Analysis of Bending and Tensile Strength of Sisal/Bamboo/Polyester Hybrid Composite

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Abstract. Nowadays composite materials are promising material which can replace metals and they can be used in different applications so studying mechanical properties of composites is crucial. Hybridization of two different fibers improves properties of composites by compensating the weak properties of individual fibers. In this study sisal and bamboo fiber hybrid polyester composite are prepared to study the effect of hybridization on strength of composites. Tensile test Samples are prepared according to ASTM D3039 and bending test samples are prepared according D790. Mats are prepared from each fiber using manual mat making machine to reduce porosity, reduce effort aligning fibers to increase strength of the composite. Sisal/Bamboo/Polyester composites are prepared for tensile and bending test by varying the mixing weight ratio of fibers to matrix ratio. Samples prepared are (0%/30%/70%), (15%/15%/70%), (10%/20%/70%), (20%/10%/70%) and (30%/0%/70%), by wt% of Sisal/Bamboo/Polyester respectively for tensile and bending test to study how hybridization affect the strength of composite. Tensile and bending strength are tested using universal tensile tester machine and 5 samples are tested for each sample to reduce errors during testing. From the test result hybridizing fibers compensate the weak properties of one by another and increase the tensile and bending strength of individual fiber polyester composite. From tensile test of different weight ratio 10%/20%/70% by wt% of sisal/Bamboo/Polyester has better strength than other ratios. From bending test of Sisal/Bamboo/Polyester hybrid composite hybridizing the sisal and bamboo 10%/20%/70% wt% improve the yield strength of pure sisal polyester composite. Generally hybridizing fibers improves the tensile and bending yield stress of individual fiber polyester composites and compensates the weak properties one fiber by the other fiber.

Keywords: Bamboo · Sisal · Bending strength · Fiber · Hybrid

1 Introduction

Nowadays the world needs materials which are renewable, biodegradable, less cost, eco-friendly, and light in weight to save power loss. In Ethiopia, these natural fibres like sisal, bamboo and jute are abundantly available, but which are not having sufficient scientific evaluation proof for their strength. Natural fiber composites has a better strength but still their strength can be improved by different methods like hybridizing. This study

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tries to know mechanical properties of Jute, Sisal and Bamboo fibers which are grown in Ethiopia and try get an optimized bending and tensile strength by hybridizing Sisal and Bamboo fibers.

The use of natural fibres for composites are increasing rather than artificial/synthetic fibres like Glass, Carbon and Kevlar. The main reason behind it is the ecological benefits, cheap cost, renewability and availability in abundance and also with good specific mechanical properties [1].

Natural fibred composites are widely used in different application areas such as automobiles, furniture, and sports equipment, due to the advantages of natural fibres compared to synthetic fibres, i.e. low cost, low density, less damage to processing equipment, renewability, and biodegradability and easily availability. Among several natural fibres like jute, sisal, bamboo etc. Bamboo fibre is the effective one for greater strength. Several bamboo species exist all around the world [2].

There are factors which affect the mechanical strength of composites, among those the ratio of fibers to matrix ratio is the one. Investigations has been made at different fiber to matrix ratio (20%/80%, 30%/70%, and 40/60% fiber to matrix ratio by weight percentage) to study effect fiber to matrix ratio on strength of composites. From the test result tensile strength composites decrease at 40 wt% of fiber and 60 wt% of matrix. On the basis of mechanical testing results it is found that 30 wt% of bamboo fibre to 70 wt% of matrix give optimum mechanical properties [3].

From the mechanical strength investigation kenaf and banana fiber with polyester composite. The bending strength of kenaf/banana hybrid fiber with polyester composite has better strength than individual kenaf and banana fiber polyester composite. From individual fiber composites kenaf fiber reinforced composite had a better bending strength than banana fiber, due to densified structure of kenaf fiber. Generally banana and kenaf fibers in the hybrid increases compressive and shear strength [4].

Many literatures show hybridizing has appositive effect on mechanical strength of composite. From bending strength test to study effect of fibers palm/jute fiber hybrid composites had better bending strength than pure palm fiber composite. In all hybrid composites bending strength on increasing weight ratio of jute fiber. The tensile strength of hybrid palm/jute composites also increases by 46% with increase of weight ratio of jute fiber (25% palm, 75% jute) as compared to pure palm fiber composites. Generally hybridization of fibers has a positive effect on bending and tensile strength of palm/jute hybrid composite [5].

