Influence of Fiber Length on Mechanical Properties of Short Randomly Oriented TerminallaBellirica (TANI) Fiber Reinforced Polyster Composites

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Abstract
Fiber-reinforced composite materials are an important class of engineering materials that offer outstanding mechanical properties with flexibility in design and ease of fabrication. The advanced composites have the advantages of light weight, corrosion resistance, impact resistance and excellent fatigue strength.Today fiber composites are widely used in diverse applications such as automobiles, aircraft, containers and piping, sporting goods, electronics and appliances. These composites are fabricated using various reinforcing materials like glass fiber, carbon fibers, graphite, kevlar fibers, etc. These fibers are non-biodegradable and offer environmental problems in disposing the scrap. The present trend of development of any technology should comply with the sustainable development and preserve the biodiversity. In view of this global concern, natural fiber reinforced composites are being envisaged that offer least problems to the environment and at the same time offer new and better materials to the society. The materials and products developed using natural fibers will not only have enhanced properties compared to the conventional thermoplastics or complete wood based products but also will be cost effective. The use of green composite materials is predicted to have tremendous market potential because of the increasing awareness of environmental issues such as biodegradation, renewable resources, CO_2 emission reduction through promotion of plantations. The researchers are exploring the application of various natural fibers like sisal, jute, kenaf, palmyra, etc., with polyester and epoxy resins as matrix materials.
The present work is aimed to prepare the laminates using the fibers of Hibiscus lampas Telugu Vernacular name: Tani, botanical name TermialiaBellirica, fiber and Isopthalic Polyester Resins are used as the matrix materials. Mechanical properties like tensile, flexural strengths are evaluated as per ASTM standards.

Keywords
Composite Materials, Natural Fibers, Resins

I. Introduction

A composite is a structural material which consists of two or more constituents. These constituents are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the other is called the matrix.For a material to be composite conditions to be satisfied are: both constituents have to be present in reasonable proportions, composite properties are noticeably different from the properties of the constituents.

Fibers: The desirable characteristics of most reinforcing fibers are high strength, high stiffness and relatively low density. A great majority of materials are strong and stiffer in the fibrous form than as the bulk material. Therefore, fibers are very effective and attractive reinforcement materials.

Matrix: The matrix serves to bind the fibers together and transfer loads to the fibers and protects them against environmental attack and damage due to handling. Matrix has strong influence on the mechanical properties as well as on the selection of fabrication process.

A. Classification of Composites

The composites materials are classified based on the type of matrix material and the type of reinforcement used.

1. Based on Type of Matrix Material

(i). Polymer Matrix Composites (PMC)

The most common advanced composites are PMC. These composites consists of a polymer (e.g., epoxy, polyester, urethane) reinforced by thin diameter fibers (e.g., graphite, aramids, boron).

(ii). Metal Matrix Composites (MMC)

The matrix materials are: Aluminum, Magnesium, Titanium and the fibers are: Carbon, Silicon carbide. Metals are mainly reinforced to increase elastic stiffness and strength, decrease large coefficient of thermal expansion and electrical conductivities.

(iii). Ceramic Matrix Composites (CMC)

The matrix materials are: Alumina (Al_2O_3), Calcium alumino silicate and the fibers are: Carbon, Silicon carbide (SIC).

2. Based on Type of Reinforcement

(i). Particle Reinforced Composites

These composites consist of particles immersed in matrices such as alloy and ceramics as shown in fig. 1. The shape of reinforcing particles may be spherical, cubic or any regular or irregular geometry.

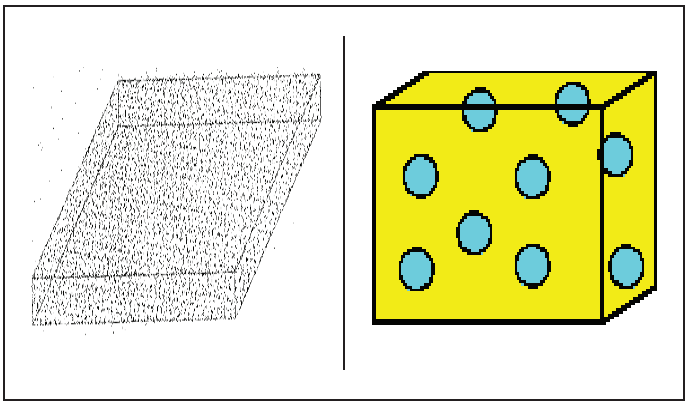

Fig. 1: Particle Reinforced Composites

(ii). Fiber Reinforced Composites

These composites consist of matrices reinforced by short (discontinuous) or long (continuous) fibers as shown in fig. Generally these are anisotropic.

