ALKALI TREATMENT OF FAN PALM NATURAL FIBERS FOR USE IN FIBER REINFORCED CONCRETE

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Abstract

It is well known that the addition of fibers to concrete mix enhances its performance. There are many types of fibers in the market, but for environmental protection purposes, the use of natural fibers rather than synthetic fibers is highly recommended. However, natural fibers are affected by the presence of Alkali environment of concrete; however, treating fibers with chemical solution reduces the effect of Alkali attack and overcomes the weak bond between the fiber and the cement matrix by formation of a rough fiber surface. Alkali treatment is one of the most used methods for treatment of natural fibers. In this study various Alkali treatment procedures on Fan Palm fibers have been used to define the optimum procedure that enhances the durability of Fan Palm natural fiber in concrete without causing serious deterioration to the fiber itself. For that, an experimental program was conducted to study the effect of different treatment procedures on the tensile strength of fibers, modulus of elasticity, and the elongation of fibers at break. Thus, the treatment was applied at various concentrations of Sodium Hydroxide solutions (1%, 2%, 4%, & 10%) and treatment durations (2 hrs , 8 hrs, & 24 hrs). From the tested fibers, the maximum tensile forces at break and elongations were recorded. From the analysis of test results it was conducted that using 4% sodium hydroxide concentration for 24 hours was the preferred treatment procedure for Fan Palm fibers.

Keywords: Alkali, treatment, natural fiber, composite, fan palm

1. Introduction

The most used material in construction industry is in no doubts Concrete. In 2009, it was stated that about 10 billion tons of concrete are poured in different types of construction all over the world each year (Hosseini, Mohamad, Nekooie, Taherkhani & Booshehrian, 2011). Concrete resists high compression strength; however, it has major problems with low tensile strength, low ductility and energy consumption. Therefore, to overcome these problems, practicing engineers and concrete mix designers have mixed fibers with concrete to produce more durable and sustainable product. Also the use of fibers in concrete mix will result in better resistance to flexural stresses, Impact stresses, and many other physical and mechanical properties (ACI 544.5, 2010; Banthia, 2008).

Various researches looked for Natural Fibers from a renewable resource that could replace steel, polypropylene, and glass fibers used in concrete (Pacheco-Torgal & Jalali, 2011; Kalia, Kaith & Kaur, 2009). From an environmental point of view, steel, glass, and synthetic fibers are relatively high expensive materials with high energy consumption and come from a non-renewable source. On the other hand, Natural Fibers are a renewable resource and available in all countries in different forms.

Concrete reinforced with Natural Fibers, in conjunction with steel rebars are generally termed Natural Fiber Reinforced Concrete (NFRC). Natural Fibers can be obtained from wood, vegetable leaves and plants; in some cases, animals are also source for Natural Fibers (Faruk, Bledzki, Fink & Sain, 2012).

Natural Fibers were investigated by many researchers for use as a construction composite material in cement paste, mortar, and concrete (Li, Tabil & Panigrahi, 2006). However, Natural Fibers have biodegradable characteristics; the alkali environment of the cement matrix leads to durability problems in the fibers. This will eventually cause reduction in fiber strength and toughness if these fibers were not treated to resist the effect of alkali attack. Moreover, weak bond interface between natural fibers and cement matrix reduces the influence of fibers to improve the performance of the new composite. In fact, in order to enhance the durability of vegetable fibers when used in concrete mix, several methods of treatment were investigated (Toledo Filho, Ghavami, England & Scrivener, 2003). One of these treatment methods is by chemical solutions, which improves the adhesion between the fiber surface and the cement matrix, hence, reducing the fiber moisture absorption, increasing the surface roughness of the fibers, removing waxes and oils from the surface of the fibers, and mainly increasing the durability of the fibers in the concrete composite. The process of extracting, processing, and chemical treatment for Natural Fibers varies from one type to another depending on its chemical properties. Alkali treatment, named also Mercerization, is a common fiber treatment chemical method that is extensively used by researchers (Hashim, Roslan, Amin, Zaidi & Ariffin, 2012; Kalia, Kaith & Kaur, 2009).

