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Mechanical Characterisation of Epoxy Resin Reinforced Natural Fibre Composites

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Abstract

Natural fibre-based composite reinforcement may eventually take the place of some traditional materials like wood and metal. The study explains the mechanical characteristics of a neem resin composite reinforced with palm fibre following treatment in an alkaline solution. The fibres were treated with sodium hydroxide solution (NaOH), and composite specimens were created at several volume percentages (10%, 20%, 30% and 40%). The hand lay-up method was used to assess the specimens. To assess the strength of the composites in accordance with the American Society for Testing Materials (ASTM) standards, various mechanical properties, including flexural, tensile and Interlaminar Shear Strength (ILSS), were evaluated on the resulting specimens. It is discovered that the aforementioned characteristics are higher for 30% of the surface. This composite exhibited a maximum tensile strength of 165 MPa, flexural strength of 190 MPa, and ILSS of 29 MPa, which are 21.21%, 7.89% and 27.58% when compared to untreated fibre in the same composition. The results showed that the combined effect of the reinforcements gave the composite better mechanical characteristics.

Major Findings: *30% palm + 70% Epoxy resin composites give better mechanical properties (Tensile strength, flexural strength, ILSS and hardness) when compared to all other composites.*

Keywords: *Epoxy Resin, Hand Layup Method, Palm Fibre, Tensile Strength*

1.0 Introduction

The materials used in the various body sections of automobiles are neither environmentally friendly nor biodegradable. One of the main industries contributing to environmental pollution with trash is the automobile sector. It is therefore imperative to substitute those components with bio-composites. One method of creating a bio-composite is to use cellulose fibre and resin in place of synthetic fibre and resin. Plastic binder (matrix) and materials sourced from plants and/or animals (reinforcements or fibres) are mixed to create natural fibre composites. The biodegradability, low processing costs, abundance, non-toxicity, and light weight of natural fibre-based composites are among their many benefits[1]. Additionally, the use of natural fibres reduces composite weight by 10% and production energy by 80% when compared to glass fibre reinforced composites[2]. The automotive, aerospace, sporting goods, electrical, and home appliance industries have all adopted natural fibre-based composites as a result of these encouraging outcomes[3,4]. Advances in composites made of natural fibres open the door to the production of hybrid composites[5], which blend two or more fibres into one matrix, or the other way around. The properties of the reinforcements and matrix, as well as the interfacial bonding between them and the matrix and the hybrid system design, determine the properties of these hybrid composites[6].

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In this research work, treated and untreated fibres were processed with different compositions (10% palm + 90% resin, 20% palm +80% resin, 30% palm + 70% resin and 40% palm + 60% resin) and hand layup technique is used to fabricate the different wt% of palm fibre reinforced epoxy resin composite material and investigate its mechanical characterisation.

2.0 Materials and Methods

2.1 Epoxy and Hardener

The amine-based hardener (*HY951*) and epoxy resin (*LY556*) were purchased from neighbourhood stores in Hyderabad, Telangana, India. To achieve optimal curing, a 10:1 ratio was used while mixing the epoxy resin with its hardener.

2.2 Palm Fibre

The palm fibers were purchased in Namakkal, India, from neighbourhood merchants, as shown in Figure 1. Palm fibres were used to prepare composites[7] in two different ways (a) as received and (b) surface treated with 5 % NaOH solution[8]. Palm fibre characteristics are shown in Table 1.

2.3 Composites Fabrication

The Hand Layup technique[9] was used to create the composite plates, as shown in Figure 1b by using epoxy resin[10,11] and Palm fibre shown in Figure 1(a). The requisite volume fraction of chopped fibres (length 30mm) was combined and haphazardly distributed over the female portion of the mould, which measured 250mm × 250mm × 3mm.

To generate the matrix system, a 10:1 ratio of resin to hardener was mixed by motorised stirrer, which was used to mix the Epoxy resin and hardener and then put into the mould for improved curing[12]. After that, the mould was left for a full day to cure. Subsequently, the composite plate as shown in Figure 1(c) was cautiously removed from the mould and allowed to cure at room temperature for ten days on a level surface. In the end, the samples were prepared in compliance with ASTM guidelines.