From study of tensile, bending and impact properties of sisal/bamboo polyester hybrid composite hybridization shows a positive effect. The tensile, bending and impact strength increase as weight ratio bamboo fibers increase in the hybrid composite as compared to pure sisal polyester composite [6].

2 Methods and Materials

2.1 Materials

Sisal Fiber

Sisal fibre is one of the most widely used natural fibres and is very easily cultivated. Sisal fibre is a promising reinforcement for use in composites on account of its low cost, low density, no health risk, easy availability and renewability. Sisal fibers traditionally used for making ropes, mats, carpets, fancy articles and others. In this research sisal plant is taken from highland of debrework wereda Amara Region, Ethiopia and extracted manually.

Bamboo Fibre

The bamboo fibre was prepared from species of Ethiopian hallow bamboo. Bamboo plants taken from Amhara Region around at Injibara (hollow bamboo). Bamboo were cut up to its culm then it just sliced in the longitudinal direction.

Matrix and Hardener

Polymer matrices can be either thermoplastic or thermoset. The most commonly used thermoset resins are epoxy, vinyl ester, polyester and phenolic. In general, the Polyester resins are being widely used for many advanced composites due to their many advantages such as Better adhesive properties, Superior mechanical properties (particularly strength and stiffness), Improved resistance to fatigue and micro cracking, Reduced degradation from water ingress (diminution of properties due to water penetration), Increased resistance to osmosis (surface degradation due to water permeability) and Good performance at elevated temperature etc. The resin used for this study is Polyester Resin with brand name of GPP (General Purpose Polyester) and catalyst used is methyl ethyl ketone peroxide with 5.8 g catalyst to 1 kg of polyester resin.

2.2 Methods

Fiber Extraction Methods for Bamboo Fiber

In this research two different methods of fiber extraction methods for bamboo fiber are used and the fiber strength are compared. Fibre are extracted according to ASTM D3379 (fiber length between 20–35 cm and diameter has a range of 0.09 mm to 0.25 mm [7] (Fig. 1).

Fig. 1. Extraction method of bamboo

Mechanical Extraction Method

- Initially bamboos of 2 years are cut and culms above 2 m from root are used in this research.
- Initially raw bamboo cut near to the culms and then cut and sliced in to four pieces.
- Those sliced pieces will be sliced again in to many very thin slices
- Dry the sliced for 5 days until it lost its moisture to facilitate easy fiber extraction.
- From those dry very thin slices of bamboo thin bamboo fibers extracted manually by hand.

Fiber Extraction of Sisal Fiber
Mechanical extraction
Fibers are extracted manually. Sisal plants are cut and fibers are extracted by eliminating resinous waste materials using knife by rasping until fiber strands are obtained (Fig. 2).

Fig. 2. Sisal plant and fibre

Mat Preparation
Preparing fibers in the form of mat has the following advantage (Figs. 3 and 4)

- It reduce time to prepare composite
- It reduce porosity of the composite so that we can make strong composite

Fig. 3. Mat preparing method

Fig. 4. Mats of sisal and bamboo fiber

Preparation of Polyester and Hardener

The matrix used to fabricate composite is general purpose polyester resin with methyl ethyl ketone per oxide catalyst. The mixing ratio is 6 g of methyl ethyl ketone per oxide for 1 kg of polyester resin.

Preparation of Composite Specimen

Composite samples are prepared with 30% fiber and 70% matrix ratio which is optimum ratio [3] by varying the weight ratio of two fibers by keeping other parameters constant from mats using hand- layup method. The mold used for preparing composites is made from rectangular wood according to ASTM D-790 and D-3039 for bending and tensile samples respectively. The sample size for bending test is length = 170 mm, width = 20 mm and thickness of 4 mm and for tensile test length 250 mm, width 25 mm and thickness-4 mm.

Tensile test samples of sisal/Bamboo/Polyester Composite

(A) Samples 1, 2, 3, 4, and 5, are made of Sisal/bamboo/polyester by differing weight ratio of fiber to matrix ratio constant according to ASTM 3039.

