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ANALYSIS OF MECHANICAL PROPERTIES OF NATURAL AND SYNTHETIC FIBRE REINFORCED POLYMER MATRIX COMPOSITES

Eazhil.K.M [1]
Mechanical Department, SNS College of Engineering, Coimbatore, T.N, India

Saravana Priyan.G [2]
Mechanical Department, SNS College of Engineering, Coimbatore, T.N, India

Sathish.S [3]
Mechanical Department, SNS College of Engineering, Coimbatore, T.N, India

Sugan Rajpandi.N [4]
Mechanical Department, SNS College of Engineering, Coimbatore, T.N, India

Sundara rajan.S [5]
Mechanical Department, SNS College of Engineering, Coimbatore, T.N, India

ABSTRACT

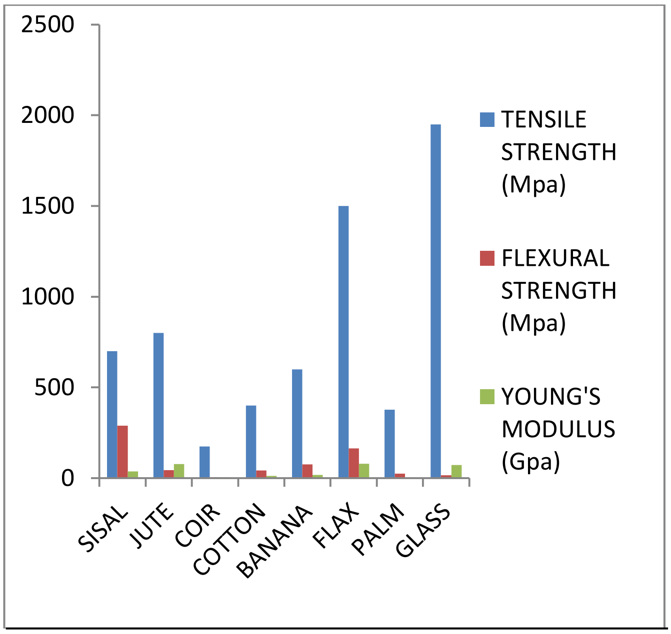
In this work, the effect of glass fibre hybridization with the randomly oriented natural fibres has been analyzed. The banana (B), sisal (S), coir(C) fibres were arranged in continuous unidirectional and rowing pattern orientations and woven E-glass (G) synthetic fibres were reinforced with epoxy matrix. Mechanical properties like tensile strength, flexural strength, impact strength, hardness were evaluated and compared. Interfacial analysis was also carried out with the help of Scanning Electron Microscope (SEM) to study the micro structural behaviour of the tested specimen .Experiments are carried out as per ASTM standards to find the mechanical properties etc.. The flexural properties were enhanced on banana-sisal-coir fibres with two layers of glass fibre rather than three layers and the laminate with sisal and three glass ply offers better impact strength.

KEYWORDS: *Natural And Synthetic Fibres , Hybrid Composites ,Mechanical Properties ,Polymer Composites.*

1. INTRODUCTION

A composite material is composed of at least two materials, which combine to give properties superior to those of the individual constituents. Now a days conventional material for the medium load applications are replaced by the composite materials. The composite materials are commonly used in an automobiles, packaging industries, aerospace ,construction and so on. Fibre reinforced polymer (FRP) composites, usually with carbon, glass, polymer or natural fibres embedded in a polymer matrix. Natural fibres are found with intellectual properties like less weight, low density, eco-friendly, high specific strength etc. However, it has some of the disadvantages like poor surface characteristics, more moisture absorption, quality variations ,etc [1]. The tensile load carrying capacity of the natural fibre reinforced composites are found to be increasing with the fibre content up to an optimum level and then start declining

