A Review on Experimental Investigations of Mechanical Properties of Composite Material used for a Manufacturing Industry Application

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Abstract— In this research composite material is manufactured by using hand layup method and mechanical properties are investigated. By using natural fibers with the epoxy and graphite fibers, the mechanical properties of the composite material show better results. Tensile strength and bending strength after testing found is very high as compared other composite material with natural fibers. At the end it is found that this graphite/epoxy/coconut coir composite material is feasible for the mechanical application. Also it is found that tensile and bending strength is high. Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Past studies show that only synthetic fibers such as glass, carbon etc., have been used in fiber-reinforced plastics. Although glass and other synthetic fiber-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. In this connection, an investigation has been carried out to make use of coconut coir, a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight but also relatively very cheap.

Keywords: Composite Material, Properties of Composite Material

I. INTRODUCTION

The advantage of composite materials over conventional materials are largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material (known as reinforcement) embedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Long fibers that are oriented in the direction of loading offer the most efficient load transfer. This is because the stress transfer zone extends only over a small part of the fiber-matrix interface and perturbation effects at fiber ends may be neglected. In other words, the ineffective fiber length is small. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and pyramid fibers.

A. *Types of Composites*

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses .Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.

II. LITERATURE REVIEW

Samson Rwawiire, BlankaTomkova, Jiri Militky, Abdul Jabbar, BanduMadhukar Kale [1] This paper tells about Natural fiber reinforced composites have attracted interest due to their numerous advantages such as biodegradability, dermal non-toxicity and with promising mechanical strength. The desire to mitigate climate change due to greenhouse gas emissions, biodegradable resins are explored as the best forms of polymers for composites apart from their synthetic counterparts which are non-renewable. In this study biodegradable bark cloth reinforced green epoxy composites are developed with view of application to automotive instrument panels.

RajendraKumar,Tejeet Singh and Harwindersinh [2] This paper present the state of the art literature review and explore the research guidelines on natural fibers polymeric composites. due to the environmental issues, cost reduction and high performance of engineering application, the demand of natural fiber is increasing day by day. reinforcement with natural fiber in composite has recently gained attention due to low cost, easy availability, low density, acceptable specific properties, ease of separation, enhanced energy recovery, bio-degradability and recyclable in nature.

D. Chandramohan& .K. Marimuthu [3] This paper focus on the interest in natural fiber-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 lignocellulosic fibers, 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 fibers used for the manufacturing of composites. The natural fiber-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.

PiyooshThori, Pawan Sharma, Manish Bhargava [4] This paper tells about, The core benefits of composite materials have their great strength and stiffness, for example Carbon Fibers have great specific strength, high modulus, good in fatigue resistance and dimensional stability and lower density Fibers. Composite materials have their high strength and stiffness, combined with low density, when compared with bulk materials, allowing fora weight reduction in the finished part.

Ahmed Elmarakbi [5] This paper tells about advanced composite materials, More advanced long fibre composites have emerged known as textile composites. Textiles are categorised into three major fabric kinds: woven, braided and knitted fabrics. They are introduced to improve the mechanical behavior of composites and to offer more choices of composite architectures.

Maya Jacob John, Rajesh D. Anandjiwala [6] This paper focus, the interest in natural fiber-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 lignocellulosic fibers, 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 fibers used for the manufacturing of composites.

Majid Ali [7] This paper presents the versatility of coconut fibers and its applications in different branches of engineering. Coconut fiber is one of the natural fibers abundantly available in tropical regions, and is extracted from the husk of coconut fruit. Not only the physical, chemical and mechanical properties of coconut fibers are shown; but also properties of composites, in which coconut fibers are used as reinforcement, are discussed. The research carried out and the conclusions drawn by different researchers in last few decades are also briefly presented. Graphs showing the relationship between different properties are also shown in this paper. Coconut fibers reinforced composites have been used as cheap and durable non-structural elements. The aim of this review is to spread awareness of coconut fibres as a composite material in engineering field.

G.Rathnakar1, Dr. H.K.Shivanand [8] This paper investigates the effect of fiber orientation on the flexural strength of fiber reinforced –epoxy laminated composite material, with the variation in the orientation of the reinforced fibers there will be a substantial variation in the flexural strength of the laminated composites. In the present paper fabrication of glass fiber reinforced laminated composites and graphite fiber reinforced laminated composites with varying orientation of reinforced fibers were prepared using the hand layup, vacuum baggage technique and these specimens are subjected to 3 point static bending testing the investigations are carried out as per the ASTM standards. Using the load - deflection graph the maximum load, maximum deflection and the flexural strength of the specimen for different laminated composites is evaluated and the appropriate conclusions are drawn.