Sample 1 = 15%/15%/70% wt% (sisal/Bamboo/polyester Hybrid Composite)
Sample 2 = 20%/10%/70% wt% (Sisal/Bamboo/Polyester Hybrid Composite)
Sample 3 = 10%/20%/70% (Sisal/Bamboo/polyester Hybrid Composite)
Sample 4 = 30%/0%/70% (Sisal/Bamboo/polyester Hybrid Composite)
Sample 5 = 0%/30%/70% (Sisal/Bamboo/polyester Hybrid Composite)

Bending Test samples of Sisal/Bamboo/Polyester Composite

(B) Samples A, B, C, D, E and F, are made of Sisal/bamboo/polyester by differing weight ratio of fiber to matrix ratio constant according to ASTM D-790.

Sample A = 15%/15%/70% (Sisal/Bamboo/polyester Hybrid Composite)
Sample B = 10%/20%/70% (Sisal/Bamboo/polyester Hybrid Composite)
Sample C = 20%/10%/70% Sisal/Bamboo/polyester Hybrid Composite)
Sample D = 30%/0%/70% (Sisal/Bamboo/polyester Hybrid Composite)
Sample E = 0%/30%/70% (Sisal/Bamboo/polyester Hybrid Composite)
Sample F = 10%/10%/80% (Sisal/Bamboo/polyester Hybrid Composite) (Fig. 5)

Finally bending samples are cut for final test According to ASTM D-790 standard (Fig. 6).

Fig. 5. Samples for tensile test

Fig. 6. Samples for bending test according ASTM D-790

Universal Tensile Testing Machine

The universal tensile testing machine was the equipment where the tensile test and bending test has been done as shown in the Figure. It has a capacity of 100 KN, during test the machine has been set to 5 mm/min (Fig. 7).

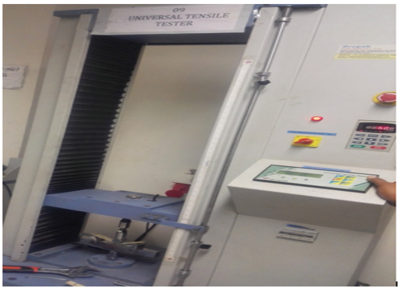

Fig. 7. Universal Tensile Tester Machine

Flexural Test

Samples for flexural test are prepared with total length of 170 mm, span length of 128 mm, width of 20 mm and thickness of 4 mm according to ASTM D790. Five samples are tested to reduce errors.

Tensile Test

Tensile test samples are cut to size of length = 250 mm, width 20 mm and thickness = 4 mm according to ASTMD3039, and 5 samples were tested and the average result has been taken. During test the machine has been set to 5 mm/min.

3 Results and Discussion

3.1 Tensile Test Result of Composite

Comparison of Tensile Yield Strength (MPa), Yield Force (KN), Elongation (mm) and Density (Kg/m^3) of sisal/bamboo/polyester composite with different weight ratio, keeping other parameters constant (Figs. 8, 9 and 10).

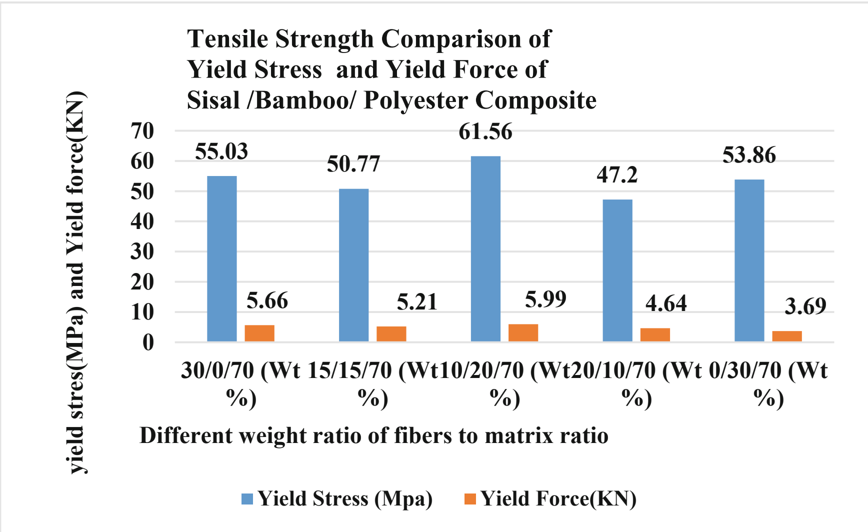

Fig. 8. Comparison of Yield Stress (MPa) and Yield Force (KN) of Sisal/Bamboo/Polyester Composite at different Weight ratio from tensile test.