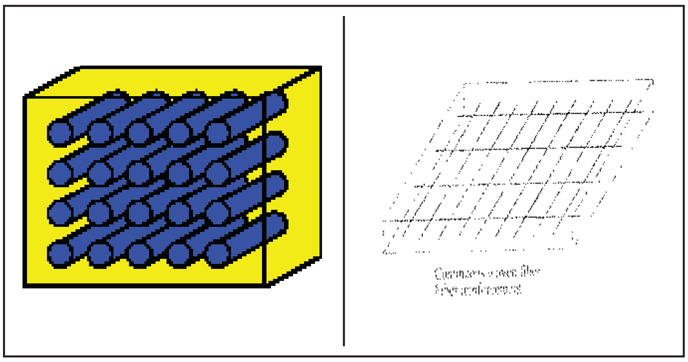

Fig. 2: Fiber Reinforced Composites

B. Natural Fiber Composites

With the increased knowledge about the nature and its resources, the humans have developed more and more skills in its exploitation. They started creating faster machines, bigger toys, without due consideration to the effects on the environment or on the people. This article reiterates the historical applications and the present day need for their renewed usage for sustainable development, the development that meets the needs of the present without compromising the ability of the future generations to meet their own needs.

C. Structure and Chemical Composition of Natural Fibers

All plant species are built up of cells. When a cell is very long in relation to its width it is called a fiber. The components of natural fibers are cellulose, hemicelluloses, lignin, pectin, waxes and water-soluble substances. The cellulose, hemicelluloses and lignin are the basic components of natural fibers, governing the physical properties of the fibers. The principal chemical constituents of fibers from various plant fibers are shown below in Table 1.

Table 1: Chemical Composition, Moisture Content and Microfebrile Angle of Vegetable fibers

Fiber	Cellulose (Wt%)	Hemicellulose (Wt%)	Lignin (Wt%)	Pectin (Wt%)	Moisture (Wt%)	Waxes (Wt%)	Microfibrillar angle (deg)
Flax	71	18.6-20.6	2.2	2.3	8-12	1.7	5-10
Hemp	70-74	17.9-22.4	3.7-5.7	0.9	6.2-12	0.8	2-6.2
Jute	61-71.5	13.6-20.4	12-13	0.2	12.5-13.7	0.5	8
Kenaf	45-57	21.5	8-13	3-5	-	-	-
Ramie	68.6-76.2	13.1-16.7	0.6-0.7	1.9	7.5-17	0.3	7.5
Nettle	86	-	-	-	11-17	-	-
Sisal	66-78	10-14	10-14	10	10-22	2	10-22
Henequen	77.6	4-8	13.1	-	-	-	-
PLAF	70-82	-	5-12.7	-	11.8	-	14
Banana	63-64	10	5	-	10-12	-	-
Abaca	56-63	-	12-13	1	5-10	-	-
Oil palm EFB	65	-	19	-	-	-	42
Oil palm mesocarp	60	-	11	-	-	-	46
Cotton	85-90	5.7	-	0-1	7.85-8.5	0.6	-
Cereal straw	38-45	15-31	12-20	8	-	-	-
Wood	45	23	27	-	-	-	-

D. Manufacturing Methods

1. Pultrusion Process

Pultrusion is a continuous molding process that combines fiber reinforcement and thermosetting resins. The pultrusion process is used in the fabrication of composite parts that have a constant cross section profile such as ladder side. Rails, tool handles etc. Reinforcement materials such as roving mat or fabrics positioned in specific location using performing shapers or guides to form the profile. Reinforcements are drawn through a resin bath or wet out where the material is thoroughly coated or impregnated with a liquid thermosetting resin.

2. Resin Transfer Moulding

Resin transfer molding is commonly referred to as closed-mold process in which reinforcement material is placed between two matching mold surfaces one being male and other being female. the matching mold set is then closed and clamped and a low viscosity thermo set resin is injected under moderate pressure (50-100 psi) into the cavity through a port or series of ports with in a mold. The resin is injected to fill all voids with in the mold set and thus penetrates and wets out all surfaces of the reinforcing materials.

3. Filament Winding

The filament winding process is used in the fabrication of tabular composite parts. Fiber glass roving strands are impregnated with a liquid thermosetting resin and wrapped onto a rotating mandrel in a specific pattern. When the winding operation is completed, the resin is cured or polymerized and a composite material is removed from the mandrel.

