

A Study On the effect of Surface treatment on the Physical and Mechanical properties of date-palm stem fiber embedded epoxy composites

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Abstract Natural fiber reinforced polymer composites are being used frequently for variety of engineering applications due to many of their advantages like ease of availability, low density, low production cost and good mechanical properties but natural fibers are more or less hydrophilic in nature. Therefore, an investigation has been carried out to make better utilization of a class of natural fiber that is date palm stem fiber, for making a wide range of products. Attempts have been made in this research work to study the effect of fiber loading on the physical, mechanical and water absorption behaviour of treated and untreated short fiber based epoxy composites. Composites of various compositions of different amounts of fiber loading are fabricated by simple hand lay-up technique. It has been observed that there is a significant effect of surface treatment of fibers on the overall properties of composites. Further enhancement of properties with lower water absorption rate was attained with glass fiber-epoxy based hybrid composites.

1. Introduction

Lately, the concept of 'eco-materials' has gained key importance due to the need of preservation of our environment. The meaning of eco-material includes 'safe' material systems for human and other life forms at all times. 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 on the development of recyclable and biodegradable materials. Past experiences have shown that it is necessary to characterize materials and determine those which are safe for both short and long-term utilization. Selection of a material system that satisfies not only industrial requirements but also this wider definition of eco-materials, as described above, is an urgent necessity. Therefore, due to the growing global energy crisis and ecological risks, natural fiber reinforced polymer composites have attracted



more researchers. The advantages of natural fibers are their availability, biodegradable and renewable nature, low density, high specific properties, good thermal properties, low energy consumption, enhanced energy recovery, non-abrasive nature and low cost. A great deal of work has been carried out to measure the potential of natural fibers like jute, coir, bamboo, sisal, banana and date palm leaf as reinforcement in polymers due to their renewable nature and good mechanical properties. Similarly, date palm fiber has also a great potential to be used as reinforcement in polymer composites. The date palm tree, a member of the palm tree family (*Phoenix dactylifera*), is normally found in the Middle East, Northern Africa, the Canary Islands, Pakistan, India, and in the United States (California). Traditionally, the leaves of date palm tree are used in making ropes, baskets and mats in many parts of the world. Date palm stem fiber is a lingo-cellulosic fiber having high toughness and aspect ratio and its composites have high impact strength with moderate tensile and flexural properties compared to other fibers like coir, sisal, pineapple, banana etc. The in-born properties of date palm fiber such as low density, low elongation at break and its specific stiffness and strength is comparable to those of glass fiber. The efficient utilization of this natural resource in making natural fiber composite will have a positive impact on environment and may improve the economic standard of rural people.

Few works have been undertaken by researchers on polymer composites using fibers obtained from different parts of date palm tree. Sbiai et al. [1] have investigated various properties of date palm leaf fiber reinforced in a poly-epoxy thermoset resin. Mahdavi et al. [2] studied the morphological and mechanical properties of 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 and that every part of date palm like trunk, rachis and petiole gives higher strength with increasing fiber loading. The tensile strength of fibers obtained from leaves and stems of date palm tree have also been investigated and compared with other natural fibers by Rao et al. [3]. Mohanty et al. [4] studied the Effective Mechanical Properties of Polyvinyl alcohol Bio-Composites with date palm Leaf fiber reinforcement. In their study, they found that acrylic acid treated date palm fiber has shown desirable tensile properties in single fiber pull out test. They have also 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. [5] 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 concluded that 5% NaOH treated date palm fiber shows optimum mechanical properties.

Mechanical properties of various date palm fiber composites produce significant strength according to various researchers. Al-Sulaiman & A. Faleh, [6] studied the mechanical properties of date palm fiber reinforced composite at high temperature curing with phenolic and bisphenol resin and observed that long fibers laminates (300 mm) have more strength than wood. Salah Amroune et al.[7] investigated the tensile properties and surface chemical sensitivity of technical fibers obtained from date palm fruit branches (*Phoenix dactylifera* L.) and found that the tensile tests clearly show that use of post-processing NaOH-based chemical treatments allow 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 [8] investigated the potential use of date palm fiber as reinforcement for polymeric composites and investigation on interfacial adhesion of date palm fiber with epoxy matrix was experimentally done by using single fiber pull out technique. The influence of NaOH concentrations (0–9%), fiber length and fiber diameter on the interfacial adhesion was also considered in this study.

Luo and Netravali [9] studied the effect of fiber content on tensile and flexural properties of pineapple fiber reinforced poly (hydroxybutyrate-co-valerate) resin composites. Chawla and Bastos [10] investigated the effect of fiber volume fraction on Young's modulus, tensile strength and impact strength of untreated jute fiber - unsaturated polyester resin composites.