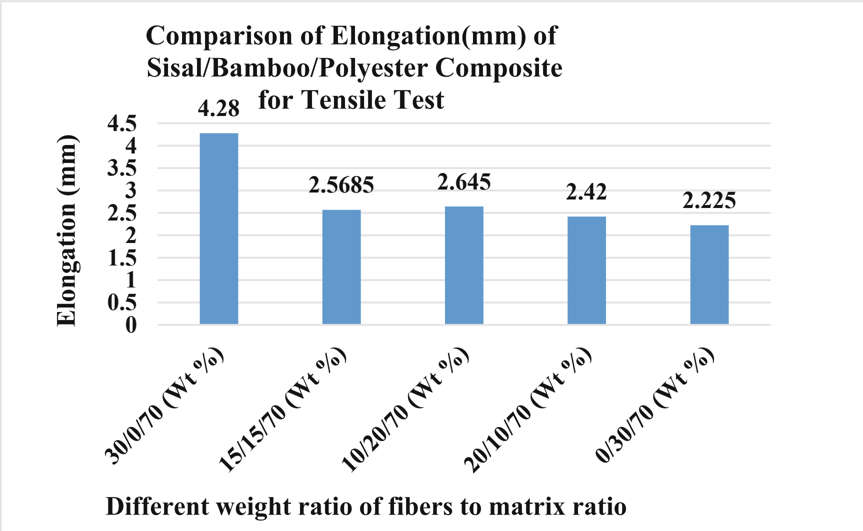

Fig. 9. Comparison Elongation (mm) of Sisal/Bamboo/Polyester Composite at different Weight ratio from tensile test.

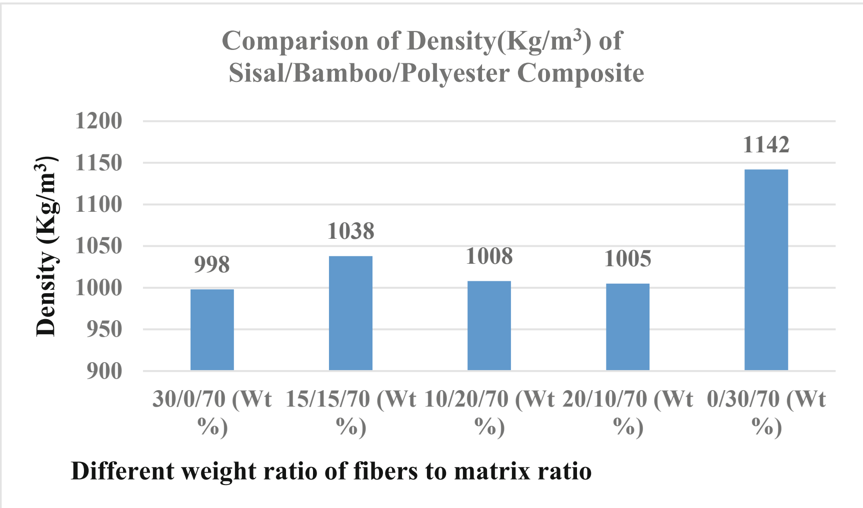

Fig. 10. Comparison Density (Kg/m^3) of Sisal/Bamboo/Polyester Composite at different Weight ratio tensile test.

3.2 Bending Test Result of Composite

Comparison of Flexural Yield Strength (MPa), Yield Force (KN), Elongation (mm) and Density (Kg/m^3) of sisal/bamboo/polyester composite with different weight ratio, keeping other parameters constant for bending test (Figs. 11, 12, 13 and 14).

