Preparation and Analysis of Mechanical Properties of Short Sisal and Glass Fiber Reinforced Composite

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ABSTRACT: The present work surveys the research work published in the field of sisal fiber reinforced polymer composites with special reference to the properties of sisal fiber, processing techniques, mechanical properties of the composites. Interest is warranted due to the advantages of these materials compared to others, such as synthetic fiber composites, including low environmental impact and low cost and support their potential across a wide range of application. The advantages of natural fiber over traditional reinforcing materials such as glass fiber, talc and mica are acceptable specific strength properties, low cost, low density, high toughness, good thermal properties and biodegradability. The combination of sisal fiber and glass fiber for reinforcing epoxy polymers gives enhanced mechanical properties. The work deals with the utilization of sisal fiber and glass fiber reinforcement in polymer. The objective of the work is to compute mechanical properties such as tensile and hardness of randomly oriented sisal fiber and glass fiber reinforced epoxy composites. In this work, sisal fiber % weight is varied from 2 to 8 with constant 2% weight of glass fiber. From the work, it was found that ductility, modulus of elasticity and hardness gradually improved.

KEYWORDS: Sisal Fiber, Epoxy, Glass fiber, tensile properties, Hardness

<https://doi.org/10.29294/IJASE.5.3.2019.1009-1016>

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1. INTRODUCTION

In the recent past, the use of polymers has become most preferred materials for various manufacturing applications due to several attractive properties, including light weight, ease of processing and cost-effectiveness [1]. Hence, many significant research attempts are made to utilize polymers in different industrial applications, using various kinds of reinforcements including fibers that are reinforced into the polymers to increase their physical and mechanical properties of the composite as whole. Due to increased environmental awareness and having more environmental regulations, the growing demand for using nonconventional materials leads to the development of renewable, recyclable, biodegradable, and sustainable and eco-friendly materials [2-6]. The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and in terms of fundamental research. These are renewable, cheap, completely or partially recyclable, and biodegradable. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. In addition, natural fibers reinforced polymers are considered as lightweight and low-cost in comparison with many synthetic composites [4-6].

Natural fibers are more comfortable to handle and which have beneficial thermal and acoustic insulation properties. Recently, a number of significant industries, such as the automotive, construction and packaging industries have been fascinated in the development of new green natural

fiber reinforced composite materials [4-7]. All natural fibers are categorized in three categories, based on main sources: animals, vegetables and minerals, as shown in Fig. 1

Recent studies have investigated the development of biodegradable composite materials using natural fibers such as pineapple [8], flax [4], bamboo [9], oil palm empty fruit bunch [10], silk [11], jute [12], kenaf [13], rice husk [14], ramie [15] and sisal [16-17], as a reinforcement for biodegradable plastics. The versatile advantages of natural fibers over man-made glass and carbon fibers are inexpensive, low density, comparable specific tensile properties, non-abrasive to the equipments, non-irritation to the skin, reduced energy consumption, less health risk, renewability, recyclability and bio-degradability [18].

Vegetable fibers are broadly comprised primarily of cellulose: examples include cotton, flax, jute, ramie, sisal, and hemp. In the manufacture of paper and cloth cellulose fibers are typically used. These fibers can be further categorized into the following:

- i. Seed fiber: Fibers collected from seeds or seed cases. Eg. cotton and kapok
- ii. Leaf fiber: Fibers collected from leaves. e.g. sisal and agave.
- iii. Bast fiber (skin fiber): Fibers are extracted from the skin or bast surrounding the stem of their respective plant which prepossess higher tensile strength than other fibers. Hence used in durable yarn, fabric, packaging, and paper. Most common example are flax, jute, kenaf, industrial hemp, ramie, rattan, soybean fiber, and even vine fibers and banana fibers.

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Received: 05.01.2019

Accepted: 25.02.2019

Published on: 27.02.2019

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- iv. Fruit fiber: Fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber.
- v. Stalk fiber: Fibers are actually the stalks of the plant. Eg. Straws of wheat, rice, barley and other crops including bamboo and grass. Tree wood is also such a fiber.

Figure 1 Source of Natural fiber [7]

Table 1: Properties of some natural fibres and the main type of glass fibre (E-glass) [19]

Fibre	Density (g/cm ³)	Length (mm)	Failure strain (%)	Tensile strength (MPa)	Stiffness/Young's modulus (GPa)	Specific tensile strength (MPa/g cm ⁻³)	Specific Young's modulus (GPa/g cm ⁻³)
Ramie	1.5	900-1200	2.0-3.8	400-938	44-128	270-620	29-85
Flax	1.5	5-900	1.2-3.2	345-1830	27-80	230-1220	18-53
Hemp	1.5	5-55	1.6	550-1110	58-70	370-740	39-47
Jute	1.3-1.5	1.5-120	1.5-1.8	393-800	10-55	300-610	7.1-39
Harakeke	1.3	4-5	4.2-5.8	440-990	14-33	338-761	11-25
Sisal	1.3-1.5	900	2.0-2.5	507-855	9.4-28	362-610	6.7-20
Alfa	1.4	350	1.5-2.4	188-308	18-25	134-220	13-18
Cotton	1.5-1.6	10-60	3.0-10	287-800	5.5-13	190-530	3.7-8.4
Coir	1.2	20-150	15-30	131-220	4-6	110-180	3.3-5
Silk	1.3	Continuous	15-60	100-1500	5-25	100-1500	4-20
Feather	0.9	10-30	6.9	100-203	3-10	112-226	3.3-11
Wool	1.3	38-152	13.2-35	50-315	2.3-5	38-242	1.8-3.8
E-glass	2.5	Continuous	2.5	2000-3000	70	800-1400	29