[2]. In the automotive industry, synthetic fibre is important for making body kits. The body shell for a car is made up of different layers of glass fibre, such as a gel-coat layer, tissue layer, matting and cloth. It gives characteristics like waterproof, lightweight and strong body kit. Glass fibre can also be a less expensive alternative to other materials. [3]. It is to be suggested that the glass fibre can be used for fabrication of light weight components used in housing sector,automobile body building, packaging industry, partition panels,etc [4]. Banana empty fruit bunch fibre is better in tensile strength than the neat polyester resin and it can be used in industrial applications such as partition panels and packaging [5]. Better mechanical properties on the sisal fibres are obtained with the particle reinforcement rather than short and long fibres reinforced composites [6]. Attention on the irregular surface area of the sisal fibres was significant in the measurement of tensile properties and Young's modulus value does not vary with respect to gauge length [7]. The surface treated sisal fibres improves
the mechanical properties by enhancing adhesion between the sisal fibres and matrix as well as between cells [8]. Coconut husk which is the principle source for the coir fibre were collected from locally available waste bunch of the coconut fruit. All the various chemicals used for extraction of the fibre are $NaClO_2$, NaOH and oxalic acid are of analytical grade obtained from Nice chemicals Cochin, India .The chemicals used are in mild concentration to accomplish the environmental friendliness. [9].A revealed that moisture absorption characteristics of the sisal fibre polypropylene composites induces the tensile strength starts to decline from the starting period of immersion and impact strength to increase initially followed by declining later As single natural fibre composites are not having sufficient strength to replace the conventional materials, the hybrid combinations of natural fibres are preferred. The mechanical and thermal properties of the jute fibre reinforced epoxy composite are found to be increased with the addition of banana fibre up to 50% by weight [10]. With the combination of banana and sisal fibre, fibre length and weight percentage are the major factors in deciding the mechanical properties [11] and in another study, banana and sisal fibre with 50:50 weight percentage showed maximum tensile strength along with 40% weight fraction of total fibre content [12]The incorporation of the glass fibres with the natural one notably enhanced the mechanical properties of the composites. Incorporation of glass fibre up to 15% by mass with 20% bananafibre improved the tensile and flexural modulus by 5-15% respectively [13]. Addition of glass fibre as extreme plies in the coir fibres considerably improved the flexural and interlaminar shear properties [14]. In another study, unidirectional glass and natural fibre composites showed superior interlaminar shear strength than the glass fibres and tensile properties can be enhanced with the addition of glass fibres [15]. The performance on tensile and flexural properties of the sisal fibre polypropylene composites with polypropylene grafted with maleic anhydride (PP-g-MA) as a compatibilizer are found to be increased with glass fibre hybridization [16]. Banana and coir fibre combination with the glass fibre exhibited better flexural properties and its mechanical properties are much affected by fibre orientation in the laminates [17].Glass fibre reinforced polymer composites can be replaced with the hybrid combination of sisal-coir-banana with glass ply[18]. There is a small work have been done on the impact of stacking sequence and addition of glass fibres with two or more natural fibres[19]. Hence, the present study is mainly focused on the influence of various stacking sequences on mechanical properties of hybrid combination of sisal ,coir ,banana and glass fibres. [20]



By above column chart, we concluded that on comparing several fibres, the availability of coir ,and banana is comparatively large while sisal and glass places next to them. They are to be economically affordable to our investment. so in our project **Banana, Coir, Sisal And Glass Fibres** are to be chosen and used as raw materials.

2. METHODOLOGY

2.1. Materials

2.1.1. Sisal Fibre And Its Extraction

Sisal (Agave sisalana) plants are more familiar with the tropics and sub tropics region as they can grow better at a temperature of more than 25ºC. These plants consist of sword shaped leaves of normally 1.5 m length and a typical plant produces around 150 leaves during its life span of 6 years. It contains about 500–800 fibres, which are normally used to make ropes, carpets etc. The matured leaves standing at an angle of more than 45_ to the upright of the plant are cut. The next stage in which the leaves are initially crushed by the rollers of rounded knife edges followed by repetitive beaten is called decortication. During this process, the fibres are extracted by squeezing out the pulpy content of the leaf. Finally the fibres are dried in sunlight for 3–4 days after washing them in clean water to remove the dusts and unwanted contents in it.

2.1.2. Banana Fibre And Its Extraction

The banana fibres are extracted from the pseudo stem of the banana plant (Musa species). These are growing up to 5–10 feet depending upon the region and climatic conditions. The length of the stalk depends upon the height of the plant and its width is about 3–5 cm with a thickness of 1–2 cm. The fibres are located at the outer sheath of the stalk. The qualified stalk of the plant is
cut to a length of 100 cm and its outer sheath is removed. Then these sections are crushed between two roller drums with scraping blades at its circumference to remove the pulpy material between the fibres. The process of stripping the fibres from the stalk is known as tuxies. Finally the fibres are completely cleaned in water to remove the waste materials and then dried in sunshine for a few days to remove the moisture content.

2.1.3. Coir Fibre And Its Extraction

Coir fibre is extracted out of the husk (mesocarp) of a coconut, the fruit of a coconut palm (Cocos nucifera L.) which is grown extensively in tropical countries. Fibres can be extracted from unripe nuts and are then called 'white coir', while 'brown coir' is extracted after ripening of the coconut. The colour of the fibres depends however also on the coconut palm species, the extraction method and eventually the time between retting and extracting Coir fibres have to prevent the nut from breaking when it falls out of the tree whereby the strength of the fibres is not as important as the energy absorption at impact. Coir fibres have a low cellulose content (32–53%) and a big micro febrile angle (30–49) [1,16] what makes that these fibres have a low strength, a low modulus of elasticity and a high strain to failure (leading to a higher impact energy at failure).

