Preparation of Ecofriendly Green Composite Material

An Experimental Analysis

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***Abstract* - Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. Without the petroleum, these composites cannot be produced. When these products reach their end of life, they will not degrade in a normal environment and are most commonly disposed of in a landfill. There is another major problem is increasing concentrations of carbon in the environment. In order to contribute to materials that are not reliant on the use of petroleum, research on "Green" Composites has been conducted."Truly green" composites are fully degradable. These composites have the desired properties that are necessary in everyday composites, but do not cause the problems that are seen with petroleum. Lastly, "Green" Composites will not pollute any other limited resource. Here the green composite is made using the sisal fiber, epoxy resin, soya bean oil and some curing agents such as HY951, Methyl ethyl ketone peroxide(MEKP) as catalyst and Cobalt Acetate as accelerator. They can be used for a wide range of applications because of their mechanical include, but are not limited to: furniture (i.e. desks, cubicles, tables), sports equipment (i.e. tennis racquets, skateboards), transportation panels (i.e. car parts, airplanes), packaging applications and housing panels (i.e. walls, floors).**

Keywords—green composite;biodegradable;sisal fibre;epoxy resin

I. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. There are much advancement brought up in the field of composites, yet there are certain drawbacks like petroleum scarcity, water scarcity, landfill problems and carbon consequences. Hence, the need for more sustainable and environmentally-friendly composites has been growing, therefore demanding the research and development of "green" composites. These composites range from applications with short-term or even one-time usage, to one to two year lifecycles, to several year lifecycles.

Research efforts on "green" composites have been focused on combining natural fibers with biodegradable resins. These composites have been favored due to their high strength and modulus, as compared to metals. The use of natural fibers in these composites has become popular due to their widespread availability throughout the world as well as their natural hollow structure. This hollow structure decreases density, allowing natural fibers to be used in lightweight composites. Additionally, a hollow structure provides acoustical and thermal insulation. The typical life cycle of these plant fibers can be seen in fig 1.1

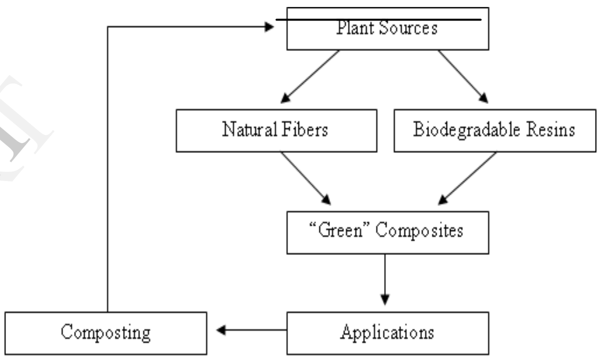


Figure 1.1 Typical Lifecycle of Natural Fiber-Based "Green" Composites

The main economic advantage of natural fibers may be found in their local availability. Automotive applications of natural fiber composites have proven themselves very well.

II . MATERIALS AND METHODS

The materials used for preparation of green composite material is as follows

- ✓ Sisal Fiber
- ✓ Epoxy Resin
- ✓ Soya beans oil
- ✓ Curing Agent (HY951)
- ✓

2.1.1 SISAL FIBER

Sisal fiber with the botanical name Agave sisalana, is a species of Agave that yields a stiff fiber used in making various products.

The sisal plant has a 7–10 year life-span and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibers. The fibers account for only about 4% of the plant by weight. A normal leaf contains 60g in which 3% weights Fiber. Sisal is considered a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine

Fig. 2.1.2 Sisal Fiber

Fiber extraction

Fiber is extracted by a process known as decortications, where leaves are crushed and beaten by a rotating wheel set with blunt knives and mechanically scraped, then water is used to wash away the waste parts of the leaf.

The fiber is then dried, brushed and baled for export. Proper drying is important as fiber quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fiber than sun drying, but is not feasible in the developing countries where sisal is produced. In the drier climate of north-east Brazil, sisal is mainly grown by smallholders and the fiber is extracted by teams using portable raspadors which do not use water.

Fiber is subsequently cleaned by brushing. Dry fibers are machine combed and sorted into various grades, largely on the basis of the previous in-field separation of leaves into size groups.

The dried fiber represents only 4% of the total weight of the leaf. Once it is dried the fiber is mechanically double brushed. The lustrous strands, usually creamy white, average from 80 to 120 cm in length and 0.2 to 0.4 mm in diameter. Sisal fiber is fairly coarse and inflexible.

It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. The sisal fiber is traditionally used for rope and twine, and has many other uses, including: paper, cloth, wall coverings, carpets, and dartboards.

