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Effect of Alkali Treatment on Mechanical, Water Absorption and Chemical Resistance Properties of Cordia-Dichotoma Fiber Reinforced Epoxy Composites

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Abstract

To instigate natural fibers in various diversified applications such as exterior parts of automobile, construction and chemical storage tanks, the natural fibers must possesses the enough impact strength, water absorption and chemical resistance properties. These days Cordia-Dichotoma fibers are gaining considerable attention vowing to their physico-chemical and Pharmaceutical properties; the reinforcement cordia-dichotoma fibers were collected from the bark of the tree and then fibers were extracted using water retting method. Compatibility may not be good in between fiber and matrix due to its hydrophilic and hydrophobic nature respectively. To overcome this, Alkali treatment (5% NaOH) was used to convert the fiber from hydrophilic nature to hydrophobic nature. In this study both untreated and 5% NaOH alkali treated cordia-dichotoma fibers were reinforced with epoxy composite by a technique called hand-lay-up. Effect of various fiber weights on impact strength, water absorption and chemical resistance of both composites that is (Raw and 5% NaOH treated). Based on the impact test results, alkali treated fiber composites enhances its impact strength some percentage than the untreated composite at 20% fiber weight. Water absorption test elucidates that alkali treated fiber composites decreases the water uptake than the untreated composite under different fiber weight ratios. Chemical resistance test revealed that the percentage of chemical absorption (weight gain) was noticed in nearly all the chemicals except a few during the increase in different fiber weight ratios. The aim of this work is to study the effect of Cordia-Dichotoma fiber weight on impact strength, water absorption and chemical resistance behavior of the epoxy composites.

Keywords: Hand lay-up, Impact strength, Water absorption, Chemical resistance

INTRODUCTION

For the past five decades, research on natural fibers was increasing significantly, due to their ample properties such as light-in-weight, corrosive resistance, bio-degradability and availability, in addition to that, they are eco-friendly and economical. However, natural fibers have some disadvantages such as high moisture absorption, low modulus, alleviated chemical resistance and poor wettability. Velmurugan et al. [1] Studied the impact strength and water absorption of palmyra and glass fiber and concluded that natural fibers have poor water resistant, lower impact strength than the glass fiber composite. Pickering et al. [2] focused on the improvement of mechanical performance of natural fiber composites (NFC) that depends on the fiber selection, fiber type, extraction, fiber processing technique as well as composite processing. Joshi et al. [3] Identified key elements and reasons for; NFC's are more environmental friendly than the glass fiber composites. Those are fiber production, high fiber content that reduces the pollutant content of polymer, light-weight that improves the fuel efficiency and reduces the emissions. Kambli et al. [4] compared the morphological and physicochemical behavior of cornhusk fibers with cellulosic and lingo-cellulosic fibers (jute). The results reveal that behavior of cornhusk and jute fibers are quasi equivalent. Goud et al. [5] investigated on Roystonea-regia fiber epoxy composite: these results revealed that increase in weight of the fiber content in epoxy matrix enhanced the uni-axial tensile, resistance to bending strength while impact strength decreases. Few researchers figured out vast benefits of these natural fibers reinforced composites as having low specific weights, relatively high strengths, low density, high stiffness and resistance to corrosion, so they find applications in automotive, interior door panels of cars, decking, structural, packing and electrical and electronics industries, boats and sports [6-8]. Nevertheless, few researchers came up with some unconstructive characteristics of natural fibers: high moisture absorbance, influence of environmental conditions - the climate, location, and weather [9-10]. As a result, the respective composite properties are unpredictable. Weyenberg et al. [10] clearly explained that, fiber processing (retting) is essential step to get the required strength of the composite otherwise some impurities (pectic) may cause local stress concentration that leads to early failure of the composite may be reported. Manimaran et al. [11];

Baskaran et al. [12] Studied the physicochemical properties such as cellulose content, lignin, hemicelluloses, density and crystallinity index of the various fibers these properties may be identified by various characterization techniques. Natural fibers have chief constituents; that include cellulose content, lignin, and hemicelluloses; However, poor bonding exist between the matrix and fiber that are hydrophobic and hydrophilic respectively [13-14].Owing to these disadvantages, mechanical properties of NFC's are poor and therefore need to improve bonding using different physical and chemical treatment methods. Mechanical grinding, hot water washing, alkali and silane are widely used physical and chemical for the purpose [15-17]. They also affect innate properties such as structural, the morphological, chemical and thermal stability. Dan-Mallam et al. [18] studied the impact strength and water absorption properties of short and long fiber hybrid composite and concluded that longer fiber hybrid composite attributed to more impact strength than short fiber hybrid composite and long fiber hybrid composite has high moisture and water absorption due to high void content in composite. Anu Gupta [24] studied the effect of fiber content on chemical absorption and water resistance of the bamboo reinforced polymer composite and concluded that chemical resistance decreases with increase in fiber fraction. Water absorption property increases with increase in fiber content and it will follow Fickian behavior. Bhagat et al. [20] investigated the effect of rate of water absorption on coir and glass fiber epoxy composite and concluded that water absorption rate increases with increase in both fibers content and fiber lengths.

