Analysis of Flexural Strength of Jute/Sisal Hybrid Polyester Composite

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Abstract. A flexural strength is one among the predominant factors for the polymer composites under perpendicular loading conditions against the axis of the member. In this study the flexural strength of Ethiopian Jute – Sisal hybrid polyester composite is investigated both analytically and experimentally. Composite test specimens have been prepared at various categories. They are based on different sequence of fibre layers: Jute-Sisal-Jute-Sisal (J/S/J/S), Sisal-Jute-Sisal-Jute (S/J/S/J) and Sisal-Jute-Jute-Sisal (S/J/J/S); fibres arrangement, based on orientation angle of fibres: [0°/45°/45°/0°], [0°/90°/90°/0°] and [45°/0°/0°/45°]; and based on concentration of fibers (weight ratio): [80% Polyester Matrix/20% Sisal/0% Jute], [81% Polyester Matrix/14% Sisal/5% Jute] and [76% Polyester Matrix/14% Sisal/10% Jute]. When comparing the results with different angle arrangement, [0°/45°/45°/0°] of fiber angled laminates is found to be most effective in flexural strength. And with different concentration of fibers in wt%, 10/14/76 [10% Jute, 14% Sisal and 76% Polyester Matrix] is found to be more satisfactory than the others in the flexural strength. From experimental result in sequence of fiber layers (S/J/S/J) has higher flexural strength than (J/S/J/S) and (S/J/J/S). From experimental result of jute/sisal polyester samples [0°/45°/45°/0°] has highest flexural strength which is 111.8 MPa and can resist maximum force of 469.5 N.

Keywords: Ethiopian Jute · Ethiopian sisal · Bending strength · Fiber · ANSYS

1 Introduction

Now sisal is strong and eco-friendly material which can be used to replace asbestos and fiberglass in composite materials in various uses including the automobile industry. Sisal is used commonly for mooring small craft, lashing, and handling cargo. Sisal fibre has several advantages in terms of product design flexibility, insulation, and noise absorption and impact resistance. Due to these properties sisal reinforced composite used in building material (like roofing sheets etc.), locomotive (like gear case, main doors etc.), automobile (like German automotive industry, door panel of E-class Mercedes etc.), aerospace and military (like transportation vehicle, safety equipment etc.) applications [1].

Jute take nearly 3 months, to grow to a height of 12–15 ft, then cut and bundled and kept immersed in water for "retting" process, where the inner stem and outer, gets

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separated and the outer plant gets 'individualized', to form a Fiber. The fiber after drying is taken to Jute mills, for getting converted to Jute yarn and Hessian. There is around 5.6 thousand tons of jute production per year in Ethiopia. Jute is a hydrophobic material and moisture absorption alters the dimensional and mechanical characteristics of jute fibers laminate [2]. Several studies have shown that the strength and stiffness of natural fiber reinforced composites are comparable with those of glass fiber composites on a per-weight basis [3, 5]. Hence, natural fibers have emerged as a green alternative to glass fiber for the production of certain semi-structural parts in various industries such as automotive, packaging and construction [6–10].

Studies have generally addressed hybridizing of fibers for the purpose of improving the performance of natural fiber composites and expand their industrial usage. One of the most effective methods used for improving the properties of natural fiber composites is hybridization which combines at least two different fiber types in a matrix to achieve optimum properties. Several studies have shown that combining natural fibers improves the resulting composite properties and compensates for the weak properties of natural fibers [1]. Li et al. [11] studied that sisal fiber is the promising reinforcement because of low density, high specific strength, no health hazards and finding applications in making of ropes, mats, carpets, baskets and fancy articles like bags etc.

2 Methods and Materials

2.1 Materials

Jute Fiber

Jute take nearly 3 months, to grow to a height of 12–15 ft. in this work jute leaves are cut and Mechanical extraction method is used to extract fibers the following procedures are used.
First sisal leaves are cut.
The fibre is extracted by rasping the leaves with a blunted knife.
Put the raw sisals on the table and rasp it until the resinous material are remove and fiber strands are obtained.

