Fabrication & Testing of Natural Fibre Reinforced Composite (Sun hemp & E-Glass)

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Abstract:

Generally a composite is combination material of two materials in which one is called the reinforcing phase, is in the form of fibres, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fibre or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibres, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fibre axis. The matrix is more ductile than the fibres and thus acts as a source of composite toughness. The matrix also serves to protect the fibres from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological and environmental applications.

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1. Introduction

A composite is a material made by combining two or more dissimilar materials in such a way that the resultant material is endowed with properties superior to any of its parental ones. Fiber-reinforced composites, owing to their superior properties, are usually applied in different fields like defense, aerospace, engineering applications, sports goods, etc. Nowadays, natural fiber composites have gained increasing interest due to their eco-friendly properties. A lot of work has been done by researchers based on these natural fibers. Natural fibers such as jute, water hyacinth, silk and coir are inexpensive, abundant and renewable, lightweight, with low density, high toughness, and biodegradable. Natural fibers such as water hyacinth have the potential to be used as a replacement for traditional materials for applications which requires high strength to weight ratio and further weight reduction. Bagasse fiber has lowest density so able to reduce the weight of the composite upto very less. So by using these fibers (water hyacinth and bagasse) the composite developed is cost effective and perfect utilization of waste product.

Natural fiber reinforced polymer composites have raised great attentions and interests among materials scientists and engineers in recent years due to the considerations of developing an environmental friendly material and partly replacing currently used glass or carbon fibers in fiber reinforced composites. They are high specific strength and modulus materials, low prices, recyclable, easy available in some countries, etc.

Tayeb [1] conducted a research to study the possibility of using this natural fiber reinforce polyester and thus opens a new way to implement locally available inexpensive fibers and produce a new material for bearing various applications. Sugarcane fiber/polyester (SCRP) and glass fiber/polyester (GRP) composites with chopped fibers randomly distributed. It was prepared using compression mould and hand-lay-up techniques. In conclusion glass fibers are poor in bonding with the matrix for C-GRP composite and on the other hand sugarcane fibers are good in bonding with the matrix for C-SCRP composite.

Cerqueira et al., [3] conducted a research to evaluate the effect of chemical modification on mechanical properties of sugarcane bagasse fiber/PP composites. Fibers were pretreated with 10% sulfuric acid solution, followed by delignification with 1% sodium hydroxide solution.

These fibers mixed with the polypropylene resin in thermo kinetic mixer and composites with 5 to 20 wt% of fibers were obtained. The mechanical properties were evaluated by means of tensile, bending and impact tests. In addition SEM analysis was performed. Results showed improved results in comparison to the polymer pure.

Yan Li et al., [2] conducted a research to study the poor interfacial bonding between the natural fibers and the polymer matrices. Two types of fiber surface treatment methods, namely chemical bonding and oxidization were used to improve the interfacial bonding. Interfacial properties were evaluated and analyzed by single fiber pull-out test and the theoretical model. Based on this study, an improved method which could more accurately evaluate the interfacial properties between natural fiber and polymeric matrices was proposed.

Rodriquez et al., [4] tries to use the sugar cane bagasse waste as reinforcement to polymeric resins for fabrication of low cost composites. They reported that composites with homogeneous microstructures could be fabricated and mechanical properties similar to wooden agglomerates can be achieved.

Joshi [5] compared life cycle environmental performance of natural fiber composites with glass fiber reinforced composites and found that natural fiber composites are environmentally superior in the specific applications studied. Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases for the following reasons, (1) natural fiber production has lower environmental impacts compared to glass fiber production, (2) natural fiber composites have higher fiber content for equivalent performance, reducing more polluting base polymer content, (3) the light-weight natural fiber composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in auto applications and (4) end of life incineration of natural fibers results in recovered energy and carbon credits.

A.N.Shah et al., [6] tries to compare the mechanical properties of natural fiber-reinforced and glass-reinforced and the results shows that the natural fibers, when introduced into the resin matrix as reinforcement, considerably improve the mechanical properties, but the improvement is much lower than that obtained by introduction of glass and other high performance fibers. Hence, the natural fibers can be used as reinforcement where modest strength and modulus are required.

