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Strength Analysis on Natural Fibre Composite Banana and Sisal Fibres with Epoxy Resin

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Abstract: The tensile strength and bending strength variation on the basis of change in mass of HEMP and SISAL fiber content in the composite. The scope of work is constraint to hemp and sisal fibre composite with epoxy as resin. Study of the characteristics of hemp and sisal fiber, to fabricate the composite of hemp and sisal fiber with epoxy resin and increase the strength of hemp fibers composited with sisal fibers using epoxy to finding the variation of tensile strength of the natural fiber composite- Hemp & Sisal with epoxy resin with different composition and finding the variation of bending strength of the natural fiber composite- Hemp and Sisal with epoxy resin with different composition and compare the mechanical properties of Hemp – Sisal composite with glass fiber.

Keywords: Composites, Natural Fibers, Hemp and Sisal Fibers

I. INTRODUCTION

In the present scenario hemp along with glass fibers are being mostly used in automobiles. Hemp along with flax or sisal will have an increase in its strength and other mechanical properties. So, we would like to consider sisal rather than flax due to its availability. In this project we analyse the combination of hemp and sisal fiber composition and compare its mechanical properties with Hemp-glass fiber combination and glass fiber with epoxy.

Here come in this study, polymer composites are the main concentration and on the basis of matrix material composition Fibrous composites are bring dealt. Natural fibers extracted from the environmental means are being reinforced by polymer i.e. epoxy and its enhancement in the strength characteristics are being studied. This study combines Fibers (Hemp, Sisal) and Polymer(epoxy) forming a bio-composite.

A. POLYMER (RIENFORCEMENT) EPOXY

Epoxy thermosets are made from epoxy resins, such as polyester thermosets. Such resins are having a viscous liquid phase and relatively low molecular weight. The viscosity of the resins relies on the extent of their molecules ' polymerization. Normal epoxy resins were formed by reacting with other chemicals with epichlorohydrin and bisphenol-A.

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A "Curing agent" (or hardener, or activator) activates the process of polymerization between resin molecules, resulting a very dense cross-linked polymer network. Diethylene-tri-amine is a curing agent that is widely used. There is no by-product produced by the exothermic reaction between hardener (curing agent) and resin (compound). In addition, during the Curing process, epoxies, like polyesters, are also shrinking. It is possible to produce epoxies such as polyesters at room conditions. Nevertheless, the curing process can also be carried out at high temperatures by careful choice of curing agents. The curing time of the process depends heavily on the selection of resin and the curing agent It may vary from minutes to 24 hours. Heat is often used to speed up the curing process. Typically, with gradual increase in temperatures, the curing time reduces almost exponentially.

Commercially Epoxies, "one-part" systems are available also "two-part" systems. Whereas "two-part" epoxies include a combination of hardener and resin, "one-part" systems are mostly pre-mixed (hardener, resin) systems. Normally, one-part systems must be preserved at temperatures as low to essentially let up the curing process and the epoxy is not cured while being processed.

Table 1: Properties of Epoxy Resin

Typical property range for Epoxies	
Specific gravity	1.2 to 1.3
Tensile Modulus(Mpa)	25000 to 45000
Tensile Strength(Mpa)	50 to 150
Water absorption(% over 24 hrs)	0.05 to 0.15
CTE(per million per C)	45 to 70

B. FIBERS

B.1. Hemp: Hemp is the most commonly utilized Natural fiber for composite reinforcement. Hemp is one of the eco-friendliest fibers, of course, as well as the OLDEST. Hemp is a yearly crop from Central Asia that has been cultivated for over twelve thousand years. Nearly fifty percent of the planet's industrial needs of hemp production is cultivated in China, as per Food and Agriculture Organization (FAO). In hemp plant, stem tissues are having fibers that help to hold the plant upright. Such fibers give the tree strength and rigidity in doing so. The good strength & rigidity of hemp fibers makes it a valuable fiber for the reinforcement of composite materials. The use of hemp for industrial and other applications has grown exponentially in present decades. Hemp accounts for less than 0.5% of total global natural fiber production.

