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Physical and mechanical properties of cement-based mortars reinforced with treated date palm fibres

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Abstract – In recent years, there has been growing interest among researchers in utilizing natural fibers as reinforcements in construction materials. This study aims to examine the impact of date palm fiber content and the combined treatment on the physical and mechanical properties of cementitious mortars reinforced with fibers. Prismatic specimens of cementitious mortar, measuring 40x40x160 mm and consisting of cement, sand, water, and fiber, were prepared with a water-cement ratio of 0.5 (W/C = 0.5). The fibers were incorporated into the cement at various mass percentages relative to the binder: 0.5%, 1%, and 1.5%, both in their raw form and after undergoing treatments (heating at 80°C + 0.5% NaOH and heating at 80°C + 1% NaOH). The results indicate that the compressive strength decreases as the fiber content increases. Notably, the combination of heat treatment followed by an alkaline solution of 1% NaOH demonstrates a significant positive effect on the performance of the mortar.

Keywords –Compressive Strength, Natural Fibre, Treatment, Temperature, Phoenis Dactylifera.

I. Introduction

In the pursuit of sustainable development, significant efforts are currently underway to create environmentally friendly construction materials [1-3]. The incorporation of plant fibers as reinforcements in cementitious materials has already resulted in numerous advancements, leading to the development of composites that are cost-effective, emit less CO2, possess favorable thermal and acoustic properties, and exhibit satisfactory mechanical behavior. Examples of plant fibers utilized for reinforcement include hemp, alfa, flax, sisal, doum, and diss [4-10].

The objective of this study is to fabricate and characterize a novel composite material comprising a cementitious matrix reinforced with fibers derived from the trunk of the date palm. Our approach is centered on understanding the behavior of both raw and treated palm fibers to determine the typical effects of chemical and thermal treatments on enhancing specific mechanical properties (such as bending and compression) and physical properties of the cementitious matrix.

II. Materials and Method

II.1. Materials:

II.1.1. Cement:

CEM I 42.5 has a Blaine-specific surface area of 3480 cm^2/g and an absolute density of 3.4 g/cm^3. Details of the chemical and mineralogical composition of the clinker are given in Tables 1 and 2, respectively.

Table 1. Elemental chemical composition of cement.

CaO	63,5
SiO_2	19,28
Al_2O_3	3,93
Fe_2O_3	4,75
SO_3	1,57
K_2O	0,42
Na_2O	0,13
MgO	0,96
CaO libre	1,07

Table 2. Mineralogical composition of clinker.

C_3S	C_2S	C_3A	C_4AF
64,71	15	2,38	14,45

II.1.2. SAND:

Calcareous sand, angular in shape and with a rough surface, has a granular class of 0/3 and a bulk density of 2.64 g/cm^3. Table 3 shows the physical properties of sand.

Table 3. Physical properties of sand.

Characteristic	**SA**
Absolute density (g/cm^3)	2.64
Bulk density (g/cm^3)	1.45
Fineness modulus	2.4
Sand equivalent (%)	76
Absorption coefficient (%)	0.72

II.1.3. FIBRES:

The fibers employed in this research comprise surface fibers extracted from date palm trees located in the Mzab Valley region of Ghardaia, Algeria (see Figure 1). These date palm surface fibers are naturally interwoven and are obtained from the trunk in the shape of an approximately rectangular mesh, measuring between 300-500 mm in length and 200-300 mm in width. The mesh consists of three layers stacked on top of each other. These fibers can be easily separated into individual strands with a diameter ranging from 0.1 to 0.8 mm when submerged in water [11].

Fig 1. Date palm fibre.

Figures and tables must be centered in the column. Large figures and tables may span across both columns. Any table or figure that takes up more than 1 column width must be positioned either at the top or at the bottom of the page.

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II.2. EXPERIMENTAL METHODS:

Mortar samples were prepared in accordance with EN 196-1 [12] with an E/C ratio of 0.5 and a C/S ratio of 1/3. The fibres were added to the cement with different mass percentages (relative to the binder) of 0.5, 1, and 1.5%.

