

## EXPERIMENTAL ANALYSIS OF THE MECHANICAL PROPERTIES OF PLA COMPOSITES REINFORCED WITH NATURAL FIBER

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**Abstract** - *This project examines the Phoenix Sp. fibre reinforced polymer matrix composites mechanical properties are influenced by the matrix material (PLA). Using an injection moulding technique, the composite was manufactured by altering the fibre length (300  $\mu\text{m}$ , 10, 20, and 30 mm) and fibre volume fraction (10, 20, 30, 40, and 50%) with random fibre orientations. The ASTM Standards were followed when testing the composite samples under the usual experimental settings. The outcomes showed that the mechanical properties are significantly influenced by the matrix material. Comparatively with PLA matrix-treated fibre showed better mechanical properties than untreated fibre.*

**Key Words:** Phoenix sp fibre, Poly Lactic Acid (PLA), compression moulding, composite, and fibre volume fraction.

### 1. INTRODUCTION

Better qualities of natural fibre reinforced composite materials include high strength, light weight, low cost, corrosion resistance, availability, and high fatigue resistance. Based on the distinctiveness, it found use in the fields of aerospace, automotive, construction, household goods, and recreational goods, among others [1–5]. Investigation of Phoenix sp. fibre reinforced composites their physical, chemical, and vibrational characteristics were examined by Rajeshkumar et al. [6]. By changing the fibre length (10, 20, 30, 40, and 50 mm) while maintaining a constant weight fraction of 10%, the characteristics were determined. Phoenix.Sp plants have historically been utilised for decorative purposes. An alternative use of these waste products is proposed in this work, namely, to obtain fibres and particles to be used as reinforcement of polymer-based composites, taking into account these plants produces a sizeable amount of agricultural wastes (especially petioles with leaves). However, in order to use natural fibres as reinforcement in composite materials, one must have a thorough understanding of those fibres characteristics and how they interact with polymer matrices. In order to assess their potential for use as reinforcement in polymer-based composites, less common natural fibres, including snake grass [7-9], Arundo Donax [10, 11], artichoke [12, 13], rice straw [14], banana empty fruit bunch [15], jowar, sisal, and bamboo [16], alf [17], and rattan [18], have

recently been studied. The literature review led to the conclusion that compression moulding would be used to create the composite, Izod impact test as well as tensile and flexure testing, would be used to determine the composite's properties.

## 2. MATERIALS AND METHODS

### 2.1 Phoenix sp. Fiber

Phoenix sp. fibre is a member of the Aceraceae family and is commonly found in places with high groundwater levels, such as India, China, Turkey, the Canary Islands, Africa, etc. The petioles of this plant contain a lot of fibres. With a knife, the petioles are removed from the plant and submerged in water. Unwanted substances in each petiole are eliminated during this water retting procedure. Then, using a laborious peeling procedure, single fibres were removed. The recovered fibres are then cleaned under running water and dried for two to three days at room temperature. The fibres were then cut with scissors to the necessary lengths (300 µm, 10, 20, and 30 mm). Table -1 displays the fibre of the Phoenix sp characteristics.

**Table -1:** Phoenix sp. Fiber properties

Property	Values
Diameter (mm)	0.5766
Density (g/cc)	1.2576
Cellulose (%)	76.13
Lignin (%)	4.29
Moisture (%)	10.41
Wax (%)	0.32
Ash (%)	19.69
Tensile Strength (MPa)	349
Young's Modulus (GPa)	7.62

### 2.2 Poly Lactic Acid (PLA)

In contrast to the majority of thermoplastic polymers, polylactic acid (PLA) comes from renewable sources such sugar cane or maize starch. Contrarily, the majority of plastics are made by distilling and polymerizing non-renewable petroleum sources. "Bioplastics" are plastics made from biomass (like PLA, for example).