The main constituents of hemp fibers are Cellulose, hemi-cellulose, lignin and pectin are key ingredients that determine fibers ' physical characteristics. The strongest and rigid organic ingredient in the fibers is cellulose.
The differentiability in its composition may be the disadvantage of hemp fibers.
Their physical and mechanical characteristics therefore always vary.

Table 2: Chemical composition of Hemp fibers

Cellulose	70 to 74
Hemi-Cellulose	17.9 to 22.4
Lignin	3.7 to 5.7
Pectin	0.9
Waxes	0.8
Moisture content	6.2 to 12

B.1.2. Hemp – Properties:

The properties of hemp fibers were found to be good enough to be introduced in reinforcement in composite materials.
i). Hemp fibers have specific strength as well as stiffness that are compared to those of glass fibers.
ii). The quantity of fiber in the composites was influenced by the tensile and flexural strength of the hemp fiber composite.
iii). The value of hemp fiber in cellulose-based composites is smaller than that of the plastic matrix and high fiber loading could lead to major material savings.
iv). iv). It's brown yellow fiber.
v). Hemp fibers, running the length of the plant, can be 3 to 15 feet long.
vi). Hemp fibre's properties are its superior strength and durability, ultraviolet light and mold resistance, comfort and good absorption.

B.2.Sisal

Sisal plant have leaves in the form of a rosette about 1.5 to 2 meters tall. Sisal spread usually occurs through the use of bulbils developed from buds in the flower stock or the growth of suckers._The sisal plant has an expected lifespan of 7-10 years and usually grows 200-250 leaves that can be used industrially. Sisal fiber is an organic fiber from the Agavaceae family of leaf fibres. This is belonging to cactus family. Sisal fiber composites have perfect elastic characteristics and are environmentally friendly and for friendly use. These are mainly used for making ropes and twine. It consists of cellulose in more amounts compare to hemicellulose, lignin, and pectin. Applications are commonly used in Shipping industry for small-scale mooring, container managing. included in composite materials in the automotive industry with fiber glass. Certain core products developed from sisal include spa goods, cat scratching posts, lumbar aid ties, carpets, sandals, garments and disk buffers, etc. This is also used as a fiber base for elevator steel cables, promoting lubrication and mobility

Table 3: Chemical composition of Sisal

Cellulose	66 to 78
Hemi-Cellulose	10 to 14
Lignin	10 to 14
Pectin	10
Waxes	2
Moisture content	10 to 22

B.2.1 Characteristics of Sisal Fibers:

i). Sisal fibers are very much durable with low maintenance with a least percentage of wear and tear, and it is Recyclable.

ii). Sisal fibers are obtained by separating the internal pulp from the external surface of the leaf.

iii).This comes as plaid, herringbone and twill.

iv). They are Anti- Static in nature, doesn't attract dust particles and also doesn't absorb moisture easily.

v). It exhibits sound absorbing properties.

vi). By treating the sisal leaves with borax we can improve the fire resistance.

Table 4: Details of Fibers

Production Details of fibers		
Fiber Type	**Botanical Name**	**Plant origin**
Hemp	Cannabis sativa	Bast
Sisal	Agavaceae	Leaf

