Characterization of Natural Fibres in Composites

M Saran Theja*, VVN Bhaskar2 S.Ramalinga Reddy3

1. Asst. Prof, Mechanical Engineering, ACEM (J.N.T.U.A), Madanapalle, Chittoor (Dist.), A.P., India.
2. Assoc. Prof, head of the Mechanical Engineering, ACEM (J.N.T.U.A), India.
3. Principal & Professor in Mech. Dept., Aditya College of Engineering [ACEM], (J.N.T.U.A), INDIA

Abstract

After World War II synthetic fibres are used mostly than natural fibres. Now-a-days due to increase of oil prices and environmental considerations. This is an interest on natural fibres use within the textile, building plastic, and automotive industries for economic development and independence versus imported material. This experimental study aims fabrication and characterization of natural fibres in composite materials. The samples are several Natural Composites and those samples are pure epoxy mat, coconut coir mat, palm fibre mat, combination of coconut coir and palm fibre mat were manufactured by using hand layup method. The weight fraction of fiber and the matrix was kept 40% - 60%. Testing is done for treated and the untreated fibres thus properties will be studied and compared with previous mechanical properties. The tests were flexural test, tensile test.

Keywords: Composites, fiber-reinforced, isotropic, matrix layer, fiber layer, coconut coir, fabricated sandwich panel, honeycomb, light weight to strength.

Introduction of Composite

A composite is combination of two materials in which one of the materials, 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, tribiological, and environmental applications. The following are some of the reasons why composites are selected for certain applications: High strength to weight ratio (low density high tensile strength), high creep resistance, high tensile strength at elevated temperatures and high toughness.

Natural Fibre Reinforced Composites

The interest in natural fibre-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lingo cellulosic fibres, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites. The natural fibre containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc.

Applications of Natural Fibre Composites

The natural fibre composites can be very cost effective material for following Applications: Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc. Storage devices: post-boxes, grain storage
silos, bio-gas containers, Furniture: chair, table, shower, bath units, etc. Electric devices: electrical appliances, pipes. Everyday applications: lampshades, suitcases, helmets. Transportation: automobile and railway coach interior, boat, etc.

Objective

1. To manufacture natural fibre composite using coconut coir, palm fibre and epoxy resin.
2. To determine the mechanical properties of natural fibre composites, Such as Tensile Test, Flexural Test, Micro Hardness Test and Impact Test.

Literature Survey

Natural fibre 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 fibres in fibre reinforced composites. They are high specific strength and modulus materials, low prices, recyclable, easy available in some countries, etc.

A lot of work has been done by researchers based on these natural fibres. Natural fibres such as jute, sisal, silk and coir are inexpensive, abundant and renewable, lightweight, with low density, high toughness, and biodegradable. Natural fibres such as jute have the potential to be used as a replacement for traditional reinforcement materials in composites for applications which requires high strength to weight ratio and further weight reduction. Bagasse fibre has lowest density so able to reduce the weight of the composite upto very less. So by using these fibres (palm fibre, coconut coir, and glassfibre) the composite developed is cost effective and perfect utilization of waste product.

A.M.Motawie, N.A.Mansour, N. G.Kandle, S.L. Abd-El-Messieh, S. M. El-Mesallamy, E.M.Sadek. [1]Study on the Properties of Carbon Reinforced Unsaturated Thermoset Polyester Resin Nanocomposites in this paper the composite specimen was fabricated by stir casting technique with different weight percentages of 3%, 6% and 9% and the different test methods are carried out to study the coefficient of friction, thermal expansion coefficient, weight loss, wear rate and hardness and the results are studied.

Beghezan [2] defines as "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings", in order to obtain improved materials.

C.Lakkad, [4] tries to compare the mechanical properties of jute-reinforces and glass-reinforced and the results shows that the jute fibres, 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 fibres. Hence, the jute fibres can be used as reinforcement where modest strength and modulus are required.