Another potential use for the natural fibers is that, it can be used as a filler fiber, replacing the glass as well as the resin in a filament wound component. The main problem of the present work has been that it is difficult to introduce a large quantity of natural fibers into the laminates because the natural fibers, unlike glass fibers, soak up large amount of resin. This problem is partly overcome when hybridizing with glass fibers is carried out.

2. Material and methods:

2.1 Raw material

a. Sun Hemp fiber.
b. Epoxy resin.
c. E-Glass

2.1.1 Sun Hemp:

Sun hemp is extensively cultivated for fiber or green manure and leaves are fed as a high protein supplement to other poorer feeds. In Sri Lanka dried leaves, bark and boiled seeds are fed to cattle. With restrictions, seed has been used as fodder in the former Soviet Union and southern Africa. It is showing promise as a forage legume for intercropping with upland rice. Leaves and stems are dried since animals do not eat sun hemp when it is green. Sun hemp should be cut for hay or ploughed in for green manure in the early flowering stage when it is 1.5-2.5 months old. Due to the shade of its dense canopy it is also used as a cover crop to suppress weed populations.

Sun hemp is a tropical or sub-tropical plant that when grown in the continental United States performs like a summer annual. It can be planted year round in Hawaii below an elevation of 1,000 feet. However, it does not perpetuate itself well and is not found in the wild. Sun hemp is adapted to a wide range of soils and performs better on poor sandy soils than most crops. It is for such situations that it has attracted attention. It grows best on well-drained soils with a pH from 5.0 to 7.5.

Epoxy resin

The large family of epoxy resins represents some of the highest performance resins of those available at this time. Epoxies generally out-perform most other resin types in terms of mechanical properties and resistance to environmental degradation, which leads to their almost exclusive use in aircraft components. As a laminating resin their increased adhesive properties and resistance to water degradation make these resins ideal for use in applications such as boat building. Here epoxies are widely used as a primary construction material for high-performance boats or as a secondary application to sheath a hull or replace water-degraded polyester resins and gel coats.

The term 'epoxy' refers to a chemical group consisting of an oxygen atom bonded to two carbon atoms that are already bonded in some way. The simplest epoxy is a three-member ring structure known by the term 'alphaepoxy' or '1,2-epoxy'. The idealised chemical structure is shown in the figure below and is the most easily identified characteristic of any more complex epoxy molecule.

Usually identifiable by their characteristic amber or brown colouring, epoxy resins have a number of useful properties. Both the liquid resin and the curing agents form low viscosity easily processed systems. Epoxy resins are easily and quickly cured at any temperature from 5°C to 150°C, depending on the choice of curing agent. One of the most advantageous properties of epoxies is their low shrinkage during cure which minimises fabric 'print-through' and internal stresses. High adhesive strength and high mechanical properties are also enhanced by high electrical insulation and good chemical resistance. Epoxies find uses as adhesives, caulking compounds, casting compounds, sealants, varnishes and paints, as well as laminating resins for a variety of industrial applications.

E-Glass

E-Glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fiber forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiberglass. Glass fibers are generally produced using melt spinning techniques. These involve melting the glass composition into a platinum crown which has small holes for the molten glass to flow.

Fabrication of composite:

The sun hemp plant is taken nearby the lake area. The stem (fiber part) is separated and allowed to dry in the sun light for 3-4 hours. The dried fiber was converted to long pieces. Then the natural fiber, resin and e-glass were taken based on the volume percentage. The Fiber, resin and e-glass were mixed by using glass rod in a bowl based on volume. The accelerator (cobalt naphthalene) and the e-glass (methyl ethyl ketone peroxide) were added to the resin. The accelerator added is 0.75% of epoxy resin and the e-glass added is 0.75% of the resin. Care was taken to avoid formation of bubbles. The methods to prepare the sample are shown in Figure 3.1, 3.2&3.3. Because the air bubbles were trapped in matrix may result failure in the material. The subsequent fabrication process consisted of putting a releasing film (wax) on the mould surface. It was left for 4 hours to allow sufficient time for curing and subsequent hardening.

The composites sheets were fabricated from sun hemp fiber, with resin matrix. The resin used was e-glass. The volume fraction of composites was maintained at 30%,20%, 50% fiber with same procedure another one plate was done by different volume 30%, 20%, 50%. After the composites fabrication cutting of the specimen is done in the desired shape to test the mechanical properties of the natural composite fiber. The tensile test samples were done by UTM (universal testing machine), the test specimens were done by Flexural test and impact test were conducted as per ASTM standard.