Table 1. Characteristics of palm fibre

S.No	Properties	Palm Fibre
1	Cellulose content %	69.1
2	Lignin content %	22.48
3	Wax content %	0.22
4	Moisture content %	8.11
5	Density g /cc	1.39

3.0 Results and Discussion

3.1 Tensile Test

The 120mm × 20mm × 3mm manufactured composite samples shown in Figure 2(a) were put through a tensile test by ASTM D 3039 standard[13], utilising a universal testing apparatus fitted with a load cell range of 100 kN. Test conditions included a 50mm gauge length and a 5 mm/min crosshead speed. In every instance, five samples underwent testing, and the tensile property of each sample was determined by averaging, and the results are shown in Figure 3(a).

Treated palm fibres with 10%, 20% and 30% show improved tensile strength which are 33.33% 28.16% and 21.21% respectively when compared to untreated fibre in the same composition, while fibre percentage raised to 40% the result got declined compared to 30%. Tensile strength of treated and untreated fibre composites are shown in Table 2.



Figure 1. **(a)** Palm fibers. **(b)** Hand layup technique. **(c)** Fabricated composite laminate.



Figure 2a Tensile strength samples after testing



Figure 2b Flexural strength samples after testing

Table 2. Tensile strength of treated and untreated fibre

S.No	Composition	Treated Fibre Tensile Strength in MPa	Untreated Fibre Tensile Strength in MPa
1	10% Palm + 90% Resin	90	135
2	20% Palm + 80% Resin	102	142
3	30% Palm + 70% Resin	130	165
4	40% Palm + 60% Resin	103	140

3.2 Flexural Test

Using the Universal testing equipment, samples measuring 120mm x 20mm x 3mm underwent the flexural test (3-point bending) following the ASTM D 790 standards as shown in Figure 2b. 50mm was the support span, and 1.25mm/min was the crosshead speed. The flexural property of each sample was determined by averaging the results of five samples, as shown in Figure 3(b).

Table 3. Flexural strength of treated and untreated fibre

S.No	Composition	Treated Fibre Flexural Strength in MPa	Untreated Fibre Flexural Strength in MPa
1	10% Palm + 90% Resin	142	163
2	20% Palm + 80% Resin	158	174
3	30% Palm + 70% Resin	175	190
4	40% Palm + 60% Resin	155	170

Table 4. ILSS of treated and untreated fibre

S.No	Composition	Treated Fibre ILSS in MPa	Untreated Fibre ILSS in MPa
1	10% Palm + 90% Resin	12	17
2	20% Palm + 80% Resin	16	23
3	30% Palm + 70% Resin	21	29
4	40% Palm + 60% Resin	15	22

Treated fibres showed improved flexural strength than the untreated fibres. Fibres with 10%, 20% and 30% show increased flexural strength, i.e., 12.88%, 9.19% and 7.89% respectively, while fibres with 40% show less strength when compared to 20% and 30%. Flexural strength of treated and untreated fibre composites is shown in Table 3.

3.3 ILSS Test

In compliance with ASTM D2344 guidelines, a universal testing apparatus was used to perform the ILSS test[14]. Ten (100mm x 25mm x 3mm) samples were examined, and the results are presented in Figure 3(c). Treated fibres show better results than the untreated ones. Fibre with 30% Palm exhibits enormous strength, which is 27.58% higher compared to the untreated fibre. ILSS values of treated and untreated fibres are shown in Table 4.

3.4 Hardness Test

Figure 3d displays the hardness values of the composites. Since the hardness values were obtained by pressing the plunger needle against the resin surface, there is no

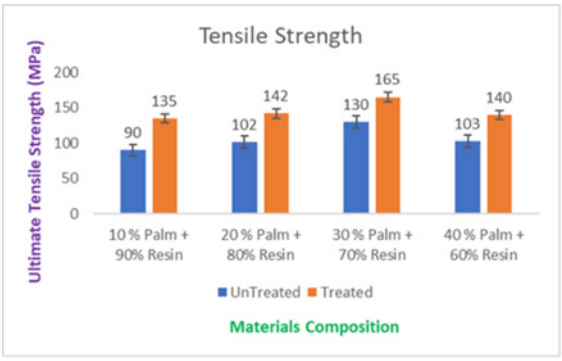


Figure 3a Ultimate Tensile Strength of Palm-epoxy composites with different weight ratios