2.1.4. E-Glass Fibre

E-Glass fibre is one of the most commonly used synthetic fibres, manufactured with the raw materials such as limestone, silica, clay, fluorspar, and dolomite. These ingredients are melted and extruded through bushings which have multiple small orifices to obtain filaments. The extruded filaments are coated with chemicals to obtain required size. The filaments are wounded together to form roving. The diameter of the filaments and the number of filaments in a roving determine its weight. The E-Glass fibre selected for this work is E-Glass woven roving of 400 gsm.

2.1.5. Epoxy

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
Phenolic
Vinyl ester

2.2. Composite Preparation

The composite laminates for this work were fabricated by **Hand Lay-Up** method. Initially, the qualified sunlight dried banana (B), sisal (S) and coir (C) fibers are segregated and chopped. two different kinds of laminates were prepared with stacking sequences

G/S/C/B/G (Laminate 1)
G/S/C/B/G (Laminate 2)

as shown in below Fig 1 & Fig 2.

Figure.1

Figure.2

In Fig.1 the laminates are to be arranged in unidirectional orientation pattern. Each fibre twigs are to be placed in 90º angle position.

In Fig.2 the laminates are to be arranged in rowing or diagonal orientation pattern. Each fibre twigs are to be placed in 45º angle position.

Composite preparation using HAND LAY-UP Method (GLASS-BANANA-COIR-SISAL-GLASS)

Table.1
Physical properties of banana, sisal and coir fibre

Properties	Banana fibre	Sisal fibre	Coir fibre	Glass fibre
Density (kg/m^3)	1350	1450	1250	2720
Flexural modulus(GPa)	4	13.5	76.68	12.4
Tensile strength(MPa)	56	67	48.2	3445
Young's modulus(GPa)	3.5	3.7	3.79	80
Elongation of break (%)	2.6	2.4	40.95	25.4
Celloluse(%)	62	66	37	80
Hemi celloluse(%)	18	13	20	23
Lignin (%)	5	10	42	20
Moisture content(%)	11	10	10.1	20

The weighted quantity of banana, sisal, coir, glass fibers and the epoxy resin were taken, the appropriate hardness also selected to fabricate the composites. The dimension of the composite materials are used in the present work was 30×30×1 cm. This had to be placed over the fixed bottom jaw after placing a polythene sheet over it to avoid deposition of squeezing resin during the process. The mixture of epoxy resin with the hardener was applied to the tray, and then it was followed by the uniform deposition of the natural fiber premixed with a predetermined percentage of the resin mixture on the tray according to the laminates needed. Finally the resin was applied at the top before compressing the laminates for about 200 Kg capacity. The pressure was applied gradually to ensure uniform distribution of resin throughout the laminate and also to remove the entrapped air. The laminate was kept under constant pressure for about nearly 8 hrs to guarantee absolute curing. The weight percentage of natural fibers, E-glass fibers, epoxy resin mixture and the laminate was measured to calculate the weight and the volume fraction of the fibers listed in Table 2. After acquiring the compressed laminate from the compression molding machine, the burs on the rough edges were cut by using saw cutter and emery sheets were used to remove the rough edges

Table.2
weight and volume fraction of natural and hybrid laminates

laminate	Orientation	Fibre (Wt.%)				Fibre (vol.%)			
		B	S	C	G	B	S	C	G
Laminate 1	uni directional	9	10	8	12	8	8	6	10
Laminate 2	Rowing	9	10	8	12	8	8	6	10

2.3. Mechanical testing

2.3.1. Tensile test

The ability of the material to stretch without breaking is termed as tensile strength. The tensile strength of the laminate was measured by the ASTM standard (American Society for Testing and Materials) ASTM: D3039. The specimen should ensure that the breakage should occur in the expected region and its necessity depends on the localization of the breakage. The ends of the specimen were clamped between the jaws. The movement of the jaw offers tensile force on the specimen. This force was recorded with respect to the change in gauge length. The tensile test was done on the FIE make Universal Testing Machine (UTM – Model UTE 40 with maximum load capacity of 400 kN). The samples were tested at a loading rate of 5 mm/min. Specimen which was cut from the three different types of laminates were subjected to tensile test for five samples er laminate to get an average value.