4. Hand Lay-Up

Hand lay-up techniques are best used in applications where production volume is low and other forms of productions would be prohibitive because of costs and size requirements.

Fig. 3: Terminalia Bellirica plants

Preferred Botanical Name: TerminaliaBellirica
Family Name: Combretaceae
Vernacular Name(s):
Tani (Telugu), Bahera (Hindi), Tani (Tamil), Bankapas (Bengali), Baheda (Marathi), Katupuvarasu (Malayalam)

II.. Literature Review

Thi-Thu-loan Doan, Hanna Broadowsky, Edith madder [1] have studied the thermal, hydrothermal and mechanical behavior of laminates made out of jute fiber and poly propylene resin.

Elisazini and Maria LetiziaFocareta[2] have studied the thermal properties of laminates made out of flax fiber and bacterial poly resin.

Execute Rooriguez, RopertoPetrucc et.al.[3], have studied the mechanical properties of composites made of jute and flax fibers and Unsaturated polyester & modified acrylic.

V. Alvarez, A. Vazquez and C.Bernal[4] have studied the fracture behavior of Laminates made out of sisal fiber-reinforced starch based composites

ElintonS.demedeiros, Kuruvilla Joseph [5] have studied the Mechanical properties of phenolic composites reinforced with Jute/cotton hybrid fabrics.

III. Fabrication of Laminates

A. Extraction of Fibers

1. TermialiaBellirica

TermialiaBellirica is a moderate-sized to large tree, up to 24-30 m tall. Characteristically found in teak forests, dry savannah and degraded dry deciduous forests. The tree is distributed in isolated patches, varying in extent in the drier parts of the Indian peninsula. Fodder: Leaves contain about 9% crude protein, but the amount varies with the age of the leaves. Fuel: TermialiaBellirica provides excellent firewood and good charcoal. Fiber: The stem yields a strong fiber largely employed for making ropes. TermialiaBellirica (TANI) plants are observed in the forest near to Mahabubabad. After cutting stem from the tree (in wet conditions), there are soked in water nearly one week after that we will hammering stem then stem will be a fiber.

Fig. 4: Stems of TerminaliaBellirica After Cutting

Fig. 5: Extraction of Fiber from the Stem of TerminaliaBellirica

Fig. 6: Fibers After Extraction

Fig. 7: Cutting of Extracted Fibers

B. Preparation of Laminate

1. Glass Plate Surface Preparation
First Wax polish is applied on the surfaces of the base plates and Poly Vinyl Alcohol (PVA) is applied with a brush and allowed to dry for few minutes to form a thin layer. These two items will help in easy removal of the laminate from the base plates. PVA also provides a glossy finish to the surfaces of the laminate. The isopthalic polyester resin is taken along with 2% each of catalyst-MEKP and accelerator- Cobalt napthalate. The weight of the resin is 10 times the weight of the fiber mat taken for the laminate.
The catalyst initiates the polymerization process and the accelerator speeds up this process. Initially the catalyst is added and then the accelerator is added next. The contents are thoroughly stirred and then placed on the base surface and spread uniformly with the brush. The fiber mat is placed over the resin mix and then trolled with the roller to wet the mat uniformly and to remove the air entrapped. Further, quantity of resin is placed over the rolled mat and once again pressing is done by the roller for uniform distribution of the resin over the surface of the mat. It is always preferable to add lesser quantity of accelerator than the specified amount of accelerator to avoid solidification of the contents before they are applied over the surfaces. Then the top base plate that was already applied with the wax and PVA is placed on the laid resin and a weight of about 1000 N is placed over for about 24 hours.

Fig. 8: Wax, PVA, MEKP.Resin

Fig. 9: Isopthalic Polyester, Surface Plate

2. Hand Lay Up Process
Fiber of required dimension is placed on the surface of above prepared mixture. Once again a mixture of resin, accelerator and catalyst are added proportionally and thoroughly mixed and laid upon the mat. Rollers are used to ensure the removal of entrapped air and uniform distribution of resin on the fiber. A weight is placed upon this. A typical hand lay-up process is shown in fig. 10.