Date palm wood flour as filler in linear low-density polyethylene matrix was studied by Seyed Mohammad Mirmehdi et al. [11]. Nabila Saadaoui et al. [12] studied the characterization of date palm lingo-cellulosic by-products and self-bonded composite materials. They found the possibility of valorising four date palm tree by-products: leaflets, rachis, leaf sheath and fibrillum as self-bonded materials. The mechanical behaviour of unidirectional hemp fiber reinforced epoxy composites was studied by Hepworth et al. [13]. The comparison showed high contents in lignin and cellulose for fibrillum, high contents in protein and hot water extracting agent for leaflets and high amount of hemicellulose and cellulose for rachis. Mechanical and thermal properties of date palm leaf fiber reinforced recycled poly (ethylene terephthalate) composites was studied by Alireza Dehghani et al. [14]. They [14] carried out Dynamic mechanical analysis (DMA) which indicated that the addition of DPLF to PETR matrix increased the toughness of the composites. The crystallization behaviour of the samples, analyzed by Differential Scanning Calorimetry (DSC) indicated an increase in the onset crystallization temperature and showed a higher degree of crystallinity of the composites as compared to PETR, demonstrating that DPLF particles could act as nucleating agents.

Though there is an extensive research on mechanical properties of date palm leaf fibers, there is very little work carried out on date palm stem composites. Again, the effect of surface treatment on the fibers on the physical and mechanical characteristics is hardly analysed.

Therefore, this paper describes about a detailed analysis of physical and mechanical characteristics of date palm-stem epoxy composites and date palm-stem hybrid composites. It also throws light on the improvement of hydrophobic properties of the composites by surface treatment methods of the reinforcing fibers.

2. Materials and Methods

2.1. Materials

1. Date palm stem fiber (DPS)
2. 5% NaOH solution
3. Glass fiber
4. Epoxy (Araldite LY-556)
5. Hardener (Aliphatic amine HY-951)

2.2. Processing of the composites

The fabrication of composite is carried out by conventional hand lay-up technique. The natural fibers of the stem of date palm (short fibers) collected from local sources are used as reinforcement and epoxy is chosen as the matrix material. The epoxy resin and the corresponding hardener are supplied by Ciba Geigy India Limited. The low temperature curing epoxy resin and hardener are mixed in a ratio of 10:1 by weight percentage. The natural date palm stem of 15 mm length is used as the reinforcement. Then the short fibers are chemically treated by 5% NaOH solution for 1hour .The treated fiber is then cleaned with water and then oven dried at 60⁰C for about 24 hours.

Three composite samples are fabricated at different fiber loading conditions. Composites of compositions 5%, 10% and 15% by weight are fabricated. NaOH treated date palm stem fibers were then fabricated for the same weight fractions. A hybrid composite (Date palm stem + glass fiber) is

also fabricated and the properties are recorded and compared with earlier observations. The detailed composition and designation of the composites are presented in Table 1, 2,3 and 4. The cast of each composite is cured under a load of about 50 kg for 24 hours. Finally, the specimens of suitable dimensions are prepared for characterization and testing.

Table 1 Designation of Composites (Un-treated DPS-epoxy composites)

Un-Treated Composites	Compositions
5% wt of fiber	Epoxy (95%) + 5% NaOH treated date palm stem fiber (DPSF) (5%)
10% wt of fiber	Epoxy(90%) + 5% NaOH treated date palm stem fiber (DPSF) (10%)
15% wt of fiber	Epoxy (85%) + 5% NaOH treated date palm stem fiber (DPSF) (15%)

Table 2 Designation of Composites (Treated DPS-epoxy composites)

Treated Composites	Compositions
5% wt of fiber	Epoxy (95%) + 5% NaOH treated date palm stem fiber (tDPSF) (5%)
10% wt of fiber	Epoxy(90%) + 5% NaOH treated date palm stem fiber (tDPSF) (10%)
15% wt of fiber	Epoxy (85%) + 5% NaOH treated date palm stem fiber (tDPSF) (15%)

Table 3 Designation of Composites (Treated Hybrid composites)

Treated Hybrid Composites	Compositions
5% wt of DPS fiber	Epoxy (90%) + 5% NaOH treated date palm stem fiber (tDPSF) + 5% NaOH treated glass fiber (tGF)
10% wt of DPS fiber	Epoxy(85%) + 10 % NaOH treated date palm stem fiber (tGF) (5% NaOH treated glass fiber (tGF)
15% wt of DPS fiber	Epoxy (80%) + 15% NaOH treated date palm stem fiber (tGF) (5% NaOH treated glass fiber (tGF)