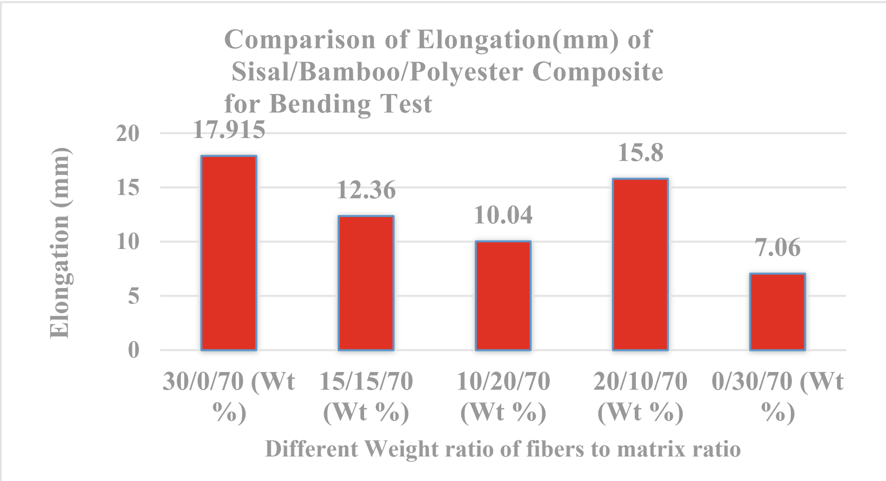

Fig. 11. Comparison Elongation (mm) of Sisal/Bamboo/Polyester Composite at different Weight ratio from bending test.

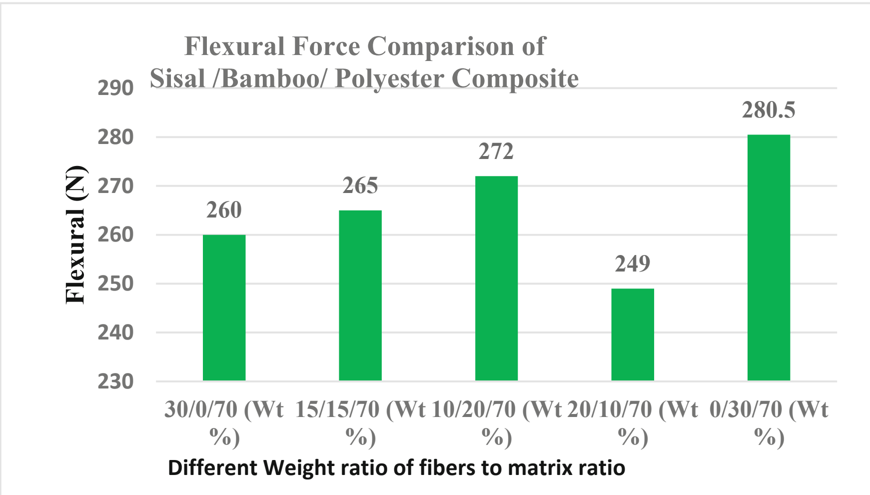

Fig. 12. Comparison Bending yield Force (N) of Sisal/Bamboo/Polyester Composite at different Weight ratio from bending test.

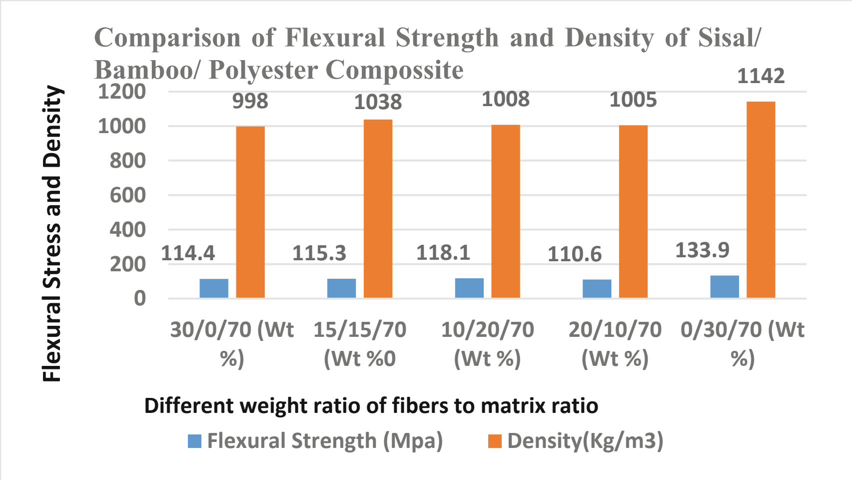

Fig. 13. Comparison Flexural Stress (MPa) and Density (Kg/m^3) of Sisal/Bamboo/Polyester Composite at different Weight ratio from bending test