II. LITERATURE RIVIEW

Organic fibers are currently an attractive alternative for glass [1], the most commonly used composite fiber. The use in industry of fibers such as flax, hemp, jute and sisal so far is limited, since there are often problems to have a durable half finished product that is consistent in quality. latest studies and analysis have demonstrated that these features can be strengthened. Considerably Natural fibers are made from the natural products like banana, jute, sisal, coir, kapok and many others [2]. Similar to glass fibers, they frequently possess outstanding mechanical characteristics such as mobility, stiffness and modulus. Recognizing that natural fibers are inexpensive and have a better stiffness per weight than glass, resulting in lighter parts, the growing demand in natural fibers is clear [3].
The effect on the environment is also lower as the natural fiber can also be reused thermally and these fabrics are the product of a renewable resource. Its mild mechanical characteristics prohibit the use of fibers in high-tech projects. The recent developments in the field of natural fibers has firstly and mostly choose jute fiber which is abundantly and economically available to initially start the experimentation. The work carried out by Palani Kumar, Hema Chandra Reddy and Ramesh deals with comparison of strength of a glass reinforced component when similar quantity of jute fiber or sisal fiber is added, which have given a ready reference that sisal fiber can improve the strength of the composite more evidently than the jute fiber [4]. The various advantages of natural fibers over manmade synthetic fiber like small specific weight, resulting in greater significant strength and rigidity than glass. This is an advantage particularly in bending rigidity parts. It is a renewable source, it takes little energy and CO_2 is used when oxygen is returned to the atmosphere. The involvement of natural fibers lowered weight by 10 percent and reduced the energy required for production by 80 percent, while the product's cost is 5 percent reduced than the components reinforced by comparable fiber glass.

Study on mechanical characteristics of Hemp –E Glass fiber reinforced polymer composites with different compositions of Hemp and E-Glass fibers were found to have best tensile and flexural strengths [5].

The experimental investigation on tensile and flexural behaviour of reinforced glass fiber epoxy composite with different weight percentage have been carried out best tensile and flexural strengths [6].

Reinforcing glass fiber into the composites of sisal polypropylene improved tensile & flexural qualities with no affecting tensile & flexural system. Using sisal fiber to glass fiber, in turn, increases thermal properties and hybrid composite waterproofing. M.K. Gupta and Srivastava has given that by using 30% of the sisal fiber content in the sisal reinforced epoxy composite the tensile and flexural properties are found to be maximum in both uni-directional and mat form of sisal composite [7].

Natural fibers are made from the natural products like hemp, banana, jute, sisal, coir and many others. These are even possessing extreme mechanical characteristics such as strength, stiffness and modulus relative to glass fibres, and natural fibers were lighter & weigh less than glass [8]. Natural fibers when treated with alkaline solution like NaOH will get improved mechanical properties [9]. Composites developed of thermoplastic, thermoset and biodegradable matrices of hemp fibers have shown better mechanical characteristics. A variety of hemp fiber surface treatments used to enhance interfacial fiber / matrix binding led to significant changes in the mechanical characteristics of the composites. [10]. This paper analyses the influence of the treatment of fiber on the mechanical characteristics of unidirectional sisal-reinforced epoxy composites. [11].

III.FIBER EXTRACTION

3.1 The study of existing system

For tensile and flexural test analysis, specimens are prepared in different volume fractions. There are many methods for the preparation of these volume fraction specimens, of which with natural polymer composites, which are designed with traditional fiber reinforced polymer composites with thermoplastics and thermosets, conventional manufacturing techniques can be utilised Such procedures involve direct extrusion, vacuum infusion, molding of compression and transfer molding of resin (RTM), compounding and molding of injection. For the insertion of fibers into the thermoplastic matrix, techniques such as extrusion, compression and injection molding are typically used.

Table 5: Classification of composite fabrication Technique based on mold type

Open Molding	Closed Molding
Hand lay-up	Compression Molding
Filament winding	Pultrusion
Spray up	Resin transfer molding(RTM)

Every fabrication method of reinforced organic fiber polymer matrix composite has its unique significance and functional characteristics, but the present work considering both drawbacks and availability and cost factors has under taken hand lay-up process as the major technique for the specimen fabrication.

Materials:

Sisal fiber is a natural fiber of Agavaceae (Agave) family3 a type of leaf fiber is extracted from sisal plant leaves traditionally used for making ropes and twine. Hemp fibers come from family of Cannabis sativa, a best fiber family, extracted from Hemp tree. Epoxy resin [L12-3202] and hardener [K6 lapox epoxy resin] are used as reinforcement material. The resin used is a bifunctional epoxy resin i.e., di-glycidyl ether of biphenyl-A where the hardener is a aliphatic primary amine.