In this study Fan Palm Fibers were used as Natural Fibers added to concrete mix. Djoudi (2012), Kriker (2007) and Ramli (2010) investigated the effects of using Palm Fibers in cement pastes and concrete mixes on the mechanical properties of the composite mix. The results showed some improvement in the performance of concrete but need more investigation especially for the treatment procedure in order to enhance the durability of these fibers in the new composite and increase the adhesion between the fibers and matrix. For that, an appropriate chemical treatment was carried out in this study to overcome problems related to alkali attack due to the presence of Natural Fibers in the concrete mix. In order to investigate the best method of alkali treatment that results in the best performance of Fan Palm Fibers for use in concrete mix to produce Natural Fiber Reinforced Concrete, the treated fibers were tested for tensile strength, percentage of elongation, and modulus of elasticity

2. Experimental Program

2.1 Materials

Fan Palm tree is a genus of Palm with a bar petiole terminated in a rounded fan of numerous leaflets, as shown in Figure (1). Fan Palm species are commonly cultivated across the United States, the Middle East, South Europe, and North Africa, where they have greatly hybridized. Fan Palms are planted in most of the main roads in urban and rural areas. It is commonly used in most gardens, public and private parks. Production of fibers from these leaves will convert the unused wasted leaves to a renewable source materials and low cost Natural Fibers that will be incorporated in concrete mixes.

Fig. 1: Fan Palm Trees

2.2 Specimen Preparation

The Natural Fibers used are extracted from the leaves of Fan Palm Trees. The preparation of the specimens is carried by following a three steps procedure. Firstly, the leaves were air dried for a week; as shown in Figure (2a), secondly, the dried leaves were split into fibers by using a handmade machine into 0.7mm to 1.0mm width for each fiber, as shown in Figure (2b). Finally, after cutting the fiber, they are washed with water to remove dust, waste, and any harmful materials before starting the chemical treatment.

(a) (b)

Fig. 2: (a) Dried Fan Palm Leaves, (b) Hand-made Machine for Cutting Fibers

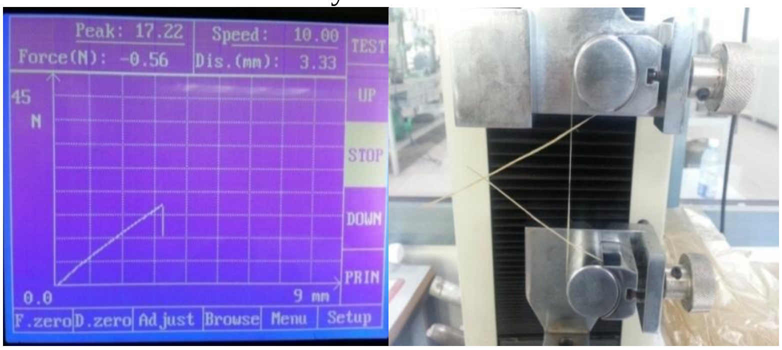
2.3 Chemical Treatment

The aim of the chemical treatment is to remove the weak boundary layers of the natural fibers, which are supposed to protect the fiber particles but have no resistance to the alkali environment of the cement, and provide thin layers that will resist the effect of alkali attack. Researchers have documented that the time of soaking and the amount of chemical solution concentration used for treatment will affect the properties of the produced fibers (Hashim, Roslan, Amin, Zaidi & Ariffin, 2012; Karthikeyan & Balamurugian, 2012). Based on this previous research, it was decided that different concentrations ratios and treatment times will be tested on the Fan Palm Fibers. For that, in each test conducted, fibers were soaked in Sodium hydroxide (NaOH) solution of specific concentration ration for a certain period of time, at room temperature.

The selected soaking durations are 1 hour, 2 hours, 8 hours, and 24 hours, and the percentages of concentration are 1%, 2%, 4%, and 10%. After soaking, fibers were immersed in distilled water for one hour to remove residual NaOH. Finally, the fibers were dried and stored in sealed plastic bags to prevent any exposure to moisture.

2.4 Testing Set-Up

The fibers were tested in the Material and Structural Engineering Laboratory of Beirut Arab University using a tensile testing machine with clamps for gripping the fiber specimen, which is the most commonly universal testing machine (ASTM D3822). This testing machine is used to pull the specimen in tension at a constant rate of load until it breaks (breaking force). The distance between the clamps was adjusted to 150 mm in all the tests representing the initial fiber length that will be used in the strain calculations; see Figure (3a). The original dimensions of the specimen were measured and recorded to calculate the cross-sectional area. The load was applied slowly on the specimen at a constant rate and recorded until failure is attained. Readings of the breaking loads is taken from the load dial gauge at the instant of fracture, as shown in Figure (3b). The testing machine was prepared with auxiliary equipment for automatic recording of data. At break, the final gauge length at failure point was measured and recorded in order to calculate the elongation, plot the load-deflection curve (P-□ □ , and determine the modulus of elasticity.