Polylactic Acid is biodegradable and resembles polypropylene (PP), polyethylene (PE), or polystyrene (PS) in terms of its properties. It can be made using currently in use manufacturing machinery (those designed and originally used for petrochemical industry plastics). As a result, production is quite inexpensive. In light of this, PLA has the second-highest volume of manufacture of any bioplastic (the most common typically cited as thermoplastic starch).

**Table -2:** PLA Properties

Property	Values
Technical Name	Poly Lactic Acid
Chemical Formula	(C <sub>3</sub> H <sub>4</sub> O <sub>2</sub> ) <sub>n</sub>

<b>Melt Temperature</b>	157 - 170 °C
<b>Typical Injection Moulding Temperature</b>	178 - 240 °C
<b>Heat Deflection Temperature (HDT)</b>	49 - 52 °C at 0.46 MPa
<b>Tensile Strength (MPa)</b>	61 – 66
<b>Flexural Strength (MPa)</b>	48 – 110
<b>Specific Gravity</b>	1.24
<b>Shrink Rate</b>	0.37 - 0.41% (0.0037 - 0.0041 in/in)

### 2.3 Manufacturing Process of the Composite

Phoenix sp. fibre will be used to make the composites in a variety of forms, including 300 µm particles and chopped short fibres that are 10 mm, 20 mm, and 30 mm long, respectively. While a ball mill was used to create a powder, the dried fibres will be trimmed to the a fore mentioned lengths using scissors. The powder will then be sieved to produce particles with a maximum size of 300 µm. The fibre volume content of the composites will be equal to 0% (i.e., neat resin), 10%, 20%, 30%, 40%, and 50%, respectively, for both the particles and the randomly oriented short fibres. The following relation is used to compute the volume fraction of fibre (Vf).

$$V_f = \frac{(W_f / \rho_f)}{(W_f / \rho_f) + (W_m / \rho_m)}$$

where f and m are the reinforcement and matrix densities (in g/cm<sup>3</sup>), respectively, and Wf and Wm are the weights of the fibre and the matrix (in g), respectively. The reinforcement will be placed on a die and the resin/hardener mixture will be poured on top of it to create composites using the compression moulding technique. According to the supplier's recommendation, the mould will be kept under 4.5 bar of pressure for 6 hours using a hydraulic press to achieve a uniform thickness throughout the entire plate. To ensure that the curing process is uniform, composite panels with the dimensions 300x300x3 mm<sup>3</sup> will undergo a post-curing process for 4 hours at 60 °C in an oven. By using a diamond saw to cut the panels, samples are acquired.

## 3. RESULTS AND DISCUSSION

### 3.1 Tensile Test

A sample is put through a controlled tension until it fails in a fundamental test for materials science called tensile testing. The most popular method for determining the mechanical properties of isotropic materials is uniaxial tensile testing. Biaxial tensile testing is necessary for materials that are anisotropic, such as textiles and composite materials. The tensile testing is done using the Universal Testing Machine (Deepak Poly Plastic Pvt. Ltd. India; Model DTRX - 30 kN) in accordance with the ASTM D638 standard. The specimens are 165 mm in length, 13 mm in width, and 3 mm in

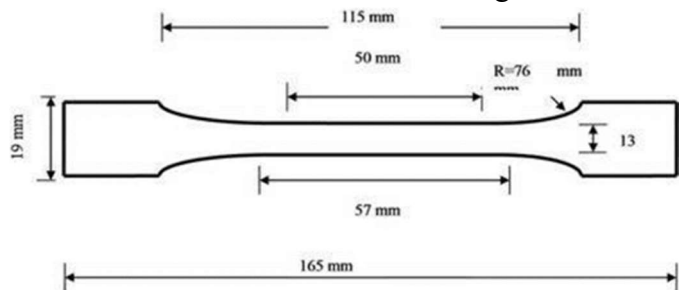
thickness. The crosshead speed was kept at 50 millimetres per minute. The experiment was carried out at room temperature.



