Study of Physical and Mechanical Properties of Palm Fibers Reinforced Cementitious Matrix

Dr. Hana aljewifi [1], Hana Farhat[2], Amal Edriss[3] and Amal Mohamed[4]

1 University of omar almukhtar,Albyda, Libya, Email: hana.aljewifi@omu.edu.ly
2 University of omar almukhtar,Albyda,Libya, Email: hanafarhat1234@yahoo.com
3 University of omar almukhtar,Albyda, Libya, Email: amalmekael@gmail.com
4 University of omar almukhtar,Albyda, Libya, Email: amalalzway@gmail.com

Abstract

The date palm is the one of the most cultivated palms around the world, since in Libya is ranked fifth in date palm cultivation; with about 4.6 million palm trees grown on an area of 27.5 thousand hectares.The present paper aims to characterize date-palm fibre-reinforced mortar, where different percent of palm fibers was added by substitution of a variable percentage of cement weight. Physical properties of fibers have been measured as volumetric density, coefficient of absorption and water content. Moreover, it is known that the natural fibers include high content of hydroxyl groups (OH) which causes the hydrophilic behavior. In order to improve this properties, palm fibers treated by immersing in alkaline solutions. Fresh mortar was studied through setting times and, for mortar cured up to 28 days, its composition which report C/S equal to 1/1.67 and W/ C = 0.57. The mechanical behavior of hardened reinforced matrix of different lengths (0.24 -19 cm) and kinds has been studied using compression test. The cubic specimens are removed after 24 hours and then conserved in water or in dry air denpending on the percentage of fibers at 28 days for mechanical testing.

Keywords: Date plam fibers, properties of fibers, cementitious matrix, alkalin treatment, compression test.

1. Introduction

Natural fibres reinforced composites are good substitute of metal or ceramic based materials in applications that may be automotive, aerospace, marine,...etc areas and their composites. Basically natural fibres got its importance because of their low cost high availability with various desirable properties [1]. Date palm trees produce a huge amount of agricultural waste in the form of dry leaves, stems, pits, seeds, etc. A typical date tree can generate as much as 20 kilograms of dry leaves per annum, as the date pits account for almost 10% of the date fruits [2]. Palm fibre is generally including cellulose (glucose units), hemicelluloses (polysaccharides), lignin (aromatic polymers and phenyl propane

monomers). Although, cellulose is resistant to hydrolysis, strong alkali, and oxidizing agents, it is degradable to some extent when exposed to chemical treatments [3]. Lignin is a complex hydrocarbon polymer. It usually gives rigidity to plant and assists in water transportation. The nature of cellulose and its crystallinity can determine the reinforcing efficiency of natural fibers [4]. In addition, the fiber density is one of the most important physical properties that contribute implementing natural fibers in different applications. It is noticed that date palm fiber have a lower density as compared to other natural fibers which give it an added value in the field of natural fiber composites. Thus, it can lead to lower weight composites suitable for automotive and space applications [5]. Mechanical properties of date palm fibers can be strongly affected and determined by chemical composition [6]. Generally, date palm fibers with higher mechanical strength possess higher cellulose content and higher degree of polymerization of cellulose. Important mechanical properties like tensile strength and Young's modulus usually increase as cellulose content and cell length increase [7]. Therefore, the surfaces of the date palm fibers are usually treated via different means in order to improve the interfacial bonds between the fibers and the matrix. Alkaline treatment is one of the most popular chemical treatments of natural fibers. The major modification done by this treatment is the disruption of hydrogen bonding in the network structure and increasing surface roughness. Alkaline treatment by sodium hydroxide (NaOH) to natural fiber can remove a certain amount of lignin, depolymerizes cellulose [8].

In this paper, The performance of cement mortar reinforced with varying percentages of treated date palm fibers is investigated to evaluate their feasibility for structural applications. This study based on the evaluation of physical and mechanical behaviour of different kinds treated or untreated fibers. The suitable three pre-treatment was then adopted while casting cement mortar mixes. This work conclude that is preferable using treated natural fibers reinforced composit.