Table 4 Designation of Composites (Treated Hybrid composites)

Treated Hybrid Composites	Compositions
5% wt of glass fiber	Epoxy (90%) + 5% NaOH treated date palm stem fiber (tDPSF) + 5% NaOH treated glass fiber (tGF)
10% wt of glass fiber	Epoxy(85%) + 5 % NaOH treated date palm stem fiber (tGF) (10% NaOH treated glass fiber (tGF)
15% wt of glass fiber	Epoxy (80%) + 5% NaOH treated date palm stem fiber (tGF) (15% NaOH treated glass fiber (tGF)

3. Results and Discussion

3.1 Physical and mechanical characterisation of composites

3.1.1 Effect of fiber content on density of composites

Density is a material property which is of prime importance in several weight sensitive applications. There is always a difference between the theoretical and the measured density values of a composite due to the presence of voids and pores. Presence of voids is one of the major factors influencing the mechanical performance of composites and the knowledge of void content is desirable for estimation of the quality of the composites. The presence of void content in the composites significantly reduces the mechanical and physical properties of the composites. Therefore, voids are undesirable in composites as they reduce the overall properties of the composites. Table 2 presents the theoretical density, experimental density and their corresponding void content of all the composite specimens. It can be observed from the table that the void content of composites decreases with increase in fiber loading. The similar trend of decrease in void content with increase in fiber loading and length has already been reported by previous researchers.

Table 2 Void fraction of composites

Composite	Density (Theoretical)	Density (Experimental)	Void content (%)
5% wt treated(DPS)	1.141	1.117	2.100
10% wt treated (DPS)	1.133	1.108	2.206
15% wt treated(DPS)	1.124	1.078	4.600
Untreated (DPS)	1.133	1.087	4.060
Untreated hybrid	1.173	1.152	1.790
Treated hybrid	1.173	1.164	0.760

Note: Here DPS stands for Date palm stem

It was also found out that compared to the untreated specimen; the chemically treated specimen had less number of voids in the composite. In the hybrid specimen sample shows least amount of void fraction in comparison to untreated and treated date palm stem/glass composite.

3.1.2 Effect of fiber content on tensile strength of the composites

The influence of fiber content on the tensile strength of the composites is shown in Figure 1. There is an improvement in mechanical properties of composites with increase in fiber content due to the fact that the interfacial adhesion between the fiber and matrix is high through an efficient load transfer between the fiber and matrix. It is evident from the Figure1 that the tensile strength of the composites increases with increase in fiber content upto 10 % by weight and goes on decreasing. This is because of the fact that up to 10 % fiber content, there is a good adhesion between fiber and matrix. As there is further increase in fiber content, there is difficulty in compatibility between fiber and matrix adhesion.

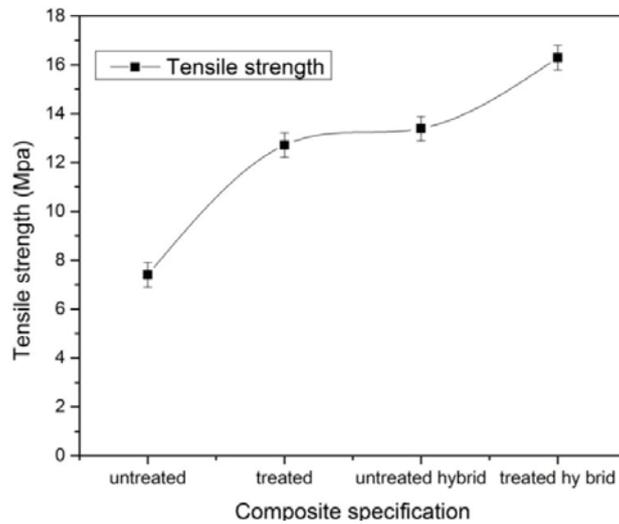


Fig.1:- Tensile strength of the untreated and treated date palm epoxy composite & date palm - glass fiber epoxy composite with 10% fiber content

3.1.3 Effect of fiber content on flexural strength of the composites

The determination of flexural strength is an important characterization of any structural material. It is the ability of a material to withstand bending forces before reaching the breaking point. The flexural strength of composites is increased from 23.20MPa to 29.03MPa for 10 wt. % and then decreased from 29.03MPa to 14.16MPa as shown in Figure 2 i.e. up to 15wt. %. It shows a linearly increasing trend up to a certain value of fiber content (10 wt. %) and suddenly drops due to breakage and pullout of individual fibers from the resin matrix. An improvement in the bonding between the reinforcement and the matrix is done by the alkali treatment which subsequently increases the flexural properties of the composites. This is because alkaline 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 is maximum in hybrid composite which has undergone surface treatment compared to all other fabrications.