Environmental impacts

Sisal farming initially caused environmental degradation, because sisal plantations replaced native forests, but is still considered less damaging than many types of farming. No chemical fertilizers are used in sisal production, and although herbicides are occasionally used, even this impact may be eliminated, since most weeding is done by hand. The effluent from the decortications process causes serious pollution when it is allowed to flow into watercourses. In Tanzania there are plans to use the waste as bio-fuel.

From several researches from various research scholars, it is proved that Sisal has superior properties than many fibers

FIBER	DENSITY g/cm3	TENSILE STRENGTH Mpa	CELL WALL THICKNESS
SISAL	1.450	468-700	12.5
COIR	1.150	175	8.00
BANANA	1.350	150-700	1.25

Table 2.1.3 Properties Of 3 Fibers

Tensile properties vary with the Length of Fiber. Due to low density & High specific properties of sisal fibers have good implications in Automotive and Transportation industries.

2.2.1 EPOXY RESIN

Epoxy resins are polyether resins containing more than one epoxy group capable of being converted into the thermoset form. These resins, on curing, do not create volatile products in spite of the presence of a volatile solvent. The epoxies may be named as oxides, such as ethylene oxides (epoxy ethane), or 1, 2-epoxide. The epoxy group also known as oxirane contains an oxygen atom bonded with two carbon atoms, which in their turn are bound by separate bonds.

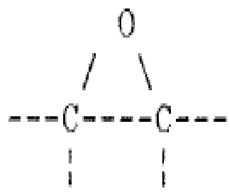


Fig 2.2.2 Oxirane

2.2.3 The manufacturing process

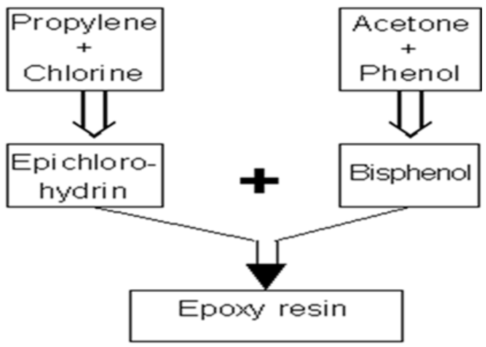


Fig 2.2.4 Manufacturing Process

In this process ECH and BPA are charged into a reactor in the ratio of 10:1. A solution of 20-40% caustic soda is added slowly to the reaction vessel as the solution is brought to the boiling point. The solution is kept boiling until 2 mol of caustic soda per mole of BPA have been added. The solution breaks up into two layers. Unreacted ECH is removed by vacuum distillation. An inert solvent is then added to the resin and the reaction is completed with excess of caustic soda solution. The resin separates into brine solution, which is thoroughly washed with water to obtain a clear resin. The solvent is removed by vacuum distillation.

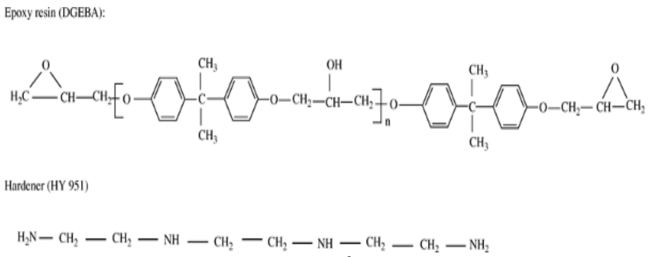


Fig 2.2.5 Structure of Epoxy Resin

Properties of epoxy resin

Mechanical Properties of epoxy resin	
Glass transition temperature (Tg)	120 - 130 °C
Tensile strength	85 N/mm²
Tensile Modulus	10,500 N/mm²
Elongation at break	0.8%
Flexural strength	112 N/mm²
Flexural Modulus	10,000 N/mm²
Compressive Strength	190 N/mm²
Coefficient of linear thermal expansion	34 10-6
Water absorption - 24 hours at 23°C	5-10 mg (0.06-0.068%)
Thermal Shock	2000 cycles (90 sec. at 75 °C, 90 sec. dwell, 90 sec. at 15°C) No effect
Thermal Decomposition	350° C

Adhesive properties

The superior adhesion of epoxy is due to two main reasons. The first is at the molecular level, where the presence of polar hydroxyl and ether groups improves adhesion. The second is at the physical level - as epoxies cure with low shrinkage, the various surface contacts set up between the liquid resin and the reinforcement are not disturbed during cure. The result is a more homogenous bond between fibers and resin and a better transfer of load between the different components of the matrix. High adhesion is especially important in resistance to micro-cracking (see later) and when using sandwich construction. The bond between the core and the laminate is usually the weakest link of the laminate, and the superior adhesive properties of the epoxy resin greatly increase the strength of the interface between skins and core.