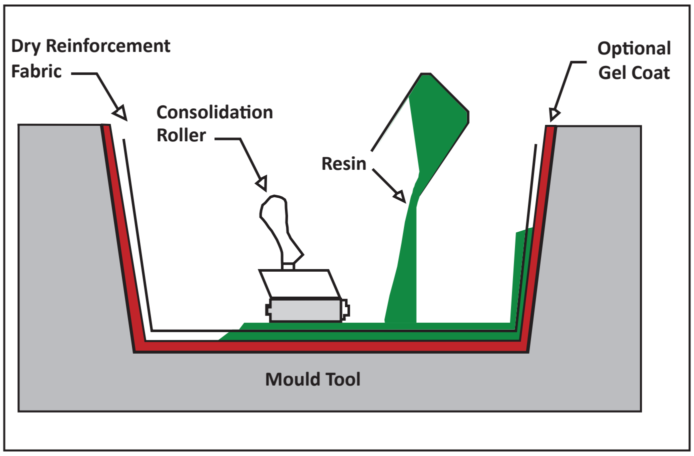

Fig. 10: Hand Layup Process

Fig. 11: Preparation of Laminate

IV. Specimen Preparation and Testing

A. Preparation of Specimens
Specimens for tensile test, flexure test, impact test and water absorption test as per ASTM standards are prepared. The dimensional details for each type of specimen are presented in respective diagrams.

1. Tensile Test Specimen
Specimens are cut from laminates on a jig saw machine as per ASTM D 638 Standards. The dimensions of the tensile test specimens are shown in the fig. 12.

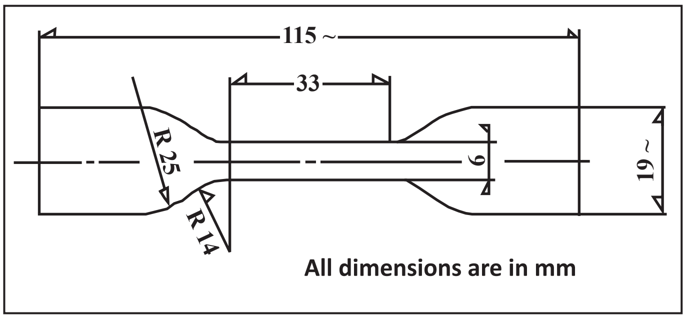

Fig. 12: Tensile Specimen

2. Water Absorption Test Specimen
Specimens for Water absorption test are cut from laminates as per ASTM D 570 standards [9]. The standard dimensions for test specimen are shown in the fig. 13.

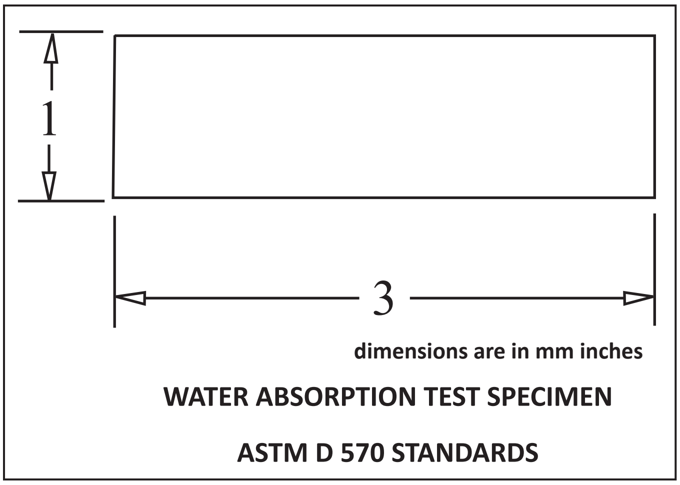

Fig. 13: Water Absorption Test Specimen

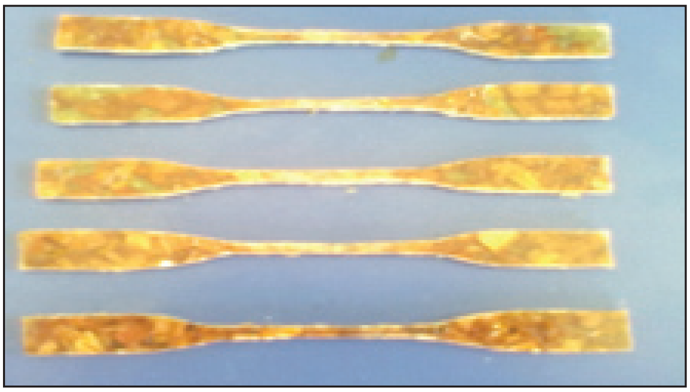

Fig. 14: Tensile Test Specimens of 5mm length fiber before Testing

Fig: 15: Tensile Test Specimens of 7mm Length Fiber Before Testing

Fig. 16: Water Absorption Test Specimen of 5mm Fiber

B. Testing & Result

Tension and flexural tests are conducted on the specimens to compare the strengths between TerminaliaBellirica and glass fiber composites.