G. Senthilkumar [6] An Experimental Investigation of Metal Matrix Composites of Aluminium (Lm6), Boroncarbide and Flyash. Experimental study the composite obtained by stir casting method by the ingredients of aluminium, boron carbide, fly ash in the different proportions. then the composite subjected to various testing machine such as pin on disc, dilatometer, abrasion testing machine to find out co-efficient of friction, wear loss, wear rate for different combinations and results were compared.

Jartiz [7] stated that "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form".

Kelly [8] very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; thecombination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

K Rana[9] in their work showed that the use of compatibilizer in jute fibres increases its mechanical properties. At 60% by weight of fibre loading, the use of the compatibilizer improved the flexural strength as high as 100%, tensile strength to 120%, and impact strength by 175%. The following conclusions may be drawn from this paper:

1. The sharp increase in mechanical properties and decrease in water absorption values after addition of the compatibilizer.
2. All these results justify that the role of jute fibre was not as a filler fibre but as a reinforcing fibre in a properly compatibilized system.
3. This system produced a new range of low-energy, low-cost composites having interesting properties and should be given priority over costly and high-energy synthesis reinforcing fibre wherever possible.

Monteiro SN. Rodriguez [10] 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.

R Gopinath[11] Mechanical Properties of sandwich Composites made using Prosopis juliflora, sisal and Glass fibers. In this paper, the mechanical properties of composite laminates made using natural fibers as sandwich material between the layers of glass fiber mats has been experimentally investigated and discussed. The fibers obtained from the bark of prosopis juliflora tree, and sisal fibers ground to various sizes were used as sandwich material.

Another potential use for the jute fibres is that, it can be used as a “filler” fibre, 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 jute fibres into the JRP laminates because the jute fibres, unlike glassfibres,soak up large amount of resin. This problem is partly overcome when 'hybrid sing' with glass fibres is carried out.

Suchetclan[12] explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They
can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

SV Joshi[13] compared life cycle environmental performance of natural fibre composites with glass fibre reinforced composites and found that natural fibre composites are environmentally superior in the specific applications studied. Natural fibre composites are likely to be environmentally superior to glass fibre composites in most cases for the following reasons: (1) natural fibre production has lower environmental impacts compared to glass fibre production; (2) natural fibre composites have higher fibre content for equivalent performance, reducing more polluting base polymer content; (3) the light-weight natural fibre 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 fibres results in recovered energy and carbon credits.

Yuvaraj[14] The primary aim of this paper is to manufacture a composite cylinder with conductive polymer layer for Solid Rocket Motor Casing. Studies are carried out to characterize the conductive polymer properties and studied in different material like CFRP with Carbon Nanotube and Copper Nanopowder and their enhancement of properties.

Materials and Methods
The following section will elaborate in detail the experimental procedure carried out during the course of our project work. The steps involved are:
1. Specimen Fabrication (Fabrication of FRP). By Hand Lay-Up method. Cutting of Laminates into samples of desired dimensions. 2. Tensile test and 3. Flexural test (3-Point Bend test)

Raw Materials
Raw materials used in this experimental work are Epoxy Resin, Hardener, Natural fibres Coconut coir and or Palm fibre.

Epoxy Resin
Epoxy resin (Araldite) LY 556 made by CIBA GUGYE Limited, having the mentioned outstanding properties has been used. Excellent adhesion to different materials, Great strength, toughness resistance, Excellent resistance to chemical attack and to moisture, Excellent mechanical and electrical properties, Odorless, tasteless and completely nontoxic, Negligible shrinkage.

Hardener
In the present work Hardener (Ardor) HY 951 is used. This has a viscosity of 10-20 poise at 250°C.

Natural Fiber
Coconut coir
Coir is a natural fibre extracted from the husk of coconut technically. Coir is a fibrous material fount between the hard internal shell and he outer. Coat of a coconut and it’s used for making products such as floor mats, doors, brushes, mattresses etc. Ropes and cordage made from coconut fibre have been in use from ancient times. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. Each cell is about 1mm (0.04in) long and 10t020µm (0.004 to 0.0008) diameter. Two types of fibre are taken in coconut coir white coir, Brown coir. Now we are using Brown coir in our project. The brown coir contains more lignin and less cellulose than the fibre such has flax and Cotton so they are stronger and less flexible.

b. Palm Fiber
Palm fibre is taken from the Leaves of the Palm tree so it’s also known as the palm leaf fibre. Palm fibre has the poor spinning characteristics the fibre is naturally hard palm fibre behaviour has been classified into two types they are Active behavior and the Passive behavior.