II.2.1. FIBRE PRE-TREATMENT:

The date palm fibers are manually cut to a length of 25 to 30 mm (as shown in Figure 2) and carefully washed with water to remove any dust particles. Subsequently, they are dried in an oven at 55°C for duration of 24 hours to achieve consistent moisture content. These dried fibers are then referred to as raw fibers. To further enhance their properties, surface treatments involving soda and temperature are applied to the dry fibers.

The initial step involves immersing the fibers in hot water at a temperature of 80°C within a container for duration of 30 minutes. Afterward, they are drained and thoroughly rinsed with ample amounts of water to eliminate organic substances. Subsequently, the fibers are dried in an oven at 55°C for a period of 24 hours, as depicted in Figure 3.

The second procedure encompasses a combined treatment involving both thermal and chemical processes. The objective of this treatment is to decrease the presence of organic substances within the palm fibers. The fibers that have undergone the 80°C treatment are immersed in a solution containing either 0.5% or 1% NaOH for 30 minutes at room temperature. Following this, the fibers are washed with distilled water to eliminate any remaining traces of sodium hydroxide from the fiber surfaces. Finally, they are dried in an oven at 55°C for 24 hours, as illustrated in Figures 4 and 5.

Fig 2. Fibres cut into pieces.

Fig3. Treatment with hot water at 80°C.

Fig 4. Treatment with hot water at 80°C + 0.5% NaOH.

Fig 5: Treatment with hot water at 80°C + 1% NaOH.

II.2.1. FLEXURAL TENSILE TEST:

The three-point bending test is conducted following the guidelines outlined in the European standard EN 196-1. Prismatic specimens measuring 4x4x16 cm^3 (depicted in Figure 6) are prepared and subjected to testing after a curing period of 30 days. The obtained values for each mix formulation represent the average of three tests. The flexural strength of the mortars is determined after the initial appearance of a visible crack, utilizing Equation 1.

Fig 6. Prismatic test tubes 4x4x16 cm^3.

II.2.2. Compression test:

The mortar specimens obtained from the 3-point bending test are subjected to compressive strength evaluation at the age of 30 days, following the guidelines of EN 196-1. The values obtained represent the average of three tests and are determined using Equation 2.

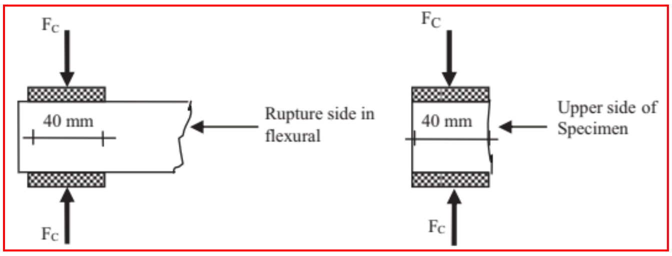

Figure 7. Compressive strength device.

II.2.3. PHYSICAL PROPERTIES:

The capillarity measurements were conducted following the AFPC-AFREM standard [13], utilizing half-tests measuring 4x4x8 cm³. To ensure uniaxial water absorption, these specimens were coated with a waterproof material on their lateral surfaces. The samples were initially oven-dried at 60°C until a stable mass was achieved, and their dry weight, denoted as M0, was determined using a precision balance with an accuracy of 0.01 g. Subsequently, the samples were left to air dry and weighed again (Mt) using the same balance to assess their weight after each submersion period. The immersion depth of the sample surfaces during the absorption test ranged from 2 to 3 mm. Following each submersion period, the samples were taken out of the water, wiped, superficially dried using absorbent paper to remove any excess water from the surface, and then weighed. The values obtained represent the average of three trials. Absorption is quantified through successive weighings, employing the following expression:

C= (M_t-M_0)/A

Where :