2.3.1 SOYA BEANS OIL

Soya bean oil is a vegetable oil extracted from the seeds of the soya bean (Glycine max). It is one of the most widely consumed cooking oils. As a drying oil, processed soybean oil is also used as a base for printing inks (soy ink) and oil paints.

Production

To produce soybean oil, the soybeans are cracked, adjusted for moisture content, heated to between 60 and 88 ºC (140–190 °F), rolled into flakes, and solvent-extracted with hexanes. The oil is then refined, blended for different applications, and sometimes hydrogenated.

Property

Soybean oil is a drying oil, which means that it will slowly harden upon exposure to air, forming a flexible, transparent, and waterproof solid.

Soy Protein

Soy protein, as well as other proteins such as wheat gluten and potato protein, have been used in commercial consumer products including plywood adhesive, coatings for paper and binders in printing ink .Soy protein is extracted from soy beans and is available worldwide. Although in the United States soy beans have mainly been used to feed animals, soy protein has good film-forming ability and has been used for sustainable films. Soy protein is commercially available in three forms: soy protein isolate (SPI), soy protein concentrate (SPC) and soy flour (SF). The compositions of these forms can be found in Table. SPI has the highest percentage of protein, and therefore has the best mechanical properties. For this reason, SPI was used as the soy protein resin in this experiment.

Composition of Commercial Soy Proteins

contents	SPI	SPC	SF
Protein %	90	68-72	46-53
Fat(acid hydrolysis) %	4-5	3-4	3-19
Ash %	5-6	5-6	-
Dietary Fiber %	-	19-20	16-18
Carbohydrates %	-	-	26-30
Moisture %	6	6-9	8-9

Soy Protein Isolate (SPI)

Due to its high availability and excellent mechanical properties, SPI has become a popular choice for resins in “green” composites. Various studies have been performed using SPI as the resin of choice. The desired use of SPI would be for engineering applications and packaging materials. However, the mechanical properties are not yet good enough for these applications, so current research is being performed to improve these properties. During the curing process, soy protein chains can cross-link between the amino acids. Modifications in soy protein have introduced new cross-links in the protein structure, in addition to the naturally occurring cross-links. Improvements in cross-linking have been shown to improve the mechanical properties in SPI because of the increased linkage between the molecules of SPI.

Plasticization of SPI

SPI has the potential to be used in engineering and packaging applications due to its desired mechanical properties. However, when dry, it has been found to be very brittle, meaning that it has a low fracture strain. This prevents it from being used in the desired applications because when brittle, it is difficult to handle and process SPI. In addition, when SPI is combined with other products, whether it is paper products or natural fibers, it should have an increased fracture strain so that it does not break before the paper and fibers, causing the composite to have lower mechanical properties.

In order to improve the ductility of dried SPI, and therefore increase the fracture strain, plasticizers are added to the SPI solution. A plasticizer is a small molecule that is added to a material to increase its ductility

It was found that glycerol was the most suitable plasticizer for soy protein plastic because of toxicity; glycerol is nontoxic, while propylene glycol is more volatile. In this study, glycerol was chosen as a plasticizer for SPI resin in order to reduce its brittleness.

It is observed that Soy protein which is obtained by Soya bean has good film forming ability, when it is solely used it is brittle but when it is extruded as Oil it is a triglycerides which are formed by combining glycerol with three molecules of Fatty acids in which Glycerol is best to increase ductility & mechanical properties.

2.4.1 CURING AGENTS

Curing agents are the substance that hardens the adhesive when mixed with resin. The hardener & catalyst is also used to cure as composite material.

Hardener

Hardener is just used to initiate curing, the ratio of adding Epoxy and hardener is 2:1.Hardener here used is HY951.

Hardener is selected based on

- ✓ Temperature
- ✓ Curing thickness
- ✓ Desired working time and curing time

Hardeners which show only low or limited reactivity at ambient temperature, but which react with epoxy resins at elevated temperature are referred to as latent hardeners. When using latent hardeners, the epoxy resin and hardener may be mixed and stored for some time prior to use, which is advantageous for many industrial processes. Very latent hardeners enable one-component (1K) products to be produced, whereby the resin and hardener are supplied pre-mixed to the end user and only requires heat to initiate curing. One-component products generally have shorter shelf-lives than standard 2-component systems, and products may require cooled storage and transport.