1. Tensile Test

In a Randomly Oriented Composite subjected to increasing longitudinal tension load, failure initiates by fiber breakage at their weakest cross sections. Tensile test is conducted on universal testing machine. Load is gradually increased and deflection is observed on extensometer.

Fig. 17: Universal Testing Machine

Fig. 18: Specimens of 5 mm Length Fiber After Testing

Fig. 19: Specimens of 7 mm Length Fiber After Testing

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Table 2: TANI Randomly Oriented Fibers of 5 mm Length

Specimen	**Width (mm)**	**Thickness (mm)**	**Area (sq.mm)**	**U.T.L (N)**	**Stress at break (N/sq.mm)**	**U.T.S (N/sq.mm)**	**Break load**
1	8.5	6.4	54.40	726.140	13.348	13.348	726.180
2	8.3	6.4	53.12	880.040	16.013	16.567	850.640
3	8.8	6.0	52.80	702.660	13.308	13.308	702.660
4	9.0	6.0	54.00	876.120	16.224	15.224	876.120
5	9.0	5.5	49.00	732.153	14.554	14.791	720.422
					Mean stress at break = 14.647	Mean U.T.S = 14.465	

Table 3: TANI Randomly Oriented Fibers of 7 mm Length:

Specimen	Width (mm)	Thickness (mm)	Area (sq.mm)	U.T.L (N)	Stress at break (N/sq.mm)	U.T.S (N/sq.mm)	Break load (N)
1	8.5	4.2	35.7	1513.132	42.082	42.384	1502.340
2	8.5	4.2	35.7	1588.580	33.760	44.498	1383.760
3	9.0	4.2	37.8	1457.060	36.996	38.511	1398.460
4	8.5	4.0	34.0	1465.120	35.020	43.052	1190.700
5	8.5	3.8	32.3	1269.100	30.735	39.291	992.740
					Mean stress at break = 35.718	Mean U.T.S=41.547	

V. Results and Discussion

A. Results for Tensile Test on 5mm length Terminalla-Bellirica Fiber Randomly Oriented specimens

Gauge Length (L) = 115 mm

Cross section area of the specimen (A)
= (width) x (thickness)
=54.4mm²

From Table 2: The Mean Stress Break point
= P/A = 14.647N /mm²

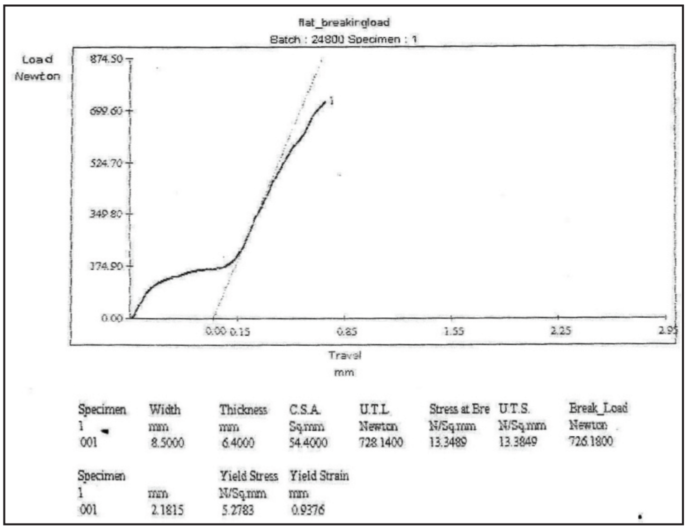
Ultimate strength obtained = 14.465N/ mm²

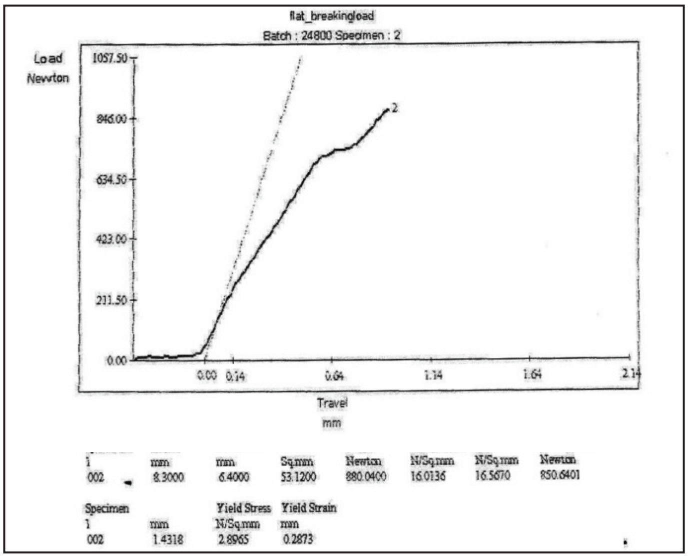
B. Results for Tensile Test on 7mm length Terminalla-Bellirica Fiber Randomly Oriented specimens

