Comparative study on effect of alkali treatment on mechanical behaviour of palm fiber reinforced epoxy composite

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Abstract — **In accordance to the present situation of environmental condition, the natural fibers offer the potential to act as a reinforcing material for polymer composites alternative to the use of glass, carbon and other man-made fibers due to its attracting properties. The natural fiber reinforced polymer composites are increasingly being used for varieties of engineering applications due to many of their advantages. Among various fibers, date palm is most widely used natural fiber due to its advantages like easy availability, low density, low production cost and satisfactory mechanical properties. For a composite material, its mechanical behaviour depends on many factors such as fiber content, orientation, types, length etc.In this connection an investigation has been carried out to make better utilization of date palm stem fiber for making value added products. Attempts have been made in this research work to study the effect of fiber loading of NaOH treated short date palm fiber ,untreated ,treated glass hybrid fiber on the physical, mechanical and water absorption behaviour of NaOH treated date palm fiber and treated and untreated date palm/glass fiber reinforced epoxy based hybrid composites.**

Index Terms— **Date Palm stem fiber, NaOH, Natural Composite, Epoxy material.**

1. INTRODUCTION

Recently, the world is facing a serious problem in developing proper methods of decomposing the solid wastes through different chemical processes with minimal energy, which are not cost-effective and may subsequently produce harmful gases during the process. This environmental issue has forced the scientists and material designers to focus considerable attention on the development of recyclable and biodegradable materials When two or more materials with different properties are combined together, they form a composite material. In general , the properties of composite material is superior in many aspects, to those of individual constituents. This has provided the main motivation for the research and development of composite materials. There are two categories of constituent materials - one is matrix and other is reinforcement. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength, stiffness etc. The objective is to take advantage of the superior properties of both materials without compromising on the weakness of either.

Composite materials having a range of advantages over other conventional materials such as tensile strength, impact strength, flexural strength, stiffness and fatigue characteristics.Because of their numerous advantages they are widely used in the aerospace industry, commercial mechanical engineering applications, like machine components, automobiles, combustion engines, mechanical components like drive shafts, tanks, brakes, pressure vessels and flywheels, thermal control and electronic packaging, railway coaches, aircraft structures etc.

1.1. Fibrous composites:

Fibers, because of their small cross- sectional dimensions are not directly usable in engineering applications. They are, therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibers together, transfer loads to the fibers, and protect them against environmental attack and damage due to handling. In discontinuous fiber reinforced composites, the load transfer function of the matrix is more critical than in continuous fiber composites. These are generally classified into two groups:

- Synthetic Fibers
- Natural Fibers

Date Palm Stem Fibre: A type of Natural fibre extracted from Date palm stem and have high tensile strength.

Constituents	Composition (%)
Cellulose	54.75
Hemi-cellulose	20.00
Lignin	15.30
Moisture	6.50
Pectin	1.20
Ash	1.75
Wax	0.50

Table: Composition of DPS fibre


FIG : Date Palm tree and DPS fibre

Advantages of composites :

- Composites generally have good resistance to corrosion.
- They generally increase mechanical damping.
- They have higher strength and toughness.
- They have excellent fatigue strength.
- They are of low cost.
- They have good tensile strength.
- They have good resistance to fire.

2. LITERATURE REVIEW:

Mahdavi et al. [1] have studied the morphological and mechanical properties of wood plastic composite fabricated by reinforcing the fibers obtained from trunk, rachis and petiole of date palm tree in high density polyethylene matrix. It has been observed that there is a significant difference between trunk and petiole on fiber length but rachis has no significant difference relative to other parts.

Sbiai et al. [2] have investigated various properties of short date palm leaf fiber reinforced in a poly-epoxy thermoset resin.

The tensile strength of fibers obtained from leaves and stems of date palm tree have been investigated and compared with other natural fibers by **K. M. M. Rao and K. M. Rao. [3].**They have observed that the tensile strength of date palm fiber is comparable to that of other fibers such as banana, bamboo, coconut and sisal. **Alawar et al. [4]** have studied the effect of different chemical treatment processes on date palm fiber surrounding the stems of date palm tree. From their work it has been observed that 5 % NaOH treated date palm fiber shows the optimum mechanical properties.

Salah Amroune et al.[5] investigated the tensile properties and surface chemical sensitivity of technical fibers from date palm fruit branches (Phoenix dactylifera L.) and found that the tensile tests show clearly that use of post-processing NaOHbasedchemical treatments allows significant increase in stress at failure and the Young's modulus with a low influence on strain at failure.

T. Alsaeed, B.F. Yousif, and H. Ku [6] investigated the potential of using date palm fiber as reinforcement for polymeric composites and interfacial adhesion of date palm fiber with epoxy matrix was experimentally investigated using single fiber pull out technique. The influence of NaOH treatment concentrations (0–9 %), fiber embedded length and fiber diameter on the interfacial adhesion property was considered in this study.

