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Experimental Investigation on Mechanical Properties of Palmyra Long Fibre Reinforced Composites

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***Abstract:** Polymers reinforced with synthetic fibers such as glass, polyester, acrylic, nylon, rayon, acetate, orlon, Kevlar bear high mechanical properties compared to natural fibres, but their adverse effects, such as peak initial costs, chemical reactivity with other materials and not suitable for some (non-efficient) structural forms, reduce demand. We are now switching gears from synthetic to natural fibers as the natural fibers are being overplayed over synthetic fibres. Here we focus primarily on testing mechanical properties such as tensile and bending. The specimens must be cut in accordance with the dimensions specified by the ASTM machine standards. The material properties and variation of the materials can be studied by changing the percentage volume composition of the fiber to the resin. The weighted ratios are taken as 40:60, 30:70, 20:80, 10:90 as the basis for making a composite. In the present work, we use the 235 * 165 * 5 dimensional mold in mm with natural fiber for reinforcement as a Palmyra fiber. To make the composite, the other materials such as Epoxy Resin(LY556) and hardener(HY951) must be added. Resin may also be called PMC(Polymer Matrix Composite). It is possible to resolve the tensile and bending properties of various composites and to draw a comparison of properties between the composites.*

***Key Words:** natural fibre, PMC(Polymer Matrix Composites), bend test, flexural test.*
Weighted ratio=weight of fibre to the weight of resin.

I. INTRODUCTION

The use of natural fibers is now in demand compared to synthetic fibers as awareness and awareness of the environment is raised among individuals. In India we know that having plenty of trees for the fiber production of various trees such as banyan, neem, palmyra, jute, sisal, banana, etc. As here we are transforming the waste material into raw material for the composite. Palmyra tree belongs to the grass scientifically called Borassus Flabellifera. India is in the highest number of Palmyra trees in first position. As of 2018, nearly 85.9 million are present in India and nearly 60 percent are present from Tamil Nadu alone.

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These composites have noticeable properties such as light weight, low material cost, moderate strength, high specific modules, renewable, environmentally friendly etc. Therefore, applications in various fields such as submarines, aircrafts, automobiles, robots, buildings are drastically increased.

As the awareness of the composites of natural fibers and many works grew sequentially. The project on the manufacture and characterization of long, reinforced polyester Palmyra, was carried out by one of the authors known as srinivasa babu, and achieved good results through the improved tensile, bending and impact properties. The other author, vijaya kumar, also obtained good results, while changing the fiber and matrix weight ratios with respect to fiber length[1-2]. T.Subramani[3] used FEM software to do the project called fiber reinforced concrete strength study using palmyra palm fiber. The mechanical characteristics such as tensile and bending are evaluated and applications from the small to big industry, including the manufacture of switchboards, hats, sleeping bags, large scale fans such as aerospace and automotive industries and other fields are discussed. It is also being utilized as a natural additive filler in natural fiber vulcanization by replacing carbon black.

With this in mind, we are now engaged in making and testing natural fiber reinforced composites with their mechanical properties. Epoxy is used as PM(POLYMER MATRIX) and natural fiber is used here as Palmyra fiber [4-5].

II. AIM & OBJECTIVE

The project's main theme is to find the mechanical properties and compare the results with the results that have been achieved.

- Study of the composite properties by varying the weighted percentage ratios.
- Observing composite results under various loads.
- Compare the expected and experimental results and draw conclusions between the different compositional composites.

III. METHODOLOGY

The following table:1, shows the sequence of the steps to be followed to determine the mechanical properties of the long fibre reinforced polymer matrix composite.

Table: 1:-Methodology

S.No.	Various Steps Involved

1	Fibre Selection
2	Chopping/cutting of long Palmyra fibre
3	Selection of Resin and Hardner
4	Separation of fibres as per weighted ratios
5	Fabrication of composite materials
6	Cutting of the specimen as per the dimensions
7	Stress vs strain for tensile test
8	Load vs displacement for tensile test
9	Stress vs strain for flexural test
10	Load vs displacement for flexural test
11	Comparison between experimental and expected

IV. FIBRE SELECTION

We are aware that India is in rank 1 in total with almost 85.9 million Palmyra trees. We generally receive different fibers of Palmyra tree. However, we do use the fibers that come from the base of the leaf and stem of the leaf, which are palm petiole fiber, either by hand or mechanically crushed. After that it will be done by using the pith's comber removal. The resulting fiber is the one that we use in this work and reminds us that the other waste materials that have more pith and poor short fiber strength are also used to make the composites. As these short and long fibres are not easily degradable they have been used for making of the composites[6-8].