Tensile test specimen composite material


Test Certificate
OMEGA INSPECTION AND ANALYTICAL LABORATORY,
COIMBATORE.
Material : Fiber Reinforced Composite
Sample ID : Diogonal Orientation
Machine : Universal Testing Machine
Sample Type : Rectangular Bar
Width : 10.13 mm
Thickness : 10.21 mm
Gauge Length : 25 mm
Results of Tension Test
Maximum Force (Fm) : 1.440 kN
Disp. at Fm : 13.000 mm
Tensile Strength (Rm) : 13.923 MPa
Graph : Load Vs Displacement

Rowing fibre laminate arrangement specimen tensile test report

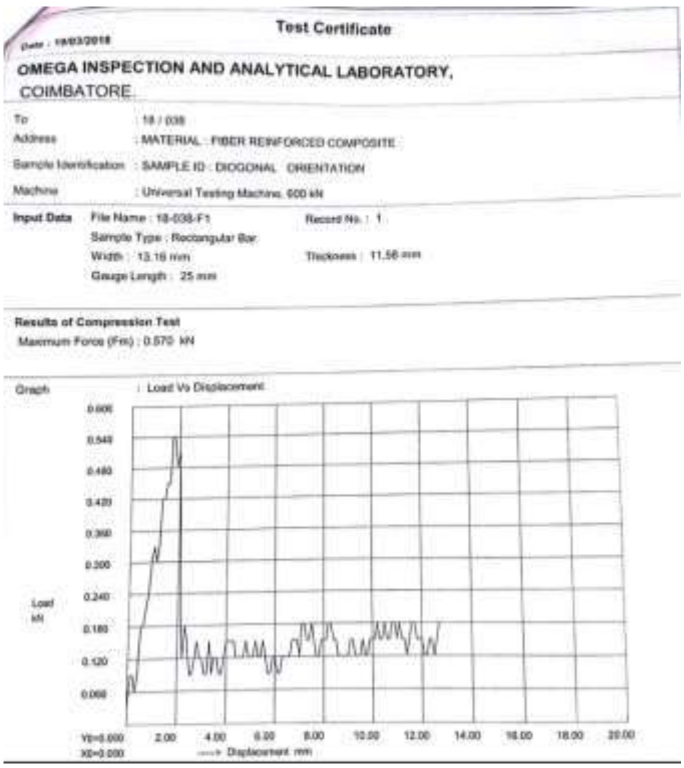

Test Certificate
OMEGA INSPECTION AND ANALYTICAL LABORATORY,
COIMBATORE.
To : 18 / 038
Address : MATERIAL : FIBER REINFORCED COMPOSITE
Sample Identification : SAMPLE ID : VERTICAL ORIENTATION
Machine : Universal Testing Machine, 600 kN
Input Data: File Name : 18-038-T2; Record No. : 1
Sample Type : Rectangular Bar; Area : 95.237 mm²
Width : 11.01 mm; Thickness : 8.65 mm
Gauge Length : 25 mm
Results of Tension Test
Maximum Force (Fm) : 3.900 kN
Disp. at Fm : 4.200 mm
Tensile Strength (Rm) : 40.951 MPa
Graph : Load Vs Displacement

Uni-Directional fibre laminate arrangement specimen tensile test report

2.3.2. Flexural test

A flexural test imposes tensile stress on the convex side and compressive stress on the concave side of the specimen which causes a shear stress along the center line. It measured the force required to bend the beam. The flexural test was performed on the OMEGA UTM. The geometrical dimension of the nominal specimen was made according to the standard ASTM: D790. The specimens were placed between two supports at a distance of 50 mm and the load was applied at the center which is called as three point bending test. The load was applied at a rate of 5 mm/min till the specimen fractures and breaks.The maximum load at failure was used to calculate the flexural stress.

Flexural test specimen composite material



Test Certificate

Date : 19/03/2018

OMEGA INSPECTION AND ANALYTICAL LABORATORY,
COIMBATORE.

