# Experimental Investigations to Improve Mechanical Properties of Sisal Reinforced E-Glass Fiber

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**Abstract:** ***The composite materials are replacing the traditional materials, because of its superior properties such as high tensile strength, low thermal expansion, high strength to weight ratio. The developments of new materials are on the anvil and are growing day by day. Natural fiber composites such as sisal polymer composites became more attractive due to their high specific strength, lightweight and biodegradability. Mixing of natural fiber with E-glass-Fiber Reinforced Polymers is finding increased applications. In this study, sisal – glass fiber reinforced epoxy composites is developed and their mechanical properties such as tensile strength, compression strength and Hardness tests are evaluated. The interfacial properties, internal cracks and internal structure of the fractured surfaces are evaluated by using Travelling Microscope. The results indicated that the incorporation of sisal fiber with E-glass can improve the properties and used as an alternate material for glass fiber reinforced polymer composites.***

**Keywords:** Sisal fiber, E-glass fiber reinforced polymer

## 1. Introduction

The term composite can be defined as a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual materials being superior to the properties of individual material that make up the composite. E-glass fiber is a lightweight, strong, and robust material used in different industries due to their excellent properties. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are very favorable when compared to metals, and it can be easily formed using molding processes. Now a day's natural fiber such as sisal and jute fiber composite materials are replacing the glass and carbon fibers owing to their easy availability and cost. The use of natural fibers is improved remarkably due to the fact that the field of application is improved day by day especially in automotive industries. Several researches have been taken place in this direction. Most of the studies on natural fibers are concerned with single reinforcement. The addition of natural fiber to the E- glass fiber can make the composite hybrid which is comparatively cheaper and easy to use.

In the present paper the physical properties of sisal–E-glass fiber reinforced composite materials is studied. The sisal–E-glass composite materials are manufactured by hand lay-up process. The properties such as tensile, compression, flexural and impact are studied and presented in detail. The results indicated that the addition of sisal in the glass fiber composite material makes the composite hybrid and it improves the mechanical properties

## 2. Materials Used

The manufacturing process for glass fibers suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals to liquid form. Then it is extruded through bushings, which are bundles of very small orifices (typically 5–25 micrometres in diameter for E-Glass, 9 micrometres for S-Glass). Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. The plastic matrix may be epoxy, a thermosetting plastic (most often polyester or vinyl ester) or thermoplastic. Common uses of fiberglass include boats, automobiles, baths, hot tubs, water tanks, roofing and pipes.

**Figure 2.1 &2.2:** E-Glass& Chopped Sisal form

Sisal fibers are extracted from the leaves of sisal plant. The fibers are extracted through hand extraction machine composed of serrated knives. The peel is clamped between the wood plank and knife and hand-pulled through, removing the resinous material. The extracted fibers are sun-dried which whitens the fiber. Once dried, the fibers are ready for knotting. A bunch of fibers are mounted or clamped on a stick to facilitate segregation. Each fiber is separated according to fiber sizes and grouped accordingly. To knot the fiber, each fiber is separated and knotted to the end of another fiber manually. The separation and knotting is repeated until bunches of unknotted fibers are finished to form a long continuous strand. This Sisal fiber can be used for making variety of products.

**2.1Physical property of Sisal fiber**

- Density (g/cm3) 1.41
- Elongation at break (%) 6–7
- Cellulose content (%) 60–65
- Young's modulus (GPa)
- 12.8 Diameter (μm) 205–230

**2.2 Fabrication**

The Specimen is made of sisal fibersheet and general purpose E-glass fibre. The evaluations of mechanical properties, specifications of sandwich specimen are shown in section. The manufacturing process consists of mould making and followed by hand lay-up manufacturing processes.

**2.3 Hand lay-up Process**

Hand lay-up is the simplest and oldest open molding method of the composite fabrication processes. It is a low volume, labor intensive method suited especially for large components, such as boat hulls. Sisal fibersheet or other reinforcing material or woven fabric or roving is positioned manually in the open mold, and resin is poured, brushed, or sprayed over and into the sheet piles. Entrapped air is removed manually with squeegees of rollers to complete the laminates structure.Room temperature curing epoxies are the most commonly used matrix resins. Curing is initiated by a catalyst in the resin system, which hardens the fiber reinforced resin composite without external heat. For a high quality part surface, a pigmented gel cost is first applied to the mold surface.