**Fig -1:** Universal Testing Machine

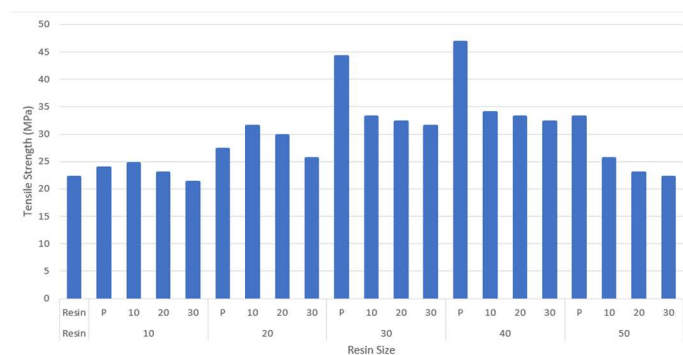
### 3.1.1 Tensile Strength

The maximum load that a material can support without breaking when it is stretched, divided by the area of the material, is its tensile strength.



**Fig -2:** Dimensions of the sample used for testing

The following results were acquired from tests that were carried out in accordance with ASTM D638 standard.



**Chart -1:** Tensile Strength Results

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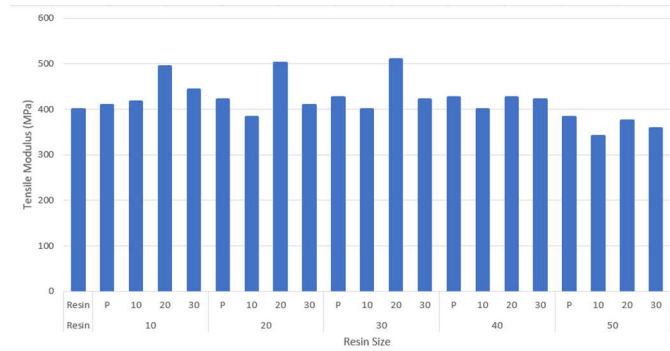
**Table -3:** Tensile Strength of various compositions

Volume Fraction (%)	Fibre Length (mm)	MPa
-	Pure Resin	22.1
10	P(300 μm)	23.8
	10	24.65
	20	22.95
	30	21.25
20	P(300 μm)	27.2
	10	31.45
	20	29.75
	30	25.5
30	P(300 μm)	44.2
	10	33.15
	20	32.3
	30	31.45
40	P(300 μm)	46.75
	10	34
	20	33.15
	30	32.3
50	P(300 μm)	33.15
	10	25.5
	20	22.95
	30	22.1

With a tensile strength of 510 MPa, the composite sample with a 40% volume fraction and P(300 μm) fibre length had the highest strength.

**3.1.2 Tensile Modulus**

A solid material's tensile modulus is a mechanical characteristic that gauges how stiff it is. Its ratio to its strain (relative deformation) when undergoing elastic deformation is known as its tensile stress (force per unit area). The following results were acquired from tests that were conducted in accordance with ASTM D638 standards. The composite sample has a 510 MPa tensile modulus and a 30% volume percentage with 20mm fibre length.



**Chart -2:** Tensile Modulus Results

The results obtained for each composition is given in the table below:

**Table -4:** Tensile Modulus of various compositions.

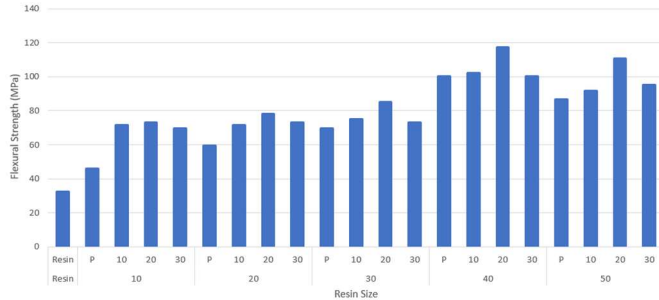
Volume Fraction (%)	Fibre Length (mm)	MPa
-	Pure Resin	400
10	P(300 μm)	408
	10	416.5
	20	493
	30	442
20	P(300 μm)	420.75
	10	382.5
	20	501.5
	30	408
30	P(300 μm)	425
	10	399.5
	20	510
	30	420.75
40	P(300 μm)	425
	10	399.5
	20	425
	30	420.75
50	P(300 μm)	382.5
	10	340
	20	374
	30	357