(a) (b)

Fig. 3: (a) Tensile Testing Machine, (b) P-□ □ curve from the testing machine screen

3. Test Results and Discussions.

The experimental testing program was conducted on untreated as well treated Fan Palm Fibers. Samples of untreated Fan Palm Fibers used in this study have the following mechanical and geometrical properties; shown in Table 1.

Table 1: Palm Fiber Mechanical and geometrical properties

Property	**Lower – Upper**
Fiber Dimensions: Thickness	0.2-0.3 mm
Width	0.7-1.0 mm
Bulk Density	600-800 Kg/m^3
Absorption To Saturation	100-200 %

To define the best procedure for treatment, tension tests were conducted on Fibers for the following concentrations of NaOH (1%, 2%, 4%, 10%), at various treatment time (1 hour, 2 hours, 8 hours, and 24 hours). It was shown that, the fiber cross section has decreased due to the removal of the weak surface layers of the natural fibers, thus, the width decreased from 1mm -0.7mm to 0.85mm - 0.65mm after treatment.

3.1 Tensile Strength Results on the Treated Fan Palm Fibers

The resulting data of tensile strengths are presented in Table 2 and plotted in Figure 4. The values shown in the table and the graph were obtained and calculated from testing of at least 20 fibers for every set, average readings were considered.

From the data presented in Table (2), it is clear that treatment for 24 hours in 4% sodium hydroxide solution concentration results in the lowest reduction in the tensile strength (7% as an average). However, using 10% solution concentration and for more than 8 hours results in serious deterioration in the fibers and undesirable reduction in the tensile strength to about 50%.

Table 2: Experimental Testing Results of the Tensile Strength for Fan Palm Specimens

NaOH concentration	**Treatment Duration**	**Tensile strength**	
(%)	(hrs)	Range (Mpa)	Average
Untreated	-----	90 - 110	100
1%	2 hrs	70 - 85	77
	8 hrs	70 - 80	75
	24 hrs	60 - 78	69
2%	2 hrs	70 - 90	80.45
	8 hrs	70 - 90	80.45
	24 hrs	75 - 90	83
4%	2 hrs	70 - 85	76
	8 hrs	80 - 90	85
	24 hrs	85 - 100	93
10%	2 hrs	60 - 80	70
	8 hrs	55 - 70	67
	24 hrs	50- 70	61

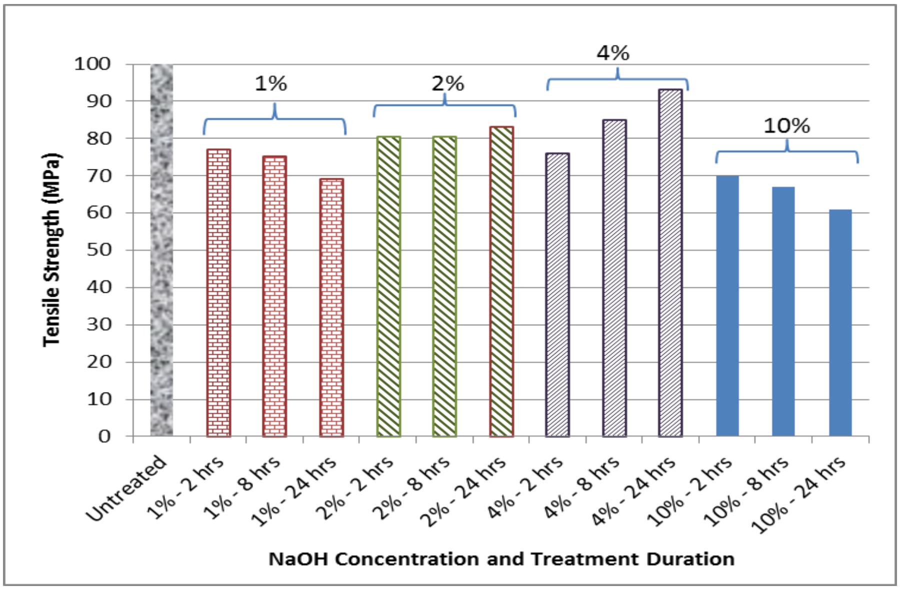


Fig. 4: Experimental Testing Results of the Tensile Strength for Fan Palm Specimens

From the tabulated data it is clear that the excess of chemical solution (10%) did not only remove part of the boundary layers of the natural fibers but moreover caused some deterioration to the fiber particles themselves that reduced the overall tensile strength. On the other hand, the boundary layers of the raw fiber are not completely removed by the chemical treatment below the 4% concentrations, hence some weakness is observed in the strengths. More tests for different concentrations and durations were applied to check that the selected concentration was the optimal one. For that, fibers were cured at 6% concentration for 24 hours, and 4% for 48 hours and one week. Figures 5 and 6 show the results of these tests. From the figures we conclude that 4% NaOH concentration for 24 hours was the optimal selection for treatment process.