**2.4 Preparation of composite specimen**

Composites are composed of resins, reinforcements, fillers and additives. Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product..The resin or polymer is the "glue" that holds the composite together and influences the physical properties of the end product the reinforcement provides the mechanical strength. The fillers and additives are used as performance aids to impart special properties to the end product.

The mechanical properties and composition of composites can be tailored for their intended use. The type and quantity of materials selected in addition to the manufacturing process to fabricate the product, will affect the mechanical properties and performance.

**Resins**

The primary functions of the resin are to transfer stress between reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. Resins are divided into two major groups known as thermoset and thermoplastic.

**Epoxy**

Thermo set epoxies are produced by the condensation polymerization of dicarboxylic acids and dysfunctional alcohols (glycols). In addition, unsaturated epoxies contain an unsaturated material, such as maleic anhydride or fumaric acid, as part of the dicarboxylic acid component. The finished polymer is dissolved in a reactive monomer such as styrene to give a low viscosity liquid.

**Reinforcements**

The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product. Reinforcements can be both natural and man-made.

## 3. Fabrication Process

The specimen for use on an automotive body made of sisal fiber material is fabricated. Wooden mould is prepared and surface finishing is done by using metal putty. PVA liquid is applied on the wooden mould as releasing agent and then another layer of gel coat is applied on the wooden mould for better surface finish of the extracted mould. It is left for curing for few hours. Resin is applied with a mixture of 2 % of accelerator MEKP (methyl ethyl ketone peroxide) and catalyst as hardener to dry. The specimen taken out of the mould after drying and the excess material at the edges are removed and the surface finishing is given to the component at the edges.

- The fabricated mould is left for curing for 24 hours.
- The wooden mould has been removed.
- The excess material has been removed from extracted mould by using hacksaw or surface machine.

**Figure 3.1:** Fabrication by hand lay-up technique (compression)

**Figure 3.2:** Fabrication by hand lay-up technique (Tensile)

### 3.1Vacuum Bagging

Vacuum bagging is a technique that uses atmospheric pressure to squeeze the resin-impregnated layers (the laminate) together, forcing them to conform to the shape of the mold. After layup is complete, the laminate layers are sealed in an airtight vacuum bag. The bag may consist of a plastic sheet that covers the layers or it may utilize top and bottom sheets that enclose the laminate and the mold. In either case, after the bag is sealed and before vacuum is applied, pressure on the inside of the bag is the same as the outside and is equal to atmospheric pressure, which is approximately 1,000 mbar (29.9 in. Hg, or 14.7 psi). A vacuum hose is connected to the bag and a vacuum pump draws the air from it. The air pressure inside the bag is reduced while air pressure outside of the bag remains at atmospheric pressure. As a vacuum is drawn on the inside of the bag, atmospheric pressure on the outside of the bag presses on the bag and squeezes the laminated layers of resin-saturated mat together against the mold, serving as a clamp that puts very uniform pressure over the entire surface of the part.

**Figure 3.1.1:** Vacuum bagging of composite

## 4. Results and Discussion

### 4.1 Tensile Test

The tensile test has widely performed the test to determine several mechanical properties of a material that are paramount in design. In this test, a standard specimen is subjected to a gradually incrementing uniaxial tensile load until it fractures. The values that may be measured from this type of test can range from but are not limited to tensile strength, ultimate strength, and elongation, modulus of elasticity, yield strength, Poisson's ratio, and strain hardening. The measurements taken during the test reveals the characteristics of a material while it is under a tensile load.