In this work, untreated and 5% NaOH alkali treated Cordia-Dichotoma fiber reinforced epoxy composites were synthesized using hand lay-up method; further, their impact strength, water absorption behavior and chemical resistance properties were investigated.

MATERIALS AND METHODS

Materials

Cordia-Dichotoma fibers (untreated and alkali treated (5% NaOH)). Epoxy resin (HY 556 grade) was purchased from Ram composites, Hyderabad.

Fiber Extraction

The fresh barks of cordia-dichotoma were collected from Dorigallu village near Ananthapuramu district, Andhra Pradesh, India. The cordia-dichotoma Fibers were peeled off carefully from the bark using sharp knife and then soaked in water for three weeks for trouble-free removal of the foreign materials and dirt adhere to the fibers (water retting process).Then the fibers were picked up and thoroughly washed in fresh water or running water and make sure that foreign materials are removed from the fiber and then permitted to dry in the sun until the fibers become dry (for a week before analysis).

Alkali treatment

Alkaline solution was prepared with 5% sodium hydroxide (5% NaOH) in glass tray to carry out the alkali treatment. Then completely dried cordia-dichotoma fibers were soaked in alkaline solution about two hours at room temperature. The process starts with soaking the fibers, rinsing then with distilled water to remove the excess NaOH adhered to the fibers; then the fibers were placed in a hot oven at 60ºC.

Composite preparation

The hand lay-up method [20] was used to synthesize the composites; a glass mould of dimensions 150 x 150 x 3 mm was used to prepare the composites. Untreated and alkali treated (5% NaOH) Cordia-Dichotoma fibers were used to prepare composites with different fiber weights (%), i.e. 10, 15, 20, and 25. At room temperature above mentioned composites were casted and allowed to cure for complete day. The cured laminates were then removed from the glass mould and post-cured in a hot air oven at 100oC for 3 hours. The composite samples were designated as UF0 (composite with pure epoxy), UF10 (10% weight of fiber without alkali), UF15 (15% weight of fiber without alkali), UF20 (20% weight of fiber without alkali), UF25 (25% weight of fiber without alkali), AF10 (10% weight of fiber after alkali treatment), AF15 (15% weight of fiber after alkali treatment), AF20 (20% weight of fiber after alkali treatment) and AF25 (25% weight of fiber after alkali treatment).

Impact Strength

Impact strength of any material is the capacity to absorb energy under shock or impact loads. The impact strength was conducted on the composite specimen (untreated and alkali treated) using the IZOD Impact tester for different weight ratios. The impact specimen was prepared according to ASTM D-256 with the dimensions of 63.5 mm (length) x 12.7 mm (width) x 3 mm (height) and also provides a V-notch at the middle of the specimen using the jig-saw [21].

Water absorption

Water uptake characteristics of untreated and alkali treated epoxy composites were investigated as per ASTM D-570-98 standards. The different fiber weight ratio samples were placed underwater in a beaker at room temperature to study the kinetics of water absorption behavior. For every 24 hours, samples were taken out from the water and surface water was removed using tissue paper and weighted instantaneously using a precise electronic balance. The % (percentage) of water uptake was calculated using following relation.

$$\%\text{ of water uptake} = \frac{\mathrm{Wt}-\mathrm{Wo}}{\mathrm{Wo}}\%$$

Where Wo is the weight of composite sample before putting into water (oven-dried weight) in grams and Wt is the weight of composite sample after taken out from the water in grams [24].

Chemical Resistance

Chemical resistance analysis was important to find the applicability of natural fiber composites in the area of chemical storage tanks and pipes. Chemical resistance was used to find the ability of a composite to withstand exposure to acids, bases, alkalis and solvents. A lot of research has been carried out on the chemical resistance of composite. Anu Gupta [24] performed the chemical analysis of the bamboo tubes of length and diameter and concluded that chemical resistance of the composite decreases with increasing weight of fiber content used for making the composite.