Sisal Fiber

Sisal leaves have a thorn at the tip and grow up to a height of 2 m and yield valuable fibre.
In this research sisal plant is taken from highland of Amhara region specifically debrework wereda and extracted manually.

Matrix and Hardener

The resin used for this study is polyester Resin with product name of OCPOL 711 (GP RESIN), which is manufactured by Ras Al Khaimah, which have low viscosity, consistent performance and doesn't contain any hazardous dilutes or extenders. Polyester resins are quite easily accessible, cheap and find use in a wide range of fields. Liquid polyesters are stored at room temperature for months, sometimes for years and the mere addition of a catalyst can cure the matrix material within a short time. They are used in automobile and structural applications.

The cured polyester is usually rigid or flexible as the case may be and transparent. Polyesters withstand the variations of environment and stable against chemicals.

The catalyst use for polyester resin is methyl ethyl ketone per oxide (MEKP) it helps the resin to solidify. The ratio of polyester to MEKP is 35 g of MEKP to 6 kg of polyester.

2.2 Methods

Alkaline Treatment of Fiber

To study the effect NaOH treatment on the flexural strength of composite jute and sisal fibres are treated at 6% and 10% concentration of fibre.

First 6% (6grams of NaOH with 100 ml water) are mixed and jute and sisal fibre are inserted in the mixture and wait for 24 h then it will be washed with water again and again then dried. For 10% concentration of NaOH the jute and sisal fibres are rinsed in mixture (10 g of NaOH in 100 ml water) for 24 h and washed using water again and again and then dried (Fig. 1).

A-NaOH
B-NaOH mixed with water
C-jute and sisal fibre rinsed in
The NaOH and water mixture
D-dried fibre

Fig. 1. Alkaline treatment process

Preparation of Polyester and Hardener

The matrix used to fabricate the fiber specimen was polyester of density 1.39 g/cm3 at 25 °C mixed with hardener of MEKP. The weight ratio of mixing polyester and hardener will be as per the supplier norms for 1 kg of polyester 6 g of MEKP.

Preparation of Composite Specimen

Sample of jute–sisal hybrid polyester composite will be prepared at different sequence of fiber layers, orientation angle and with different concentration of fibers (weight ratio) and with different percent of NaOH treatment.

The fabrication of the composite material is carried out through the hand lay-up technique. The mold used for preparing composites is made from rectangular wood having dimensions of 112 mm × 170 mm for each sample.

Sample Preparation Steps

The materials used for the experiment is prepared by hand layup process. Extracted sisal and jute fibers are used specimen preparation.

First, the fibers are dried under sunlight for 3 to 5 h.

Step 1- First applying the releasing agent (wax) on the mold;
Step 2 - Implementation of the first layer of resin with a brush over the releasing agent;
Step 3 - Positioning the first jute fiber blanket on the resin;
Step 4 - Apply resin on jute fiber blanket, using a brush;
Step 5 - Elimination of air bubbles using the roller across the surface;
Step 6 - positioning the second layer jute fiber on the resin;
Step 7 - Apply resin on jute fiber blanket, using a brush;
Step 8 - positioning the first sisal fiber blanket on the resin;
Step 9 - Apply resin on sisal fiber blanket, using a brush;
Step 10 - Elimination of air bubbles using the roller across the surface;
Step 11 - Positioning the second layer sisal fiber on the resin;
Step 12 - Apply resin on sisal fiber blanket, using a brush;
Step 13 - Elimination of air bubbles using the roller across the surface;

Finally, these laminas are kept in press for over 24 h to get the perfect shape and thickness (Fig. 2).

Fig. 2. Prepared samples

2.3 Simulation Method

In this work, software package ANSYS version 15 is used to calculate the flexural strength of sisal jute hybrid polyester composite of different angle arrangement of fibres. Specific properties of reinforced composite are given as inputs for ANSYS program and then the results are obtained for the given data.