3.2 Sisal

Sisal leaves are harvested from the field and cut into 500 mm longitudinally sliced lengths and sliced and washed using a 2:1 liquid volume benzene-ethanol mixture. Sisal fibers are soaking with required concentration in NaOH solution while being warmed at a temperature of approximately 80^0C and stir for 90 mins. Sisal pre-treatment with NaOH can partially remove lignin and hemi-celluloses and often lead to fiber losing weight inorder to measure the quantity of content extracted, the alkali treated items are purified and cleaned to pH6 with distilled water and dried under vacuum in order to eliminate free water and cut to the appropriate sizes.

3.3 Hemp:

Hemp fibers are received from the farm and chop into 500 mm longitudinally sliced lengths and cut and cleaned using a 2:1 liquid volume benzene-ethanol blend. Hemp fibers were submerged with the required concentration in NaOH solution while being heated at a temperature of approximately 70^0C and stir for 2 hours Hemp pre-treatment with NaOH may primarily eliminate lignin and hemi-celluloses and may lead to fiber weight reduction. In order to measure the quantity of material taken away, the alkali treated products were filtered and cleaned to pH6 with distilled water and dried under vacuum in order to eliminate free water, chop it to the required sizes and store it in an airtight container.

3.4 Preparation of Epoxy and Hardener:

The composite surface is formulated using epoxy resin [L12-3202] thickness 1.15 to 1.2 g / cc and [K6 lapox epoxy resin] density 0.97-0.99 g / cc. The epoxy and hardener weight ratio is 9:1. Resin was purchased from local sources.

3.5 Mould Preparation:

The mold is produced of a 50* 50 cm mallex sheet and the rubber block piece is fastened on four sides to the sizes of 300* 300 mm. The manufacturing process is carried out by hand lay-up the mould with a releasing agent to ensure that the art does not stick to the surface. Mallex sheet wrapped the top and bottom plates and the fibers were pressurized with epoxy to prevent debris from entering composite parts throughout curing.

3.5.1 Hand lay-up Technique:

Hand layup technique is traditional process to fabricate composite. There is also a minimum infrastructural prerequisite for this form. The storage steps are very basic.

First of all, the mold layer is coated with a release gel to stop plastic from binding to the surface. On top and bottom of the mold board, thin plastic sheets are used to get a good surface. In the top and bottom of the mold pan, thin plastic sheets are used to achieve the product's food layer coating.

Reinforcement in the shape of woven mats or chopped string mat is cut according to the length of the mold and put between Perspex layer on the surface of the mold. Instead thermosetting polymer in liquid form is blended mixture with a recommended hardener (curing agent) and poured on the mat layer already put in the mould. With the support of a brush the polymer is evenly spreaded The next layer of the mat is then placed on the polymer surface and a roller is switched with a mold pressure on the mat-polymer surface to remove the air inclusions and the excessive polymer for every layer of polymer and mat, the method is repeated until the desired layers are stacked. The gel is coated on the internal surface of the top mold plate after positioning the plastic sheet, which is then stored on the stacked layers and the pressure is introduced After either curing at room temperature or at certain temperatures, mold is opened and the composite component formed is extracted and further refined. The recovery time based on the type of polymer used in the manufacturing of composites.

3.5.2 Fabrication of Composite:

Fabrication of Composite is done by using Hand Rolling process or Hand layup process. Take a mould which is made up of rubber having slots to fill the fiber. Fill the entire mold with fiber content and weigh the fiber filled in the mould. After completion of weighing take 25% hemp and 75% of sisal and fabricate the composite by hand rolling process using epoxy resin and hardener in 9:1 ratio. Repeat the process for different composition like 50% hemp and 50% Sisal and 75% hemp and 25% sisal. Dried for about 24 hours (One day). Thus final composite was resulted.