Chemical resistances of different composite specimens were performed using ASTM D-543-87 method. By considering three acids such as hydrochloric acid (HCl), acetic acid (CH_3COOH) and Nitric acid (HNO_3); Two alkalis namely Sodium hydroxide (NaOH) and Ammonium hydroxide (NH_4OH); a salt sodium carbonate (Na_2CO_3); and two organic compounds such as Benzene (C_6H_6), Carbon tetra chloride (CCl_4).In every case, five different pre weighed (oven-dried) samples were engrossed in the respective chemical solutions for 24 hours. Then take out sample and immediately washed with distilled water by pressing all sides with a tissue paper at room temperature. Finally samples were weighted and the percentage of chemical resistance was calculated in terms of weight loss or weight gain using following equation

$$\%\text{ of chemical resistance} = \frac{(\text{Wf}-\text{Wi})}{\text{Wi}}\%$$

Where Wi is Initial weight of the composite and Wf is weight after definite interval [20].

RESULTS AND DISCUSSION

Impact strength

Izod impact strength results were given in table 1, for untreated and alkali treated cordia-dichotoma fiber epoxy composites at a choice of fiber weight and the related plot was shown in the figure 1. Impact strength of the composite was found to be increased with increasing untreated fiber weight up to 25 wt %, in epoxy matrix. It was found that Impact strength (124.4 %) was highest for the composite UF25. However, the impact strength values of the composite were decreased after alkali treatment (103.93 %) at 25% fiber weight, the impact strength was decreased by 16.45 %. The main reason for this was, during the impact considerable part of energy absorption takes place through the fiber pull-out process, but after alkali treatment, due to the removal of soluble greasy contents from the fiber, strong mechanical interlocking develops between fiber and matrix, and fiber pull-out was reduced. This, in turn, decreases the impact strength [21, 23].

Table 1: Impact strength of untreated and alkali treated Cordia-Dichotoma fiber composite.

Type of Composite	Fiber Weight (%)	Impact strength (J/m)
Pure epoxy	0	27.5591
Untreated fiber reinforced polymer composite(UF)	10	40.9449
	15	74.0157
	20	99.2126
	25	124.4094
Alkali treated fiber reinforced polymer composite (AF)	10	36.2205
	15	59.8425
	20	72.4409
	25	103.9370

Water absorption

Water absorption test was used to find out the quantity of water absorbed under 24 hour's immersion. Water absorption depends on the matrix, fiber content, method of fabrication and environment condition. Water absorption of Cordia-Dichotoma epoxy composite was shown in Table 2. The fiber absorbs water may be presence of hydroxyl groups which absorb water through the formation of hydrogen bonding [22]. All composites show a sharp increment in water uptake at the beginning (up to 72 hours) and later reaching to a saturation point where no water is absorbed after 192 hours with the maximum water absorption being 6.07 % and 5.13 % for untreated and alkali treated 25 wt % fiber epoxy composites, respectively. These results were depicted in Figure.2.The amount of water absorption was typical of Fickian diffusion, which explains that rapid water absorption takes place at the beginning of contact of matter to water; subsequently, a saturation point is reached. Since the composites were produced using hand-lay-up method, water absorption was through the porosities in the fiber-matrix interface. Cordia-Dichotoma was a plant based natural fiber, the presence of free cellulose hydroxyl groups leads to water uptake. The low percentage of water absorption is attributed to the hydrophobic nature of epoxy matrix and alkaline treated epoxy composite shows lower water absorption rate because alkali treated fiber is less hydrophilic as number of hydrophilic hydroxyl groups reduce by react which 5 % NaOH which leads to prohibiting of water from substrate of composite [21-23].

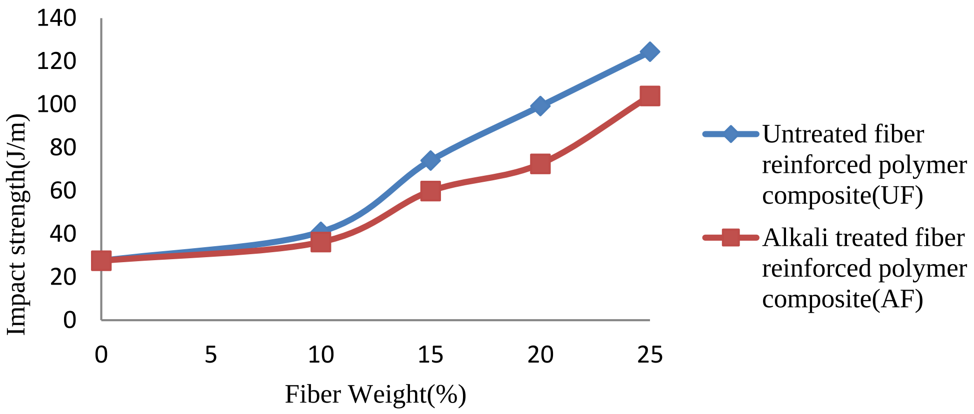

Figure 1: Effect of fiber weight on impact strength of untreated and alkali treated composites.