E11, E22, G12 and vxy of jute and sisal fibers are found from published source [12, 13].

Unidirectional Continuous Fiber Angle –Ply Lamina
The following equations are used to calculate the elastic properties of an angle-ply lamina in which continuous fibers are aligned at angle θ with positive x axis as a reference.

$$\frac{1}{Exx} = \frac{cos^4\theta}{E11} + \frac{sin^4\theta}{E22} + \frac{1}{4}(\frac{1}{G12} - \frac{2V12}{E11})sin^2 2\theta$$
$$\frac{1}{Eyy} = \frac{sin^4\theta}{E11} + \frac{cos^4\theta}{E22} + \frac{1}{4}(\frac{1}{G12} - \frac{2V12}{E11})sin^2 2\theta$$
$$\frac{1}{Gxy} = \frac{1}{E11} + \frac{2V12}{E11} + \frac{1}{E22} - (\frac{1}{E11} + \frac{2V12}{E11} + \frac{1}{E22} - \frac{1}{G12})cos^2 2\theta$$
$$vxy = Exx\left[\frac{V12}{E11} - \frac{1}{4}\left(\frac{1}{E11} + \frac{2V12}{E11} + \frac{1}{E22} - \frac{1}{G12}\right)sin^2 2\theta\right]$$
$$vyx = \frac{Eyy}{Exx}\, vxy$$

Input Data
See Table 1.

Table 1. ANSYS input values

Angle	Ex (GPa)	Ey (GPa)	Ez (GPa)	vxy	vxz	vyz	Gxy (GPa)	Gxz (GPa)	Gyz (GPa)
00	10.62	6.75	6.75	0.36	0.36	0.44	2.448	2.448	2.32
900	6.75	10.62	10.62	0.23	0.23	0.19	2.448	2.448	2.82
450	6.8	6.88	6.88	0.40	0.40	0.40	3.20	3.20	2.44

ANSYS Simulation Method for Discontinuous Fibers
A thin lamina containing randomly oriented discontinuous fibers exhibits planar isotropic behavior. The properties are ideally the same in all directions in the plan e of the lamina. For such a lamina, the tensile modulus and shear modulus are calculated from

$$Erandom = \frac{3}{8}E11 + \frac{5}{8}E22, Grandom = \frac{1}{8}E11 + \frac{1}{4}E22, vrandom = \frac{Erandom}{2Grandom} - 1$$

2.4 Flexural Test

Samples are prepares according to ASTM D790-10, with dimensions its value became Span length = 128 mm, width = 20 mm, thick = 4 mm & its overall length is greater than 20% of support span length i.e. 170 mm (Table 2).

Universal testing machine with the specification listed below was used during testing, from each type 5 samples were tested and the average of the three sample is taken for the experimental result (Table 3).

Table 2. Source for ANSYS for random oriented fibre

Concentration by weight% of (JSP)	Erandom (GPa)	Grandom (GPa)	vrandom
0/20/80	6.655	2.456	0.355
5/14/81	7.222	2.661	0.356
10/14/76	8.204	3.016	0.36

Table 3. UTM adjusted parameter for the test

UTM capacity	100 kN
Load speed	0.1 kN/s (1 MPa/s)
Displacement	0.2 mm/min
Extension	0.01 mm/s (0.02%/s)