Parameters Used:

i) Mould Dimensions for Tensile Test: 160 * 13 * 3
ii) Mould Dimensions for Bending Test: 100 * 25 * 3
iii) Mould Dimensions for Impact Test: 63.5 * 12.5 * 10
iv) Epoxy Used: L-12(3202)
v) Epoxy Density: 1.0 gram/cubic centimetre
vi) Hardener Density: k-6
vi) Weight Ratio of Epoxy and Hardener: 9:1

IV. TESTING METHODS

4.1 Tensile Testing:

Tension experiment is a basic mechanical experiment in which, until failure, the specimen is subjected to uni-axial tension. Study results are widely used to select a product for an assignment, to monitor performance and to decide how a material can be subjected to other forces

It is possible to determine characteristics such as ultimate tensile strength, peak elongation and area reduction. This sample specimen is charged in a very regulated way when calculating the load added and the sample's elongation over a certain length.

4.1.1 Tensometer

Samples are designed according to the standard ASTM D638M-89 consisting of tabs at both ends. The machine's maximum capacity is 20KN for research, which operated on belt drive and pulley mechanism by supplying an external electrical power source. Speed rate is 0.2 mm/min.

Table 6: Specifications table for Tensometer.

Load	0 to 2000kg
Elongation	0 to 200mm
Accuracy	0.001
Gauge length	60 mm
Specimen Dimensions (in mm)	160 * 12.5 * 3

4.1.2. Procedure for Tensile test:

1) The specimen is fixed between right cross head and left cross head.
2) Switch on the power supply such that the load is applied gradually using belt and
pulley mechanism.
3) This setup is connected to a digital meter then the required values those are load and elongation are noted down through that electronic meter up to the specimen fails.

Fig 1: Test samples of Tensile test

4.2 Bending Testing:

Bending experiment is an important form for mechanical experiment. Findings are widely used to pick a product for a task, to monitor performance, and to determine that a material may respond under other forces

It is possible to distinguish characteristics such as bending strength peak elongation. This sample specimen is loaded in a very regulated manner when calculating the load added and the sample's elongation over a certain length.

4.2.1 Tensometer

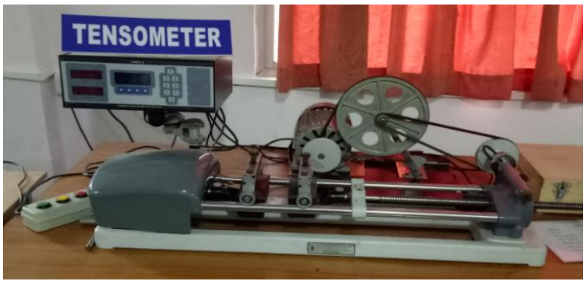


Fig -2 Tensometer setup

Samples are designed according to the standard ASTM D638M-89 consisting of tabs at both ends.

The machine's maximum capacity is 20KN for research, which operated on belt drive and pulley mechanism by supplying an external electrical power source. Speed rate is 0.2 mm/min.
Specimen used to test:Specimen Dimensions: 100 * 25 * 3

4.2.2. Procedure Bending Testing:

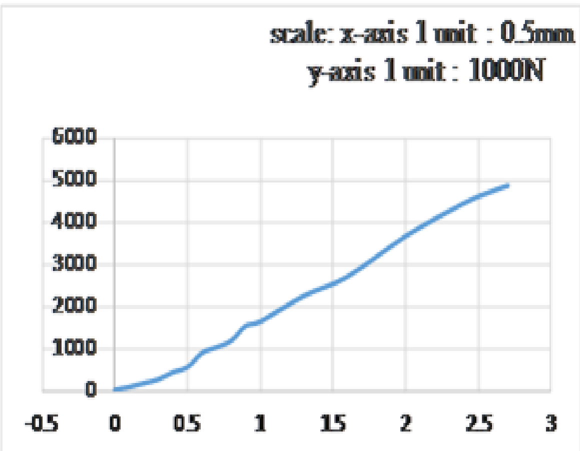
1) The specimen is fixed between right cross head and left cross head.
2) Switch on the power supply such that the load is applied gradually using belt and pulley mechanism.
3) This setup is connected to a digital meter then the required values those are load and elongation are noted down through that electronic meter up to the specimen fails.