C: Capillary absorption coefficient (kg/m²),

Mt: Mass of the test piece at time t (kg),

M0: Initial mass of the test piece (kg),

A: Immersed cross-section of the specimen (m²),

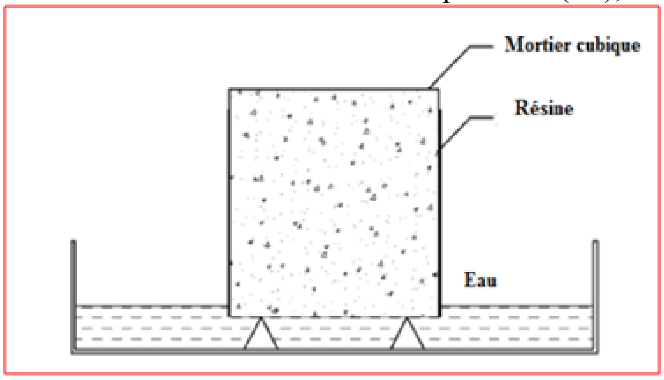

Fig 8. Schematic diagram of the capillary absorption system.

III. RESULTS AND INTERPRETATION:

III.1. FLEXURAL TENSILE STRENGTH:

In Figure 9, the graph depicts the variation of flexural strengths in cement-based mortars as a function of the content of raw and treated date palm fibers. The findings demonstrate that the flexural tensile strength increases with an increase in the proportion of palm fiber. Notably, the 30-day flexural tensile strength of the fiber-reinforced mortars treated at 80°C+1% NaOH exhibits a significant enhancement of approximately 36.85% compared to the untreated (raw) mortars, with an optimal fiber content of 1.5%. This observed behavior can be attributed to the effect of NaOH treatment on the fibers. The treatment eliminates amorphous substances present on the outer surface of the palm fibers, resulting in a clean and rough surface. This, in turn, enhances the interlocking and interfacial adhesion between the fiber and the cementitious matrix, consequently leading to an increase in the tensile strength of the cementitious mortars utilizing treated fibers [14,15].

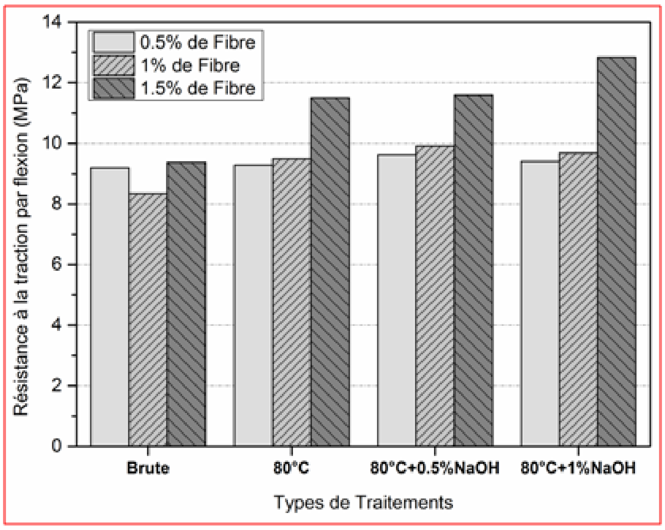

Fig 9. Flexural tensile strength of date palm fibre-reinforced mortars at 30 days.

III.2. COMPRESSIVE STRENGTH:

Figure 10 illustrates the relationship between the compressive strength of mortars tested at 30 days and the percentage of both untreated and treated date palm fibers incorporated. The findings reveal that the compressive strength value decreases as the proportion of these fibers in the mortars increases. This phenomenon is consistent with the observations of various researchers, who have noted that the inclusion of plant fibers has a detrimental impact on the compressive strength of cementitious materials. This can be attributed to the increased presence of defects in the cementitious matrix resulting from the uneven distribution of fibers within the mixture. As the fiber content rises, the cohesion of the mortars diminishes and porosity increases, leading to a significant decline in their compressive strength [11, 16, 17].