**UTM Machine specification**

- Tensile clearance working piton : 50 to 700 mm
- Jaws for round bar : 10 to 30 mm
- Clearance between compression plates :700mm
- Diameter of compression plates : 120 mm
- Motor for oil pump (3-phase, 50HZ) : 1HP, 440 V

**Universal testing machine (Tensile test)**

**Specifications of specimen**

| S.No | Parameters | Specifications |
|---|---|---|
| 1 | Length | 150 mm |
| 2 | Thickness | 2 mm |
| 3 | Breadth | 30mm |

**Experimental calculations**

**For Tensile Test**

**i) 10 layered Sisal and E-glass fiber**

Yield stress = Yield load /Original Area
=$0.3x10^3$ /4500
=$0.066N/mm^2$

Ultimate Stress = Ultimate load / Original Area
= $5.2x10^3$ /4500
= 1.155 N /$mm^2$

Breaking stress = Breaking load / Original Area
= $1.2x10^3$ / 4500
= 0.266 N /$mm^2$

Percent of elongation = ((elongated length–Original length)/Original length) x100%
= ((152.7-150)/150) x100%
= 1.8 %

Elongation = 81 $mm^2$

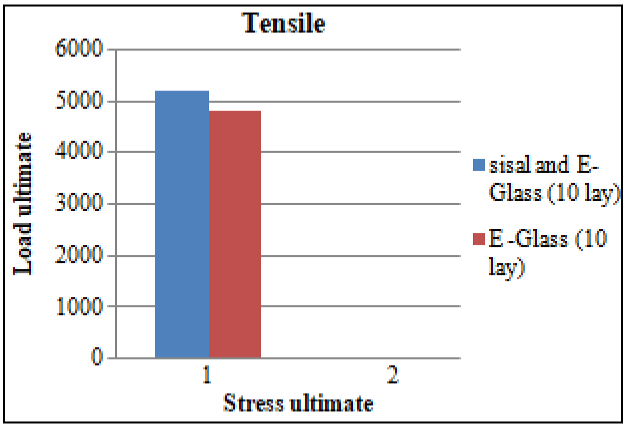
**ii) 10 layered E-glass fiber**

Yield stress = Yield load /Original Area
=$0.12x10^3$ /4500
=$0.026N/mm^2$

Ultimate Stress = Ultimate load / Original Area
= $4.8x10^3$ /4500
= 1.06 N /$mm^2$

Breaking stress = Breaking load / Original Area
= $0.8x10^3$ / 4500
= 0.17 N /$mm^2$

Percent of elongation = ((elongated length–Original length)/Original length) x100%
= ((151.6-150)/150) x100%
= 1.06 %
Elongation = $48mm^2$




**Graph 4.1:** Tensile value comparison between the sisal fiber &E-glass fiber and E-glass fiber

**4.2 Compression test**

Compression testing is a very common testing method that is used to establish the compressive force a material and the ability of the material to recover after a specified compressive force is applied and even held over a defined period of time.The aim of a compression test is to determine the behavior of a material while it experiences a compressive load by measuring fundamental variables, such as, strain, stress, and deformation. By testing a material in compression, the compressive strength, yield strength, ultimate strength, elastic limit, and the elastic modulus among other parameters may all be determined.

**UTM Machine specification**

- Tensile clearance working piton : 50 to 700 mm
- Jaws for round bar : 10 to 30 mm
- Clearance between compression plates :700mm
- Diameter of compression plates : 120 mm
- Motor for oil pump (3-phase, 50HZ) : 1HP, 440 V

### 4.2 Universal testing machine (compressive test)

**Specifications of specimen**

| S.No | Parameters | Specifications |
|---|---|---|
| 1 | Length | 40 mm |
| 2 | Thickness | 2 mm |
| 3 | Breadth | 40 mm |

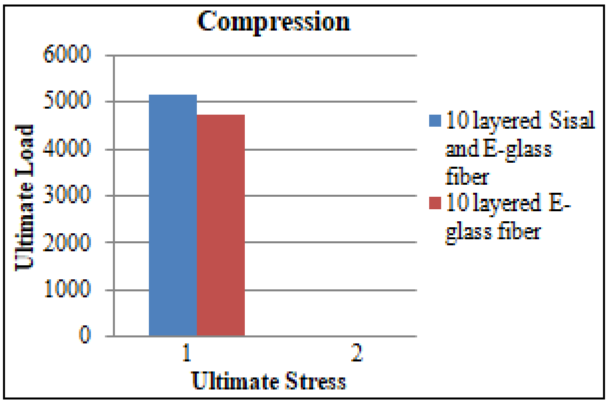
**Experimental calculations:**

**For compression**
**i) 10 layered Sisal and E-glass fiber**
Ultimate stress = ultimate load/Original Area
$= 5.15\text{x}10^3/1600$
$= 3.21 \text{ N/mm}^2$.