Fig 1: Different types of Palmyra fibres

The density of Palmyra fiber as 1100kg /m^3 for 0.45mm to 0.60mm in diameter based on Palmyra information from other papers. Here we use the palm petiole fiber, which was extracted and dried, to strengthen it. The fiber material procured from Devi Exports in West Godavari as shown in Fig.1.

V. CUTTING OF THE LONG PALMYRA FIBRE

We ordered the length of this fiber as nearly 250 mm so we could cut in mm according to the dimensions of the mould (235mm x 165mm x 5mm). Here we cut the Palmyra fiber to 23.5 and 16.5 cm as we make the composite in a series of layers perpendicular to the alignment (as shown in Fig.2). Through the cutting machine available in pit, we cut this material.

Fig.2: Chopped / cut fibres of length 23.5cm and 16.5cm as per the requirement.

VI. SELECTION OF RESIN

Araldite (LY556) made by the HERENBA brand has good properties to be used as a PM (Polymer Matrix) and purchased from the Hyderabad SREE Industrial Composites pvt. Ltd. Density of the selected resin is 1163kg/m^3[9].

The outstanding properties of resin are as mentioned below:
Free from internal stresses.

- Good adhesion with other materials.
- High dimensional stability.
- High resistance to chemical attack.
- Low shrinkage.
- Odourless , tasteless and completely non-toxic in nature.

VII. SELECTION OF HARDENER

Hardener(HY951) made by the brand HERENBA and purchased from the Hyderabad SREE Industrial Composites pvt. Ltd. Epoxy hardener is added to the epoxy resin to get the ultimate properties. It's not being used as a catalyst. Hardeners have the following properties given below:

- Gel time.
- Mixed viscosity.
- Remould time of the epoxy resin.

While applying the epoxy resin, the hardener's function depends on the physical characteristics[10].

VIII. SEPERATION OF FIBRES AS PER WEIGHT PERCENTAGES

We are calculating to obtain the composite to show good results when we test in order to know what weight percentage ratio to get maximum properties.

Table2: weighted ratios and their weights

S.No.	Weight percentage ratio	Weight of resin	Weight of fibre	Total weight of composite
1	60:40	135.28	85.30	220.59
2	70:30	155.83	63.97	221.80
3	80:20	180.38	42.65	223.03
4	90:10	202.9	21.32	224.25

IX. MATERIALS REQUIRED

The materials which are used to fabricate the composite:

- Mould of dimensions 235mmx165mmx5mm with wood, nuts, bolts, smooth wood sheet.
- Aluminium foil, stirrer.
- Epoxy resin with its hardener.
- Glass jar, digital weight measuring machine.
- 10 kg weight with pad for weight bear.

X. PROCESS OF FABRICATION

Firstly, we must use the mould of the above-mentioned dimensions. All four side walls and its base of the mold must first of all be rounded by the aluminum foil, as shown in Fig2. We have to attach all the sides to the base with nuts and bolts. After we have to arrange the fiber perpendicularly as the 23.5 cm cut-length fiber is to fit along the length of 23.5 cm and 16.5 cm cut-length fiber along the width of 16.5 cm, as per the 3 types of volume percentage distribution. The number of layers depends on the fiber quantity. To obtain the required properties, the hardener must also be added to the resin. Suppose if we take 100gm of resin, then we need to add 10gm of hardener. Once the fibers are put perpendicularly to the weight percentage ratios, the liquid (epoxy resin+hardener) must be poured in accordance with the calculated weights[11]. The resulting one is the liquid composite to dry for one day. In order to achieve good results we must place the weights on the pad that is on top of the composite.