2. Materials

2.1. Mortar preparation

A fin to obtain liquid mortar, fin sand (0-2 mm) determinates using sieve analysis according to ASTM-C136/C136M and their finesse module (FM) = 1.63, portlandite cement type CEM I-I-42.5 N from Al Fatiah Quarry. Table 1 given principal composition of mortar.

Table1: cementitious matrix composition (kg/m^3).

Cement	Sand	Water	W/C
350	570	200	0.57

2.2. Date palm fibers characterization

In this research a palm tree was used from the coastal region of the Jabal Al Akhdar. Figure 1 appeared some kinds of fibers after extracted from date tree. It then been sieved to make sure it is free from any impurities and the fibers are assured to be loosen and prepared to be cut into required length for consistence in this study. Since such fibers should be having the same geometrically approximately for use in the experimental program, it is reasonable to generalize the similar physical properties to the same type of fibers. The basic physical properties of the extracted fiber are classified in the [9].

Figure 1. Fibers extracted from palm tree.

Nevertheless, like other natural fibers, date palm fibers have to be pretreatment to produce moisture repellency and resistance to environmentale, …ects. Consequently to improve the mechanical properties. Alkaline treatment is one of the most popular chemical treatments of natural fibers. There are several studies evaluating the use of different types of natural fibers in concrete and mortar applications after treatment process, where fibers treated with 0.173% $Ca(OH)_2$ displayed better tensile strengths and stiffness properties. 2% NaOH treated palm fibers showed an increase in tensile and considerable advancement in surface morphology. Microscopic examinations were demonstrated the effectiveness of the chemical pretreatment on the date palm fiber, where untreated fibers are demonstrated having a weak outer layer that can prevent strong bonding with the matrix in one hand, and another treated one where the weak outer layer was removed through the treatment process which can lead to stronger bonding with the matrix [10]. For more detailed of alkali solution preparation see [9]. Fibers have been treated with four methods as following before inclusion in the matrix: 1)- untreated fibers; 2)- With water; 3)- NaOH of 2%; 4)- calcium hydroxide, Ca(OH)2 of 0.172% respectively.

Physical property has been studied using water content and coefficient of absorption test. Values have varied between (24-122%) and (43-479%) respectively, more detailed in [10]. Apparent density dry (less than 0.2 g/cm3) and dapparent density wet (0.25-0.4 g/cm3) of trunk leaf. In addition, mechanical property has effected by tensile test using SM100 Universal material testing machine capacity 100 kN (10 ton). Figure 2a) demonstrated that length of fiber hasn't influence on max. tensile force than treatment methods. It is evident that alkaline methods lead to improve tensile strength of fibers due to the reasons previously explained. Therefore, Figure 2b) showing that water treatment have superior values of max. tensile force, but it is necessary take standard deviation into account. Failure form take palce at medium of samples as appeared in figure 3 for all treatment methods. Treatment with alkaline solutions confirms the results shown in previous studies [11] in terms of increasing the tensile strength of palm fibers Figure 2c. The difference in cross section and type of the fiber plays a major role on the deformation of the samples as shown in figure 2d.