Fig 3: Test samples of Bending test

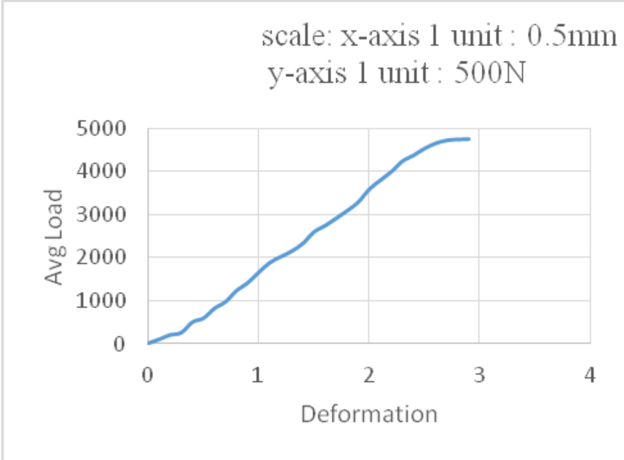
4.3 Impact testing:

Impact strength is the material's ability to overcome an unexpectedly added load and is defined in terms of energy. Sometimes calculations using the Izod impact strength test and Charpy impact test, each testing the impact energy needed to break a specimen.
In the case of a defect or notch and quick loading situations, the Charpy test, Izod test and other impact measures evaluate material toughness and impact strength. This damaging test involves breaking a notched sample and calculating the amount of energy that is consumed during fracture, by the material. Impact analysis is intended to test a material's susceptibility to failure to a surprise force introduced. The experiment calculates the strength of the impact or the energy consumed before the break.

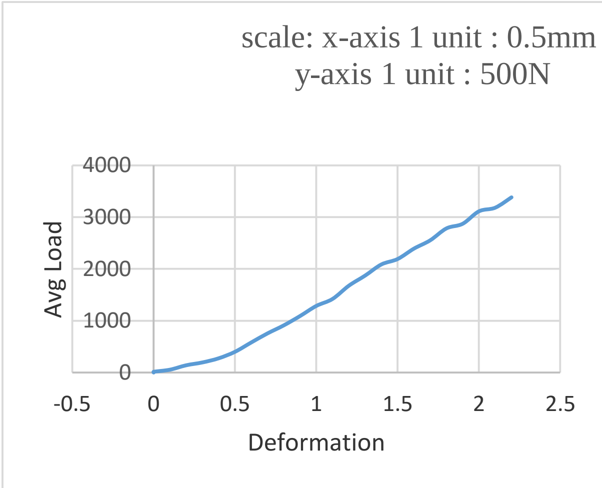
V. EXPERIMENTAL VALUE GRAPHS



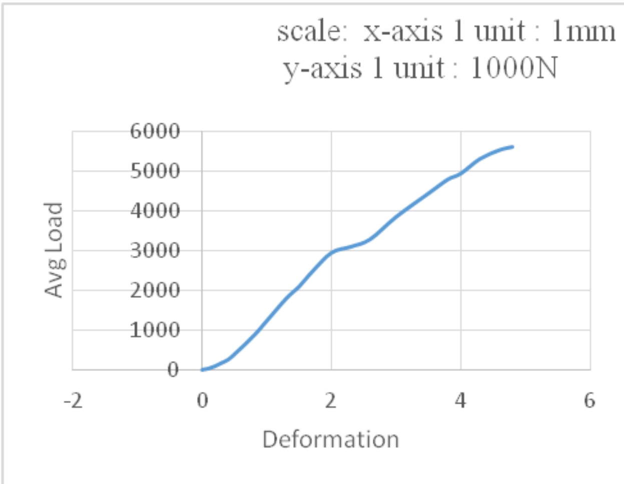
Graph-1. Load vs Deformation for H0%and S100% Tensile testing