Active behavior-Palm fibre has a slight pleasant straw like odors even slight moisture may impart a musty odor to palm fibre after a time. As Upholstery stuffing.

Passive behavior-Palm fibre is sensitive to unpleasant (or) pungent odors. For example Fish meal stowed nearby may result in considerable depreciation of the palm fibre.

Moisture/RF Humidity
Palm fibre requires particular temperature, humidity/moisture and possible ventilation conditions they are given below

<table>
<thead>
<tr>
<th>Designation</th>
<th>Humidity/water conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative humidity</td>
<td>65%</td>
</tr>
<tr>
<td>Water content</td>
<td>12%</td>
</tr>
<tr>
<td>Maximum content</td>
<td>65%</td>
</tr>
</tbody>
</table>

Methodology
Fabrication of Composite Fibre-Hand Lay-Up Technique
The fibre piles were cut to size from the Palm fibre cloth. The appropriate numbers of fibre plies were taken: two for each. Then the fibres were weighed and accordingly the resin and hardeners were weighed. Epoxy and hardener were mixed by using glass rod in a bowl. Care was taken to avoid formation of bubbles. Because the air bubbles were trapped in matrix may
result failure in the material. The subsequent fabrication process consisted of first putting a releasing film on the mould surface. Next a polymer coating was applied on the sheets. Then fibre ply of one kind was put and proper rolling was done. Then resin was again applied, next to it fibre ply of another kind was put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until eight alternating fibres have been laid. On the top of the last ply a polymer coating is done which serves to ensure a good surface finish. Finally a releasing sheet was put on the top a light rolling was carried out. Then a 20 kg weight was applied on the composite. It was left for 72 hrs to allow sufficient time for curing and subsequent hardening.

**Procedure**

1. Bottom layer of the Die is covered with the Aluminum foil sheet.
2. The Wax is applied on the Aluminum foil sheet it is used for easy removing of composites from foil sheet.
3. Then the mixture of epoxy resin and hardener is placed on the sheet and palm leaf fibres mate is dipped.
4. After that Male die is compressed for some times.
5. This process is repeated for others also.

**General Overview**

The composites sheets were fabricated from Natural fibre, with (Coconut/Palm) and resin matrix. The resin used was epoxy resin. The weight fraction of composites was maintained at 40% fibre and 60% resin. Number of plies for each fibre taken was two i.e. total number of plies used in hybrid composite are four. Four natural hybrid composites are made i.e. pure epoxy mat, untreated short palm fibre, Treated Coconut long fibre and Treated Palm long fibre fabrication cutting of the specimen is done in the desired shape to test the mechanical properties of the natural hybrid composite fibre. The tensile and flexural testing of the samples was done by UTM (universal testing machine). The Micro Hardness and Impact test has been conducted.

**Mixing Ratio’s**

For the preparation of the composite we calculate the percentage of fibres, polymer and hardener required from the table we come to know about the amounts accurately.

**Table: Mixing Ratios**

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Natural Fibre (%)</th>
<th>Epoxy (%)</th>
<th>Hardener (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>15+15</td>
<td>60</td>
<td>10</td>
</tr>
</tbody>
</table>

**Mould Preparation**

First of all the mould for the composite is prepared. We have to prepare moulds of size 200x200x5 mm for the preparation of required composite. A clean smoothed surfaced M.S iron is taken and the Die is made of two plates one is male Die and another is female Die in female die the mixture composites are poured by the hand Lay-Up method and Male die is covered at the top for 72 hours. We give a cover to the iron die with a non-reactive thin Aluminum foil sheet. Then the wax is applied on it due to easy removal of the Natural fibre fabricated. According to the ASTM Standards the various Samples cutted and this conducted.
Polymer-Hardener Mixture Preparation

For the making of good composite the measurement of the samples should be accurate and the mixture should be very uniform. We take accurate amount of polymer which we have calculated earlier and 10% of its hardener. Then this mixture is stirred thoroughly till it becomes a bit warm. Bit extra amount of hardener is taken for the wastage in the process. Hardener should taken very minutely because little extra amount of hardener can spoil the composite.