The most used natural fibers are cotton, flax and hemp, although sisal, jute, kenaf, and coconut are also widely used. Hemp fibers are mainly used for ropes and aerofoils because of their high suppleness and resistance within an aggressive environment. Hemp fibers are, currently used as a seal within the heating and sanitary industries.

Animal fibers generally comprise proteins; examples include silk, wool, angora, mohair and alpaca.

- i. Animal hair (wool or hairs): Fiber or wool taken from animals or hairy mammals. Eg. sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair etc.
- ii. Silk fiber: Fiber collected from dried saliva of bugs or insects during the preparation of cocoons. Examples include silk from silk worms.

Avian fiber: Fibers from birds, e.g. feathers and feather fiber

Although mineral-based natural fibres exist within the asbestos group of minerals and used extensively in composites, and are avoided due to associated health issues (carcinogenic through inhalation/ingestion) and are banned in many countries. [19].

The drawbacks such as incompatibility with the hydrophobic polymer matrix, the inclination to form aggregates during processing, and also poor resistance to moisture greatly reduce the potential of natural fibers to be employed as reinforcement in polymers [1-4]. Table 01 shows properties of some natural fibers and the main type

of glass fiber (E-glass). It can be seen that, flax, hemp and ramie fiber are amongst the cellulose-based natural fibers having the highest specific Young's moduli and tensile strengths [19].

Generally, higher performance is achieved with fibers having higher cellulose content and with cellulose microfibrils aligned more in the fiber direction, which tends to occur in bast fibers (Eg. flax, hemp, kenaf, jute and ramie) that have higher structural requirements in providing support for the stalk of the plant [19]

Due to the immense scope for development of natural fiber reinforced polymer composites and to find, an alternative to the glass fiber reinforced composites is imminent due to its non-biodegrading property. So, development of a high performance composite using natural fibers has been a major area of concern. The natural fiber reinforced composites was synthesized by using sisal and glass fiber reinforced with epoxy resins. The main objective of the present work is to fabricate of a new class of epoxy-based composites reinforced with randomly oriented short sisal fibers. Prepare specimens by varying the percentage weight of glass fiber and sisal fiber. Investigate mechanical properties such as tensile strength, flexural strength and hardness. Study the influence of percentage of glass fiber on mechanical properties of the composites.

Figure 2 Schematic work-flow of proposed work.

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2 EXPERIMENTAL METHODS AND MATERIALS

2.1 Fiber Material

Sisal fibre is extracted from the leaves of the plant *Agave sisalana*, which was originated from Mexico and is now mainly cultivated in East Africa, Brazil, Haiti, India and Indonesia [16, 17, 20]. Sisal fiber is one of the most widely used natural fibers and is very easily cultivated. Sisal is a perennial plant identified by its 50 – 150 thick, spiky, long and rigid spirally arranged leaves. Upon maturation, pale yellow/shiny white fiber can be extracted from leaves by retting followed by washing and drying.

A sisal plant produces about 200 ± 250 leaves and each leaf contains 1000 ± 1200 fiber bundles, which is composed of 4% fiber, 0.75% cuticle, 8% dry matter and 87.25% water [1]. Therefore, normally a leaf weighing about 600 g will yield about 3% by weight of fiber with each leaf containing about 1000 fiber [21]. Fig. 2 shows sisal plants and fibers after extraction. Sisal fiber contains 78% cellulose, 8% lignin, 10% hemi-celluloses, 2% waxes and about 1% ash by weight. These large variations in chemical compositions of sisal fiber are a result of its different source, age, measurement methods, etc. The length of sisal fiber is between 1.0 and 1.5 m and the diameter is about 100 ± 300 μ m [16, 17, 21].

2.2 Matrix

Commercially available Polymer Lapox L12 epoxy resin and K-6 hardener supplied by "KATWA SOFTWARE TECHNOLOGIES" used in this work. The Lapox L12 epoxy resin had density of 1.15 gm/cm^3 , viscosity of 9000-12000 mPa.s at 25 °C. The hardener used was K-6 having density of 0.954 gm/cm^3 .

2.3 Extraction of Fiber and Mould Preparation

The processed sisal fibers and glass fibers were taken from local manufacturing suppliers. And these fibers are chopped to average length of 2-3 mm in the laboratory using scissors. Aluminum was used for preparation of tensile test specimen mold. The size of mould for tensile test specimen was $230 \times 160 \times 3$ mm. The size of mould used for preparation of hardness test specimen mold was $120 \times 80 \times 6$ mm. Based on the size of the mould for both tests, the amount of weight of fiber matrix quantity was calculated. The specimens were prepared with varying percentage composition of sisal with fixed percentage composition of glass fiber.

