ISSN (Online): 2455-7838
SJIF Impact Factor (2017): 5.705

EPRA International Journal of

Research & Development

(IJRD)

Monthly Peer Reviewed & Indexed
International Online Journal

Volume: 3, Issue:6, June 2018

Published By :
EPRA Journals

SJIF Impact Factor: 5.705 Volume: 3 | Issue: 6 | June | 2018 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)

EXPERIMENTAL INVESTIGATION OF MECHANICAL PROPERTIES OF BAMBOO-FLAX-SISAL FIBRE REINFORCED COMPOSITES

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ABSTRACT

This paper performs a systematic study of the extraction, preparation and mechanical behaviour of a fully continuous unidirectional bamboo-flax-sisal fibre-epoxy composite and cross ply bamboo-flax-sisal fibre-epoxy composite. In this work, the addition of bamboo fibre with the unidirectional (90°) oriented and cross plied (45°) oriented natural fibres has been analysed. The Flax (F), Bamboo (B), Sisal (S) fibres were arranged in continuous orientations and reinforced with Epoxy matrix. Mechanical properties like tensile strength, flexural strength, impact strength, hardness and torsion strength were evaluated and compared between two patterns of composite. The hardness properties of the cross plied pattern composite is increased when compared to unidirectional pattern.

KEYWORDS: *Unidirectional, Cross Plied, Mechanical Properties, Bamboo-Sisal-Flax*

1. INTRODUCTION

A composite is a material which is made up of two or more materials with significantly different properties. When they are combined they make a new material, with properties which are different to the original materials.

A Composite material is a material made from two or more constituent materials with significantly different physical and chemical properties that when combined, produce a material with characteristics different from individual components. There are two different types of constituent materials that make up a composite. They are matrix and reinforcement materials.Composites are usually made up of resins, reinforcements, fillers and additives. A bulk or resin material - known as a 'matrix' - acts as the 'glue' which holds the composite together and will play an important role in defining the property and characteristic of the final composite.

Fibre-reinforced composite materials consist of fibres of high strength and modulus embedded in or bonded to a matrix with distinct interfaces (boundaries) between them. In this form, both fibres and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. In general, fibres are the principal load-carrying members, while the surrounding matrix keeps them in the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages due to elevated temperatures and humidity, for example. Thus, even though the fibres provide reinforcement for the matrix, the latter also serves a number of useful functions in a fibre reinforced composite material.

Composites are fibre-reinforced used in a variety of products, applications and industries. While the term "composite" can apply to any combination of individual materials, that have been impregnated with a resin matrix. Combining fibres with resin matrix results in composites that are strong, lightweight, corrosionresistant and dimensionally stable. They also provide good design flexibility and high dielectric strength, and usually require lower tooling costs. Because of these advantages, composites are being used in a growing number of industries, such as recreational boating applications.

High-strength lightweight premium composite materials such as carbon fibre and epoxies are being used for aerospace applications and in high performance sporting goods. Composites superior electrical insulating properties also make them ideal for appliances, tools and machinery. Tanks and pipes constructed with corrosionresistant composites offer extended service life over those made with metals

Natural fibres have traditionally been used in all cultures of the world to meet basic requirements of clothing, storage, building material, and for items of daily use such as ropes and fishing nets. The application of composites has widely increased due to development of new fibres such as carbon, boron and aramids, and new composite systems with matrices made of metal and ceramics.

2. MATERIALS

2.1 Bamboo Fibre Extraction

The bamboo fibre is made from the starchy pulp of bamboo plants. This textile fibre is fabricated from natural bamboo and other additives. Bamboo fibre is a regenerated cellulose fibre, which is produced from bamboo pulp, processed from bamboo culms.There is a

limited knowledge regarding bamboo fibre extraction, only a few investigations have been done with different processes to define the mechanical properties and the usage of bamboo fibre as reinforced polymer composite.

Bamboo strips with the size of chips was soaked in 4% mass over volume of NaOH for 2 hours to influence on cellulosic and non-cellulosic parts. This method was repeated several time under a certain pressure for extracting fibre in the form of pulp. Soaked bamboo strips with the small size in sodium hydroxide for 72 hours to facilitate fibre extraction. extracted fibre by using different percentage of sodium sulphite, sodium silicate and sodium polyphosphate solution. Bamboo chips were dried for 30min at 150ºC and dipped in water at 60ºC for 24 hours and then dried in air. Later, the fibres were washed with hot water and then treated with xylanase. After, cooking and bleaching bamboo fibres, they were treated in sulphuric acid solution. The size of obtained fibre was 2.5mm.