Fig.2: Fabrication process of a composite.

Table2: Specimens of different weighted ratio

S.No.	Weight percentage ratio(fibre: matrix)	Specimen
1	60:40	Failed
2	70:30	Successful
3	80:20	Successful
4	90:10	Successful

XI. EXTRACTION OF COMPOSITE FROM MOULD

On the next day of fabrication, we can remove the composite from the mold simply by removing the weights, nuts and bolts, since the aluminum foil is soft and easy to remove. In this respect, aluminum foil acts as an insulation agent so that the liquid composite and mold can not be sticked together[12].

Fig.3: composite after removal from mould.

XII. CUTTING OF THE COMPOSITES AS PER DIMENSIONS

As we know, the composites extracted are 235mm x65mmx5mm in size. The composite must be cut in the shape that dumb-bell for tensile and the other shape for other test specimen in order to be tested for the composites (as shown in Fig.4 and Fig.5). The following image shows the shape and size of the specimens for various tests.

Fig.4: Cut specimen for flexural test.

Fig.5: Cut specimen for tensile test.

TESTINGS (Tensile & Flexural)

1) TENSILE TEST:

The specimen has to be prepared as per the standards of the testing machine ASTM D 638 TYPE 1[13].

- The specimen has to be checked for the dimensions.
- The specimen is clamped in the tensiometer's fixture. The machine is switched on and the stepper motor slowly applies the tensile force on the specimen and at some point of stress or critical load is applied the specimen will fracture.
- The stress and strain values were noted from the computer as it was readings were interlinked to the computer.

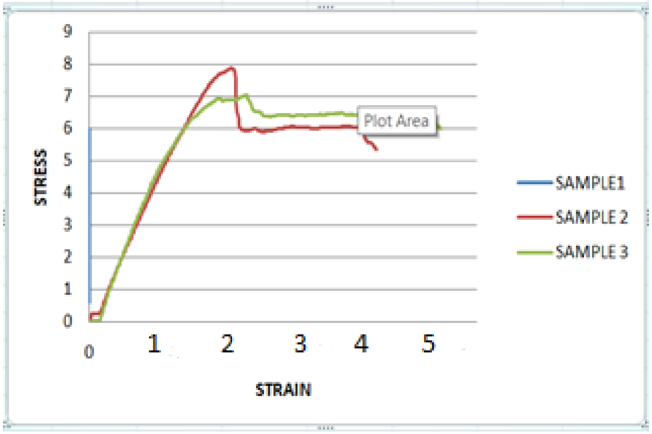
Note:

- If 1mm< thickness< 14mm------ASTMD638
- If thickness<1mm-----------ASTMD882

Fig.6: Tensile Testing Machine

XIII. STRESS Vs STRAIN UNDER TENSILE TEST

We carried out the tensile test for 3 different types of weighted ratios such as 70% & 30%, 80% & 20%, 90% & 10%[14]. For each sample, we get the Stress vs Strain graph and we've drawn the graph so that all three stress- strain diagrams are in one graph(as shown in Graph1).



Graph1: Stress vs Strain for three different types of composites for Tensile test.

NOTE:

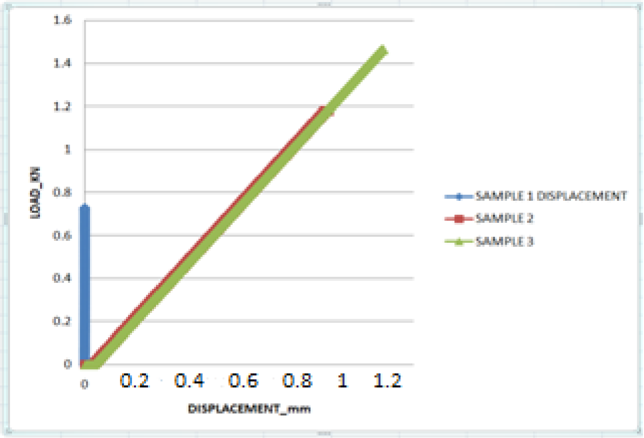
- SAMPLE1 represents 70% & 30%.
- SAMPLE2 represents 80% & 20%.
- SAMPLE3 represents 90% & 10%.