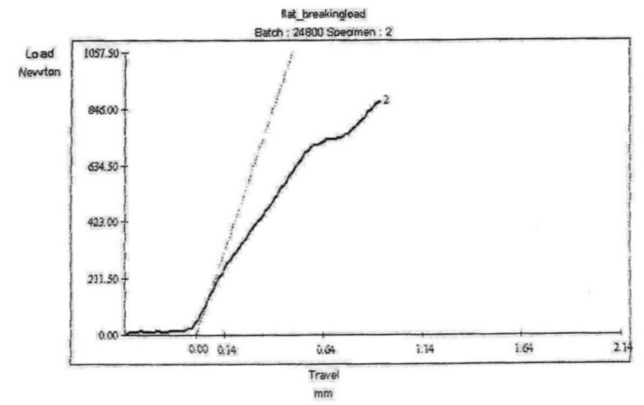
Gauge length (L) = 115 mm
Cross section area of the specimen (A)
= (width) x (thickness)
=35.7mm²

From Table 3: The Mean Stress Break point
= P / A = 35.718N/mm²

Ultimate strength obtained = 41.547 N/mm²

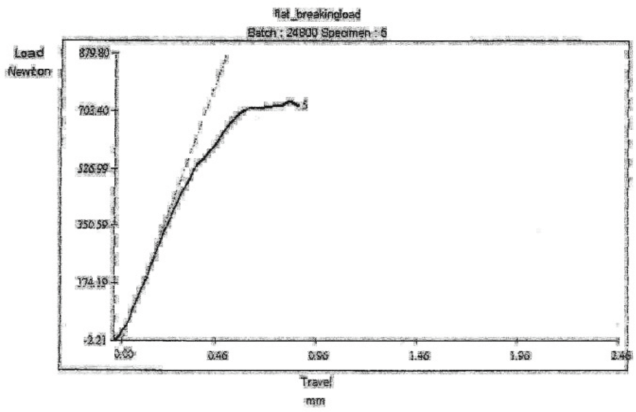






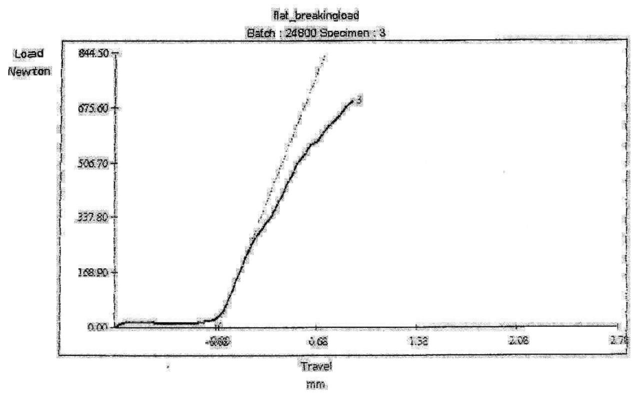
Specimen	Width	Thickness	C.S.A.	U.T.L.	Stress at Bre	U.T.S.	Break_Load
1	mm	mm	Sq.mm	Newton	N/Sq.mm	N/Sq.mm	Newton
002	8.3000	6.4000	53.1200	880.0400	16.0136	16.5670	850.6401

Specimen		Yield Stress	Yield Strain
1	mm	N/Sq.mm	mm
002	1.4318	2.8965	0.2873



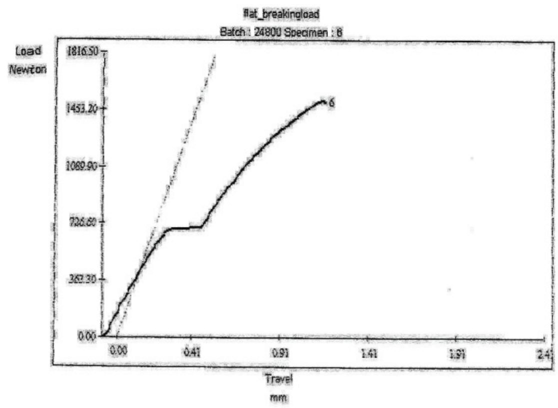
Specimen	Width	Thickness	C.S.A.	U.T.L.	Stress at Bre	U.T.S.	Break_Load
1	mm	mm	Sq.mm	Newton	N/Sq.mm	N/Sq.mm	Newton
005	9.0000	5.5000	49.5000	732.1826	14.5540	14.7916	720.4225