III. Materials and Methodology

The raw materials used in this work are
1) Coconut coir fibers.
2) Graphite fibers.
3) Epoxy resin

A. Coconut Coir Fiber:

Coir is a lignocelluloses natural fiber. It is a seed-hair fibe robtained from the outer shell, or husk, of the coconut, the fruit of Cocosnucifera, a tropical plant of the Arecaceae (Palmae) family.

PROPERTIES	COCONUT COR FIBRE
Moisture content %	10-11
Density (kg/m^3)	1104
Flexural modulus (GPa)	2-5
Lumen size (mm)	5
Tensile strength (MPa)	15-327
Young‟s modulus (GPa)	4-6

B. Graphite Fibers:

Carbon fiber is defined as a fiber containing at least 92 wt % carbon, while the fiber containing at least 99 wt % carbon is usually called a graphite fiber [1]. Carbon fibers generally have excellent tensile properties, low densities, high thermal and chemical stabilities in the absence of oxidizing agents, good thermal and electrical conductivities, and excellent creep resistance.

Density gm/cc	Density 1.42gm/cc
Flexural Strength(N/mm^2)	424
Maximum Deflection, mm	1.94

C. Epoxy Resin:

Epoxy resins are polyether resins containing more than one epoxy group capable of being converted into the thermo set form. These resins, on curing, do not create volatile products in spite of the presence of a volatile solvent.

Characteristics	Epoxy Resin
Flexural strength	Best
Tensile strength	Best
Elongation %	Lowest
Water Absorption	Lowest

Hardness	Best
Cure Time	5-7 Days
Working Time	in- 6 Hours

IV. Preparation of Mould

Wooden mould having dimensions of 300x300x7mm3and 300x300x10mm3is used for composite fabrication.

A. Determination of coconut coir fiber volume fraction (30%) for 300x300x7 mm3mould:

From the definition the fiber volume fraction Vf

$$V_f = \frac{v_f}{v_c} \quad .... (1)$$

Where, Vf= volume fraction of fiber
vf = volume of fiber
vc= volume of mould
The volume of mould Vc= 0.300 x 0.300 x 0.007 = 6.3 x 10-4 m3

Vf =Vf* Vc…. (2)

Density of fiber = mf/vf …. (3)

Mass fraction mf= 1.104 x 189=208.656 grams

B. Determination of coconut coir fiber volume fraction (40%) for 300x300x10 mm3mould:

From the definition the fiber volume fraction Vf

$$V_f = \frac{v_f}{v_c} \quad .... (1)$$

Where, Vf= volume fraction of fiber
Vf = volume of fiber
Vc= volume of composite
The volume of composite Vc= 0.300x0.300x0.010 = 9x10-4 m3

Vf =Vf* Vc…. (2)

Density of fiber = mf/vf …. (3)

Mass fraction mf= 1.104x360=397.44grams

C. Determination of Graphite fiber volume fraction (15%) for 300x300x7 mm3mould:

From the definition the fiber volume fraction Vf

$$V_f = \frac{v_f}{v_c} \quad .... (1)$$

Where, Vf= volume fraction of fiber
Vf = volume of fiber, Vc= volume of composite

Vf =Vf* Vc…. (2)

Density of fiber = mf/Vf …. (3)

Mass fraction mf= 1.42x94.5=134.19 grams

D. Determination of Graphite fiber volume fraction (20%) for 300x300x10 mm3mould:

From the definition the fiber volume fraction Vf

$$V_f = \frac{v_f}{v_c} \quad .....(1)$$

Where, Vf= volume fraction of fiber
Vf = volume of fiber
Vc= volume of composite

vf =Vf* vc…. (2)

Density of fiber = mf/vf …. (3)

Mass fraction mf= 1.42x180=255.6grams

V. Density of Epoxy Resin

Density of epoxy resin used for manufacturing coconut coir and graphite fibers composite is 1.15gm/cc

VI. Manufacturing of Composite

1) Step 1: Personal preparation
2) Step 2: Weighing of fibers
3) Step 3:- Pour wax in mould
4) Step 4: Lay on the fiber layers and Wet out the Layer
5) Step 5: placing the release paper on the layer
6) Step 6: applying load
7) Step 7: Trimming and Cutting

VII. Analysis of Test Specimen

The present work deals with the characterization of composite specimen prepared by performing various mechanical tests like tensile loading and Flexural Loading (3 point loading)

A. Mechanical Tests:

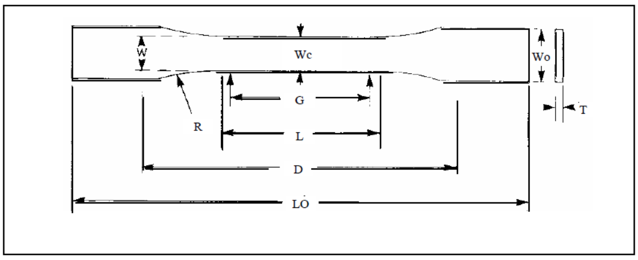
The mechanical testing has been done on the composite laminate specimens as per the guidelines given in ASTM standards for the respective tests.