In Graph1, we see that the maximum tensile strength of the SAMPLE2 is nearly 8MPa and almost 3 to 4 percent. We can see that the SAMPLE1 has almost 0.375 percent strain and almost 6MPa. SAMPLE3 has a tensile strength of almost 7 MPa and a percentage of strain of almost 4.75.

Fig.7: Tensile test specimen after testing.

XIV. LOAD VS DISPLACEMENT UNDER TENSILE TEST

Similarly, we performed the tensile test for three different weighted ratios such as 70% and 30%, 80% & 20%, 90% &10%. For each sample we obtain the load versus displacement graph, so that all three load displacement diagrams are drawn in one graph(shown in Graph2).



Graph2: Load vs Displacement for three different types of composite materials.

The maximum load of Sample1 is 0.34KN and the maximum shift is 0.08 to 0.1 mm. The maximum load of sample 2 is 0.44KN and the maximum shift is between 0.9 mm and 1 mm. The maximum load capacity of the sample 3 is 0.38KN, with a maximum discharge of almost 1.2 mm.

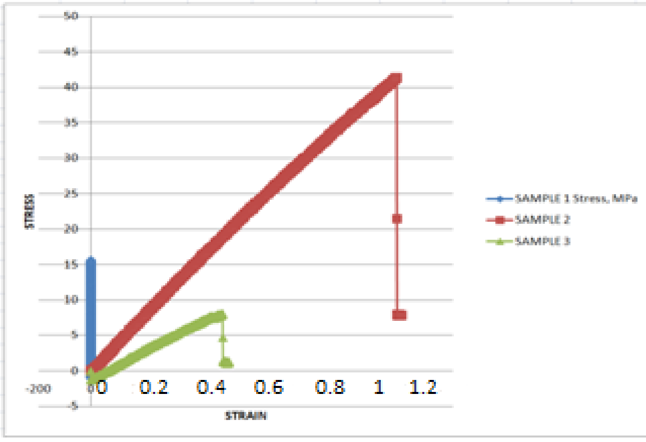
XV. FLEXURAL TEST

The Flexural strength is the combination of tensile, compressive and shear strength. A test specimen called ASTM D790 can perform the flexural test. The specimen must be cut in form according to the standard dimensions of the ASTM D790. In the process of loading 3 points, failure of the specimen and results may be noted. In load vs deflection curve and stress vs strain curve, the readings are noted[15-16]. The specimen shall be placed as shown in the

fig.
Fig.8:Automated 3 point bending machine

XVI. STRESS VS STRAIN UNDER FLEXURAL TEST

We carried out the flexural test for 3 different weighted ratios such as 70% & 30%, 80% & 20%, 90% & 10%. For each sample, we get the Stress vs Strain graph and we've drawn the graph so that all three stress-strain diagrams are in one graph (shown in Graph3).



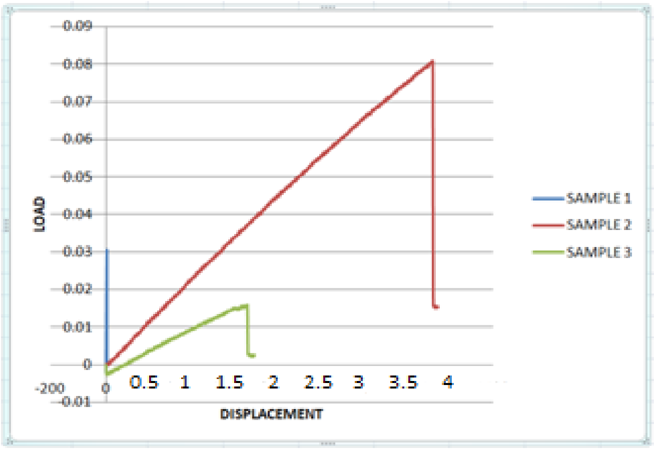
Graph3: Stress vs Strain for three different composites for flexural test.