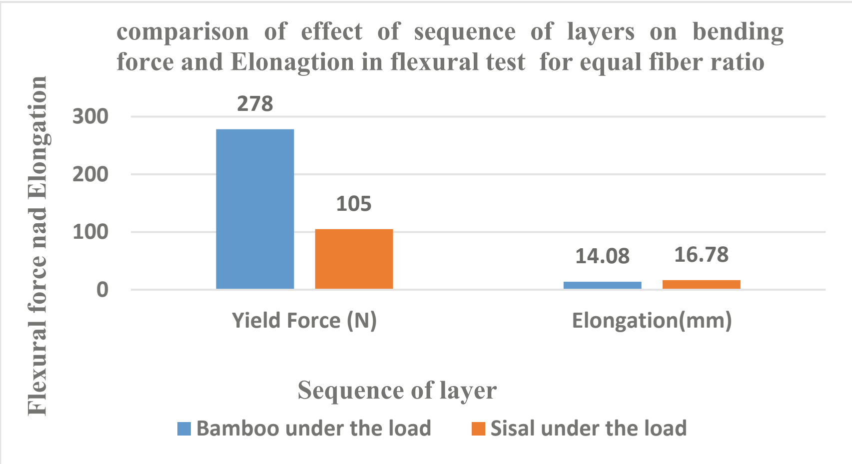

Fig. 14. Comparison Flexural yield force (N) and Elongation (mm) of Sisal/Bamboo/Polyester Composite with the same fiber Weight ratio from bending test.

3.3 Discussion

From tensile test of Sisal/Bamboo/Polyester hybrid composite 0/30/70 wt% 55.03 MPa, and 30/0/70 wt% has 53.86 MPa by hybridizing the sisal and bamboo 10/20/70 wt% improve the yield strength to 61.56 MPa.

From elongation result 30/0/70 wt% has large elongation of 4.28 mm whereas 0/30/70 wt% composite has small elongation of 2.225 mm and hybrid composite of 10/20/70 wt% has 2.645 mm.

From bending test of Sisal/Bamboo/Polyester hybrid composite 30/0/70 wt% has bending stress 114.4 MPa, and 0/30/70 wt% has bending stress of 133.9 MPa by hybridizing the sisal and bamboo 10/20/70 wt% has yield strength of 118.1 MPa. from bending elongation result 30/0/70 wt% has large elongation of 17.28 mm whereas 0/30/70 wt% composite has small elongation of 7.06 mm and hybrid composite of 10/20/70 wt% has 10.04 mm. comparing bending force of composites pure bamboo polyester composite has 260 N, and pure sisal composite has 280.5 N, hybrid composite of 10/20/70 by wt% has bending force of 272 N.

3.4 Failure Modes

Failed flexural and tensile specimens are shown in the figure below. Flexural specimens at the mid span of its length, due to matrix and fiber breakage (Fig. 15).

Fig. 15. Bending and tensile samples after failure

4 Conclusion

From experimental test sisal/bamboo hybrid fiber polyester composite the following conclusions can be made.

- From tensile test of Sisal/Bamboo/Polyester hybrid composite hybridizing the sisal and bamboo to 10/20/70 wt% improve the yield strength to 61.56 MPa which is more than pure sisal and bamboo composites this is due to hybridization.
- From elongation result pure sisal composite has large elongation of 4.28 mm whereas pure bamboo composite has small elongation of 2.225 mm and hybrid composite of 10/20/70 wt% improve the elongation of pure bamboo composite.
- Comparing density of composites pure bamboo polyester composite has 1142 kg/m^3, and pure sisal composite has density of 998 kg/m^3, hybrid composite of 10/20/70 by wt% has a density of 1008 kg/m^3.
- From bending test of Sisal/Bamboo/Polyester hybrid composite hybridizing the sisal and bamboo 10/20/70 wt% improve the yield strength of pure Sisal composite.

- From bending elongation result hybrid composite of 10/20/70 wt% improves the elongation of pure bamboo composite due to hybridization compensates the weak property of bamboo fiber.
- From bending test to study the effect of sequence of layers bamboo layers under the load resist more load than when sisal layers are under the load but the elongation is better when sisal layers are under the load this is due to the loads are more shared by outer layers.
- Generally hybridizing natural fibers compensate the weak properties of one fiber by the other gives a better result in the bending and tensile test.

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