Specimen		Yield Stress	Yield Strain
1	mm	N/Sq.mm	mm
005	0.1599	2.4178	0.2791



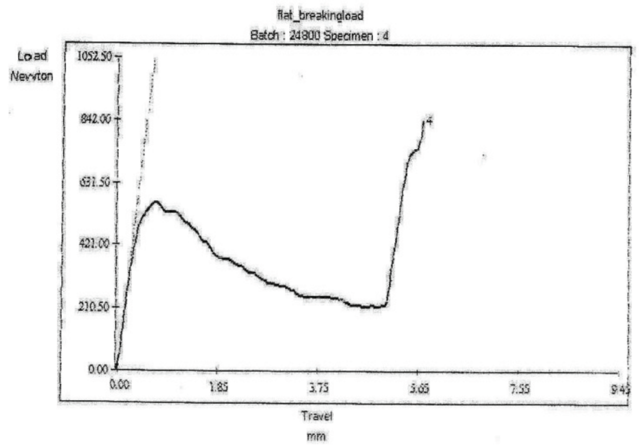
Specimen	Width	Thickness	C.S.A.	U.T.L.	Stress at Bre	U.T.S.	Break_Load
1	mm	mm	Sq.mm	Newton	N/Sq.mm	N/Sq.mm	Newton
003	8.8000	6.0000	52.8000	702.6600	13.3080	13.3080	702.6600

Specimen		Yield Stress	Yield Strain
1	mm	N/Sq.mm	mm
003	2.8738	3.2295	0.6052



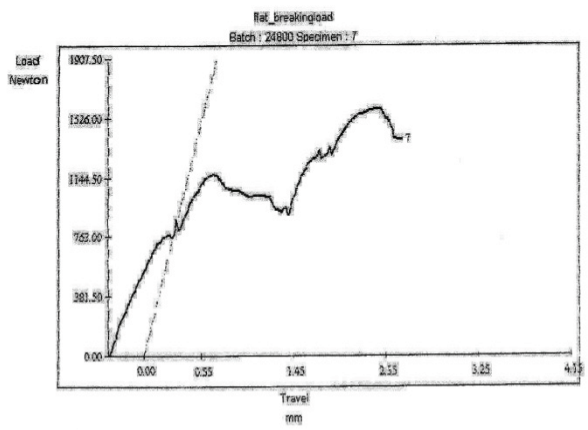
Specimen	Width	Thickness	C.S.A.	U.T.L.	Stress at Bre	U.T.S.	Break_Load
1	mm	mm	Sq.mm	Newton	N/Sq.mm	N/Sq.mm	Newton
006	8.5000	4.2000	35.7000	1513.1201	42.0824	42.3843	1502.3401

Specimen		Yield Stress	Yield Strain
1	mm	N/Sq.mm	mm
006	0.3449	11.5294	0.4941



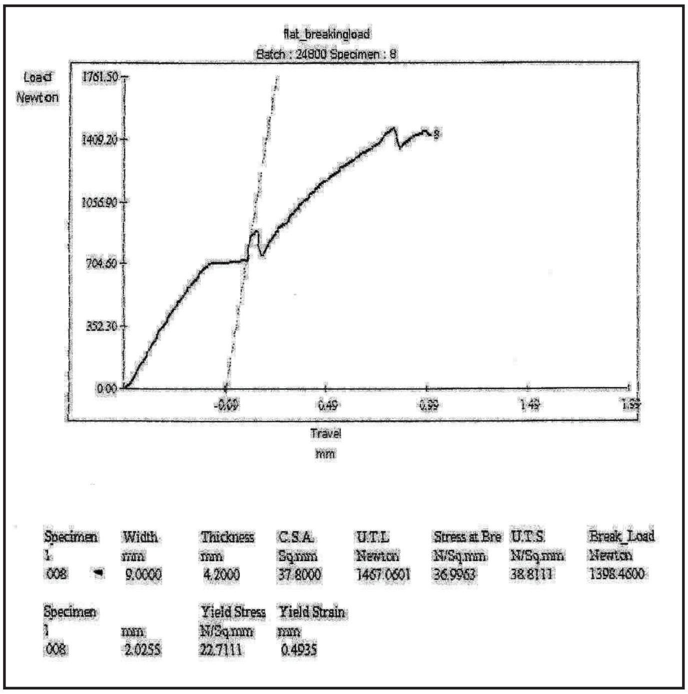
Specimen	Width	Thickness	C.S.A.	U.T.L.	Stress at Bre	U.T.S.	Break_Load
1	mm	mm	Sq.mm	Newton	N/Sq.mm	N/Sq.mm	Newton
004	9.0000	6.0000	54.0000	876.1201	16.2244	16.2244	876.1201