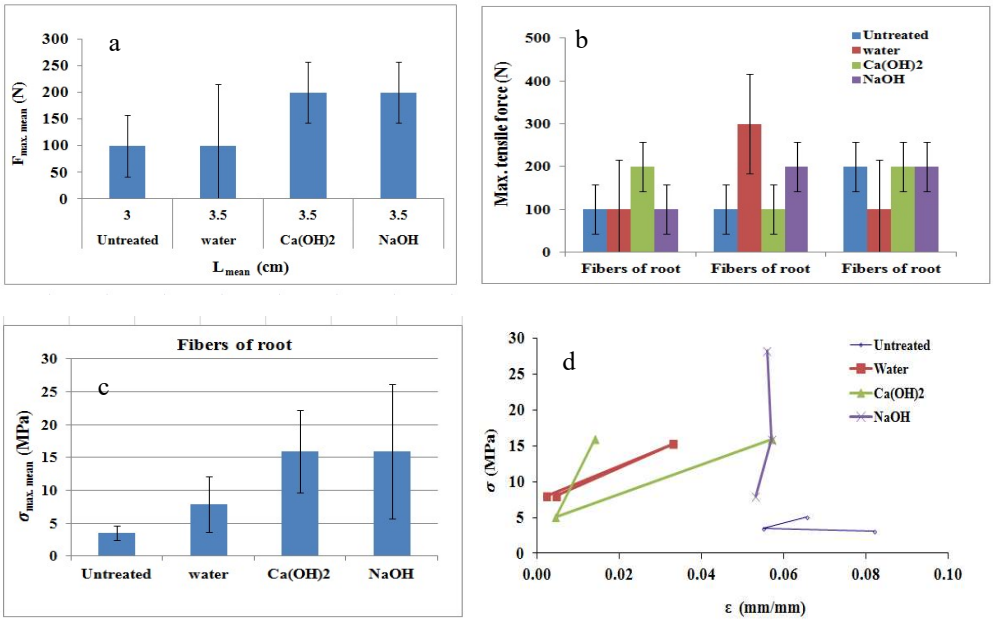

Figure 2: Tensile test results: a). Influenced treatment method and length of leaf of root on max. tensile force; b). Influenced treatment methods on F_{max} of leaf of root.

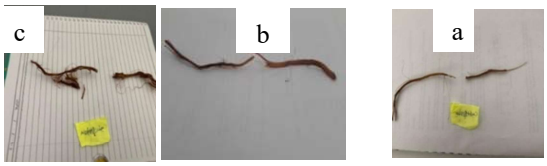

Figure 3: Tensile test results of treated leaf of root: a). with Ca(OH)2 of 0.172% ;b).with NaOH of 2%; c). with water.

2.3. Date palm fibers reinforced mortar

Date palm fibers was added as percenrtage of cement weight when mixing mortar, see previous section 2.1. The mixing process is carried out by mixing the dry materials first, sand and cement during 1min. Then add the percentage pretreatment methods and type of the selected date palm fiber. Mixing water is added with the addition of absorption water if the mortar is needs it, taking into account that the total mixing time does not exceed 5min. This mixed was effected manually because using the electrically mixer lead to the fiber wrapped around the paddle, and cement and sand are deposited in the mixing bowl after adding water. Percentage of fibers determins the cure methods this meaning that as the percentage is elevated the dry care methods will use because the sample after 24h removed of moulde became brittle and can't cure in water. It is important to note that when the longue fibers are introduced into mortar as, so, it is difficult to obtain homogeneous samples as well as these fibers require large molds, vice versa. Cubes specimens (5x5x5 cm or 7x7x7 cm) are conserve in mould for 24 h then it is taken out from mould and cured in water for 28 days. The dimensions of the molds depend on % of fiber that has been introduced. So figure 4 is shown an example of two samples after casting.

Figure 4: prepared date palm fiber (remaining on sieve 0.6 mm) reinforced mortar introduced as percentage of cemen weight.

3. Influence treatment methods on:

3.1. Physical property

3.1.1.Volumic density of composite

For cement mortar (ref) was conserved in water at 28 days, their volumetric weight is equal to 2.3 g/cm^3, but introduce root fibers or wet root lead to decreasing volumetric weight by small percentage, Whatever type of treatment for fibers, see figure 5. The treatment in dry air at 30°C reduced the volumetric

weight due to the drying of the pores, and no role of treated fibers on volumetric weight as shown in the figure 6. Moreover, no significant effects of the type of treatment and the method of conserving the samples on the average volumetric weight for all used fibers are shown in the figure 7.

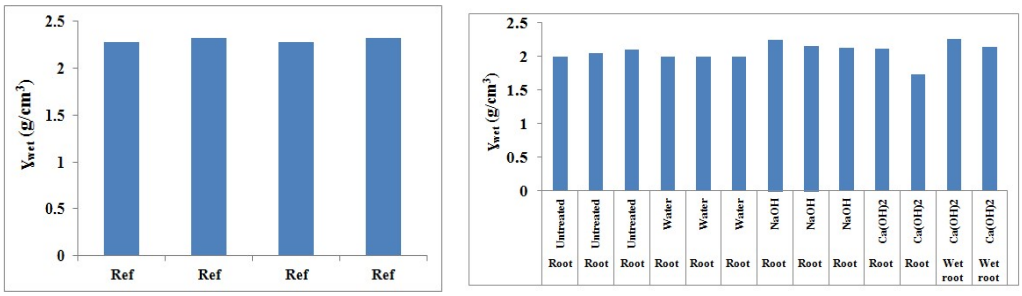

Figure 5: Volumetric density of ref (left), root fibers (right).