2.2 Flax Fibre Extraction

Flax is the most strongest among the natural cellulosic fibres. It is a bast fibre. Flax fibre is extracted from the skin of the stem of the flax plant. Flax fibre is soft, and flexible bundles of fibre have the appearance of blonde hair.Processing Bundles are kept side by side horizontally and immersed in water 20-25 cm deep with bamboo or stoned or wooden logs. The retting process is completed within three days (72 hours). Clostridium bacteria are associated with the soil of stem and help in early retting of bundles. After three days the bundles are washed thoroughly with fresh water. After washing, these bundles are stand on ground for sun drying.

2.3 Sisal Fibre Extraction

Sisal Fibre is one of the most widely used natural fibre and is very easily cultivated. It is obtain from sisal plant. It is highly renewable resource of energy. Sisal fibre is exceptionally durable and a low maintenance with minimal wear and tear. Sisal (*Agave sisal Ana*) is an agave that yields a stiff fibre traditionally used in making twine, rope and also dartboards. (The term may refer either to the plant or the fibre, depending on context.) Traditionally used for rope and twine, sisal has many uses, including paper, cloth, wall coverings and carpets. The sisal plant has a 7-10 year life-span and typically produces 200-250 commercially usable leaves. Each leaf has an average of around 1000 fibres. The fibres account for only about 4% of the plant by weight. Sisal is a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine. Each leaf contains a number of long, straight fibres which can be removed in a process known as decortication. During decortication, the leaves are beaten to remove the pulp and plant material, leaving the tough fibres behind.

Fibre name	**Cellulose (%)**	**Lignin (%)**	**Hemi-cellulose (%)**
Bamboo	26-65%	20 to 31%	30%
Flax	71%	2.2%	18.6 to 21.6%
Sisal	78%	12.1%	27.5%

Table 2.1 Chemical Composition Of Fibres

Properties	**Bamboo fibre**	**Flax fibre**	**Sisal fibre**
Density (kg/m^3)	1100	1540	1450
Flexural strength(MPa)	32	165	286.8
Tensile strength(MPa)	800	1450	700
Young's modulus(GPa)	32	80	38
Elongation of break (%)	23.8	2.2	22.5

Table 2.1 Physical And Mechanical Composition Of Fibres

2.4 Epoxy Resin

Epoxy resin is a member of the epoxy oligomer class. It forms a three dimensional structure when it reacts with the hardener or curing agent. It is possible to change the properties of the epoxy resins with different epoxy oligomers and by choosing various curing agents. The resin system holds everything together, and transfers mechanical loads through the fibres to the rest of the structure. The blending ratio of the resin with the hardener is 10:1 by weight. The most commonly used thermosetting resins are: Polyester, Epoxy, Vinyl ester.

These resins are thermosetting polymers and are used as adhesives, high performance coatings and potting and encapsulating materials. These resins have excellent electrical properties, low shrinkage, good adhesion to many metals and resistance to moisture, thermal and mechanical shock. Viscosity, epoxide equivalent weight and molecular weight are the important properties of epoxy resins. [Araldite (LY 556) epoxy resin]

Araldite, produced this new synthetic resin adhesive for bonding metals, glass, porcelain, china and other materials. Araldite adhesive sets by the interaction of a resin with a hardener. Heat is not necessary although warming will reduce the curing time and improve the strength of the bond. After curing, the joint is claimed to be impervious to boiling water and all common organic solvents.

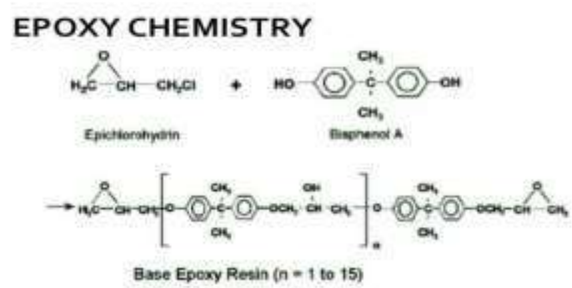

Fig 2.1 Chemical Formula For Epoxy

2.5 Preparation Of Composite

The fibres are chopped in required length to prepare the composite.

Fig 2.2(a) Bamboo **Fig 2.2(b) Sisal** **Fig 2.2(c) Flax**

The hybrid composites are prepared by the compression mould technique in vertical alignment method and diagonal method. A Premium quality gel (polyester gel) is applied on the mouldsurface,the gel application is must ,as it helps in demoulding composite after the reinforcement process is done.The fibres are placed in mould and resin is poured. Resin should be mixed with hardener in correct proportions and then it is poured in mould.The composites were prepared based on weight percentage in the ratio of 30:70(fibre: matrix).During the composite preparation the air bubbles are removed carefully by using a roller.The mold is closed and then it is placed on the hydraulic press, a compressive pressure (2 bar) is applied for 12 hours over the mold at the atmospheric temperature.