(a)  (b) 

Fig. 1 (a), (b) Natural Fibre before drying

Fig 2 Natural Fibre after drying

Fig 3 E Glass

Mechanical evaluation:

The mechanical governing parameters such as tensile stress, hardness and compression stress values were evaluated on the fabricated composites respective machines. The composite specimens for all the tests were polished and ground before evaluation.

Calculation of sample preparation:

For the preparation of the composite we calculate the percentage of fibers and polymer required. From the Table 3.1 we come to know about the amounts accurately.

Table 1Concentration of Sample Preparation

Sample Number	Sun Hemp (volume)%	E-Glass (volume)%	Epoxy resin (volume)%
1	30	20	50

2	20	30	50

Mould preparation:

First of all the mould for the composite is prepared. We have to prepare mould of size *300x300x300 mm* for thepreparation of required composite.

Figure 4 Mould for composite

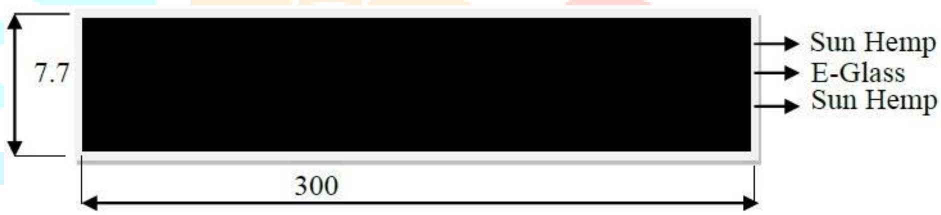

Figure 5 Sun Hemp 30% and E Glass 20% mould

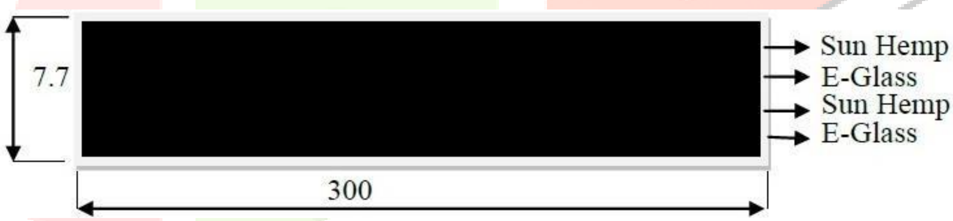

Figure 6 Sun Hemp 20% and E Glass 30% mould

3. Experimental details:

Cutting of test specimen to as per ASTM Standard:

Water jet cutting machine is used for cutting the composite sheet, for various experiments:

- Tensile test specimen was cut into dog bone shape 166x22x7.7 mm (ASTM D 3039). Refer Fig 7.
- Flexural test specimen was cut into 100x14x7.7 mm (ASTM D 790). Refer Fig 8.
- Impact test specimen was cut into 67x14x7.7 mm (ASTM D 256). Refer Fig 9.