For instance, Kriker et al. in their 2005 study [11] reported that the compressive strength decreases with both increasing fiber content and fiber length. They found that a concrete specimen reinforced with 2% volume fraction of date palm fibers, with a fiber length of 15 mm, exhibited 90% of the compressive strength compared to the non-fiber-reinforced concrete specimen. In contrast, a specimen reinforced with 3% fiber of 60 mm length displayed only 55% of the compressive strength of ordinary concrete. The authors attributed this reduction to the amplified presence of defects and the non-uniform distribution of fibers.
Furthermore, it has been observed that fiber-reinforced mortars treated at 80°C+1% NaOH exhibit greater strength compared to raw fiber mortars. This enhancement can be attributed to the reduction in amorphous materials within the fibers resulting from the combined thermal-alkaline treatment. This treatment affects the intrinsic water absorption of the fibers and generates a rough surface that improves the adhesion between the fiber and the cementitious matrix.

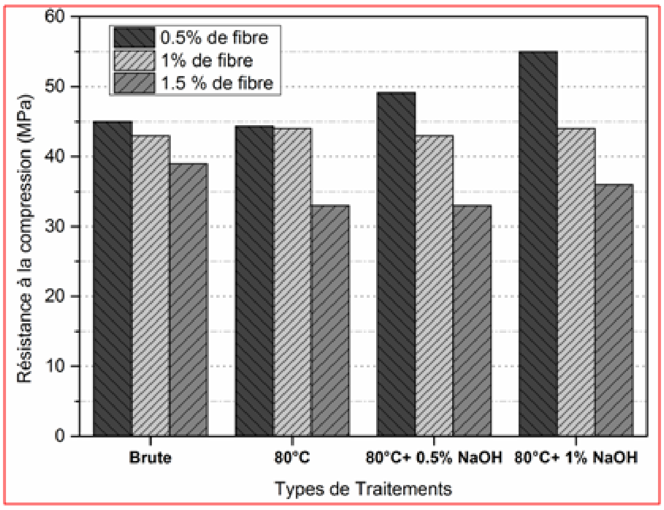

Fig 10. Compressive strength of mortars reinforced with date palm fibres at 30 days.

III.3. PHYSICAL PROPERTIES:

Figure 11 presents the outcomes of capillary absorption tests conducted on samples comprising both raw and treated fibers after a 30-day curing period. The results reveal that the absorption capacity rises as the dosage of fibers increases. Additionally, it is observed that the absorption value of mortars reinforced with raw palm fibers is higher compared to those reinforced with treated fibers.
The results obtained from the experimental investigation provide valuable insights into the performance of cement-based mortars reinforced with date palm fibers. The discussion of these results focuses on the flexural tensile strength, compressive strength, and physical properties of the mortars.

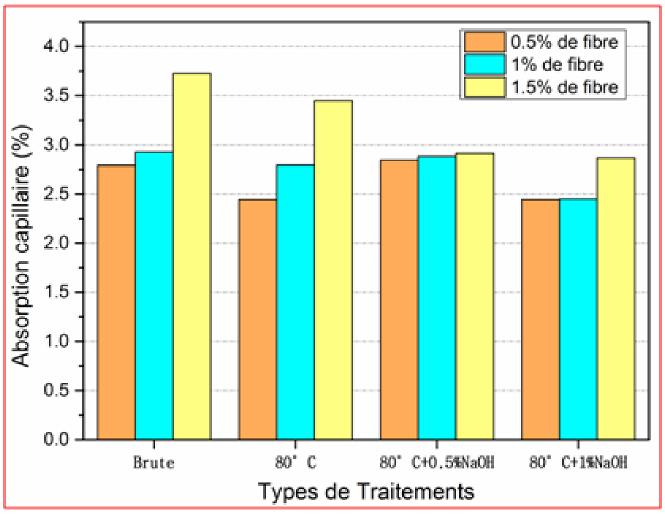

Fig 11. Capillary absorption at 90 minutes of composite-reinforced composites.