B. Tensile Test:

Tensile test is a measurement of the ability of a material to with stand forces that tend to pull it apart and to what extent the material stretches before breaking.

1) Test type:
According to ASTM D638, tensile testing has been carried out. The specimen with the gauge length of 115 mm was considered for the investigation of tensile properties

2) Test specimen:
According to ASTM (D638), dumbbell shape specimen is needed for reinforced composite testing.



C. Flexural Test (3 Point Loading):

Flexural strength also known as modulus of rupture is a mechanical parameter for brittle material defined as the material's ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture. This test method determines the flexural properties of specimen under defined condition.

Flexural stress, = $\sigma = \frac{3PL}{2bd^2}$ ... (8)

σ= stress in the outer specimen at midpoint, MPa
P= applied load force, in Newton, N
L= support span, mm
b= width of beam tested, mm
d= depth of beam tested, mm

VIII. EXPERIMENTAL RESULTS

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The tensile test is carried out on standard size specimen by applying load and the elongation of the specimen over the span distance is measured.

A. Result Table:

Load (KN)	Tensile Strength (MPa)	Tensile Modulus (MPa)	Elongation (mm)	% Elongation
5.00	28.39	$13.9x10^3$	0.1	0.21
5.4	30.66	$13.8x10^3$	0.3	0.22
5.6	31.80	$13.6x10^3$	0.4	0.23
5.7	32.37	$13.4x10^3$	0.6	0.24
5.8	32.94	$10.2x10^3$	0.8	0.32
6.2	35.21	$7.3x10^3$	1.2	0.48
6.4	36.34	$5.04x10^3$	1.8	0.72
6.8	38.62	$4.3x10^3$	2.2	0.88
7.00	39.75	$3.2x10^3$	3.1	1.24
7.00	39.75	$3.01x10^3$	3.3	1.32
7.1	40.32	$2.19x10^3$	4.6	1.84
7.2	40.89	$1.23x10^3$	8.3	3.32
7.4	42.03	$1.05x10^3$	10	4.00
7.6	43.16	$0.963x10^3$	11.2	4.48
7.9	44.87	$0.919x10^3$	12.2	4.88

Table 5.1: tensile properties of 7mm thickness composite

Load (KN)	Tensile Strength (MPa)	Tensile Modulus (MPa)	Elongation (mm)	% Elongation
5.00	20.00	$7.6x10^3$	0.1	0.28
5.2	20.8	$7.5x10^3$	0.3	0.29
5.4	21.6	$7.3x10^3$	0.6	0.30
5.7	22.8	$7.1x10^3$	0.8	0.32
5.9	23.6	$5.9x10^3$	1.0	0.40
6.2	24.76	$5.16x10^3$	1.2	0.48
6.3	25.15	$3.93x10^3$	1.6	0.64
6.6	26.4	$2x10^3$	3.3	1.32
6.8	27.18	$1.51x10^3$	4.5	1.80
7.1	28.20	$0.86x10^3$	8.2	3.28
7.4	29.6	$0.74x10^3$	10	4.00
7.9	31.55	$0.68x10^3$	11.6	4.64
8.2	32.54	$0.55x10^3$	14.7	5.88
8.6	33.90	$0.52x10^3$	16.3	6.52

Table 5.2: tensile properties of 10mm thickness composite

B. Following graphs shows the results of tensile strength:

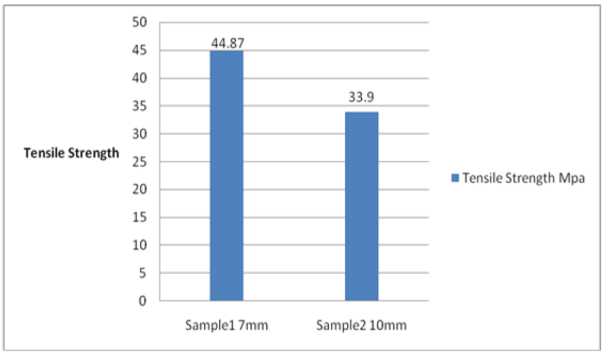


Fig. 5.2.1: Tensile strength of the composite material.

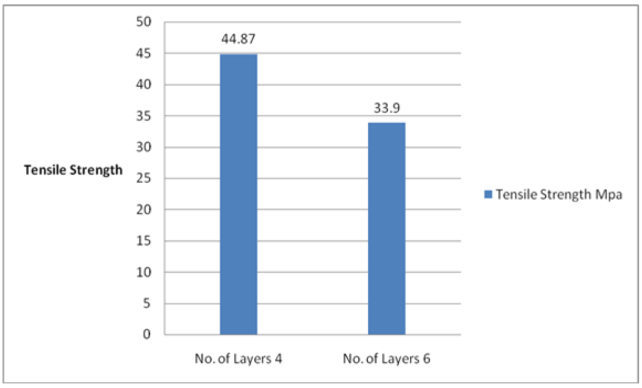


Fig. 5.2.2: Tensile strength of the composite material for varying layers.