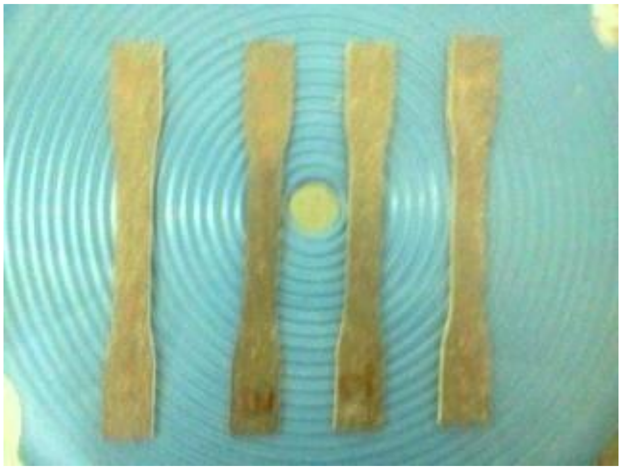

Figure 7 Tensile test specimen

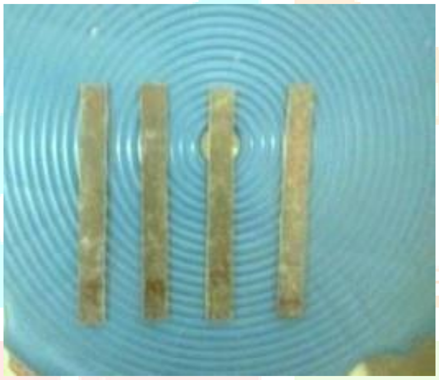

Fig 8 Flexural Test Specimen

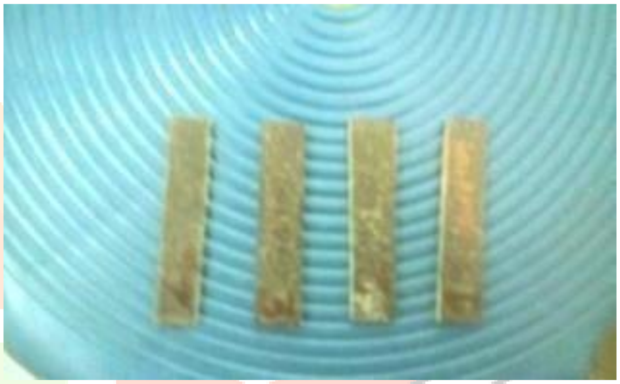

Fig 9 Impact test Specimen

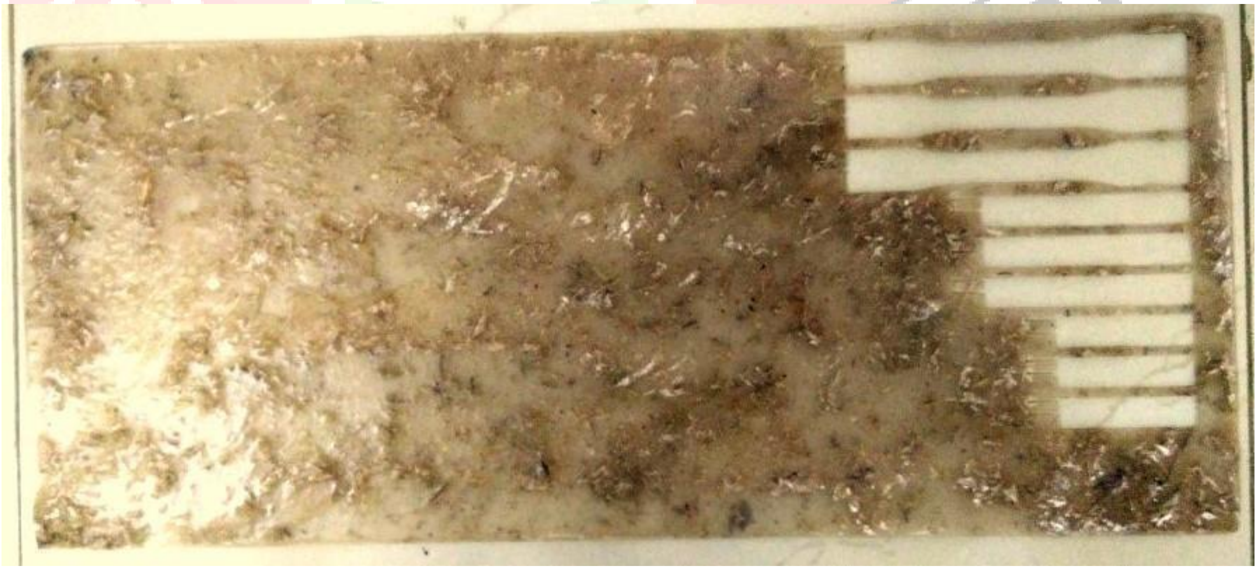

Fig 10 Composite sheet after water jet cutting

Tensile test:

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The commonly used specimen for tensile test is the dog-bone type. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is (250x25x7.77) mm. Refer Figure 3.11 for broken sample after tensile test.

Typical points of interest when testing a material include, ultimate tensile strength or peak stress offset yield strength which represents a point just beyond the onset of permanent deformation and the rupture or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine and results are analyzed to calculate the tensile strength of composite samples.

Fig. 8 Broken Samples after the test

Flexural test:

The flexure test method measures behavior of materials subjected to simple beam loading. Most commonly the specimen lies on a support span and the load is applied to the center by the loading nose producing three point bending at a specified rate. The test was carried out as per the ASTM standard D785 procedure. Refer Figure 3.13 for broken samples after flexural test.