IV.DISCUSSION:

The flexural tensile strength of the mortars showed a significant improvement with an increase in the content of palm fibers. This can be attributed to the reinforcing effect of the fibers, which enhance the resistance to tensile forces in the cementitious matrix. The interlocking and interfacial adhesion between the treated fibers and the matrix were enhanced due to the NaOH treatment, resulting in a cleaner and rougher fiber surface. This improved adhesion contributed to the increased flexural tensile strength observed in the mortars reinforced with treated fibers.
The findings are consistent with previous studies [14,15], which have also reported an increase in flexural tensile strength with the addition of treated plant fibers. The removal of amorphous substances from the fiber surface and the resulting roughness

play a crucial role in improving the mechanical properties of the composite material.

In contrast to the positive effect on flexural tensile strength, the incorporation of date palm fibers led to a decrease in the compressive strength of the mortars. This is a well-known phenomenon observed in cementitious materials reinforced with plant fibers. The decrease in compressive strength can be attributed to the introduction of defects and the non-uniform distribution of fibers within the matrix.

The presence of fibers creates voids and weak points in the cementitious matrix, reducing its overall cohesion and increasing porosity. As the fiber content increases, these effects become more pronounced, leading to a significant decline in the compressive strength of the mortars. This behavior is in line with the findings of other researchers [11, 16, 17], who have reported similar trends in the compressive strength of fiber-reinforced cementitious materials.

However, it is worth noting that mortars reinforced with treated fibers exhibited higher compressive strength compared to those reinforced with raw fibers. The combined thermal-alkaline treatment resulted in a reduction of amorphous materials within the fibers and improved the adhesion between the fibers and the matrix. This enhanced adhesion contributed to a relatively higher compressive strength in the mortars incorporating treated fibers.

The capillary absorption tests revealed that the absorption capacity of the mortars increased with an increase in the dosage of palm fibers. This can be attributed to the porous nature of the fibers, which provide additional pathways for water absorption within the composite material. The higher absorption value observed in mortars reinforced with raw fibers compared to treated fibers can be attributed to the presence of organic substances and residual impurities on the surface of raw fibers, which facilitate water absorption.

The results are consistent with the nature of plant fibers, which are known to have inherent water absorption characteristics. The findings suggest that the use of palm fibers, whether treated or untreated, can affect the water absorption behaviour of cementitious mortars. This information is important for understanding the moisture-related properties and durability of the composite material.

In conclusion, the experimental results highlight the influence of date palm fibers on the mechanical and physical properties of cement-based mortars. The flexural tensile strength was improved with the addition of treated fibers, attributed to enhanced adhesion and interlocking. On the other hand, the compressive strength decreased with an increase in fiber content due to the introduction of defects and the non-uniform distribution of fibers. The capillary absorption tests showed increased absorption with higher fiber dosage, with higher values observed in mortars reinforced with raw fibers. These findings contribute to the understanding of the performance of fiber-reinforced cementitious.

V. CONCLUSION:

In conclusion, the study focused on investigating the effects of date palm fibers on the mechanical and physical properties of cement-based mortars. The following general conclusions can be drawn:

- The incorporation of date palm fibers led to an improvement in the flexural tensile strength of the mortars. The treated fibers, subjected to an 80°C+1% NaOH treatment, exhibited the highest enhancement in flexural tensile strength compared to raw fibers. The treatment removed amorphous substances from the fiber surface, resulting in a clean and rough surface that enhanced the interlocking and adhesion between the fibers and the cementitious matrix.
- The compressive strength of the mortars decreased with an increase in the content of date palm fibers. This reduction can be attributed to the presence of defects and the non-uniform distribution of fibers within the matrix. As the fiber content increased, the cohesion of the mortars decreased, and porosity increased, resulting in a significant decline in compressive strength. However, mortars reinforced with treated fibers showed higher compressive strength compared to those reinforced with raw fibers, indicating the beneficial effect of the thermal-alkaline treatment on fiber-matrix adhesion.
- The capillary absorption tests demonstrated that the water absorption capacity of the mortars increased with higher fiber dosages. Mortars reinforced with raw fibers exhibited higher absorption values compared to those reinforced with treated fibers. This can be attributed to the presence of organic substances and impurities on

the surface of raw fibers, which facilitated water absorption. The water absorption behavior of the mortars is influenced by the nature of the fibers and has implications for the moisture-related properties and durability of the composite material. Overall, the study highlights the potential of date palm fibers as a reinforcement material in cement-based mortars. The treatment of fibers with NaOH and the control of fiber content can effectively enhance the flexural tensile strength and improve the adhesion between fibers and the cementitious matrix. However, it should be noted that the compressive strength of the mortars may be compromised with higher fiber dosages. These findings contribute to a better understanding of the mechanical and physical properties of fiber-reinforced cementitious materials and provide insights for the development of sustainable and eco-friendly construction materials in the context of sustainable development.