3 Results and Discussion

3.1 ANSYS Result

ANSYS Result

See Fig. 3

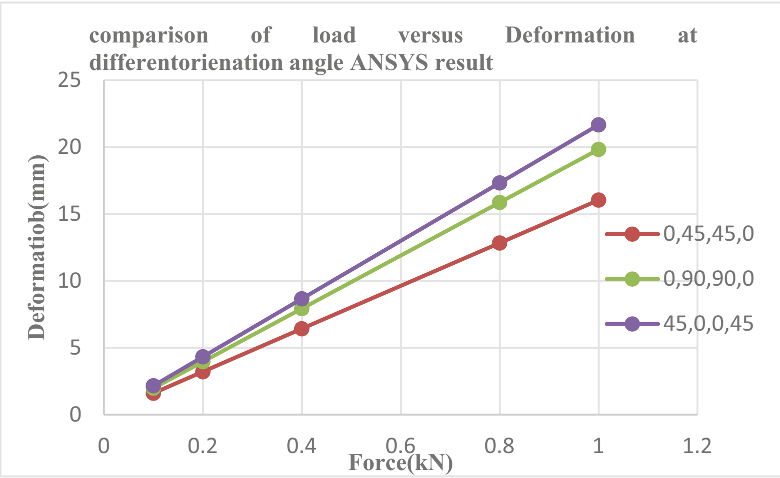

Fig. 3. Comparison of load versus deformation at different orientation angle ANSYS result

ANSYS result for different concentration of fibres

See Fig. 4

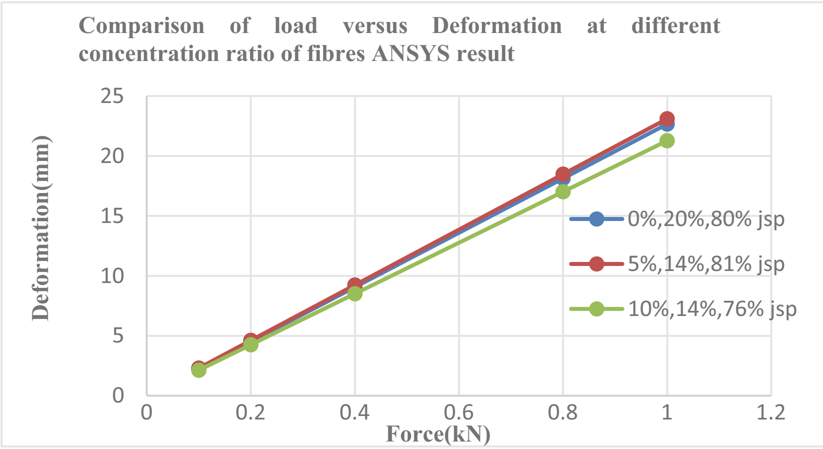

Fig. 4. Comparison of load versus Deformation at different concentration of fibre Weight ratio ANSYS result

3.2 Experimental Result

See Figs. 5, 6, 7 and 8.