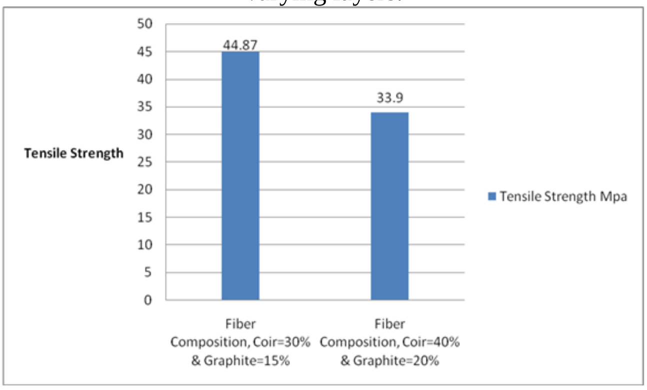


Fig. 5.2.3: Tensile strength of the composite material for varying fiber proportion.

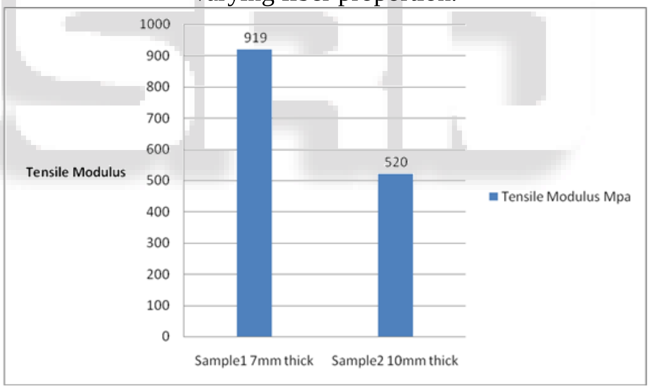


Fig. 5.2.4: Tensile modulus of the composite material

Comparison of the tensile properties of various composites fibers with present work

Composite combination	Thickness of composite	Tensile strength (MPa)	Young's modulus (MPa)	Fiber proportion content	Author
Glass fiber and banana fiber with epoxy resin	7mm	33.30	--------------------	20% glass fibers and 30% banana fibers	R.Sakthivel et al

Coconut shell and palm fruit	5mm	31.00	--------------------	25% coconut shell and 25% palm fruit	S.I.Durowaye et al
Epoxy with bark cloth	7mm	33	3Mpa	50% bark cloth	S.Rwawiireet al
Abaca fiber with epoxy	6mm	53.00	--------------	40% abaca fiber	R.Sridharet al
Coconut coir and graphite fibers with epoxy resin	7mm	44.87	$0.919x10^3$	30% of coconut coir fiber and 15% graphite fibers	J.K.Romanet al

C. *Flexural Test Results:*

Load (KN)	FLEXURAL Strength (MPa)	FLEXURAL Modulus (GPa)	Elongation (mm)	% Elongation
5.5	3030.6	52602.76	0.1	0.037
5.5	3030.6	4782.06	1.1	0.407
5.5	3030.6	1753.42	3	1.11
5.5	3030.6	1195.517	4.4	1.628
5.5	3030.6	751.468	7	2.59
5.52	3041.6	527.94	10	3.7
5.56	3063.67	409.050	13	4.81
5.6	3085.71	366.843	14.6	5.402
5.6	3085.71	252.637	21.2	7.844
5.7	3140.8	247.798	22	8.14

Table 5.3.1:Flexural properties of 7mm thickness composites

Load (KN)	FLEXURAL Strength (MPa)	FLEXURAL Modulus (GPa)	Elongation (mm)	% Elongation
5.2	1404	1698.66	0.1	0.037
5.28	1425.6	862.39	0.2	0.074
5.28	1425.6	143.73	1.2	0.44
5.3	1431	108.2	1.6	0.592
5.3	1431	52.4	3.3	1.22
5.3	1431	38.4	4.5	1.665
5.3	1431	32.66	5.3	1.961
5.3	1431	28.38	6.1	2.257
5.34	1441.8	27.25	6.4	2.368
5.36	1447.2	21.35	8.2	3.034
5.4	1458	17.63	10	3.7
5.4	1458	17.126	10.3	3.811
5.42	1463.4	15.26	11.6	4.292
5.42	1463.4	14.878	11.9	4.403
5.46	1474.2	12.133	14.7	5.439
5.48	1479.6	11.25	15.9	5.883
5.5	1485	11.022	16.3	6.031
5.52	1490.4	10.9951	16.4	6.068
5.54	1495.8	10.968	16.5	6.105