REFERENCES

[1] Boucedra A, Bederina M, Ghernouti Y. Study of the acoustical and thermo-mechanical properties of dune and river sand concretes containing recycled plastic aggregates. Construction and Building Materials. 2020;256:119447.

[2] Hichem B, Bederina M, Makhloufi Z. Physico-mechanical and microstructural properties of an eco-friendly limestone mortar modified with styrene-polyacrylic latex. Journal of Building Engineering. 2020;32:101463.

[3] Bendjillali K, Boulekbache B, Chemrouk M. Durability assessments of limestone mortars containing polypropylene fibres waste. Advances in concrete construction. 2020;10:171-83.

[4] Ahmad R, Hamid R, Osman S. Physical and Chemical Modifications of Plant Fibres for Reinforcement in Cementitious Composites. Advances in Civil Engineering. 2019;2019:1-18.

[5] Benaimeche O, Carpinteri A, Mellas M, Ronchei C, Scorza D, Vantadori S. The influence of date palm mesh fibre reinforcement on flexural and fracture behaviour of a cement-based mortar. Composites Part B: Engineering. 2018;152:292-9.

[6] Yan L, Chouw N, Huang L, Kasal B. Effect of alkali treatment on microstructure and mechanical properties of coir fibres, coir fibre reinforced-polymer composites and reinforced-cementitious composites. Construction and Building Materials. 2016;112:168-82.

[7] Carada P, Fujii T, Okubo K. Effects of heat treatment on the mechanical properties of kenaf fiber2016.

[8] Ardanuy M, Claramunt J, Toledo Filho RD. Cellulosic fiber reinforced cement-based composites: A review of recent research. Construction and Building Materials. 2015;79:115-28.

[9] Achour A, Ghomari F, Belayachi N. Properties of cementitious mortars reinforced with natural fibers. Journal of Adhesion Science and Technology. 2017;31(17):1938-62.

[10] Achour A, Aziez MN, Ghomari F. Influence de la valorisation des fibres végétales de Diss (Ampelodesmos mauritanicus) traitées sur le comportement mécanique des composites à matrice cimentaire2018.

[11] Kriker A, Debicki G, Bali A, Khenfer MM, Chabannet M. Mechanical properties of date palm fibres and concrete reinforced with date palm fibres in hot-dry climate. Cement and Concrete Composites. 2005;27(5):554-64.

[12] N.E. 196-1 MoTC. Part 1: Determination of Mechanical Strength France 2006.

[13] Arliguie G. HH. Grandeurs associées à la durabilité des bétons: GranDubé". Presses Ecole Nationale des Ponts et Chaussées, Paris, France, p. 437. 2007.

[14] Cao Y, Shibata S, Fukumoto I. Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments. Composites Part A: Applied Science and Manufacturing. 2006;37(3):423-9.

[15] Sedan D, Pagnoux C, Smith A, Chotard T. Mechanical properties of hemp fibre reinforced cement: Influence of the fibre/matrix interaction. Journal of the European Ceramic Society. 2008;28(1):183-92.

[16] Ozerkan NG, Ahsan B, Mansour S, Iyengar SR. Mechanical performance and durability of treated palm fiber reinforced mortars. International Journal of Sustainable Built Environment. 2013;2(2):131-42.

[17] Hamzaoui R, Guessasma S, Mecheri B, Eshtiaghi AM, Bennabi A. Microstructure and mechanical performance of modified mortar using hemp fibres and carbon nanotubes. Materials & Design (1980-2015). 2014;56:60-8.