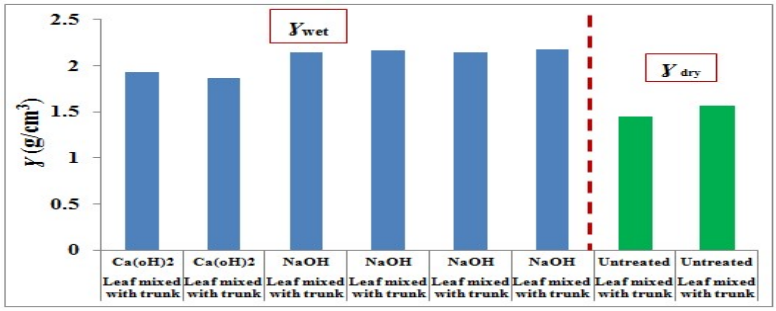

Figure 6: Volumetric weight dry and wet of mixed fibers.

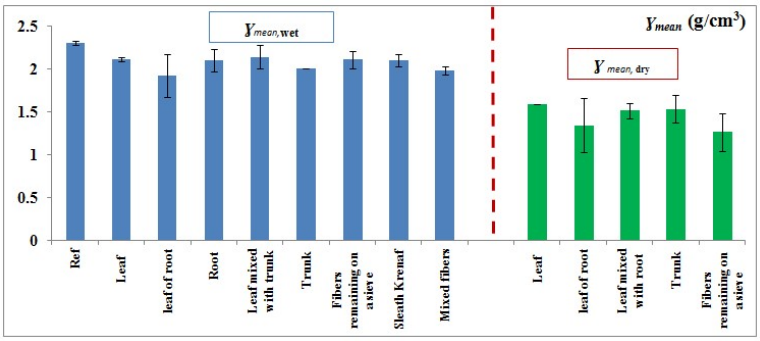

Figure 7: Average volumetric weight dry and wet of all used fibers.

3.2. Mechanical property

3.2.1. Maximum compression load

Mechanical testing of hardened mortar samples after 28 days of curing tests was performed cubical samples were subjected to compressive loading based on

ASTM C109/C109M where the maximum load and stress at failure were recorded. The figure shows several samples of untreated leaf root or treated with sodium hydroxide. It is noted that the alkalin treatment leads to an improvement in the compressive strength compared to untreated leaf root (figure 8.a). Thus, calcium hydroxide will also improve the resistance. It is noticed that the high strength values in some untreated cases the difficulty in controlling the dimensions and quantity of the fiber during casting process (figure 8.b).

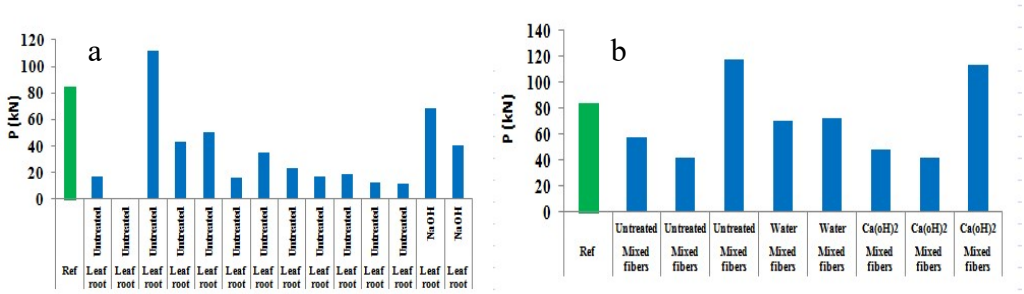

Figure 8: Max. compression load values of ref, (left), mixed fibers (right).

Figure 9 shows that treatment with calcium hydroxide is better than sodium and untreated fiber, where the coefficient of variation between these cases must be taken into account. Likewise, the type of fibers plays an essential role in improving resistance.

