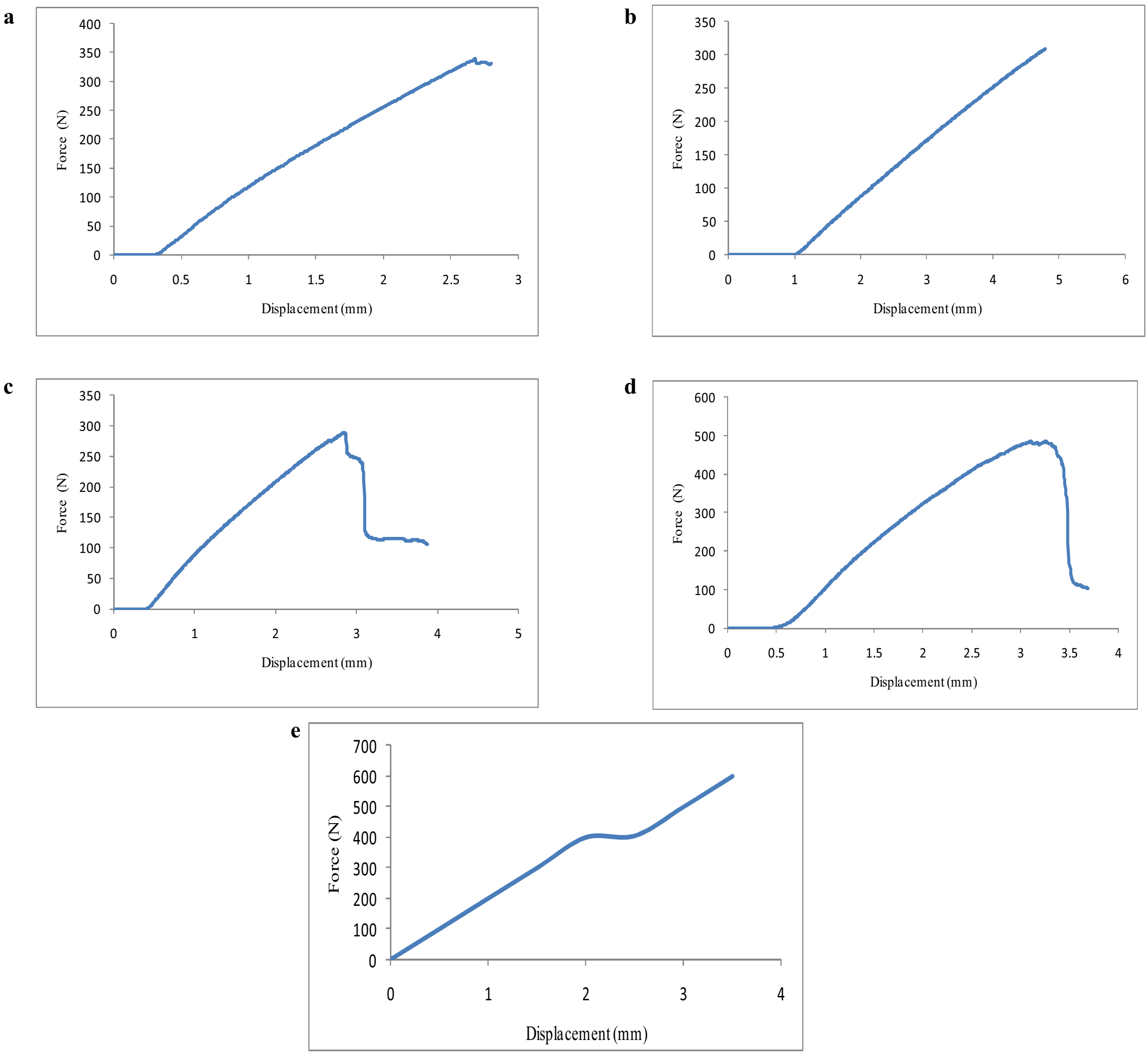


Fig. 4. Force Displacement diagrams (Flexural), (a) S15; (b) S20; (c) S25; (d) S30; (e) S30 (M).

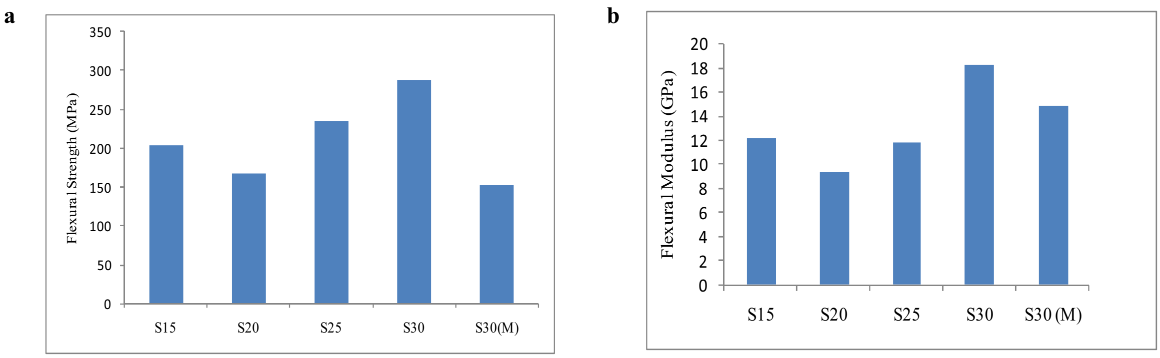


Fig. 5. (a) Effect on increasing sisal fibre content on (a) Flexural Strength; (b) Flexural Modulus.

4. Conclusions

It is seen that by using 30 wt % of sisal fibre content in the sisal fibre reinforced epoxy composite the tensile and flexural properties are found to be maximum in both the forms. The tensile strength, tensile modulus, flexural strength and flexural modulus are found to be 132.73 MPa, 673 MPa, 288.6 MPa, and 18.21 GPa respectively. These values are found to be improved in case of unidirectional as compared to the mat form by 48.6, 70.3, 89.7, and 23% respectively.

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