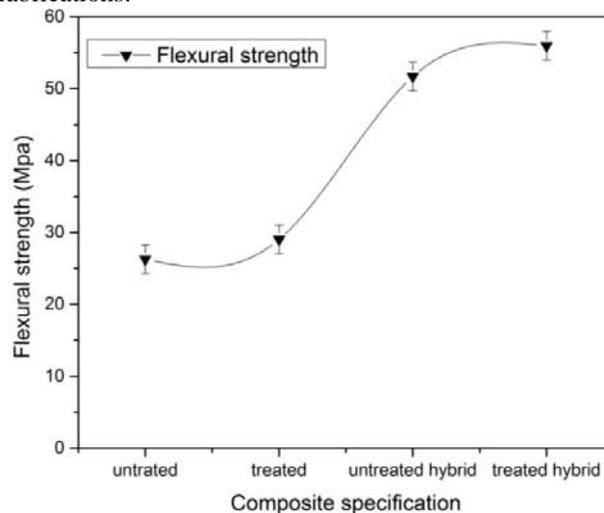


Fig. 2:- Flexural strength of the untreated, treated, date palm - glass fiber epoxy hybrid composite with 10% fiber content.

3.1.4. Effect of fiber content on water absorption of the composites

The water absorption behaviour of treated and untreated date palm epoxy composites as well as glass hybrid composites was studied. It was observed that the amount of water absorption decreases with increase in filler content. The water absorption of alkali treated composites is also considerably less than the untreated composites. In case of untreated composites the poor wettability and adhesion between untreated date palm towards epoxy resin are attributed to the hydrophilic nature of date palm fiber. This hydrophilicity is responsible for the higher percentage water uptake in untreated date palm composites. The water absorption of glass reinforced date palm epoxy composites is less than that of date palm epoxy composites. In case of glass reinforced date palm epoxy composites, the fibers are arranged randomly and in closely packed manner in which water impermeable glass fibers act as barriers and prevent the contact between water and hydrophilic date palm fibers, and hence prevent the water absorption of date palm fibers.

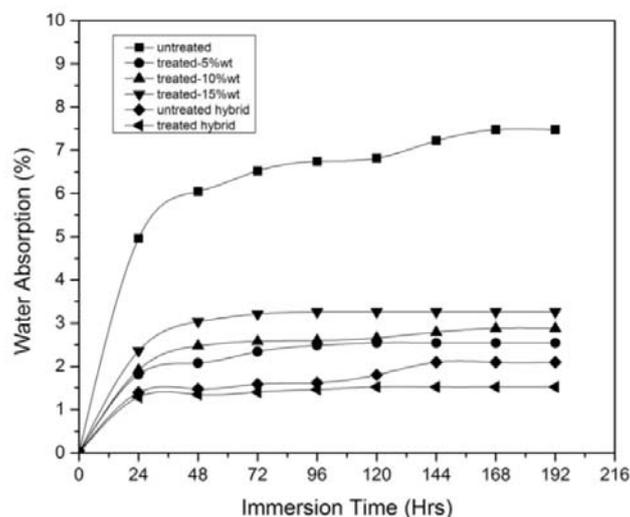


Fig. 3:- Effect of immersion time on water absorption properties of composite

4. Conclusions

The experimental investigation on the physical, mechanical and water absorption behaviour of treated and untreated date-palm composites as well as its hybrid composites led to the following conclusions:

1. The successful fabrication of date-palm stem composites and its hybrid (date palm stem-glass epoxy composites) by simple hand lay-up technique were possible.
2. The present investigation revealed that increase in fiber content; surface modification of fibers by chemical treatment and use of secondary inorganic filler with desirable properties significantly influences the properties of the composites. The maximum tensile strength and flexural strength is obtained for composites reinforced with fibers treated with 10% NaOH. Hybrid composites using only 5% of chemically treated fibers exhibit significant enhancement in mechanical properties.
3. The water absorption rate gradually increases with increase in fiber content irrespective of the orientation of the fibers. The maximum amount of water absorption is distinguished for composites with 10 wt.% date palm stem composites. The water absorption rate gradually decreases as from untreated specimen to chemically treated specimen as there is reduction in

number of voids. Again, due to NaOH treatment the hydrophilic nature of DPS fiber also decreases. The water absorption of glass reinforced DPS epoxy hybrid composites is less than that of DPS –epoxy composites. In case of glass reinforced date palm epoxy composites, the fibers are arranged randomly and in closely packed manner in which water impermeable glass fibers act as barriers and prevent the contact between water and hydrophilic DPS fibers and hence prevent the water absorption of date palm fibers.

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