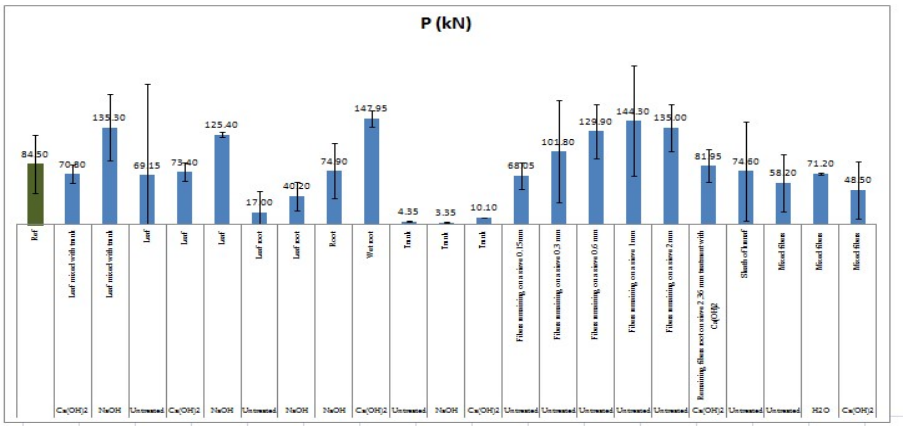

Figure 9: Mean compression load of ref and all treated and untreated fibers, and coefficient of variation.

3.2.2. Maximum compression stress

The difference in cross section of the fiber and the difficulty in controlling the amount of fibers inside the composite causes difficulty in determining the effect of the type of treatment on the compressive strength, see figure 10, 11.

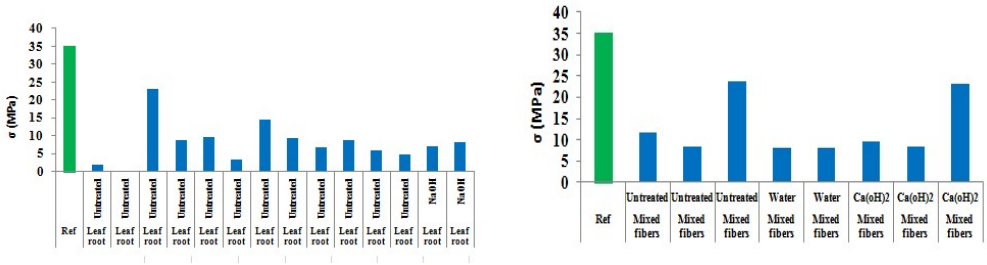

Figure 10: Max. compression resistance of ref, leaf root (left), mixed fibers (right).

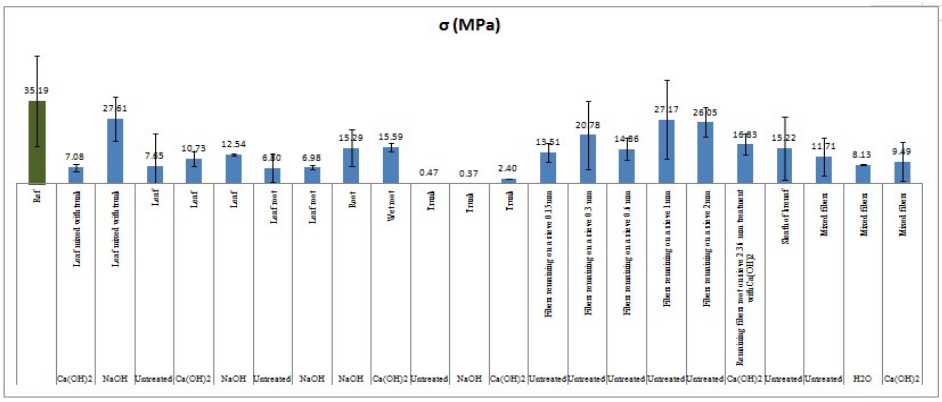

Figure 11: Mean compression resistance of ref and all treated and untreated fibers, and coefficient of variation.

4. Influence of date palm fiber type on:

4.1. Mechanical property

4.1.1. Maximum compression load

Figure 12 appeared that leaf fibers improves the maximum compressive load compared to trunk fibers due to the difference in the structure of fibers, especially when treated with sodium hydroxide..