Breaking stress = Breaking load / Original Area
$= 2.3\text{x}10^3/1600$
$= 1.437 \text{ N/mm}^2$.

**ii) 10 layered E-glass fiber**
Ultimate stress = ultimate load/Original Area
$= 4.7\text{x}10^3/1600$
$= 2.93 \text{ N/mm}^2$.

Breaking stress = Breaking load / Original Area
$= 1.4\text{x}10^3/1600$
$= 0.875 \text{ N/mm}^2$.




**Graph 4.2:** Compression value comparison between the sisal fiber &E-glass fiber and E-glass fiber

### 4.3 Brinell Hardness Test

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. The Brinell hardness test method as used to determine Brinell hardness is defined in ASTM E10.Brinell testing often use a very high test load (3000 kgf) and a 10mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

**Specification of Brinell hardness test machine**
- Load range : 500 kgf to 3000 kgf
- Maximum test height : 250 mm
- Depth of throat : 150 mm
- Size of base : 255 x 495 mm
- Machine height : 860 mm
- Net weight : 210 kg

**4.3 Brinell hardness testing machine &Brinell microscope**

**Experimental calculation**
Load: 500 kgf and 1000 kgf

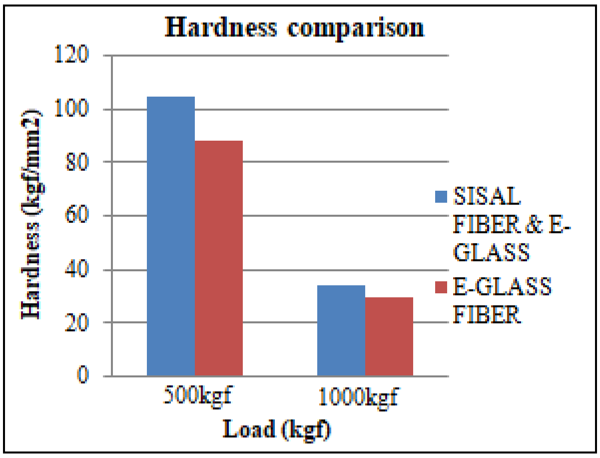
$$\text{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

**Where:**
**P = applied force (kgf)**
**D = diameter of indenter (mm)**
**d = diameter of indentation (mm)**

The hardness of material is

**Table 4.3:** Comparison of hardness values of the composite reinforced materials

| Material | 500kgf | 1000kgf |
|---|---|---|
| Sisal Fiber & E-Glass | 104.31 kgf/mm$^2$ | 34.24 kgf/mm$^2$ |
| E-Glass Fiber | 87.72 kgf/mm$^2$ | 29.77 kgf/mm$^2$ |




**Graph 4.3:** hardness comparison between the sisal fiber &E-glass fiber and only E-glass fiber

## 5. Conclusion

A new type of fiber reinforcement composite was experimentally investigated. The mechanical properties of Sisal fiber, E-glass fiber and reinforced epoxy hybrid composites have been investigated. The advantage of material selected is Bio-degradable in nature. The present work was aimed at reducing the weight of material there by increasing the load bearing capacity. A hybrid material is fabricated by considering Sisal fiber, E-glass by hand lay-up technique thereby performed Tensile, Compressive test.

It has been proved from the experiments that the hybrid material is superior in Tension, Compression and having a hardness value of 91.5kgf/mm$^2$ for a given load of 100 kgf. and hardness value of 75.075kgf/mm$^2$ for a given load of 500kgf. The hybrid material is having low density and high stiffness to weight ratio. The overall cost of the manufacturing process will reduce. Hand layup technique is used in the fabrication process for fabricating any real time component. This method is useful for small scale industries for mass production.

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