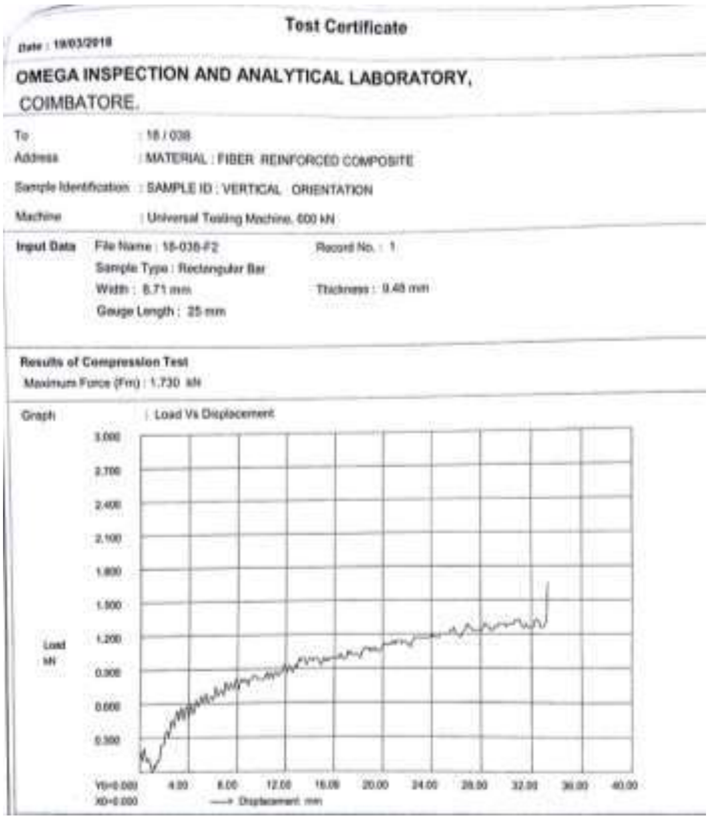
To : 18 / 038
Address : MATERIAL : FIBER REINFORCED COMPOSITE
Sample Identification : SAMPLE ID : DIOGONAL ORIENTATION
Machine : Universal Testing Machine, 600 kN

Input Data
File Name : 18-038-F1 Record No. : 1
Sample Type : Rectangular Bar
Width : 13.16 mm Thickness : 11.56 mm
Gauge Length : 25 mm

Results of Compression Test
Maximum Force (Fm) : 0.570 kN

Graph : Load Vs Displacement

Rowing fibre laminate arrangement specimen flexural test report



Test Certificate

Date : 19/03/2018

OMEGA INSPECTION AND ANALYTICAL LABORATORY,
COIMBATORE.

To : 18 / 038
Address : MATERIAL : FIBER REINFORCED COMPOSITE
Sample Identification : SAMPLE ID : VERTICAL ORIENTATION
Machine : Universal Testing Machine, 600 kN

Input Data
File Name : 18-038-F2 Record No. : 1
Sample Type : Rectangular Bar
Width : 8.71 mm Thickness : 9.48 mm
Gauge Length : 25 mm

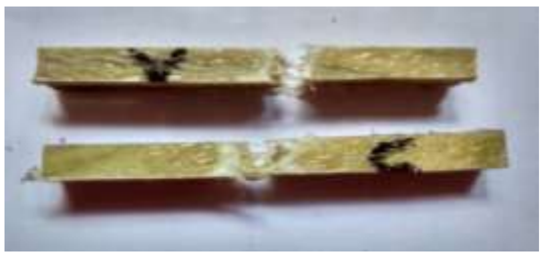
Results of Compression Test
Maximum Force (Fm) : 1.730 kN

Graph : Load Vs Displacement

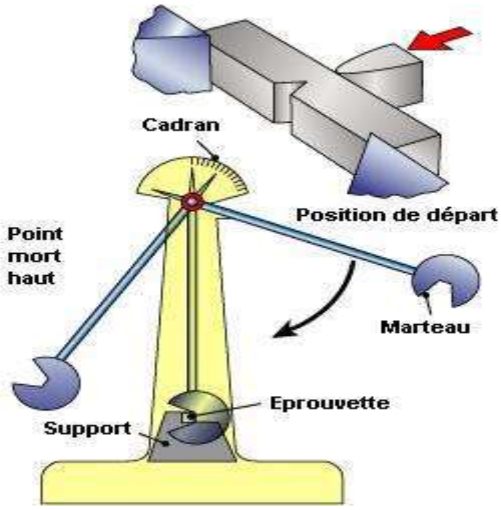
Uni-Directional fibre laminate arrangement specimen Flexural test report