Catalyst:

Catalyst is used to stimulate the matrix to form. Methyl ethyl ketone peroxide (MEKP) is used as a Catalyst in this composite. MEKP is less sensitive to Shock & temperature. MEKP is unstable in pure form, they are mixed with inert compounds to form catalysts i.e.) is Dilute solutions in industry.

Dilute solution of 30 – 60% of MEKP are used in Industry as a catalyst initiates cross linking of unsaturated resins. The ratio is, for 1litre of resin 10ml of catalyst is added.

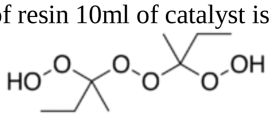


Fig 2.4.2 Methyl ethyl Ketone Peroxide

MEKP is a catalyst used in the composites industry for many resins. It reacts with the resin to turn it from a liquid to a solid (cure it). MEKP is organic peroxide. Due to this mixing, MEKP can be bought in various grades, which can give a range of gel times. Whilst various types of catalysts are available to cure polyester and vinyl ester resins, MEKP is the most widely used in contact molding for room temperature cure. MEKP allows Epoxy resins to cure by reacting with the promoter in the resin, or with heat. This starts the chemical reaction of the resin with the styrene monomer (present in the resin) allowing crosslink's to form between them. These crosslink's act as braces, joining the components in the liquid resin together. When some of the crosslink's have formed, the resin forms a gel and is said to be "gelled". When most of the crosslink's have formed, the resin forms a solid and is said to be "cured". Since MEKP must start a chemical reaction within the resin it must be a reactive compound. This makes it one of the most hazardous materials in the composites industry, since it can react with other materials causing a fire or with the human body resulting in chemical burns.

ACCELERATOR

Cobalt Acetate is used as Accelerator

Fig 2.4.3 Cobalt Acetate

Accelerator is used to make to react the catalyst and resin with fiber. Here Cobalt acetate is used as a Accelerator Which is formed by reaction between cobalt oxide or hydroxide & acetic acid.

$CoO + 2\ HC_2H_3O_2 \rightarrow Co\ (C_2H_3O_2)_2 + H_2O$

Dilute solutions of Cobalt acetate is used to cure with epoxy resin.

III. COMBINATION OF THESE MATERIALS

The combination of all the above mentioned material Sisal fiber, Epoxy resin, Soya beans oil & curing agents are obviously our Composite material. This material is formed by Compression molding technique. After it is cured it has Better Mechanical properties.

In-corporation of Sisal fibers in an Epoxy resin produces Stiff and strong composite materials. Because of the low density of the sisal fiber, however, the specific strength of sisal composites was comparable with that of glass composites. The unidirectional modulus of sisal-epoxy composites was found to be about 8.5 GPa. This study indicated the feasibility of developing composites incorporating one of the abundantly available natural fibers, to be used in the field of consumer goods, low cost housing and civil engineering structures. The reason why vegetable oils are widely used as plasticizers is because the high numbers of carbon-carbon double bonds present in vegetable oils make them a good target for manipulation into some other useful products like in this case - from soybean oil into epoxidized soybean oil. The epoxide group is more reactive than double bond, thus providing a more energetically favorable site for reaction and making the oil a good hydrochloric acid scavenger and plasticizer. Curing of Epoxidized soya beans oil with sisal fibers increases better Adhesive properties, high strength and stiffness, improved resistance to fatigue &Micro-cracking and greater resistance to water.

IV. MECHANICAL TESTING

Mechanical testing are implemented to check the following mechanical properties

- ✓ Tensile Strength
- ✓ Flexural Strength
- ✓ Impact Strength

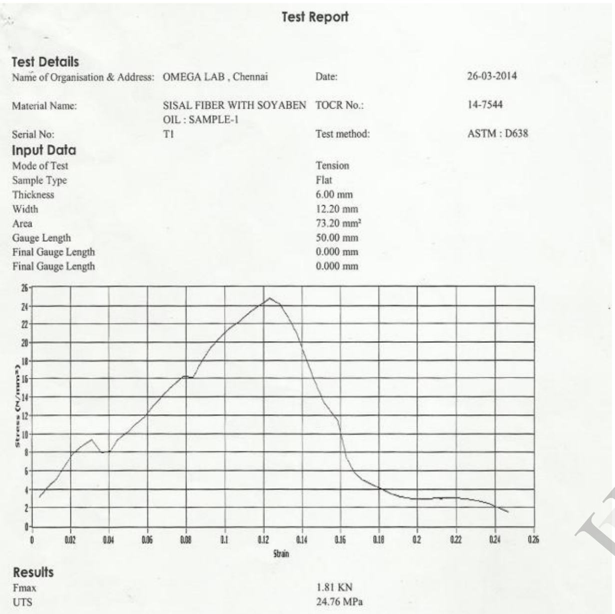
TENSILE STRENGTH:

Tensile strength is the maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material.