Table 5.3.2: Flexural properties of 10mm thickness composites

D. *Following graphs shows results of flexural strength:*

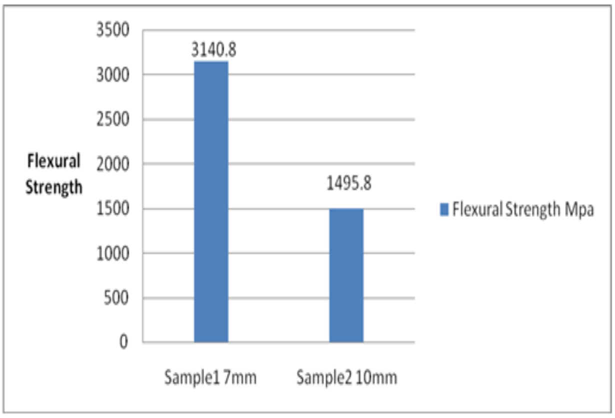


Fig. 5.4.1: flexural strength of the composite material

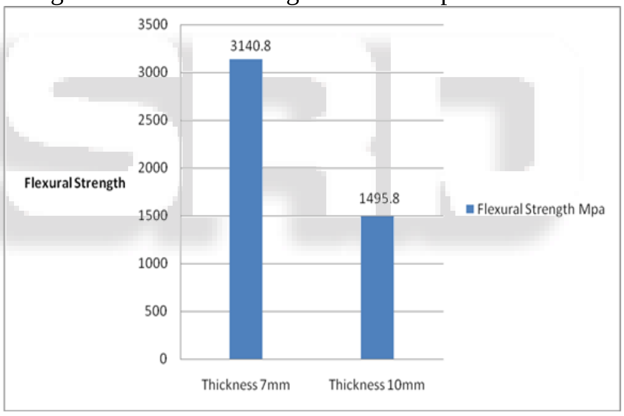


Fig. 5.4.2: flexural strength of the composite material for varying thickness.

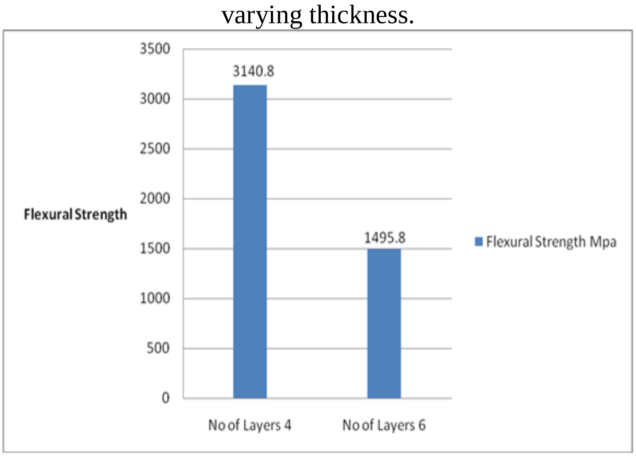


Fig. 5.4.3: flexural strength of the composite material for varying layers.

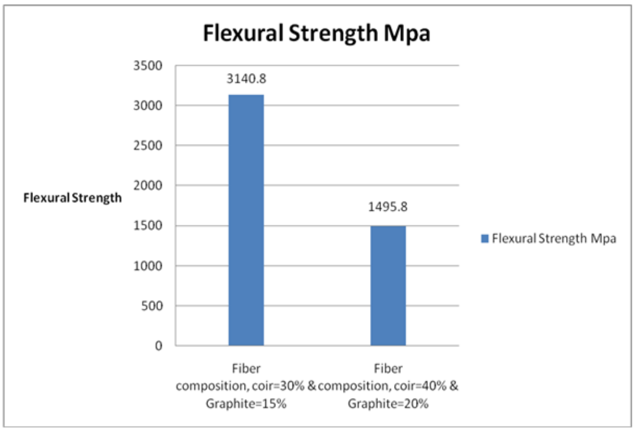


Fig. 5.4.4: flexural strength of the composite material for varying fiber proportion.

