Mechanical properties of short and randomly oriented Borassus Flabellifer (Asian Palmyra) Sprouts fiber reinforced epoxy composites

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Abstract
Fiber-reinforced composite materials consist of fibers of high strength and modulus embedded in or bonded to a matrix with distinct interfaces (boundaries) between them. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. The objective of this study is to evaluate mechanical properties such as tensile, flexural and impact properties of natural fiber (Asian Palmyra sprouts) reinforced composites (NFRC). The fiber content in NFRC was varied from 20 to 40 by % volume. The results revealed that the tensile, flexural and impact strength increased with increase in fiber content. Further, the density of the natural fiber was measured by theoretical method.

Keywords: Natural fiber reinforced composites (NFRC); Mechanical Properties; Asian Palmyra Sprouts fiber; Epoxy resin

1. Introduction
Many countries have imposed rules and regulations to reduce solid waste in material manufacturing industries in order to protect the environment [1]. Natural fiber reinforced polymer composites are emerging as new eco-friendly polymeric composite materials and are offering commercial and engineering applications and techno-economic advantages, like, low price, low density, acceptable specific strength and specific stiffness, reduced tool wear and non-abrasiveness[2]. Polymer matrix composites possesses interesting properties like high specific strength and stiffness, good fatigue performance and damage tolerances, low thermal expansion, corrosion resistance and low energy consumption during fabrication of composites [3].

Natural fiber composites are used in various applications, in components subjected from light to moderate loadings, in many cases substituting polymers or fiberglass composites [4]. The fibre has been mainly used in rope, twine, coarse cloth and paper. However, nowadays, there is demand for this fibre to be used as reinforcement for polymers [5]. Natural fibers are grown as agricultural plants in various parts of the world and are commonly used for making ropes, carpet backing, bags, and so on. The components of natural fibers are cellulose micro fibrils dispersed in an amorphous matrix of lignin and hemicelluloses. Depending on the type of the natural fiber, the cellulose content is in the range of 60–80 wt% and the lignin content is in the range of 5–20 wt%. In addition, the moisture content in natural fibers can be up to 20 wt% [6].

The Borassus Flabellifer is a tall and erect palm, and can live 100 years or more and reach a height of 30 m, with a canopy of large, fan-shaped leaves several dozen found spreading 3 m across [7]. Natural fibers like bamboo, banana, jute, coir, sisal and hemp in their natural form as well as several waste cellulosic products such as wood flour, shell flour and pulp have been used as reinforcing agents of different polymer composites. Several researchers have reported the behaviour of natural fibers and their composites by incorporating the fiber in matrices before and after chemical treatments [8-12]. The tensile properties of sisal, hemp, coir, kenaf, and jute reinforced composites have been studied [13], and reported that among all the composites, hemp reinforced composite exhibited the highest mechanical properties whereas coir showed the lowest. Mechanical properties of jowar, bamboo and sisal fiber reinforced polyester composite were investigated, and found that modulus of jowar fiber composite is higher than sisal and bamboo fiber reinforced composites. The tensile properties of sisal, hemp, coir, kenaf, and jute reinforced composites have been increased with increase of fiber volume fraction [14]. Natural fiber composites provide
comparable specific strength with that of synthetic fiber composites, due to the low density offered by natural fibers [15]. Borassus Flabellifer is renewable and abundantly available in nature. This economical source compared to other natural sources is still underutilized. The overall objective of this work is to study the effect fiber loading on a mechanical properties such as tensile, flexural and impact properties.

2. Experimental Procedures

2.1 Materials

General purpose epoxy resin, methyl ethyl ketone peroxide and cobalt naphthenate were purchased from Subh Resins & Fuels Pvt Ltd, Hyderabad.

2.2 Extraction of fibers

The Asian Palmyra raw sprouts collected from local sources. First the external layer of sprouts was removed. Further, the fibers (thin layer of the sprouts skin) extracted by hand peeling. The extracted fibers were treated with 1% NaOH solution for half an hour and then thoroughly washed in distilled water to remove unwanted particles. The fibers were dried for one day at room temperature. Further, the fibers were kept in hot air oven for 2h at 70°C to ensure that maximum moisture was removed.

2.3 Fabrication of composites

Polymer Matrix composites were prepared, using epoxy matrix to assess the reinforcing capacity of Asian Palmyra Sprouts fibers. The quantity of accelerator and catalyst added to resin at room temperature for curing was 1.5% by volume of resin each. Hand lay-up method was adopted to fill up the prepared mould with an appropriate amount of epoxy resin mixture and Asian Palmyra Sprouts fibers, starting and ending with layers of resin. Fiber deformation and movement should be minimized to yield good quality, fiber reinforced composites. Therefore at the time of curing, a compressive pressure of 0.05 MPa was applied on the mould and the composite specimens were cured for 24 h. The specimens were also post cured at 70°C for 2 h after removing from the mould. Composite samples were prepared with five different percentage volumes of Asian Palmyra Sprouts Fibers.