Sample 1 can bear up to almost 16MPa of maximum stress and the percentage of strain is almost equal to 0.85 to 0.9 percentage. Sample2 can bear up to 41MPa of maximum stress and the percentage of strain is almost 1.7. Sample3 can withstand maximum stress up to 8.3MPa and strain up to almost 0.46 %.

Fig.9: Bending test specimen after testing.

XVII. LOAD VS DISPLACEMENT UNDER FLEXURAL TEST

We carried out the flexural test for 3 different types of weighted ratios such as 70% & 30%, 80% & 20%, 90% & 10%. For each sample, we get the Load vs Displacement graph so that all three stress-strain diagrams are in one graph(as shown in Graph4).



Graph4: Load vs Displacement for three different composite materials.

Sample1 can bear the maximum load up to 0.031KN and displacement up to 0.12mm. Sample2 can bear the maximum load up to 0.081KN and displacement up to 3.9mm. Sample3 can bear the maximum load up to 0.017KN and displacement up to 1.7mm.

XVIII. RESULTS

Here we compare the expected and experimental results. We check whether or not the manufactured specimen has met the desired requirements such as tensile strength, flexural strength. If not, the following reason has been mentioned.

XIX. EXPERIMENTAL RESULTS

The ASTM D638 & ASTM D790 can be used to obtain the tensile and flexural properties of Palmyra fiber reinforced composite(as shown in Table3).

Table3: Strengths of different composites for tensile and flexural tests.

COMPOSITION / TESTS	60&40	70&30	80&20	90&10
Tensile (MPa)	Failed	6	8	7
Flexural (MPa)	Failed	16	41	8.3

Table4: Maximum Loads that can bear by the different composition weights for tensile and flexural tests.

COMPOSITION / TESTS	60&40	70&30	80&20	90&10
LOAD(KN)	Failed	0.34	0.44	0.38

EXPECTED RESULTS

Based on the information obtained from previous literature, the maximum tensile strength, flexural strength and loads for different Palmyra composites for tensile and flexural tests is as shown in Table5.

Table5: Expected results of the composite.

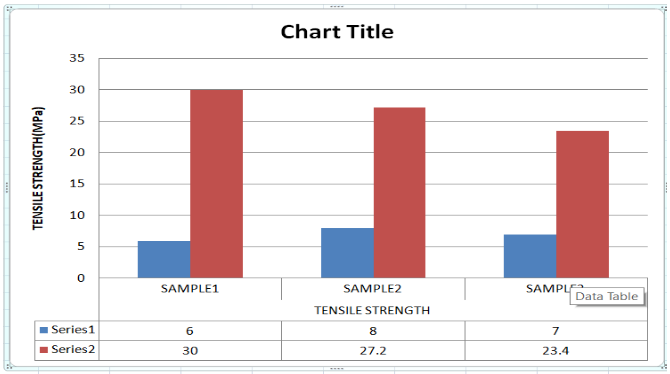
COMPOSITION / TESTS	60&40	70&30	80&20	90&10
TENSILE in (MPa)	failed	30	27.2	23.4
FLEXURAL in (MPa)	failed	57.3	55.2	45.4
LOAD in N	failed	1200	1120	1030

XX. COMPARISON BETWEEN EXPERIMENTAL & EXPECTED RESULTS

The experimental and expected results of tensile, flexural and maximum loads applied during tensile testing are compared here. The percentages in tensile strength, flexural strength can be known here. The tensile and flexural strength percentage is so high, since we take 10, 20, 30 and 40 fiber percentages. We have known that the palmyra fiber has a high specific volume so that the occupied volume is more and so has poor results for 40% and 30% of the fiber composition. Specific volume, fiber orientation, holes, specimen piling are the factors that reduce tensile strengths and flexural strengths[17].

XXI. TENSILE STRENGTH COMPARISON

Here we can see that the column chart is compared with the experimental and expected results. By this we can know that, due to deburring, hole formation fiber orientation, the percentages decrease the tensile strength of 3 samples(as shown in Graph5).



Graph5:Tensile strengths vs different samples.