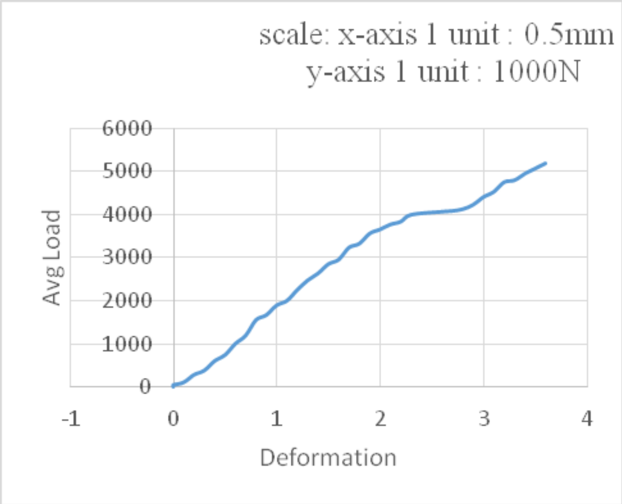
Graph-2 Load vs Deformation for H25% and s75% Tensile testing



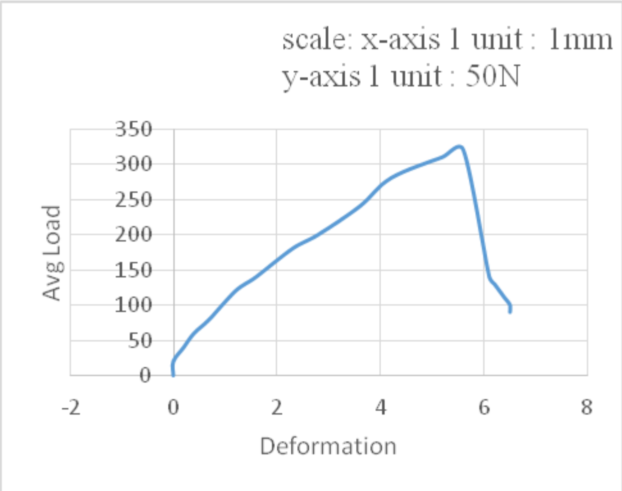
Graph-3 Load vs Deformation for H50% and S50% Tensile Testing



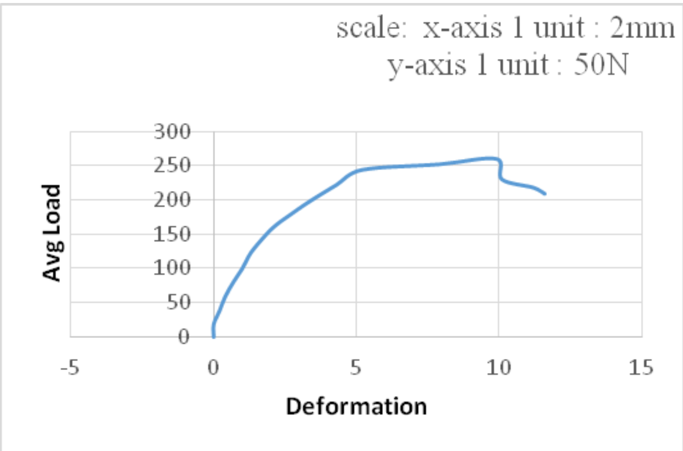
Graph-4 Load vs Deformation for H75% and S25% for Tensile testing



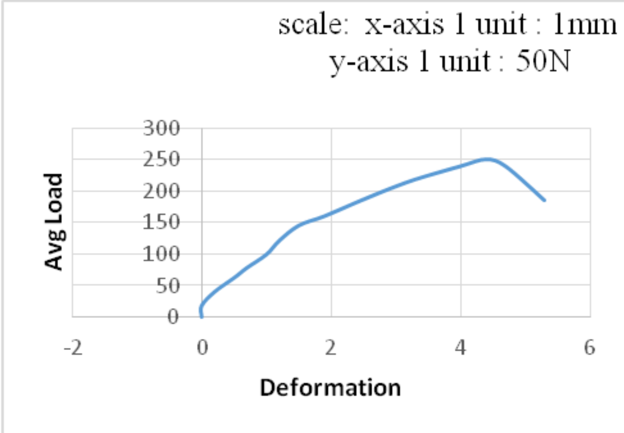
Graph-5 Load vs Deformation for H100% and S0% Tensile testing