The tensile test is generally performed on flat specimens. During the test a uniaxial load is applied through both the ends of the specimen. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 638. The length of the test section should be 150 mm. The tensile test is performed in the universal testing machine (UTM) Instron 1195 and results are analyzed to calculate the tensile strength of composite samples.

TENSILE TEST REPORT

SAMPLE 1


Test Report

Test Details

Name of Organisation & Address:	OMEGA LAB , Chennai	Date:	26-03-2014
Material Name:	SISAL FIBER WITH SOYABEN OIL : SAMPLE-1	TOCR No.:	14-7544
Serial No:	T1	Test method:	ASTM : D638

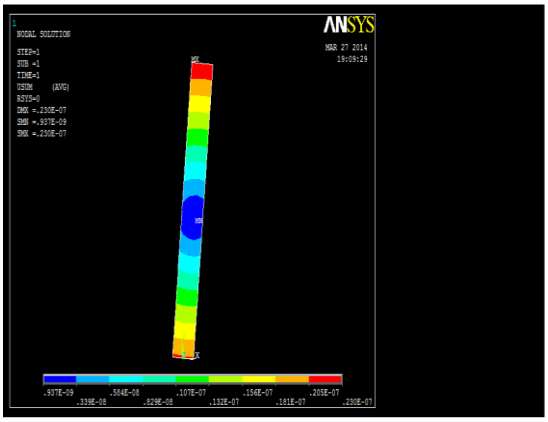
Input Data

Mode of Test	Tension
Sample Type	Flat
Thickness	6.00 mm
Width	12.20 mm
Area	73.20 mm²
Gauge Length	50.00 mm
Final Gauge Length	0.000 mm
Final Gauge Length	0.000 mm

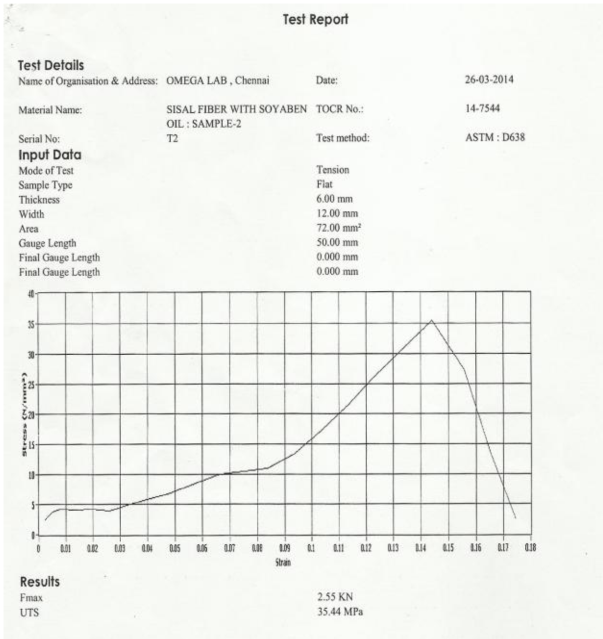
Results

Fmax	1.81 KN
UTS	24.76 MPa

DEFORMATION ANALYSIS OF SAMPLE 1 USING ANSYS SOFTWARE



SAMPLE 2


Test Report

Test Details

Name of Organisation & Address:	OMEGA LAB , Chennai	Date:	26-03-2014
Material Name:	SISAL FIBER WITH SOYABEN OIL : SAMPLE-2	TOCR No.:	14-7544
Serial No:	T2	Test method:	ASTM : D638

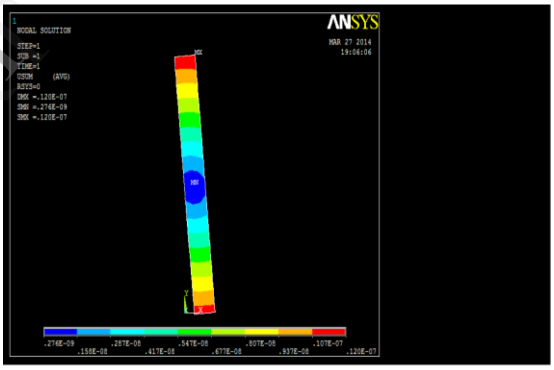
Input Data

Mode of Test	Tension
Sample Type	Flat
Thickness	6.00 mm
Width	12.00 mm
Area	72.00 mm²
Gauge Length	50.00 mm
Final Gauge Length	0.000 mm
Final Gauge Length	0.000 mm