Casting

First of all mould release was spread all over the die it is the mixture Short natural fibre chemically treated composites. This sample is then left for 72 hours. The composite gets dried up in 72 hours in which the silk fibre and the polymers adheres itself tightly in the presence of hardener. After a day we put out the weights. Then carefully the nailed bits are removed from the Iron Die. Now we have the composite attached with the Aluminum foil sheet. The hardener has so strong effect that it attaches the sheet with the composite. This attachment is slowly and gently hammered on the boundary of its attachment when the aluminum sheet and the composite separate out. Then we see whether any undesired voids are left behind. We fill the voids with polymer and the sample is prepared.

Casting Samples

Experimental Procedure

Cutting of Laminates into Samples of Desired Dimensions

A Wire Hacksaw blade was used to cut each laminate into smaller pieces, for various experiments:

Tensile Test- Sample was cut into dog bone shape (150x10x5)mm.

Flexural Test- Sample was cut into flat shape (20x150x5)mm, in accordance with ASTM standards.

Flexural Test

Flexural strength is defined as a materials ability to resist deformation under load. The short beam shear (SBS) tests are performed on the composites samples to evaluate the value of inter-laminar shear strength (ILSS). It is a 3-point bend test, which generally promotes failure by inter-laminar shear. This test is conducted as per ASTM standard using UTM. The loading arrangement is shown in figure. The dimension of the specimen is (20x150x5) mm. It is measured by loading desired shape specimen (6x6-inch) with a span length at least three times the depth. The flexural strength is expressed as modulus of Kilo Newton (KN). Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by third-point loading is lower than the MR determined by center-point loading, sometimes by as much as 15%. The ILSS values are calculated as follows, Where, P is maximum load, b the width of specimen and t the thickness of specimen. The data recorded during the 3-point bend test is used to evaluate the flexural strength also. The flexural strength (F.S) of any composite material is determined using the following equation.

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 (150x10x5) mm. Typical points of interest when testing a material include ultimate tensile strength (UTS) or peak stress offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) Instron 1195 and results are analyzed to calculate the tensile strength of composites.

Flexural Test

Three point bend test was carried out in an UTM machine in accordance with ASTM standard to measure the flexural strength of the composites. All the specimens (composites) were of rectangular shape having dimension of (150x20x5) mm. The span length was 75mm. The experiment was conducted on all the four samples. The results are tabulated.

Table: Composition Ratio Table

<table>
<thead>
<tr>
<th>Sample</th>
<th>Natural fiber</th>
<th>Epoxy (%)</th>
<th>Hardener (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>15-15</td>
<td>60</td>
<td>10</td>
</tr>
</tbody>
</table>

Three point bend test was carried out in an UTM machine in accordance with ASTM standard to measure the flexural strength of the composites. All the specimens (composites) were of rectangular shape having dimension of (150x20x5) mm. The span length was 75mm. The experiment was conducted on all the four samples. The results are tabulated.
Table. Flexural Test. It is found that the flexural strength for long Coconut fibre 205N and Palm fibre 665N. Variation of force with extension in 3-point bend test.