2.4 Density of the fiber

Density of the fiber was measured by using the theoretical method. The diameter of fiber was measured by using the Coordinate Measuring Machine (CMM). The diameters of a total four fibers were measured at different locations on a fiber. The mean diameter is determined and the variation in the diameter along the length of the fiber is found to be negligible and so the mean diameter of each fiber is taken as the average of diameters at those measuring points. The cross sectional area of the fiber was measured by using the mean diameter.

\[ \text{Density} (\rho) = \frac{m}{V} = \frac{m}{Al} \]

Where \( m \) = mass of the fiber

\( V \) = Volume of the fiber

\( A \) = Cross sectional area of the fiber

\( L \) = length of the fiber

2.5 Mechanical Properties of Composites

2.5.1 Tensile test

The tensile behaviour of the Asian Palmyra Sprouts Fiber Reinforced Plastic (ASPFRP) composites were prepared as per the standard ASTM D 638M [16]. The composite specimens with 165 mm long 12.7 mm wide and 3 mm thick were prepared. Three identical composite specimens were tested for each percentage volume fraction of fiber. The specimens were tested at a cross head speed of 2.5 mm/min, using a Tensile testing machine supplied by Associated Scientific Engg. Works, New Delhi.

2.5.2 Flexural test

Three point bend tests were performed in accordance with ASTM D 790M [17] test method I (procedure A) to measure flexural properties. The specimens were 125 mm long, 12.7 mm wide and 3 mm thick. In three point bending test, the outer rollers were 64 mm apart and samples were tested at a strain rate of 0.2 mm/min. A three point bend test was chosen because it requires less material for each test and eliminates the need to accurately determine center point deflections with test equipment. Three identical specimens were tested for each composition and all the specimens were tested at a cross head speed of 2.5 mm/min, using tensile testing machine. Flexural strength (\( \sigma \)) and modulus (\( Ef \)) in the composite was calculated using the following relationships:

\[ \sigma = \frac{3Pl}{2bt^2} \]

Where \( \sigma \) is bending strength (N/mm²)

\( P \) – The maximum load (N)

\( L \) - The distance between supports (mm)

\( b \) - Width of the specimen

\( t \) - Thickness of the specimen

\( m \) - The slope of the initial straight portion of the load deflection curve.

2.5.3 Impact test

Izod impact test notched specimens were prepared in accordance with ASTM D256 to measure impact strength. The specimens were 64 mm long, 12.7 mm wide and 3mm thick. A sharp file with included angle of 45° was drawn across the center of the saw cut at 90° to the sample axis to obtain a consistent starter crack. The samples were fractured in a plastic impact testing machine (capacity-21.68 J), supplied by M/s International equipments, Mumbai, India. A total of three samples were tested for each composition and the mean value of the absorbed energy taken. The impact strength (kJ/m²) was calculated by dividing the recorded
absorbed impact energy with the cross-sectional area of the specimens.

3. Results and Discussions

3.1 Density of the fiber

The density of the Asian Palmyra sprouts fiber was measured as 1.32 g/cm³ by using the theoretical procedure. It is comparatively lower than all the known natural fibers like Hemp, Jute, Ramie, Sisal, Flax and Cotton.

The densities of various natural fibers [18] are given in Table 1

| Name of the Fiber   | Asian Palmyra | Hemp | Jute | Ramie | Cor | Sisal | Flax | Cotta |
|---------------------|---------------|------|------|-------|-----|-------|------|-------|
| Density (g/cm³)     | 1.32          | 1.48 | 1.84 | 1.5   | 1.25| 1.12  | 1.4  | 1.51  |

3.2 Tensile strength

The variation of mean tensile strength and tensile modulus of composite with varying fiber content is presented in Figure 2. It was clearly evident that with increasing the fiber content in the epoxy matrix, the tensile strength is also increasing. This is due to the fact that the epoxy resin transmits and distributes the applied stress to the sprouts fibers resulting in higher strength. The tensile strength of the composite at maximum fiber content (40% volume of the fiber) is found to be 38.58 MPa. The tensile strength as well as tensile modulus of composite considered in this study is far better than that of Asian Palmyra fiber reinforced epoxy composites [7]. Further, it was found that the failure of specimen is Asian Palmyra sprouts fiber from the specimen. The tensile test report of the composite at volume fraction (0.42) of fiber is shown in Figure 3.

3.3 Flexural Strength

The flexural behavior of Asian Palmyra sprouts fiber reinforced composites is presented in Figure 3. These plots exhibit the similar trend observed for tensile properties and same cause is attributed as stated above. The flexural strength of the composite at maximum fiber (40% volume of the fiber) content is about 109.17 MPa. The flexural strength of composite considered in this study is better than that of coir, kenaf, hemp, sisal, and jute [18] fiber reinforced composites.

3.4 Impact Strength

The results of pendulum impact test are shown in Figure 4. As the volume fraction of Borassus fiber increases, the value of impact strength increases. The impact strength of the composite at maximum fiber (40% volume of the fiber) content is found to be 23.62 KJ/m². The impact strength of Asian Palmyra sprouts fiber composite is better than kenaf, jute and very close to coir [18] fiber reinforced composites.

4. Conclusions

The reinforcing action of the fibers. Thus the composites of Jute, Pineapple leaf fiber and Glass fiber epoxy composites were found to be light in weight, possessed better mechanical properties. Hence these composite materials can be used for applications such as automobile parts, electronic packages, building construction etc.

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