Results

Fmax	2.55 KN
UTS	35.44 MPa

DEFORMATION ANALYSIS OF SAMPLE II USING ANSYS SOFTWARE



FLEXURAL STRENGTH:

Flexural strength is an object's ability to bend without obtaining any major deformities

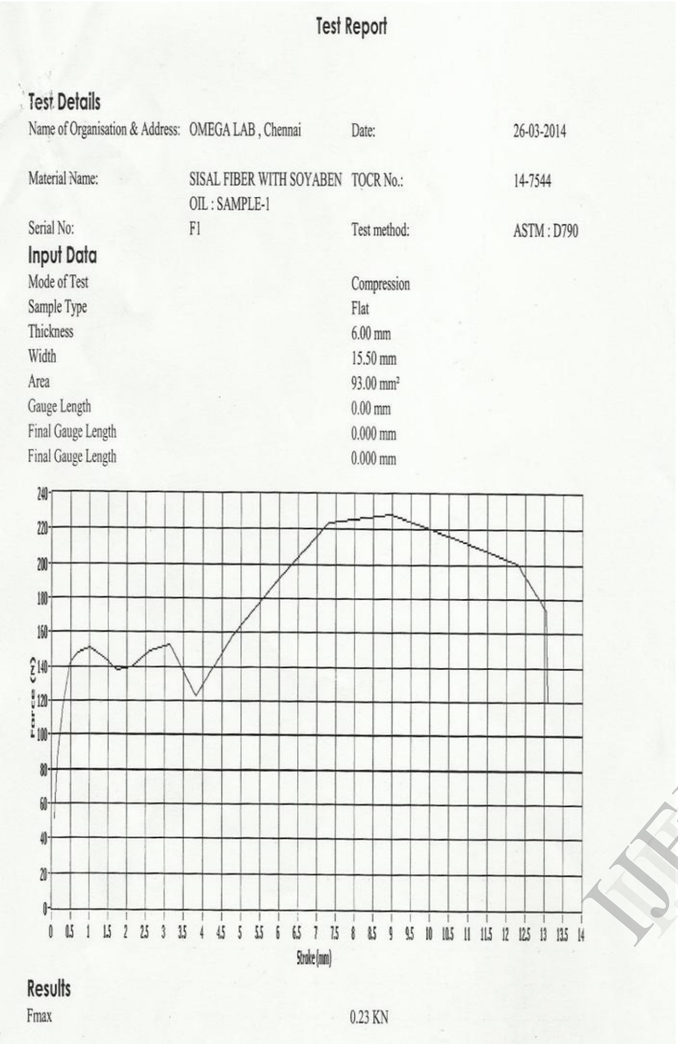
The short beam shear (SBS) tests are performed on the composite samples at room temperature to evaluate the value of flexural strength (FS). It is a 3-point bend test, which generally promotes failure by inter-laminar shear. The SBS test is conducted as per ASTM-790 using the same UTM. Span length of 150 mm and the cross head speed of 1 mm/min are maintained. Flexural test on sisal fibers reinforced with epoxy composite specimens is performed. The flexural strength (F.S.) of any composite specimen is determined using the following equation.

$$F.S = 3PL/2bt^2$$

Where, L is the span length of the sample. P is the load applied; b and t are the width and thickness of the specimen respectively

FLEXURAL TEST REPORT

SAMPLE1


Test Report

Test Details

Name of Organisation & Address:	OMEGA LAB , Chennai	Date:	26-03-2014
Material Name:	SISAL FIBER WITH SOYABEN OIL : SAMPLE-1	TOCR No.:	14-7544
Serial No:	F1	Test method:	ASTM : D790

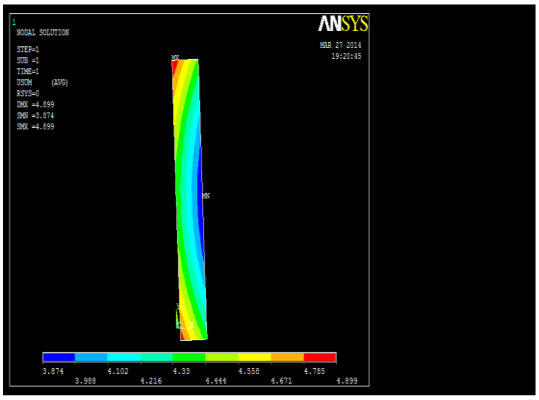
Input Data

Mode of Test	Compression
Sample Type	Flat
Thickness	6.00 mm
Width	15.50 mm
Area	93.00 mm²
Gauge Length	0.00 mm
Final Gauge Length	0.000 mm
Final Gauge Length	0.000 mm