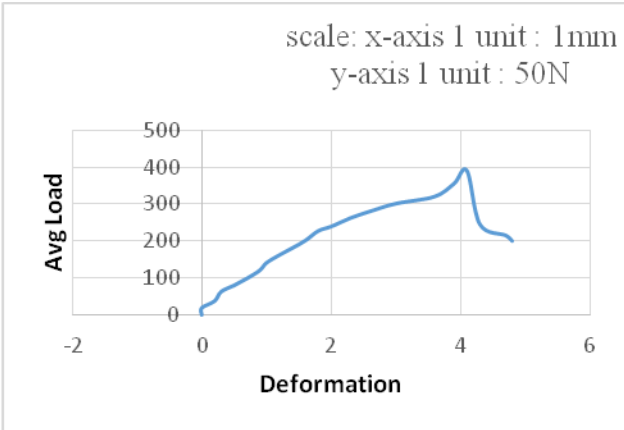
Graph-6 Load vs Deformation for H0% and S100% Bending testing



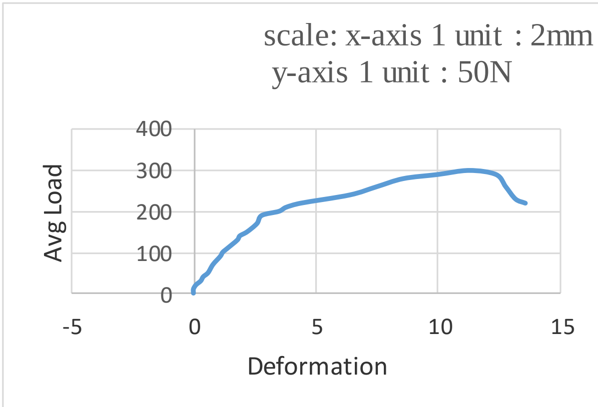
Graph-7 Load vs Deformation for H25% and S75% for Bending testing



Graph-8 Load vs Deformation for H50% and S50% for Bending Test



Graph-8 Load vs Deformation for H75% and S25% Bending test



Graph-10 Load vs Deformation for H100% and S0% Bending Test

V. RESULTS

Table 7: Experimental Values for Tensile test

Percentage (%)	Maximum load in Newton
Hemp 0 & Sisal 100	4870
Hemp 25 & Sisal 75	4760
Hemp 50 & Sisal 50	3380
Hemp 75 & Sisal 25	**5610**
Hemp 100 & Sisal 0	5180

Table 8: Experimental Values for Bending test

Percentage (%) of Hemp	Maximum load in Newton
Hemp 0 & Sisal 100	320
Hemp 25 & Sisal 75	260
Hemp 50 & Sisal 50	250
Hemp 75 & Sisal 25	**390**
Hemp 100 & Sisal 0	300

Table 9: Experimental values for Impact test

Percentage (%) of Hemp	Impact Energy in Joules
Hemp 0 & Sisal 100	**0.64**
Hemp 25 & Sisal 75	0.49
Hemp 50 & Sisal 50	0.25
Hemp 75 & Sisal 25	0.27
Hemp 100 & Sisal 0	0.2

VI. CONCLUSIONS

Conclusions:

Hemp's tensile strength can be increased when composited with sisal fiber in different compositions. The result clearly indicates that sisal - hemp are in same proportion and at the percentage of Hemp 25% and sisal 75% then the tensile strength is slightly reduced. The hemp fiber proportion is high compared to sisal i.e., Hemp 75% and sisal 25% then the composite acquired very high strength.

The bending strength of hemp increases when composited with sisal fiber in different compositions. When sisal - hemp are in same proportion and at the percentage of Hemp 25% and sisal 75% then the flexural strength is slightly reduced. While hemp fiber proportion is high compared to sisal i.e., Hemp 75% and sisal 25% then the composite acquired very high strength.

The fabricated Hemp-sisal composite fiber exhibits better mechanical properties than Hemp-E glass and E-glass Epoxy Composite materials. So This data can be much useful for further research on replacement of Glass fibers in automobile applications to reduce environmental effects.

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