2.3.3. Impact test

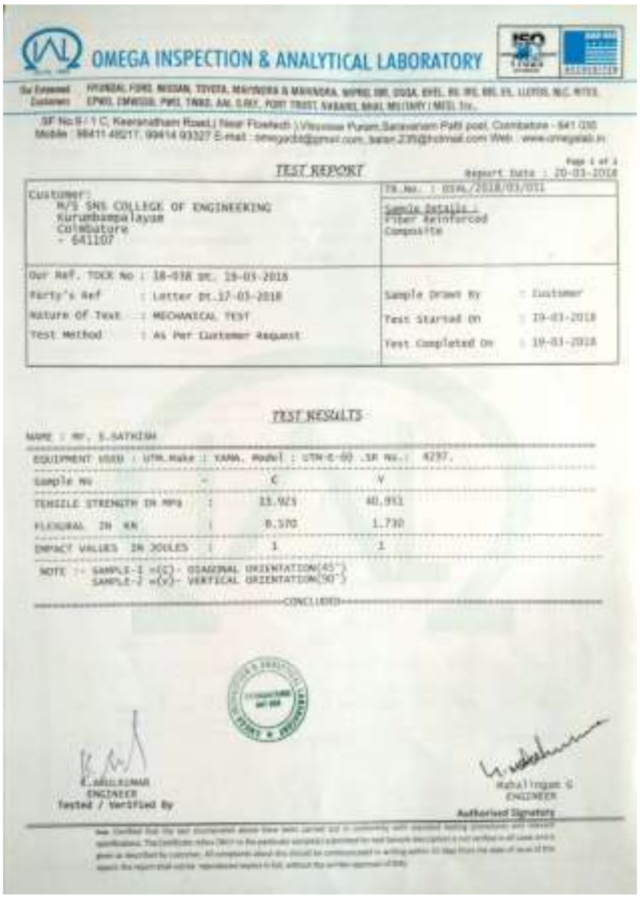
The capability of the material to withstand suddenly applied load is its impact strength. The impact strength of the laminates was tested by Charpy impact test rig. This test measured the kinetic energy needed to initiate the fracture and to continue until the breakage of specimen. The standard dimension for the Charpy test is ASTM: D4812. The test specimen was kept vertically with the help of grippers and the pendulum was blown from one side which strokes it with kinetic energy. The energy absorbed by the material before it fractured is recorded on the scale which was used to measure the toughness and ductility.



Impact test specimen composite material



Charpy impact test values up to 1Joules for test specimen


OMEGA INSPECTION & ANALYTICAL LABORATORY

SF No 9 / 1 C, Keeranatham Road, Near Flowtech, Vilgiri Puram, Saravanam Patti post, Coimbatore - 641 035

TEST REPORT

Page 1 of 1
Report Date : 20-03-2018

Customer:
M/S SNS COLLEGE OF ENGINEERING
Kurumbampalayam
Coimbatore
- 641107

Sample Details :
Fiber Reinforced Composite

Our Ref. TOCK No : 18-038 Dt. 19-03-2018
Party's Ref : Letter Dt.17-03-2018
Nature Of Test : MECHANICAL TEST
Test Method : As Per Customer Request

Sample Drawn By : Customer
Test Started On : 19-03-2018
Test Completed On : 19-03-2018

TEST RESULTS

NAME : MR. S.SATHISH

EQUIPMENT USED : UTM.Make : YANA, Model : UTM-E-60 .SR No.: 4297.

Sample No	C	V
TENSILE STRENGTH IN MPa	33.925	40.951
FLEXURAL IN KN	0.570	1.730
IMPACT VALUES IN JOULES	1	1

NOTE :- SAMPLE-1 =(C)- DIAGONAL ORIENTATION(45°)
SAMPLE-2 =(V)- VERTICAL ORIENTATION(90°)

CONCLUDED

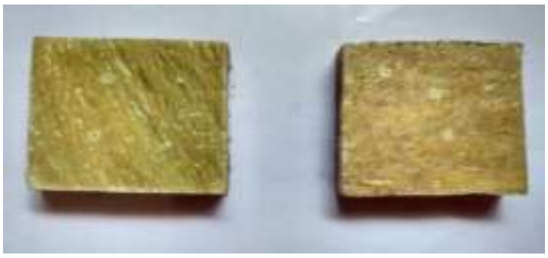
Tested / Verified By

Authorised Signatory

Overall test results for Tensile, Flexural and impact tests for our composite specimen

2.3.4. Hardness Test

The Rockwell hardness number represents the additional depth to which a test ball or sphere-conical penetrator is driven by a heavy load beyond the depth of a previously applied light load. The load carry out from hardness test is 150kg. Top hardness numbers that are obtained from hard materials indicate a shallow indentation while low numbers found with soft materials indicate deep indentation. The standard dimension for the hardness test is ASTM : D785.The increment of penetration depth for each point of hardness on the Rockwell mount is 0.00008 inch. For example, if a piece of steel measures Rockwell C 58 (extremely hard) at same point and C 55 at another, the depth of penetration would have been 0.00024 inch deeper at the softer spot



Hardness test specimen composite material

Unidirectional fibre arrangement pattern	**Glass-Sisal**	**Glass-Banana**
Rockwell Hardness	**51B**	**45B**
Loadapplied-150kg/f	**40B**	**68B**
1/8''ball indenter	**71B**	**56B**
	70B	**73B**