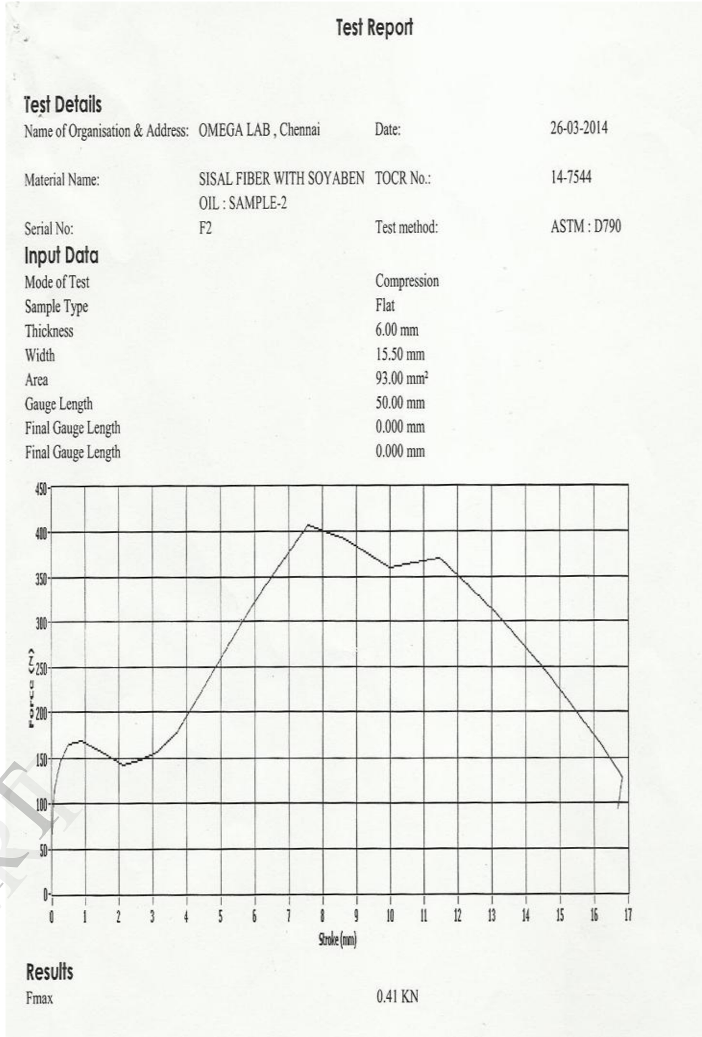
Results

Fmax	0.23 KN

DEFORMATION ANALYSIS OF SAMPLE 1 USING ANSYS SOFTWARE



SAMPLE 2


Test Report

Test Details

Name of Organisation & Address:	OMEGA LAB , Chennai	Date:	26-03-2014
Material Name:	SISAL FIBER WITH SOYABEN OIL : SAMPLE-2	TOCR No.:	14-7544
Serial No:	F2	Test method:	ASTM : D790

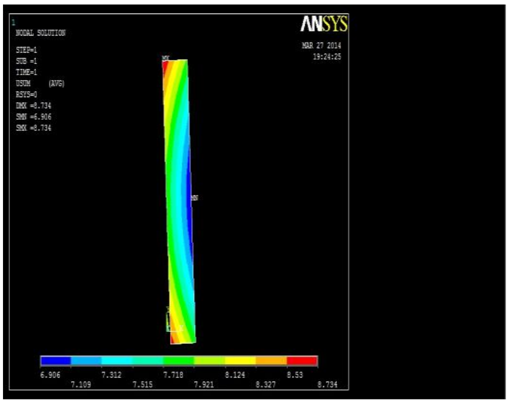
Input Data

Mode of Test	Compression
Sample Type	Flat
Thickness	6.00 mm
Width	15.50 mm
Area	93.00 mm²
Gauge Length	50.00 mm
Final Gauge Length	0.000 mm
Final Gauge Length	0.000 mm