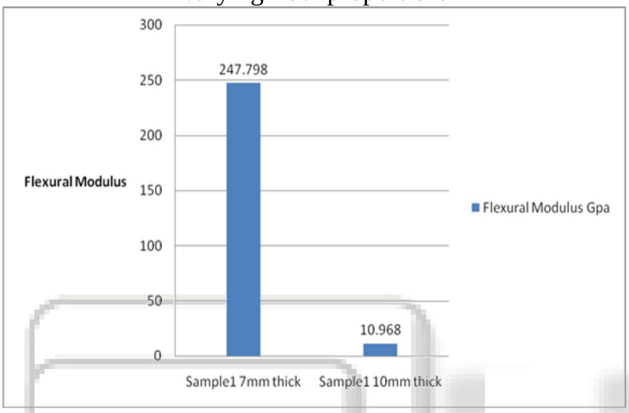
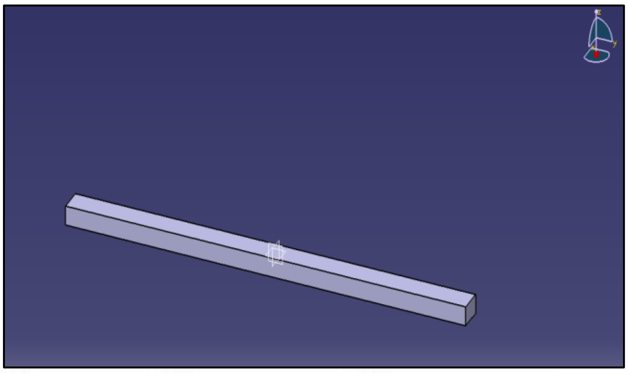


Fig. 5.4.5: flexural modulus of the composite material

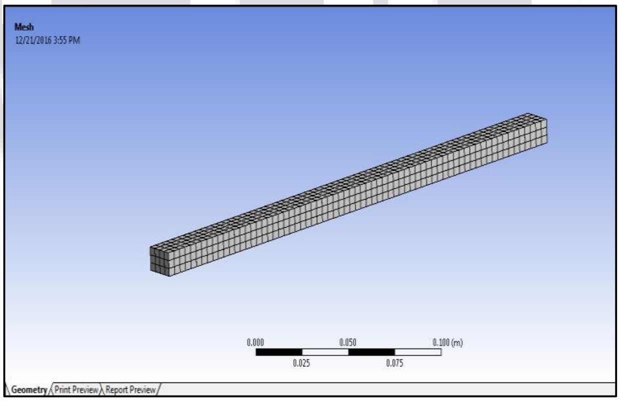
Composite combination	Thickness of composite	Flexural strength (MPa)	Young's modulus (GPa)	Fiber proportion &content	Author
Glass fiber and banana fiber with epoxy resin	7mm	163.1	---------------	20% glass fibers and 30% banana fibers	R.Sakthivel et al
Coconut shell and palm fruit	5mm	38.328	--------------------	25% coconut shell and 25% palm fruit	S.I.Durowaye et al
Glass & graphite with epoxy	4mm	716.50	--------------	26% glass and 26% graphite	G.Rathnakar et al
Epoxy with bark cloth	7mm	207	1.4	50% bark cloth	S.Rwawiireet al
Coconut coir and graphite fibers with epoxy resin	7mm	3140.8	247.798	30% coconut coirand 15%graphite fiber content	J.K.Roman et al

Table 5.5: shows the results of other composites which is compared with Coconut coir and graphite fibers with epoxy resin.

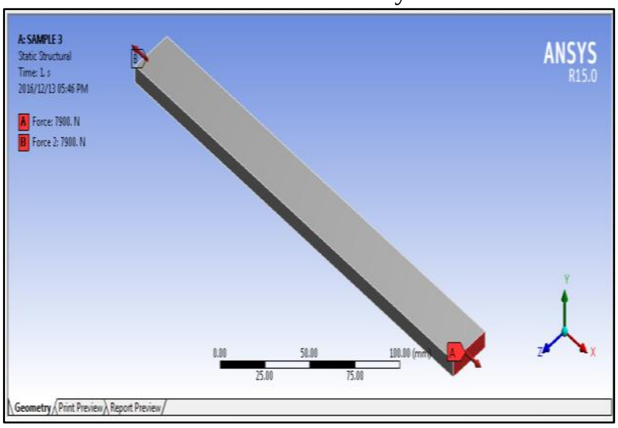
IX. Analysis of Composite Material by using Ansys:



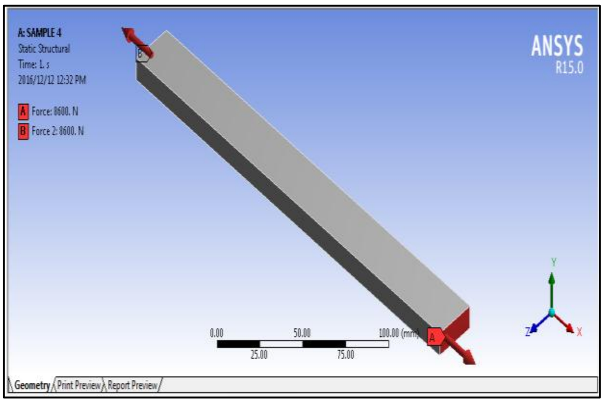
The solid model of composite material is created in CATIA V5