The composition of test specimens for tensile and hardness are as shown in Table 2 and Table 3

Figure 3 Sisal plants and fibers after extraction.

Table 2: Composition table for tensile test specimens

Sample ID	Epoxy		Sisal fiber		Glass fiber	
	%wt	Wt in gm	%wt	Wt in gm	%wt	Wt in gm
S1	96	137.28	2	2.34	2	2.34
S2	94	134.42	4	4.68	2	2.34
S3	92	131.56	6	7.02	2	2.34
S4	90	128.70	8	9.36	2	2.34

Table 3: Composition table for Hardness test specimens

Sample ID	Epoxy		Sisal fiber		Glass fiber	
	%wt	Wt in gm	%wt	Wt in gm	%wt	Wt in gm
S1	96	73.92	2	1.26	2	1.26
S2	94	72.38	4	2.52	2	1.26
S3	92	70.84	6	3.78	2	1.26
S4	90	69.30	8	5.04	2	1.26

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2.4 Composite Preparation

- i. Weighing the calculated amount of Glass fiber and sisal fiber as above calculated proportion in digital weighing machine as shown in Fig. 4. The least count of digital weighing machine is 0.0001gms.
- ii. Cutting the long length glass fiber into 3mm short length fibers for random orientation of glass fiber as shown in Fig. 5
- iii. Mixing the chopped glass fiber with calculated amount of epoxy (weighed) and the mixture is stirred for uniform mixing then heated up to certain duration in bath sonicator as shown in Fig. 6 and 7. To reduce viscosity of epoxy that will help in uniform distribution of mixture when it is pouring.
- iv. Calculated amount of sisal (weighed) is mixed with heated mixture (glass fiber + epoxy) and stirred for uniform mixing then mixture is again heated for certain duration as shown in Fig. 8
- v. After heating of mixture (sisal + glass fiber + epoxy) is added as shown in Fig. 9, by calculated amount of hardener, properly stirred.
- vi. Then pouring composition mixture in to the aluminum mold as shown in Fig. 10, and allowed it for solidifying process as shown in Fig. 11. Before pouring, foil the mold with aluminum foil.
- vii. After solidifying, the mold is de-molded and specimen plates were taken out and as shown in Fig. 12. This procedure repeated for all the type of composition.

Figure 4 Weighing of Glass fiber and Sisal fiber

Figure 5 Cutting Glass fiber to 3mm short length fiber

Figure 6 Mixing of Glass fiber

Figure 7 Mixture heating in bath sonicator

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Figure 8 Mixing the sisal to the mixture

Figure 9 Adding hardener to mixture

Figure 10 Pouring

Figure 11 After pouring

Figure 12 Specimen after de-molding

After demoulding, the standard test specimens were cut according to ASTM Std. ASTM Std. D3039 for tensile test specimen and D785 for hardness. The composite specimens were casted as per the ASTM D 3039 to measure the tensile properties. The gauge length, width and thickness of the specimens were 100, 13 and 3 mm,

respectively. The hardness properties of the composites were studied by applying indentation load normal to surface of the test specimen. Three specimens of varying fiber composition were tested to investigate tensile strength and hardness.

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3. RESULTS AND DISCUSSION

3.1 Tensile Properties

The prepared composite specimens S1, S2, S3 and S4 as discussed in Table 02 are subjected for tensile loading. The values of load and displacement for corresponding

samples were obtained from the post processor of UTM machine. The values of load were noted down to calculate stress values. Similarly in order to get the corresponding strain values, displacement with respect to gauge length were also recorded.

Figure 13 Stress Against Strain for Various Test Specimens

Figure 14 Variation of hardness for different test samples

The Fig. 13 shows that the stress increases linearly with respect to strain for all composites. The tensile modulus of S2 specimen having 4% sisal, 2% glass fiber, 94% epoxy was found to maximum when compared to other test specimens. With increase in composition of sisal fiber, tensile modulus decreased.

3.2 Hardness

The hardness of the composite samples was determined by using Rockwell hardness testing machine. For each of the specimen, surface hardness was obtained. The results were tabulated and variations of the hardness against various specimens are shown in Fig. 14.

4. CONCLUSION

With the aim of development and study on mechanical properties of sisal and glass fiber based composites have been studied in this work. The ductility was observed to be more in case of S2 (composition 8% sisal and 92%

epoxy) sample. Young's modulus was more in case of S3 (composition 6% sisal and 94% epoxy) sample. Now on addition of 2% wt of glass fiber to the sisal fiber reinforced composite ductility was more in case of S1 (composition 2% sisal, 2% glass fiber and 96% epoxy) sample and Young's modulus was more in case of S2 (composition 4% sisal, 2% glass fiber and 94% epoxy) sample. Hardness was observed to be more in case of S4 (8% sisal, 2% glass fiber and 90% epoxy) sample, increase in fiber content (fiber load) enhances the hardness value of sisal and glass fiber reinforced epoxy composite. The results obtained from this work shows better mechanical properties for the casted composite samples.

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