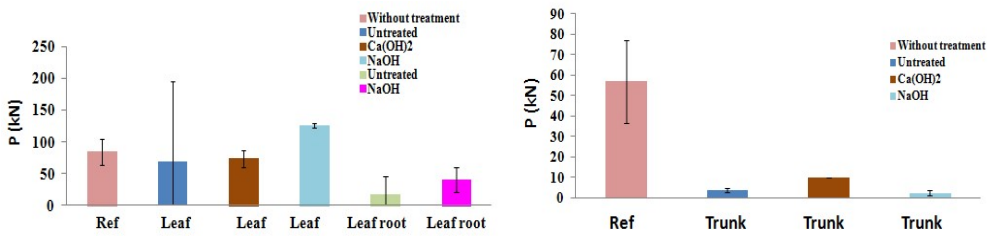

Figure 12: Mean compression load values of ref, leaf, leaf root (left), trunk (right).

4.1.2. Maximum compression stress

As we explained previously, the difference in cross section along fibers and the type of fibers play essential role on maximum resistance, as shown in figure 13.

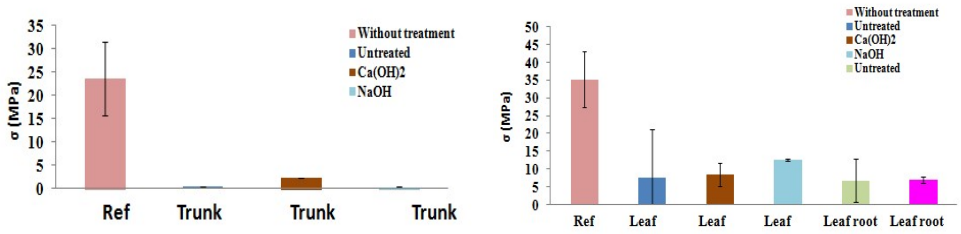

Figure 13: Mean compression strength of ref, leaf, leaf root (left), trunk (right).

5. The effect of fibers percentage on compressive behaviour

As the palm fibres derived from plant, is exhibited different mechanical characteristics when used in cement composites, because of their variety in molecular structure and composition [3]. Thus increasing the percentage of fibers lead to decreasing compression load values. So augmentation % of fibers into the mortar lead to raise the heterogeneity of composite structural, especially the fibers of large dimensions, see figure 14.

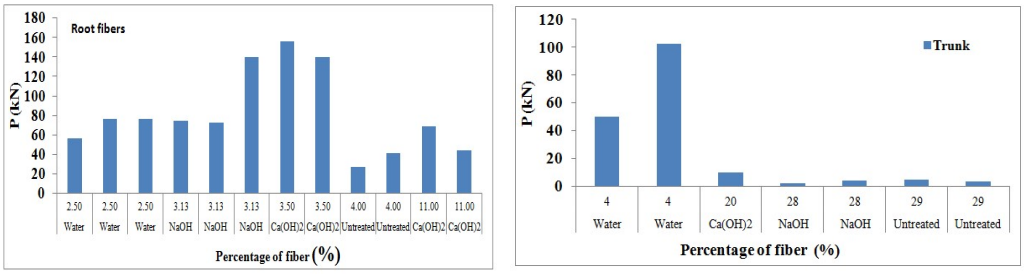

Figure 14: The effect of % root (right), % trunk fibers (left) on max. compression load.

6. Conclusion

Using palm fibers as a partial substitute for cement inside concrete can achieve efficiencies at different rates between 0.6 and 70 %. This concrete achieves satisfactory results in dry areas to avoid the water absorption problems of the fibers. The physical properties that were studied showed that palm fiber has a high absorption coefficient as indicated in [9]. Also, curing cementitious matrix based cement reinforced with date palm fibers in the dry air leads to a reduction in the volumetric density, as there is no alternative when replacing the fiber with

a ratio of 25% with cement weight. However, no role of treated fibers on volumetric weight. It is noted that the mechanical properties depend mainly on treating the fibers with alkaline solutions to reduce the percentage of pores at the interface and thus increase the compressive strength. And complicity structural of date palm fibers influence directly on compressive strength calculation.

7. References

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