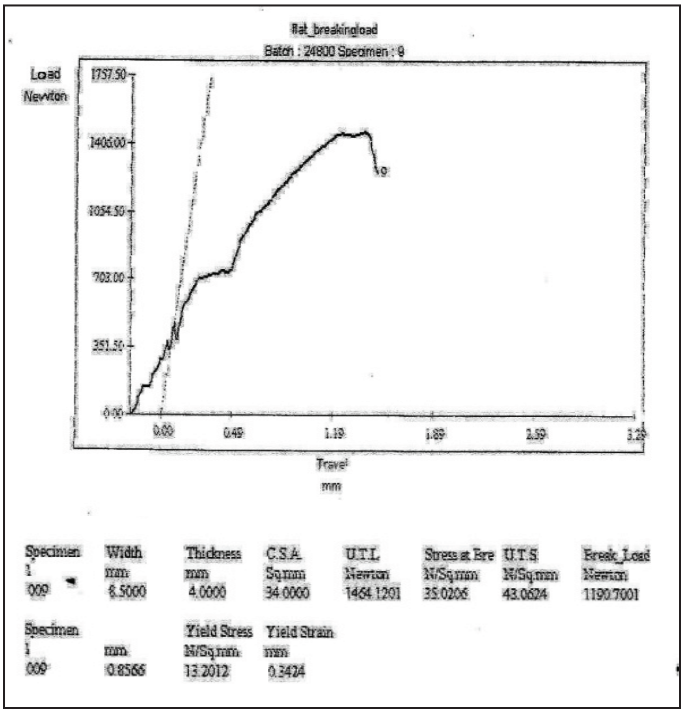
Specimen		Yield Stress	Yield Strain
1	mm	N/Sq.mm	mm
004	0.2020	8.6567	1.4370



Specimen	Width	Thickness	C.S.A.	U.T.L.	Stress at Bre	U.T.S.	Break_Load
1	mm	mm	Sq.mm	Newton	N/Sq.mm	N/Sq.mm	Newton
007	8.5000	4.2000	35.7000	1588.5801	38.7608	44.4980	1383.7600

Specimen		Yield Stress	Yield Strain
1	mm	N/Sq.mm	mm
007	1.4053	24.1843	1.2737





Water Absorption Test:

Original weight (w) =8.98gms

Change in weight (Δw) =9.63gms

Percentage of water absorption

= (Δw-w)x100/w

= (9.63-8.98)x100/8.98

= 7.238%

Water absorption test for randomly oriented fibers of 7mm length:-

Original weight (w) =9.16gms

Change in weight (Δw) =9.45gms

Percentage of water absorption

= (Δw-w) x100/w

= (9.45-9.16)x100/9.16

= 3.166%

Water absorption test for randomly oriented fibers of 10mm length:-Original weight (w) =9.16gms

Change in weight (Δw) = 9.45gms

Percentage of water absorption

= (Δw-w) x100/w

= (9.30-9.16)x100/9.16

= 1.528%

As the fiber length is increasing hardness is increases.

VI. Conclusions and Scope For Future Work

Stems of TermialiaBellirica plants are collected from Mahabubabad forest and fibers extracted from the stem. Randomly Oriented single layered laminates are prepared using Isopthalic polyester resin supplied by Ecmas Resins Private Limited, Hyderabad. Fiber, matrix volume ratio of 1:10 is applied. 5 Standard test specimens are prepared for Randomly Oriented lamina of 5mm, 7mm length fibers respectively as per ASTM standards. Tensile experiment is conducted. The observed test results are compared with available results in the literature.

The specimens exhibited comparable values of, tensile strength with those available in the literature for similar situation. However, it is noticed that the material has exhibited extremely low impact resistance.

Comparing to the hibiscus lampas, termialia bellireca is grater tensile value. Because of did not sufficient strength either fiber or resin of hibiscus lampas.

However, it can be suggested that higher values of the strength parameters can be obtained by taking a Randomly Oriented laminate of two or more layers instead of a single lamina with more strands of fibers of 7mm length. Further, it can be suggested to use another type resin to achieve superior mechanical properties and water resistance by conducting tensile test and water absorption test on 5mm and 7mm fiber lengths we got good results on 7mm length when compared to 5mm fiber length 5mm fiber length has absorbed more water than 7mm fiber length.

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