Table 2: Water absorption properties of untreated and treated fiber epoxy composites.

Hours	UF0	UF10	UF15	UF20	UF25	AF10	AF15	AF20	AF25
24	0.2037	1.3410	1.4210	1.4901	1.7479	0.9251	1.2680	1.4126	1.4901
48	0.5092	1.6284	1.9538	1.9868	2.2999	1.1101	1.4370	1.5613	2.1523
72	1.1202	2.7778	3.1972	3.2285	3.3119	1.9426	2.0287	2.1561	2.4007
96	1.4257	3.3525	3.5524	3.6424	3.7718	2.2202	2.3669	2.3792	2.7318
120	1.7312	3.9272	3.9964	4.0563	4.1398	2.8677	3.1276	3.1970	3.5596
144	2.0367	4.5977	4.7069	4.7185	5.0598	3.1452	3.2967	3.4944	3.8079
168	2.1385	5.0766	5.1510	5.5464	5.8878	3.2377	3.6348	3.7175	4.0563
192	2.3422	5.2682	5.5950	5.8775	5.9798	3.3302	3.8884	4.0149	4.5530
216	2.3422	5.2682	5.7726	5.8775	6.0718	3.7003	3.8884	4.2379	5.0497

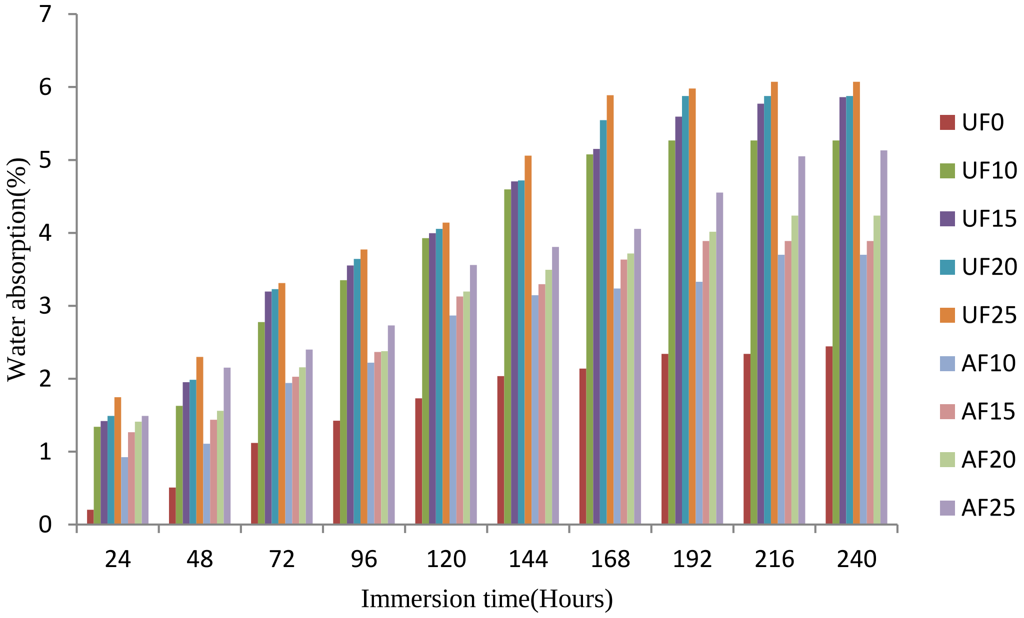

Figure 2: Water absorption characteristics of untreated and treated fiber epoxy composites.

Chemical resistance

The percentage (%) absorption of untreated and alkali treated Cordia-Dichotoma fiber epoxy composite increases with increase in fiber weight in most of chemicals. This was presented in Table 3. It means their chemical resistance decreases with increase in fiber weight. This decrease in chemical resistance is due to exposure of more fibers to chemicals. The weight gains of the composite specimen correspond to a healthier interaction with the fluid and therefore show the poor chemical resistance. On the contrary, less absorption corresponds to better chemical resistance. Amid all the chemicals, samples have revealed maximum absorption for HNO_3. Generally, the percentage (%) absorption was larger for aqueous solutions, and this result may be due to the hydrophilicity of the fiber. This conclusion is supported by the weight increase in the presence of these liquids with increasing fiber content [24].Figure 3 shows the percentage (%) absorption of untreated and alkali treated Cordia-Dichotoma fiber epoxy for different samples.