Jyoti R. Mohanty et al.[7] studied the Effective Mechanical Properties of Polyvinyl alcohol Bio-Composites with Reinforcement of Date Palm Leaf Fibers. In their study they found that acrylic acid treated date palm fiber has shown good tensile properties in single fiber pull out test. **S.G.Taghavi [8]** studied on effect of water absorption on the mechanical properties of glass/polyester composites.

3. EXPERIMENTATION :

3.1. Fiber preparation methods

The natural mat consists of single fibers crossing each other. Due to their exposure to the natural environment, the natural fibers were contaminated with a large amount of sand and dust. The samples were washed with fresh water and manually dismantled into bundles of virgin fibers.The fibers were dried at room temperature and cut to the desired length. In this study, fibers were treated with Sodium hydroxide and hydrochloric acid, with various concentrations.

First, fibers were soaked in 5%, 2.5%, 1.5%, 1%, and 0.5% NaOH at 100 °C for 1 h. Similarly, the second treatment method consisted of soaking fibers in 0.3, 0.9 or 1.6N HCl at 100 °C for 1 h. At the end of treatment process fibers cooled to room temperatures, rinsed with fresh water, and dried in a vacuum oven at 60 °C for 24 h. Finally, fibers were preserved in airtight aluminium foil to reduce moisture absorption until they were used.

FIG 3.1.1. : Fibre Structure

3.2. Preparation of Epoxy based composite

The fabrication of composite slab is carried out by conventional hand layup technique. The chemically treated date palm steam fibers (DPS) was used as reinforcement and epoxy is taken as matrix material. The low temperature curing epoxy resin and hardener are mixed in a ratio of 10:1 by weight percentage. Then these mixture of DPS, epoxy resin and hardener was poured over a silica gel which is placed in the mold. Then the mixture was left to solidify. Then the composite was pulled out of the mould, and then we got the final finished composite.

Finally, the specimens of suitable dimensions are cut with the help of hack saw for characterization and testing. Seven composite samples are fabricated with 0.1, 1, 0.5, 3, 5, 7, 10 % NaOH treated DPS reinforcement.

FIG 3.2.1: Preparation of Epoxy Based composite

4.TESTS:

4.1. Density Test :

The theoretical density of composite material can be calculated using the formula given by **Agarwal and Broutman**.

$$\rho_{ct} = \frac{1}{\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}}$$

Where, w and ρ represent the weight fraction and density respectively.

The suffix f, m and ct stands for fiber, matrix and composite material respectively. The actual density (ρce) can be calculated experimentally by simple water displacement technique. In the present work, since some of the composites are hybrid type i.e. glass fiber and date palm stem fiber (DPS) the above expression for density has been modified for them as:

$$\rho_{ct} = 1 \Big/ \left\{ \left(\frac{w_{f_1}}{\rho_{f_1}} \right) + \left(\frac{w_m}{\rho_m} \right) \right\}$$

where, the suffix f1 and f2 stand for the date palm stem fiber (DPS) and glass fiber and m stands for the matrix respectively. The volume fraction of the voids (VV) in the composite is calculated by following equation:

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$$V_V = \frac{\rho_{ct} \quad \rho_{ce}}{\rho_{ct}}$$

4.2. TENSILE TEST :

The tensile test is generally performed on a flat specimen. Tensile test of composite sample is carried out as per ASTM D 638 test standard. In tensile test, a uniaxial load was applied through both the ends. The tensile test specimens for date palm stem (DPS)/glass fiber reinforced epoxy hybrid composites. The experimental set up and loading arrangement of specimen for tensile test is as follows.

FIG 4.2.1. Setup for Tensile test

4.3. FLEXURAL TEST:

Flexural test is done to determine the capability of a material to withstand the bending before reaching the breaking point. This test is done on a three point bend test using Instron- UK-3382. Flexural test of composite sample is carried out in ASTM D 790 test standard .A span of 40 mm is taken and cross head speed is maintained at 2mm/min.

FIG 4.3.1. Setup for Flexural test

5. EXPERIMENTATION RESULT:

Physical and mechanical characteristics of composites:

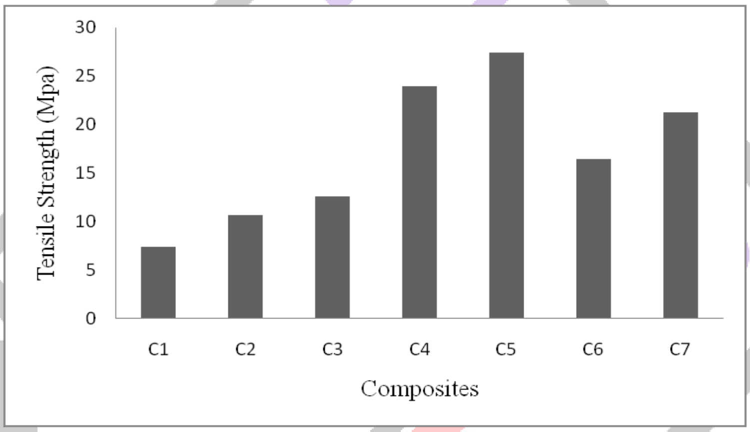
5.1. Effect of alkali treatment on density of composites:

Composite	Theoretical Density	Experimental density	Void (%)
C1	1.133	1.087	4.060
C2	1.182	1.149	2.79

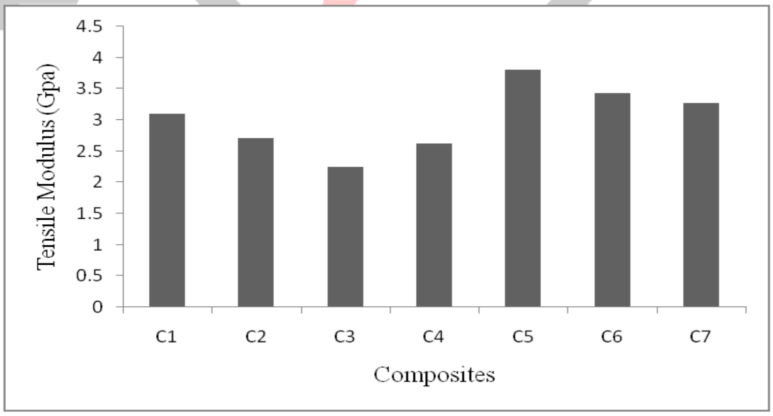
C3	1.182	1.150	2.70
C4	1.182	1.163	1.60
C5	1.182	1.167	1.26
C6	1.182	1.168	1.18
C7	1.182	1.150	2.70

5.2. Effect of alkali treatment on tensile strength and tensile modulus of composites:

The influence of alkali treatment on the tensile strength of the composites is shown in Figure 1. A remarkable increase in tensile strength can be observed with the increase in the percentage of alkali treatment (up to 5%)of date palm fiber epoxy based composites. This is due to the proper removal of part of lignin present in the fibre surface which enhances the surface roughness and allows better mechanical interlocking between the fiber and matrix. However, further increase in percentage of alkali treatment i.e 7% and 10% there is a decrease in the tensile strength. The reason may be due to the change in micro structure of date palm fibre. The maximum tensile strength is observed for the composite with 5% alkali treatment and 10wt% fibre loading.



GRAPH 5.2.1. Tensile strength of the alkali treated DPS palm fibre epoxy composite

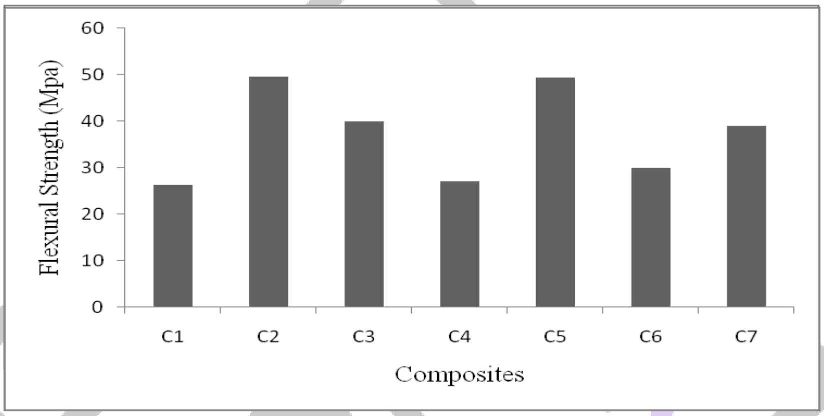


GRAPH 5.2.2. Tensile modulus of the alkali treated date palm fiber epoxy composites

5.3. Effect of alkali treatment on Flexural strength and flexural modulus of composites:

The determination of flexural strength and flexural modulus is an important characterization of any structural material. It is the ability of a material to withstand the bending before reaching the breaking point as shown in Figure 1 and 2 respectively. The flexural strength of composite is increased due to improvement in the bonding between the reinforcement and the matrix is done by the alkali treatment. The reason for this is that the alkali treatment improves the adhesive property of date palm fiber surface by extruding hemi- cellulose, thereby producing rough surface topography.It is also observed that the flexural strength and flexural modulus of 5% treated composite is maximum among all the composites.

GRAPH 5.3.1. Flexural strength of the alkali treated date palm fiber epoxy composites



GRAPH 5.3.2. Flexural modulus of the alkali treated date palm fiber epoxy composites

CONCLUSION:

The experimental investigation on the physical, mechanical and water absorption behaviour of treated, untreated reinforced epoxy based hybrid composites lead to the following conclusions:

1. The successful fabrication of treated, untreated date palm stem fiber reinforced hybrid epoxy composites and treated date palm stem epoxy composite by simple hand lay- up technique was possible.

2. The present investigation revealed that fiber loading and chemical modification and hybridization significantly influences different properties of composites. The maximum tensile strength, flexural strength, tensile modulus, flexural modulus is obtained for composites reinforced with 5 % NaOH(10%wt) treated fiber loading epoxy composite.

SCOPE FOR FUTURE WORK:

There is a wide scope for future scholars to explore the current research area. The present work can be further extended to study other aspects of composites like use of other natural fibers and evaluation of their dynamic mechanical, thermal, tribological properties and the experimental results can similarly be analyzed.

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