### 3.2 Flexural Test

Using the same Universal Testing Machine, the flexural test (three-point bending) was performed in accordance with ASTM D790-10 requirements. In each instance, test samples of 64 x 12.7 x 3 mm<sup>3</sup> were evaluated along a span length of 48 mm, and the average value was recorded as the flexural property of the corresponding composites.

### 3.2.1 Flexural Strength

The highest bending stress that a material can withstand before giving way is known as its flexural strength. Utilizing a transverse bending test with a three-point flexural test procedure is the most popular method for determining a material's flexural strength. Other names for flexural strength include bending strength, rupture modulus, and transverse rupture strength.



**Chart -3:** Flexural Strength Results

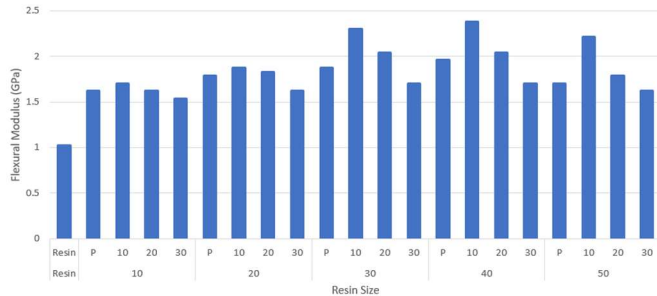
**Table -5:** Flexural Strength of various compositions

Volume Fraction (%)	Fibre Length (mm)	MPa
-	Pure Resin	32.3
10	P(300 μm)	45.9
	10	71.4
	20	73.1
	30	69.7
20	P(300 μm)	59.5
	10	71.4
	20	78.2
	30	73.1
30	P(300 μm)	69.7
	10	74.8
	20	85
	30	73.1
40	P(300 μm)	100.3
	10	102
	20	117.3
	30	100.3
50	P	86.7
	10	91.8
	20	110.5
	30	95.2

The following results for various composite compositions were obtained following tests that were conducted in accordance with ASTM D790-10 standards. With a flexural strength of 117.3 MPa, the composite with a 40% volume fraction and 20mm fibre length had the highest strength.

### 3.2.2 Flexural Modulus

A material's physical characteristic indicating its capacity to bend is called flexural modulus. It is the ratio of stress to strain during a flexural deformation, or bending, in mechanical terminology. As required by ASTM D790-10, tests were conducted.



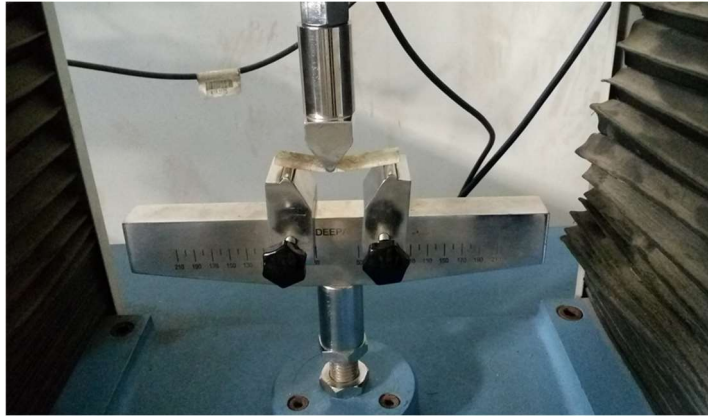
**Chart -4:** Flexural Modulus Results

With a 2.38 GPa Flexural Modulus, the composite with a 40% volume percentage and 10mm fibre length was the strongest. Table -6 lists the Flexural Modulus of the composite's various components.