Table 3: Chemical absorption of untreated and treated fiber epoxy composites

Chemicals	Untreated Fiber composite					Alkali treated fiber composite			
Fiber Weight (%)	UF0	UF10	UF15	UF20	UF25	AF10	AF15	AF20	AF25
HCL (10%)	0.8230	1.7926	2.2539	3.1746	3.6541	1.5365	1.8980	2.0408	2.4361
HNO_3 (40%)	0.5241	2.5547	3.9053	4.0724	4.7138	2.1898	3.0769	3.5068	4.2649
CH_3COOH (8%)	0.2045	0.8444	1.2956	1.5801	1.6298	0.3619	0.5889	0.7901	0.9313
NaOH (10%)	0.3341	1.2837	2.2926	3.0405	3.8988	1.0270	1.6376	2.2523	3.1612
NH_4OH (10%)	-1.7182	1.4249	2.4735	3.3257	4.3979	1.2953	2.3557	3.0963	4.0838
Na_2CO_3 (20%)	0.3141	1.0681	2.1251	2.5698	2.8659	0.8011	1.7710	2.2346	2.5589
C_6H_6	0.6012	0.6562	0.8065	1.1198	1.8849	0.3937	0.6912	0.8959	1.6865
CCl_4	0.2774	0.6974	1.0101	1.1351	1.4388	0.4184	0.6313	0.7946	1.0277
C_7H_8	0.3429	0.4932	1.2032	1.3970	1.6512	0.3699	0.8021	1.1641	1.5480

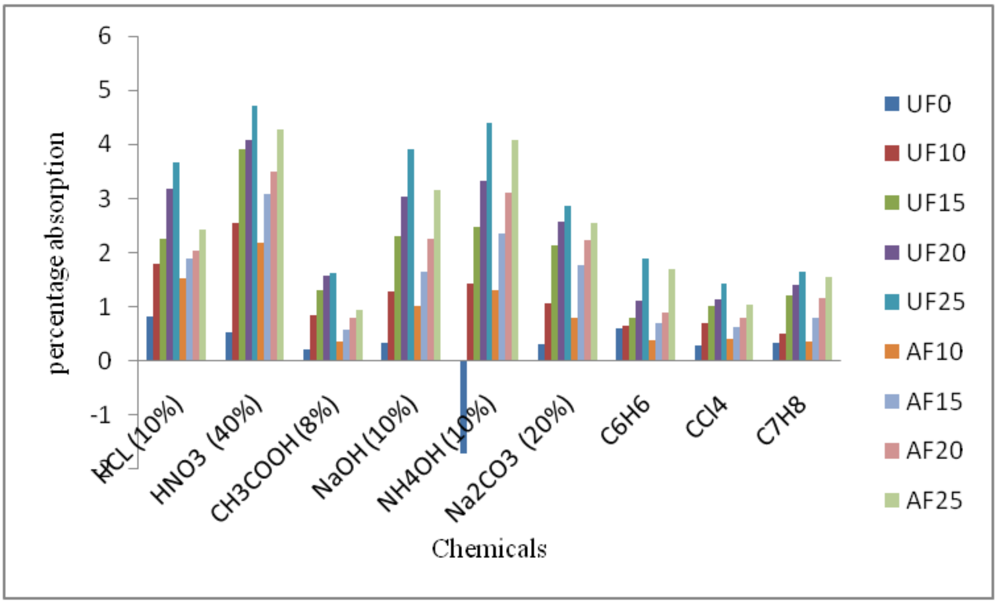

Figure 3: Shows chemical absorption of untreated and treated fiber epoxy composites

CONCLUSIONS

In this work, the effect of Cordia-Dichotoma (untreated and treated) fiber weight on impact strength, water absorption and chemical resistance behavior of the epoxy composites were investigated; it may be concluded that

1. Cordia-Dichotoma fiber reinforced epoxy composites were

synthesized using hand lay-up method.

2. Impact strength increases with the increase in fiber weight; however, impact strength of untreated fiber composites (124.40 J/m) was more in comparison to the alkali treated fiber composite (103.93 J/m).

3. Chemical resistance decreases with increase in fiber weight and was maximum for 25 wt% fibers; treated fiber composites posses more chemical resistance than the untreated fiber composite.

4. Water absorption increases with increase in fiber weight and follows Fickian behavior. Untreated fiber composite absorbs more water than the treated fiber. This may be attributed to the hydrophilic nature of untreated fibers.

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