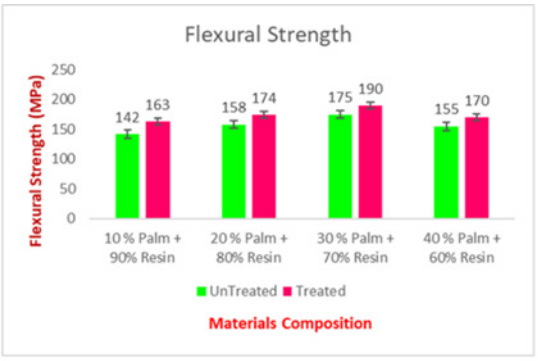
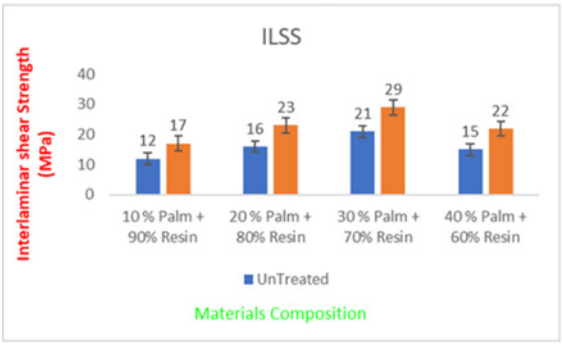


Figure 3b Flexural Strength of epoxy -Palm reinforced Composites



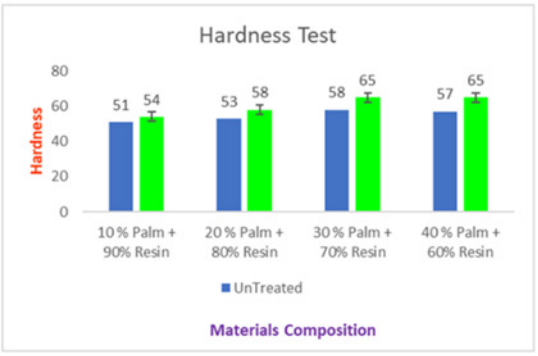


Figure 3. **(a)** Ultimate Tensile Strength of Palm-epoxy Composites with different weight ratio. **(b)** Flexural Strength of epoxy -palm reinforced composites. **(c)** ILSS of Palm-epoxy reinforced composites. **(d)** Hardness of Palm-epoxy reinforced composites.

barrier or resistance in the matrix. Due to the tiny ends of the fibre, the interface is either on the resin matrix or at the interface where the fibre and matrix converge[15]. For the processed palm fibre-epoxy resin composite, the maximum hardness value was 65 shore-D- D for compositions of 30% (30% Palm + 70% epoxy Resin) and 40%. (40% Palm +60 % epoxy Resin). Treated fibres with 10%, 20%, and 30% show improved hardness of 5.55%, 8.62% and 10.76% respectively compared to the untreated fibre with the same composition. Table 5 shows the Hardness value of treated and untreated fibre composites.

Table 5. Hardness of treated and untreated fibre

S.No	Composition	Treated Fibre Hardness	Untreated Fibre Hardness
1	10% Palm + 90% Resin	51	54
2	20% Palm + 80% Resin	53	58
3	30% Palm + 70% Resin	58	65
4	40% Palm + 60% Resin	57	65

4.0 Conclusion

For the palm fibre reinforced epoxy resin composite, the hand lay-up approach proved to be an effective fabrication technique. The elimination of lignin, hemicellulose, and other contaminants from the fibre surface during the alkaline treatment increased the raw fibre density. This experimental observation demonstrates the effective inclusion of palm fibres at varying fibre volumes, leading to an improvement in the composites' tensile, flexural, ILSS and hardness properties. According to the experiment, treated palm fibre exhibits significantly improved flexural, ILSS, and tensile strength capabilities as compared to unprocessed palm fibre. When compared to the other volume percentage of composites, 30% of processed fibre loading showed the greatest benefit because of improved dispersion, fibre wettability, and interfacial bonding strength between palm fibre and epoxy resin matrix. Thus, the goal of this effort is to reduce the massive amount of palm waste that ends up in landfills.

5.0 Author Contribution

Conceptualization: T. Srinivasa Rao, Methodology : T.S.Krishna Kumar, Writing - Original Draft : T.S.Krishna Kumar, Writing - Review and Editing : Nagasrisaihari Sunkara, Formal analysis : T. Srinivasa Rao, Investigation : Namala Kiran Kumar , Resources : Nagasrisaihari Sunkara.

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