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Gauge length (mm)</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
<th>Extension (mm)</th>
<th>Maximum load (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Epoxy</td>
<td>50.8</td>
<td>12.7</td>
<td>5</td>
<td>12</td>
<td>145</td>
</tr>
<tr>
<td>Untreated palm &amp; coconut core short fibre</td>
<td>50.8</td>
<td>12.7</td>
<td>5</td>
<td>12</td>
<td>155</td>
</tr>
<tr>
<td>Treated coconut long fibre</td>
<td>50.8</td>
<td>12.7</td>
<td>5</td>
<td>37</td>
<td>205</td>
</tr>
<tr>
<td>Treated Palm long fibre</td>
<td>50.8</td>
<td>12.7</td>
<td>5</td>
<td>3.8</td>
<td>665</td>
</tr>
</tbody>
</table>

**Tensile Test**

Tensile test was also carried out on UTM machine in accordance with ASTM standard. All the specimens were of dog bone shape of dimension (150x10x5) mm. The results are tabulated.

**Table. Tensile Test**

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Gauge length (mm)</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
<th>Extension (mm)</th>
<th>Maximum load (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Epoxy</td>
<td>60</td>
<td>13</td>
<td>5</td>
<td>9.3</td>
<td>495</td>
</tr>
<tr>
<td>Untreated palm and coconut core short fibre</td>
<td>60</td>
<td>13</td>
<td>5</td>
<td>13.1</td>
<td>590</td>
</tr>
<tr>
<td>Treated coconut long fibre</td>
<td>60</td>
<td>13</td>
<td>5</td>
<td>8.6</td>
<td>680</td>
</tr>
<tr>
<td>Treated Palm long fibre</td>
<td>60</td>
<td>13</td>
<td>5</td>
<td>4.3</td>
<td>785</td>
</tr>
</tbody>
</table>

**Ultimate Stress and Yield Stress:**

The following bar diagram shows the Ultimate stress value and Yield stress value of the various type of the natural fibre composites. By comparing and seeing the Chemically Treated Long Palm Fibre are having good stress values with both Ultimate stress and the Yield stress in the Tensile test. The Maximum Ultimate stress value is 14 N/mm² and The Maximum Yield stress value is 13 N/mm². The Palm fibre is having good Mechanical properties if we use this natural fibre it will have the good Stress values. The following Bar diagram shows the Elongation of the various type of the natural fibre composites. By comparing and seeing the Chemically Treated Long Palm Fibre is having less elongation percentage. The Palm fibre is having good Mechanical properties if we use this natural fibre it can able to withstand the good load capacity without elongation.

**Cost Analysis:**

<table>
<thead>
<tr>
<th>Element Description</th>
<th>Fiber</th>
<th>Resin</th>
<th>Fabrication</th>
<th>Cutting</th>
<th>Testing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost(INR)</td>
<td>200</td>
<td>2500</td>
<td>4000</td>
<td>300</td>
<td>3000</td>
<td>10000</td>
</tr>
</tbody>
</table>

**Conclusions**

1. The palm, coconut fibres was successfully used to fabricate natural composites with 40% fibre and 60% resin; these fibres are bio-degradable and highly crystalline with well aligned structure. So it has been known that they also have higher tensile strength than glass, good elasticity, and excellent resilience and in turn it would not induce a serious environmental problem like others.

2. The flexural strength of pure epoxy resins 145N with 15.5% elongation. With increase of fibre loading capacity by 20% (Untreated fibre), the flexural strength value increases to 155N with 21.833% elongation for untreated short palm fibre.

3. The tensile strength of epoxy is 495N with increase of fibre loading capacity by 20% the tensile strength increase will increases upon 590N for the untreated short fibre. So, it is clearly indicates that inclusion of natural fibres improves the load bearing capacity (Tensile strength) and the ability to withstand bending (flexural strength) of the composites.

4. In Flexural test for the treated multidirectional discontinuous coconut long fibre loading capacity is 205N less while comparing with the treated multidirectional discontinuous palm long fibre 655N.

5. In Tensile test for the treated multidirectional discontinuous coconut long fibre loading capacity is 680N less while comparing with the treated multidirectional discontinuous palm long fibre 785N.

6. From the impact test and the Micro hardness test it is clearly studies the hardness and strength of the composites.

7. By comparing the Flexural strength, Tensile strength, Hardness number and Impact test of the composites with varying Natural fibre, the best mechanical property results are obtained with treated multidirectional discontinuous palm long fibre combination.

**Acknowledgements**

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