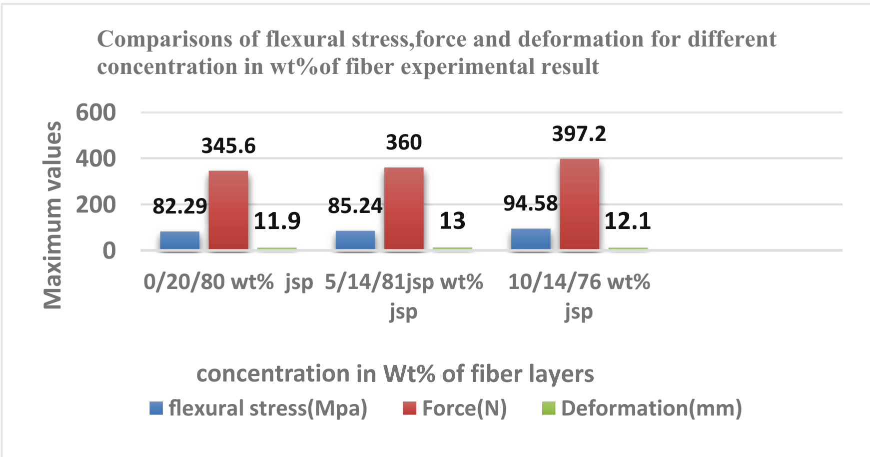

Fig. 5. Experimental results of different concentration of fiber

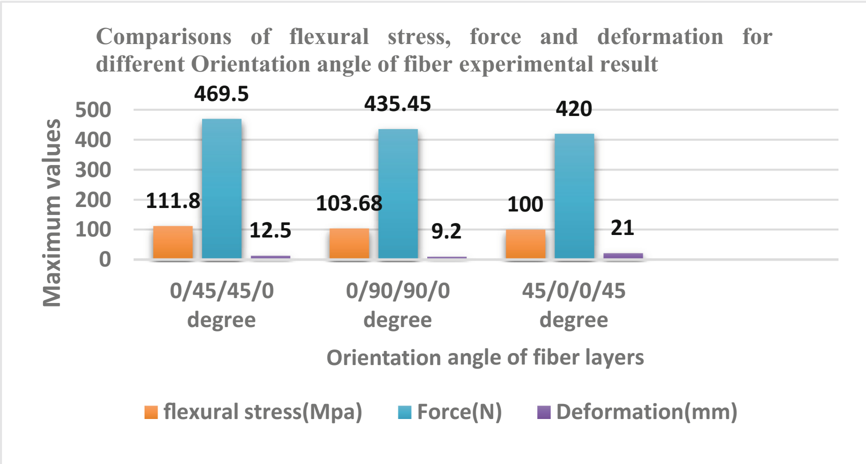

Fig. 6. Experimental results of different sequence of fiber layers

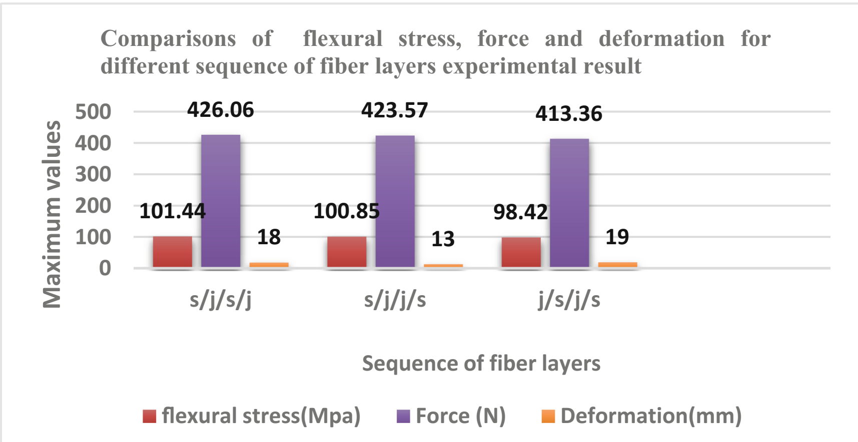

Fig. 7. Experimental results of different arrangement of angle orientation fibers

3.3 Discussion

Generally ANSYS and experimental results have the same result in case of different angle arrangement of fibers and with different concentration of fibers in wt% in both cases [0/45/45/0] and 10/14/76 wt% of fibers have best flexural strength respectively.

From comparison of ANSYS result by angle orientation of fibres [$0^0/45^0/45^0/0^0$] has least deformation. And also it has least induced stress than other arrangements. So it will have better flexural strength.