Results

Fmax	0.41 KN

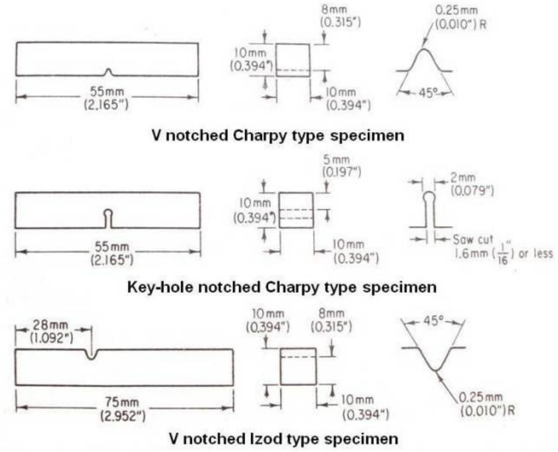
DEFORMATION ANALYSIS OF SAMPLE 2 USING ANSYS SOFTWARE



IMPACT TEST:

Impact resistance is the ability of a material to resist breaking under a shock loading or the ability to resist the fracture under stress applied at high speed. Impact behavior is one of the most widely specified mechanical properties of the engineering materials.

Both Izod and Charpy methods perform impact tests on sisal fibers reinforced with epoxy composite specimens as per ASTM-D256.



Izod&Charpy specimen specifications

V. ADVANTAGES & APPLICATIONS

As a result of this Composite material, it will provide Better Mechanical properties & Major advantages.

ADVANTAGES

- ✓ Major advantage is to provide High strength with decrease in Weight.
- ✓ Maximize the Percentage of natural compounds in Composites.
- ✓ Green materials in the composites are biodegradable and Eco-friendly.
- ✓ Less wear during processing and low energy consumption during extracting and wide varieties of natural fibers are locally available.
- ✓ Reduced equipment & subsequent reduction on retooling cost will make these composites more attractive.
- ✓ Increase in Tensile, Impact & Flexural Properties.
- ✓ Improved resistance to fatigue and micro cracking and low viscosity which makes the fiber impregnation easy.
- ✓ Epoxy resins mixed in these composites have far better adhesive properties, strength & stiffness than polyester and vinyl ester resins.
- ✓ Good electrical insulation properties, increased chemical resistance after curing and Resist the effects of Water.
- ✓ It is a Cost-Effective Technique.
- ✓ In automobiles like car weight reduction up to 35% is possible. This can be translated into lower fuel consumption and the lower environmental impact.

APPLICATIONS

- ✓ Automobile Industry-Lighter, stronger, Wear resistance, rust-free, aesthetics.
- ✓ Door panels,
- ✓ Headliners,
- ✓ Package trays,
- ✓ Dashboards,
- ✓ Trunk liners,
- ✓ Hoods &
- ✓ Spoilers.

- ✓ Aerospace: Lighter, stronger, temperature resistance, smart structures, wear resistance

- ✓ Aircraft:
- • Struts,
- • Fairings,
- • Outboard and inboard flaps,
- • Rudders,
- • Spoilers
- ✓ Rockets & missiles:
  -frame, turbo-motor stators, etc.
- ✓ Satellites:
  -Antennae, frames, structural parts
- ✓ In construction field such as False ceilings, Partition purposes, Doors.
- ✓ For indoor structural applications in housing including interior decorations, board used for flooring & walls which will be attractive and will decrease the cost of construction
- ✓ Furniture, Boxes for agriculture purposes, Rims, Mobile panels, Toys, Ships and so on
- ✓ In automobiles like car weight reduction up to 35% is possible. This can be translated into lower fuel consumption and the lower environmental impact.
- ✓

VI. PHOTOS OF COMPLETED GREEN COMPOSITE

VII. OVERALL TEST RESULT

Samples	Tensile Strength (MPa)	Flexural strength (KN)	Impact strength (Joules)
Sample 1	24.76	0.23	2
Sample 2	35.44	0.41	2

VIII. CONCLUSION

It has Major advantages as using this composite materials for different applications in automobiles, construction, agriculture, furniture, etc… and where weight should be ignored with high strength is required, it is capable and potential for such aspects and It can be used as a supplement and eventually replace petroleum-based composite materials & glass reinforced composites in many applications, offering new agricultural, environmental, manufacturing, and consumer benefits. If safety measures are correctly followed no problem will arise.

IX. REFERENCES

1. COMPOSITE MATERIALS SCIENCE AND ENGINEERING -Krishnan K. Chawla
2. COMPOSITE MATERIAL -Deborah D. L. Chung
3. COMPOSITE MATERIALS AND STRUCTURES - P. K. Sinha
4. REINFORCED COMPOSITES Materials, Manufacturing, and Design -P.K. Mallick
5. NATURAL FIBERS, BIOPOLYMERS AND BIOCOMPOSITES

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