Rowing fibre arrangement pattern	**Sisal**	**Banana**
Rockwell Hardness	**68B**	**61B**
Loadapplied-150kg/f	**88B**	**47B**
1/8''ball indenter	**42B**	**42B**
	51B	**52B**

Hardness readings for Test specimen

2.3.5 SEM Analysis

SEM studies have been performed to study the failure analysis of the tested specimen. The region which has to be scanned is coated with a layer before inspection. The tensile test specimen image illustrates the fiber pullout characteristics of the glass fiber and fiber breakage of the banana and sisal fibers and it is shown in Fig. 1. From Fig. 2, it is observed that the hardness test specimen illustrates formation of the void between the fibers and matrix is greatly affecting the mechanical properties of the laminates.. In the charpy impact test specimen , crack formation is initiated at the micro level as depicted in Fig. 3.It has been observed that, the crack was mainly due to the inappropriate adhesion between fibers and matrix and the poor load transferring capacity between the fibers. The SEM image of the natural fiber with three alternate layers of natural fibres subjected to flexural test is as shown in Fig. 4. In hybrid combinations, the glass fiber plays a vital role in determining flexural properties. The majority of the load was absorbed by these fibers, after its failure the remaining load was transferred to the banana and sisal fibers. Fig. 5. The glass fiber alone shares some of the energy with the fibers in horizontal orientation as it was in woven form... Fig. 6.. From the above studies, it is evident that the presence of voids, improper adhesions between the fibers and matrix, fiber pull out are the major causes for the laminate failure

SEM ANALYSIS SPECIMEN

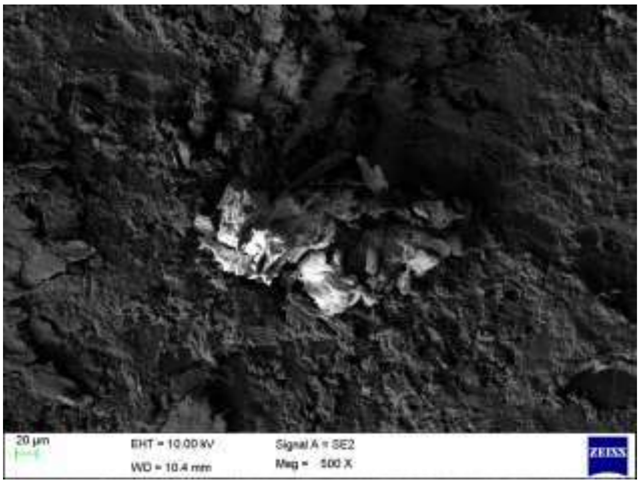


Fig-1: Fibre pullout in Tensile test specimen.