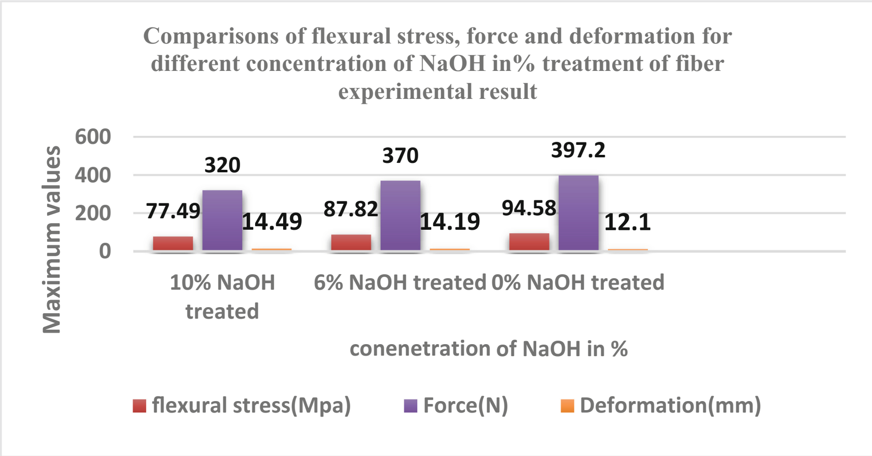

Fig. 8. Experimental results of NaOH treated samples at different concentration

Whereas, $[45^{\circ}/0^{\circ}/0^{\circ}/45^{\circ}]$ has largest deformation than $[0^{\circ}/45^{\circ}/45^{\circ}/0^{\circ}]$ and $[0^{\circ}/90^{\circ}/90^{\circ}/0^{\circ}]$. From experimental result in sequence of fiber layers s/j/s/j has higher flexural strength than j/s/j/s and s/j/j/s. whereas j/s/j/s has least strength. But s/j/j/s has least deformation than others arrangement which shows sequence of layers has effect on flexural strength of composite. From fiber concentration 10/14/76 wt% of fibers (JSP) has highest flexural strength than 0/20/80 and 5/14/81 concentration in wt% of (JSP). But 5/14/81 has better strength than 0/20/80 which shows a positive effect of hybridization.

Failure Modes

The intact and damaged specimens of flexural tests are depicted in figure below. In the case of flexural test, bending failure on the tension surface of specimens was due to matrix and fiber breakage and most of the samples fail at mid-span (Fig. 9).

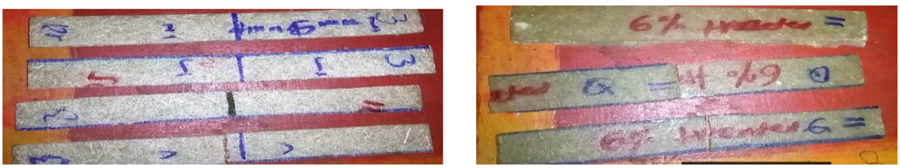

Fig. 9. Failure modes of samples after test

Comparison of Experimental with ANSYS Result See Table 4.

Table 4. Comparison of experimental result with ANSYS result

Arrangement of layers	Applied Load (N)	Stress (Mpa)		
		ANSYS result	Experimental result	% Error
0°/45°/45°/0°	469.5	101.24	111.8	9.4
0°/90°/90°/0°	434.5	94.53	103.08	8.29
45°/0°/0°/45°	420	81.5	100	18.5

4 Conclusion

From experimental investigation of jute/sisal polyester composite the following conclusions can be made.

- The flexural properties of jute/sisal polyester composite have better strength at [0°/45°/45°/0°] orientation angle than [0°/90°/90°/0°] and [45°/0°/0°/45°] orientation arrangement.
- The flexural properties of jute/sisal polyester composite decreases when it is treated with 10% NAOH in concentration.
- The flexural properties of jute/sisal polyester composite improved when two natural fibers are hybridized.
- The flexural properties of jute/sisal polyester composite depends on sequence of fiber layers and better flexural strength is found on s/j/s/j arrangement than s/j/j/s and j/s/j/s arrangement.
- But s/j/j/s arrangement has less deformation than s/j/s/j and j/s/j/s arrangement.
- The flexural properties of jute/sisal polyester composite improved when continuous fibers are used than chopped fibers.
- From experimental result of jute/sisal polyester samples with concentration 10/14/76 wt% of fibers (JSP) has highest flexural strength which is 43.35 Mpa and fails at force 326.5 N.
- From experimental result of jute/sisal polyester samples [0°/45°/45°/0°] has highest flexural strength which is 111.8 MPa and maximum force 469.5 N.

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