**Table -6:** Flexural Modulus of various compositions

Volume Fraction (%)	Fibre Length (mm)	GPa
-	Pure Resin	1.02
10	P(300 μm)	1.615
	10	1.7
	20	1.615
	30	1.53
20	P(300 μm)	1.785
	10	1.87
	20	1.8275
	30	1.615
30	P(300 μm)	1.87
	10	2.295
	20	2.04
	30	1.7
40	P(300 μm)	1.955
	10	2.38
	20	2.04
	30	1.7
50	P(300 μm)	1.7

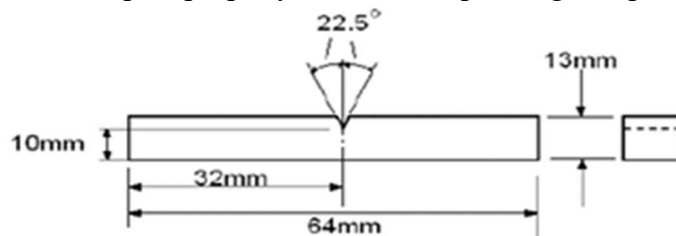
	10	2.21
	20	1.785
	30	1.615



**Fig -4:** Sample Used for flexural Test

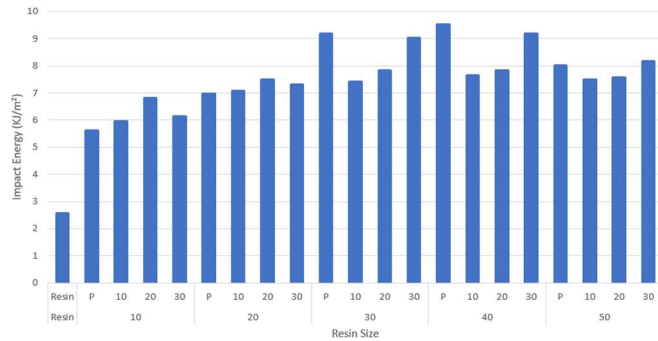
### 3.3 Izod Impact Test

A common test to determine the impact energy required to fracture a material is the Izod impact test. Engineers and scientists can use this test to evaluate a part or component's fracture qualities. The results of the Izod impact test are used to predict how different materials will behave under impact loading. Izod impact tests were performed using the IM245 impact testing equipment (Deepak Poly Plastic Pvt. Ltd. India) with a capability of 0 to 15 J in accordance with ASTM D256-10 standards. In each instance, test samples of 64x12.7x3 mm<sup>3</sup> were evaluated, and the average result was recorded as the impact property of the corresponding composites.



**Fig -3:** Dimensions of sample used for Izod Impact testing

Izod impact tests were carried out and Impact Energy for various compositions were obtained.



**Chart -5:** Impact Energy Results

Impact Energy results for various compositions are given in Table -7.

The composite with 40% volume fraction and P(300 µm) fibre length showed the highest Impact test of 9.52 KJ/m<sup>2</sup>.

**Table -7:** Impact Energy for various compositions

Volume Fraction (%)	Fibre Length (mm)	KJ/m <sup>2</sup>	
-	Pure Resin	2.55	
10	P(300 µm)	5.61	
	10	5.95	
	20	6.8	
	30	6.12	
20	P(300 µm)	6.97	
	10	7.055	
	20	7.48	
	30	7.31	
30	P(300 µm)	9.18	
	10	7.395	
	20	7.82	
	30	9.01	
	40	P(300 µm)	9.52
		10	7.65
20		7.82	
30		9.18	
50	P(300 µm)	7.99	
	10	7.48	
	20	7.565	
	30	8.16	



**Fig -5:** Izod Impact Test

#### 4. CONCLUSIONS

According to test results, composites with a 40% volume fraction had greater overall tensile strength, flexural characteristics, and impact qualities than composites with pure resin and other volume fractions. The tensile modulus of the composites with a 30% volume fraction and 20mm fibre length increased by 21.56% compare with pure PLA resin.

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