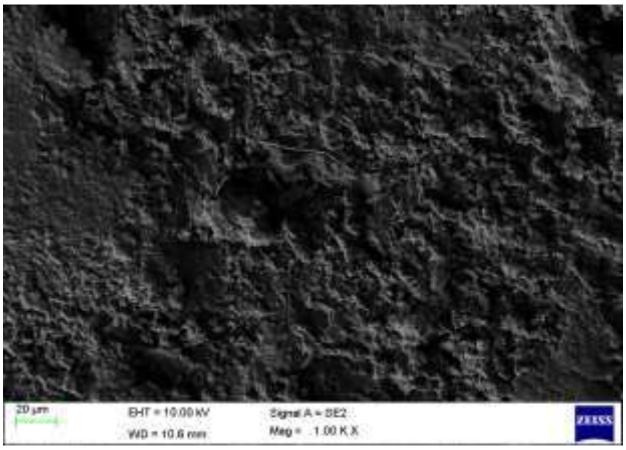


Fig-2 : Micro cracks in tested specimen

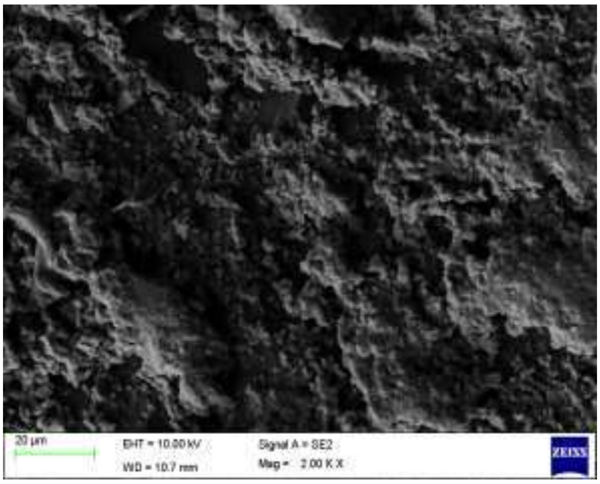


Fig-3 : Fibre breakage& discontinuity in tested specimen

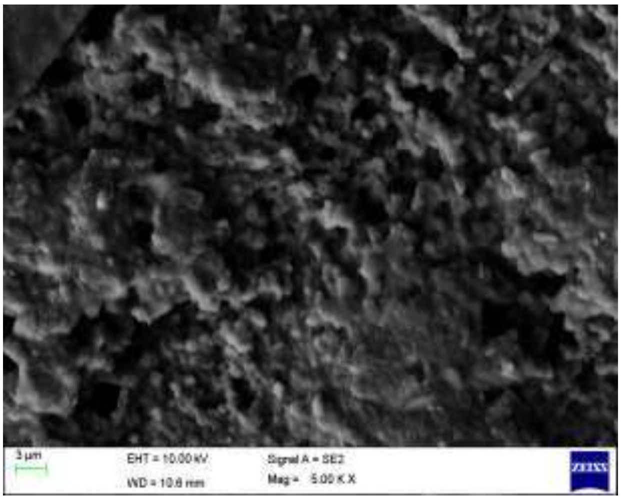


Fig-4: Improper Adhesions in tested specimen

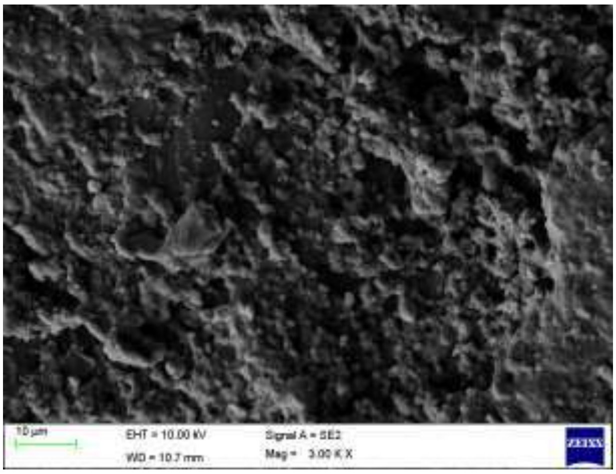


Fig-5: voids in tested specimen

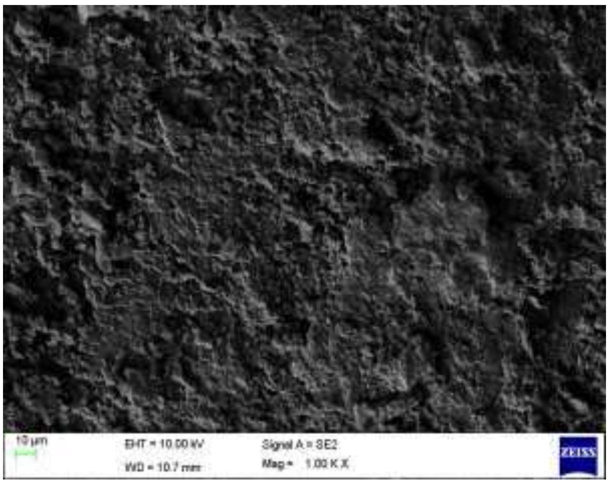


Fig-6: Laminate failure in tested specimen

SEM Interfacial Analysis image for tested specimen used in Tensile testing

From the observations, the hybrid composite laminates are showing moderate performance than the natural and synthetic fibre composites. Hence it is suitable for the medium load applications such as welding helmet, chair, table, roof, and automobile body panels.

3. CONCLUSION AND RESULTS

The mechanical properties of the hybrid combination of glass with banana, sisal and coir were studied in this work. The composites were fabricated by hand layup technique and tested according to ASTM standards. From the obtained results, the following conclusions are derived. It has been observed that the various properties of the composites are greatly influenced by the fibre loading and fibre length. From the ASTM mechanical property tests, a gradually increase in tensile, flexural and impact strength can be observed with the increase in the fibre length up to 15 mm of composites, Conversely, further increase in fibre length i.e. 20 mm there is a decrease in the strength properties. The hardness value increases with increase in fibre length. As far as the influence of fibre loading is concerned composites with 5wt% fibre loading shows enhanced hardness value as compared to 10wt%. The rate of moisture absorption increases with increase in both fibre loading and fibre lengths. The maximum water absorption rate is observed for composites with 10wt% fibre loading and at 20mm fibre length. The interfacial analysis (SEM) revealed that tensile, flexural and impact performances are affected by the factors such as poor adhesion between fiber and matrix, formation of micro cracks, presence of voids and fiber pullout.

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