Fig. 9 Samples after flexural test

Impact test:

The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals, but similar tests are used for polymers, ceramics and composites. Izod

Impact test specimen is machined to a square or round section, with either one, two or three notches. The specimen is clamped vertically on the anvil with the notch facing the Hammer. Refer Figure 3.14 and 3.15 for impact testing machine and broken samples after impact test.

4. Results and Discussion:

Tensile test values:

Tensile test was also carried out on UTM machine in accordance with ASTM D638 standard. All the specimens were of dog bone shape of dimension (250x25x2.5) mm.

Table 2 Tensile strength values

Sample number	Cs Area mm²	Peak load KN	Elongation %	UTS N/mm²
1	100.31	3.87	5.00	38.60
2	100.31	3.57	4.66	38.71
3	100.31	3.98	5.00	37.89
4	102.56	5.33	6.02	52.00
5	102.86	5.46	6.80	51.89
6	100.56	5.58	5.99	52.06

The Tensile test for 6 samples has been conducted and the resulting Graphs for Force Vs Stock is shown below.

Flexural Strength values:

Flexural test was also carried out on UTM machine in accordance with ASTM D790 standard. All the specimens were cut into (130x13x2.5) mm. The results are tabulated in the Table 4.2.

Sample calculation for sample 1:

- Flexural strength
  Flexural strength = (3x40x100) / (2x14x7.772) = 75.84 Mpa
- Flexural modulus
  Flexural modulus= (1003x.77) / (4x14x7.773x3.7) = 28.31 Gpa
  Where, F= load applied w, b= width
  L= span length d= deflection

Sample number	Cs Area (mm²)	Peak load (KN)	Flexural strength (MPa)	Flexural modulus (GPa)
1	195.44	0.77	75.48	28.31
2	195.86	0.88	74.89	29.24
3	194.86	0.89	75.92	27.18
4	185.61	0.75	78.21	30.16
5	184.89	0.79	77.36	31.10
6	185.98	0.80	78.96	30.86

Impact Test values:

Impact test is carried out in IZOD method using impact test machine. Refer Table 4.3 for the impact value in joules. The test specimen is machined to a square or round section, with either one, two or three notches. The specimen is clamped vertically on the anvil with the notch facing the Hammer. A test specimen is machined to a *10x10mm* (full size) cross-section, with either a ―V‖ or ―U‖ notch. Sub-size specimens are used where the material thickness is restricted. Specimens can be tested down to cryogenic temperatures.

Table 3 Impact Test Values

Sample Number	Hardness Value (Joules)
1	2.02
2	2.02
3	2.00
4	2.00
5	2.04
6	2.08

Shore Hardness Test:

Shore hardness test is carried out in IZOD method using Shore Hardness test machine. Refer Table 4.4 for the hardness value in joules. Shore Hardness is a measure of the resistance a material has to indentation. There are different Shore Hardness scales for measuring the hardness of different materials (soft rubbers, rigid plastics, and super soft gels, for example). These scales were invented so that people can discuss these materials and have a common point of reference.

Table 4 Shore Hardness Test Values

Sample Number	Hardness Value (Joules)
1	81
2	80
3	82
4	77
5	76
6	77

5. Conclusion:

The feasibility of utilizing the agro-residue as an alternative reinforcement in thermoplastics was studied. Based upon the above analyzed samples and their results, the following conclusions have been drawn,

- All Samples subjected to tensile test shows that the composite sample with 30% fiber obtains high tensile strength and by addition of E-Glass reinforcement its ultimate tensile strength increases further.
- All samples subjected to flexural test shows that the composite material with 20%.
- Fiber has more flexural strength when compared with other composite samples.
- All samples subjected to impact test shows that the composite with 30% natural fiber has absorbed maximum energy during fracture.
- All samples subjected to shore hardness shows that the composite with 30% natural fiber has absorbed maximum energy during fracture

Hence, it can be concluded that the sample with the fiber reinforcement effectively improves the tensile, flexural and impact strength when compared to the pure polymer and the composite with the 30% fiber shows promising results in both the flexural and impact tests when compared with the other sample Since, the flexural strength is high it can be used for car interior. The composite hardness high it can be used at panels,doors.

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