NOTE:

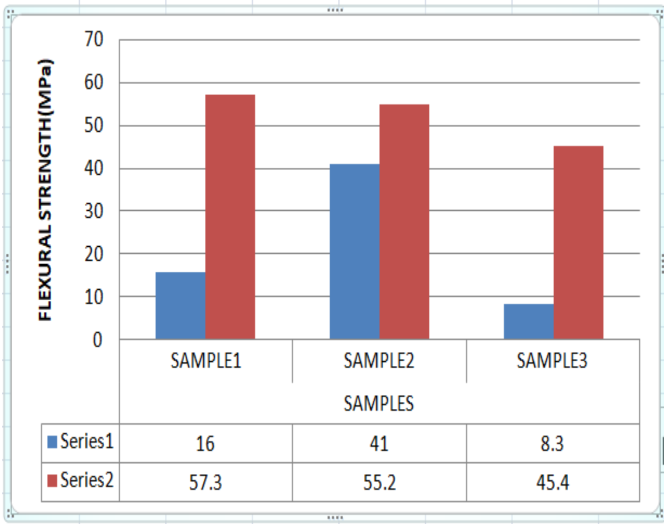
- Series1 represents experimental results.
- Series2 represents expected results.

The tensile strength of sample 1 was reduced by almost 80%. The strength of the sample2 tensile decreased by almost 70.6 percent. The tensile strength of sample3 was reduced by almost 68 percent. We need to take care of the dimensions of the specimen before installing the specimens in the standard ASTM machines. Because of this, we filed the surfaces of the specimens as some of the specimens have the extra thickness as needed.

filed surface fiber strength is reduced and the overall tensile strength is reduced. These holes are formed due to non-uniform PMC distribution. Due to these, the tensile strength gets decreased. These are the two main factors that predominantly decrease specimen strength.

XXII. FLEXURAL STRENGTH COMPARISON

The flexural strength of sample1 was reduced by nearly 81.72 percent (as shown in Graph6). The flexural strength of sample2 was not significantly affected by the distribution of PMC. After the composite had been removed from die, the composite thickness ranged from 4 to 4.5 mm as per the ASTM standards. In this case, deburring is not necessary.



Graph6: Flexural strengths vs different samples.

XXIII. LOAD COMPARISON

The tensile strength of sample 1 was reduced by almost 73.84 percent. The tensile strength of sample2 was reduced by almost 63.63 percent. The strength of the sample3 tensile decreased by almost 65.45 percent(as shown in Fig.10). We need to take care of the dimensions of the specimen before installing the specimens in the standard ASTM machines. Because of this, we filed the surfaces of the specimens as some of the specimens have the extra thickness as needed. Specific fiber volume is so high that for less weight, fibers will take more volume. filed surface fiber strength is reduced and the overall tensile strength is reduced.

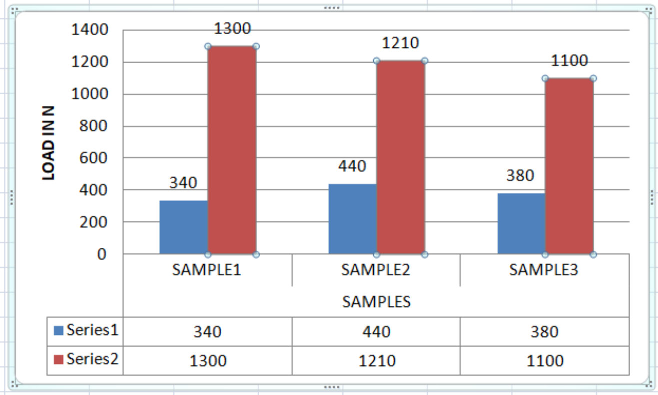


Fig10:Load vs different samples

XXIV. CONCLUSIONS

All streams now focus on natural fiber reinforced composite materials. Among all other natural fibers,palmyra fibers are very attractive because it has high tensile strength, impact and flexural strength in comparison with carbon fiber. Present work shows that 60 to 70% of the tensile and bending strengths are reduced due to hole, manufacture, piling and other features. Finally, we get the maximum tensile strength of 80 & 20 composition samples with 8MPa for sample 2. Sample2 with 41MPa has the highest flexural strength. It has been observed that there is a lot of scope for the palmyra fibre with polymer matrix as reinforced composites.

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