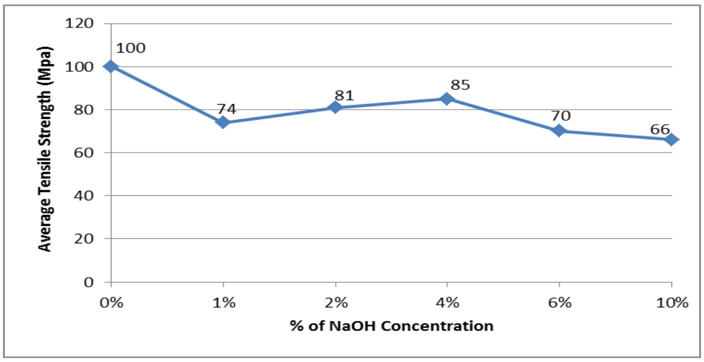


Fig. 5: Average Tensile Strength for Fibers Treated with Different NaOH Concentrations

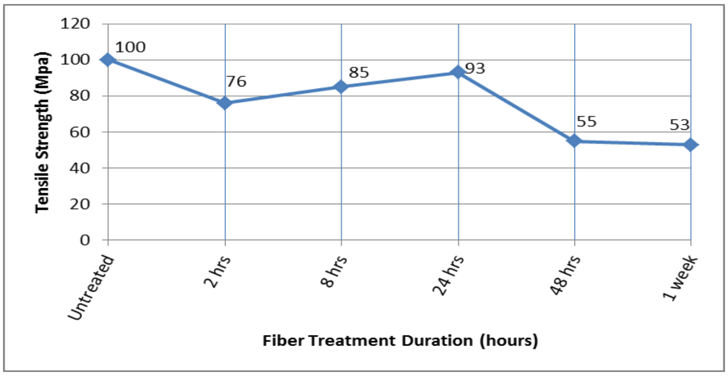


Fig. 6: Effect of treatment duration on Fiber Tensile Strength for NaOH Concentrations

3.2 Modulus of Elasticity and Elongation

The resulting data of the modulus of elasticity and the fiber elongation at break are presented in Table (3). The results shown in the table were obtained and calculated from testing of at least 20 fibers for every single set. From the data presented in Table (3), it is clear that the treatment process has no major effect on the modulus of elasticity and the fiber elongation for the Fan Palm fibers at break parameters.

Table 3: Test Results for the Modulus of Elasticity and Elongation for the Fan Palm fibers

NaOH concentration	Duration	Modulus of Elasticity	Elongation at Break
(%)	(hrs)	(Gpa)	(%)
Untreated	-----	4.5 - 6.5	1.5-2.0%
1%	2 hrs	3.7 – 4.3	2%
	8 hrs	4.0 – 4.5	2%
	24 hrs	4.0 – 5.0	1.5%
2%	2 hrs	4.0 – 6.0	1.5-2.0%
	8 hrs	4.0 – 6.0	1.5-2.0%
	24 hrs	4.5 – 7.5	1.6-1.8%
4%	2 hrs	3.5 – 5.5	1.5-2.0%
	8 hrs	4.0 – 5.0	1.5-2.0%
	24 hrs	4.5 – 6.5	1.5-2.0%
10%	2 hrs	3.5 – 4.0	1.5-2.0%
	8 hrs	4.0 – 4.5	1.5-2.0%
	24 hrs	4.5 – 5.0	1.0-1.5%

4. Conclusion

The weak surface layers of natural fibers have always shown no protection to fiber particles against alkali attacks of the cement. The results presented in this study show the effect of alkali treatment (Mercerization) on the Fan Palm Fibers. The experimental program conducted in this research comprised of testing mechanical properties of Fan Palm Fibers when immersed and soaked in sodium hydroxide solutions for different concentrations (1%, 2%, 4%, 10%), and for different durations of soaking(1hr, 2hrs, 8hrs, and 24hrs). It has been shown that the treatment that produces the higher tensile strength with the required roughness was obtained by treating the fibers for a duration of 24 hours in a solution of 4% sodium hydroxide. The modulus of elasticity and percentage of elongation were not significantly affected by the treatment process. Moreover, a reduction in the dimensions of the fibers was shown after treatment due to the removal of the weak surface layers. However, using high concentration and long durations of treatments caused serious deterioration to the fiber particles themselves which were clearly observed from the high reduction in the tensile strength of the treated fibers.

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