Fig 2.3 Making Of Composite In Closed Moulding

Fig 3.9(a) Final Product Of Unidirectional Ply

Fig 3.9(b) Final Product Of Cross Ply

3. MECHANICAL TESTING

3.1 Hardness Testing

The Rockwell hardness test method, as defined in ASTM E-18, is the most commonly used hardness test method.The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force is applied to a Laminate using a diamond or ball indenter.This preload breaks through the surface to reduce the effects of surface finish.

After holding the preliminary test force for a specified dwell time, the baseline depth of indentation is measured. Hardness testing is often used for material assessment, in research and development work, and in quality control of production processes. It indicates the properties of a material such as wear resistance, ductility, and strength.

Fig 3.1 Hardness Testing Machine

Fig 3.2 Specimen After Hardness Test

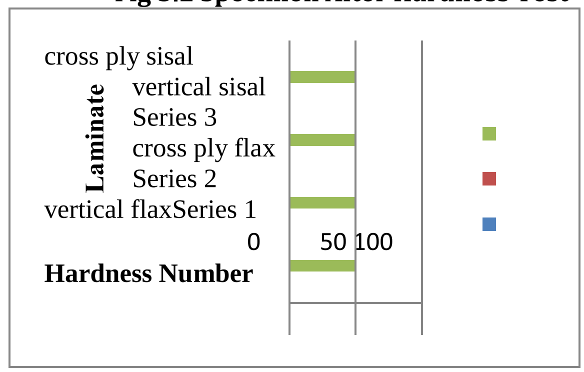

Fig 3.3 Hardness Number With Respect To Orientation Of Composite.

The result says that this cross plied composite(94 HRB) which contains higher hardness number amd higher wear resistance when compared to aluminium (86 HRB). So the aluminium will be replaced with this composite material.

3.2 Tensile test

Specimens are placed in the grips of a Tensile Test Machine at a specified grip separation and pulled until failure. A typical test speed for standard test specimens is 2 mm/min.According to ASTM D3039 the standard specimen size for tensile testing is 10mm × 25mm × 250mm. Tensile properties such as tensile strength, tensile (elastic) modulus and elongation at break for the composites are measured based on the ASTM D 638 standards. The required specimens are cut into a standard size of 165mmX13mmX5mm for a gauge length of 50 mm. The electronic tensometer setup is used to perform the tensile testing with a cross-head speed of 1 mm/min using the load cell of 5 KN. The results are standardized based on the five identical test specimens, which are utilized for each testing. The tensile testing machine is shown in Figure.

Fig 4.1 Tensile Testing Machine

Fig 4.2 Specimen Tested Under Tensile load

Type of fibre	Tensile strength (MPa)	Tensile modulus (GPa)	Strain at break (%)
Unidirectional ply	43.97	2.40	1.67
Cross ply	48.60	2.63	2.04

Table 3.1 Tensile Strength And Tensile Modulus Of F/B/S Composite

The characteristics statistical parameters for tensile strength and tensile modulus of the raw and treated fibres are reported in table. It is observed that the values of both tensile strength and tensile modulus of cross plied composite is greater than uni directionally plied orientation. Finally this composite will replace the application of wood because of wood contains lesser tensile strength (40Mpa) when compared to F/B/S composite. Although the making of composite is higher in cost they will withstand more then the wood.

4. CONCLUSION

In this present work the bamboo, flax, sisal are chopped into required length to prepare the tri-laying pattern of polymer composite(F/B/S) using compression moulding technique and the following conclusion are made based on the extensive experimental work.

The average percentage of improvement between the (F/B/S) cross ply pattern to unidirectional pattern is 5.6% in tensile strength and 2.2% in tensile modulus respectively.

The average percentage of improvement in hardness between (F/B/S) cross ply pattern to unidirectional pattern is 26%. The hardness values are (94,86), (71,82) is cross ply and unidirectional respectively.

The variation between cross ply and unidirectional ply is lesser in amount, but the cross ply pattern has more capacity to withstand under the above mentioned test process. So here we concluded that the cross ply has more capacity then the unidirectional pattern. The cross plied composite will be the better replacement for aluminium when compared to its hardness property and then replaced with wood due to the higher tensile property when compared to the wood.

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