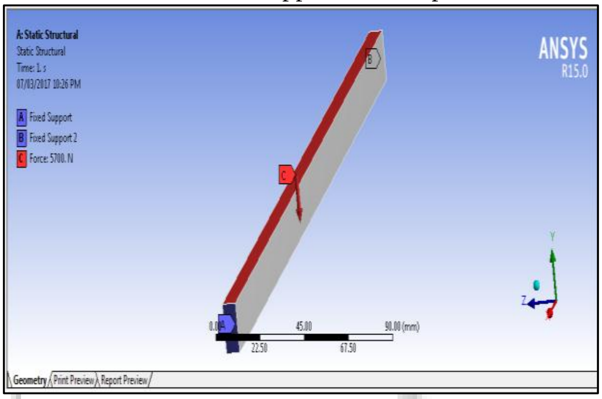
Meshed Geometry



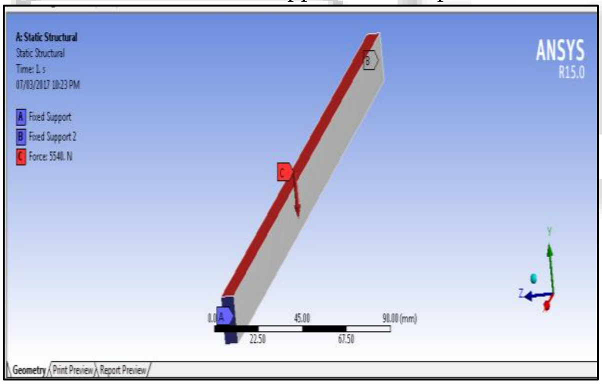
Tensile Load applied on sample1.



Tensile Load applied on sample2



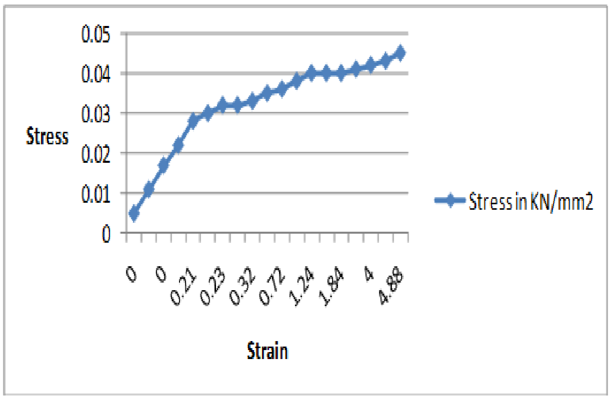
Flexural Load applied on sample1



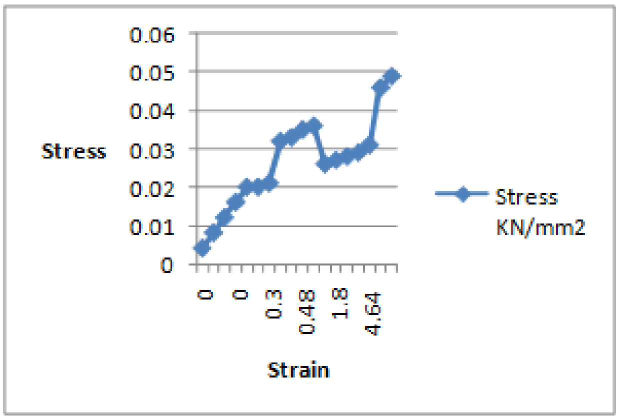
Flexural Load applied on sample2.

X. FEA RESULTS

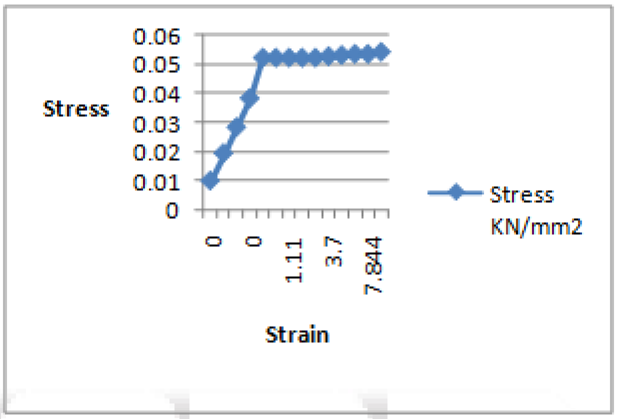
A. Stress – Strain Graph:



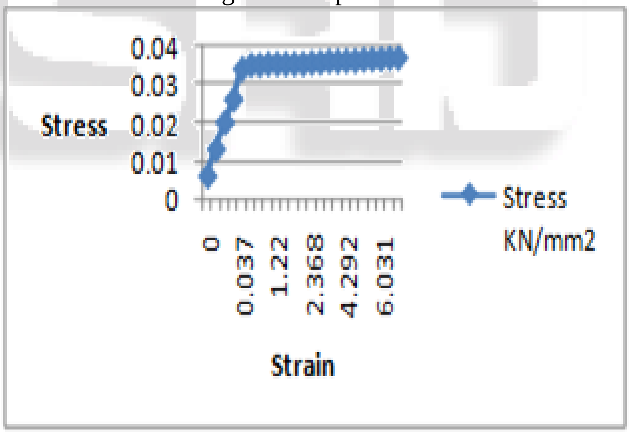
Stress-Strain Diagram for Specimen 1 Tensile Test



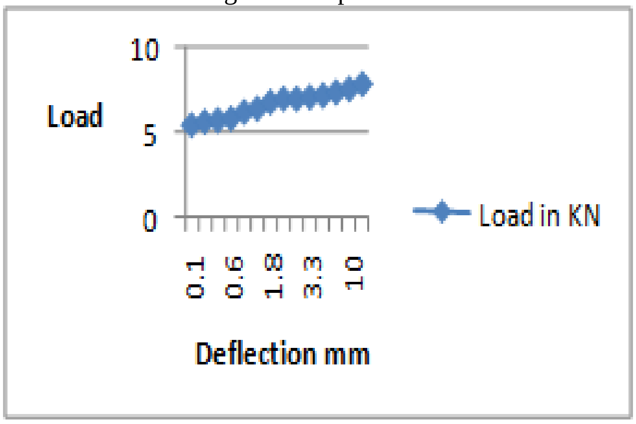
Stress-Strain Diagram for Specimen 2 Tensile Test



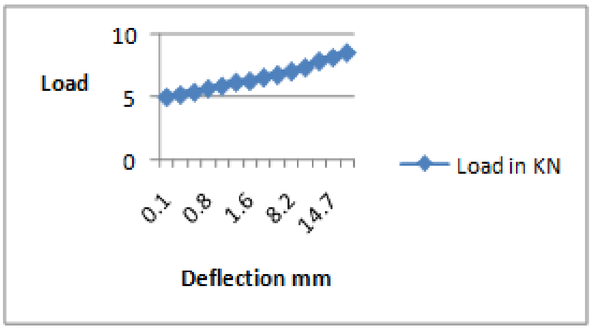
Stress-Strain Diagram for Specimen 1 Flexural Test



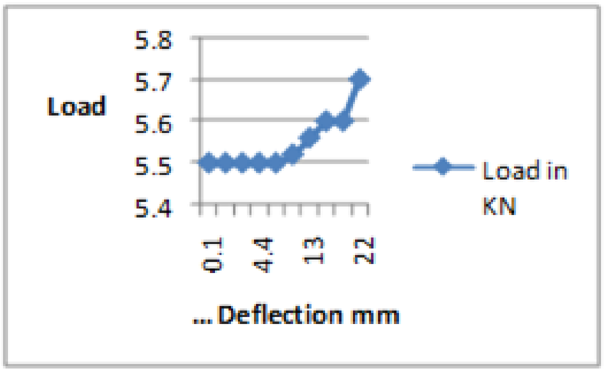
Stress-Strain Diagram for Specimen 2 Flexural Test



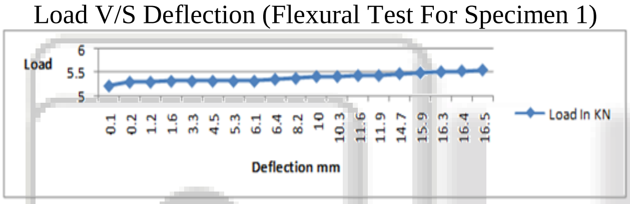
Load V/S Deflection (Tensile Test For Specimen 1)



Load V/S Deflection (Tensile Test For Specimen 2)



Load V/S Deflection (Flexural Test For Specimen 1)



Load V/S Deflection (Flexural Test for Specimen 2)

XI. Finite Element Analysis Results

Types of Strength	Composite Specimen	
	Sample 1	Sample 2
Tensile Strength	44.857 MPa	32.571 MPa
Flexural Strength	3062.4 MPa	1488.7 MPa

XII. Comparisons of Results Obtained

Types of Strength	Sample specimen 1		Sample specimen 2		% of difference between experimental and FEA	
	Experimental	FEA	Experimental	FEA	Sample 1	Sample 2
Tensile strength (MPa)	44.87	44.857	33.90	32.571	0.028 %	3.9 %
Flexural strength (MPa)	3140.80	3062.4	1495.8	1488.7	2.4 %	0.47 %

XIII. Conclusion

By FEA analysis, maximum tensile strength for 7mm composite is 44.857 MPa. Maximum tensile strength for 10mm composite is 32.571 MPa.

By FEA analysis, maximum flexural strength for 7mm composite is 3062.4 MPa. Maximum flexural strength for 10mm composite is 1488.7 MPa.

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