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Characterization of biosourced materials cement- date palm fibers

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Abstract

The objective of this work is the use of biosourced materials in wall coverings to improve thermal insulation. This study may contribute to the development of sustainable building and effective renovation. The natural fibers used in this work as reinforcement are the fibers of the date palm clusters collected from Biskra (Algeria). The used matrix is cement (Portland cement pozzolan CEM II / A-P 42.5 N) supplied by the cement company of HammaBouziane, Constantine, Algeria. Samples prepared with four different weight fractions (0, 1, 3 and 5%) of DPF are tested after grinding. The characterization of these samples was performed by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA).

FTIR and XRD analysis show that the addition of fibers does not affect the chemical composition of the matrix. The DSC and TGA results show that the addition of date palm fibers has an impact on the thermal properties of the matrix. According to the obtained results, composites containing date palm fibers have in practice excellent properties that can compete with building materials.

Keywords: Biosourced materials; DPF; FTIR; DSC; XRD; TGA.

1. Introduction

Reducing the energy consumption of buildings is a major challenge in sustainable development. According to Asdrubali et al [1], buildings consume about 40% of the world's energy, 25% of the world's water and 40% of the global resources. In the context of sustainable construction, the new regulations on thermal insulation in the construction sector promote the development of new materials based on plant fibers to build energy-efficient buildings while ensuring the housing comfort [2]. Among these new materials, there are biocomposites composed of mineral binders reinforced with plant fibers (vegetable waste) to take advantage of the physical properties of plant fibers and the mechanical properties of the inorganic binder [3]. In particular, there are many benefits to use natural fibers such as: made from a renewable resource and require low energy consumption during their manufacturing [4]. Algeria is one of the countries that contain a multitude of plant materials (the date palm, cork, ...), however, their recovery remains insufficient mainly in building sector [5].

Several investigations have been carried out in the reinforcement of different composites with date palm fibers. Benmansour et al [6] developed a new material containing date palm fibers in mortar, in their study the thermal conductivity of the material decreased by 56% by adding 5% of fibers to the matrix.

Kriker et al [7] evaluated the mechanical properties of concrete with date palm fibers. Abani et al [8] studied the thermal behaviour of plaster reinforced with (DPF). Their results showed that the studied composite had excellent hygrothermal properties. Haba et al [3] conducted research on the measurement of water vapour permeability and sorption isotherm of these new biocomposite materials. All of the reported research has shown interesting experimental results which conclude that the addition of DPF in building materials was a very promising initiative to obtain a new low cost insulation material. This aim of this work is to study the impact of the date palm fibers inclusion on the chemical and thermal properties of Portland cement.

In this work, X-ray diffraction, Fourier transform infrared spectrometry, thermogravimetric analysis and differential calorimetry have been used for prepared samples characterization.

2. Materials and samples preparations

2.1. Materials

2.1.1. Portland cement (PC)

The chemical composition of this matrix is given in Table 1

Table 1: The chemical composition of Portland cement

Elements	wt. %
CaO	64,5-67%
SiO_2	23-25%
$Al2O_3$	4,5-7,0%
$Fe2O_3$	0,2%
MgO	3,5%
SO_3	0,5-1,0%
MnO	0,2%

2.1.2. Date palm fibres (DPF)

The date palm wood used in this work is collected from the oases of Biskra (Algeria). The renewable part of the palm used is thecluster (bunch) of DegletNourvariety (Figure 1). The fibers are used after being dried at 60 ° C in the laboratory's Memmert oven for 24 hours and crushed using an electric grinder. The choice of this renewable part of the date palm was made for its thermophysical properties found in the literature [5].

Figure 1. Date palm cluster

2.2. Sample preparation

Four samples of the same mass composed of Portland cement (CB0, CB1, CB3 and CB5) are prepared with the addition of DPF mass fractions of 0, 1, 3 and 5%, respectively.
Each sample is mixed and kneaded until homogeneous. Prepared samples were characterized using FTIR, XRD, DSC and TGA methods.

3. Characterization methods

3.1. X-ray diffraction (XRD) analysis

X-ray diffraction (XRD) of the samples analysis was performed using a copper anode and CuKα radiation at 45 kV and 40 mA in the 2θ = (20-65) ° range.

The X'Pert PRO PANalytical diffractometer was used to study the effect of the addition of DPP on the mineral phases of X-ray diffraction with Portland cement (XRD).

3.2. Differential scanning calorimetry (DSC) and Thermogravimetric analysis (TGA)

Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) were performed in the temperature range of 21-320 ° C with a heating rate of 10 K / min. The measurements were carried out in a nitrogen atmosphere with a flow rate of 20 ml / min.

The NETZSCH Jupiter STA 449 F3 calorimeter (NETZSCH, Selb, Germany) was used to study the thermal properties of prepared materials

3.3. FT-IR analysis

To measure the influence of the addition of DPF on the chemical composition of Portland cement, the JASCO FT / IR-6300 Fourier Transform Infrared Spectrometer has been used. The spectra range was raised between 4000 and 600 cm^{-1} and the band intensities were expressed in transmission factor (% T).

4. Results and discussion

4.1. X-ray diffraction (XRD) analysis

Figure 2 presents the XRD diagram of the DPF which shows a principal peak at 2θ = 21.5° corresponding to the crystallographic plane (002) of cellulose I [9].

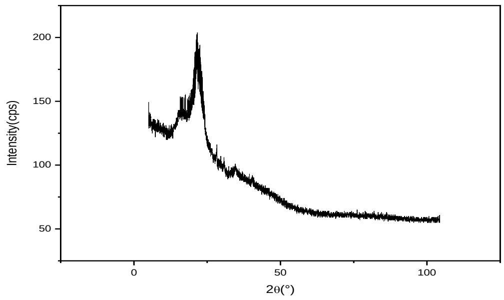
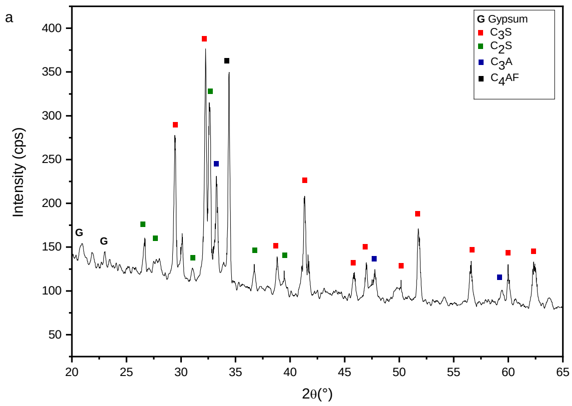


Figure 2. XRD patterns of date palm Fiber (DPF)



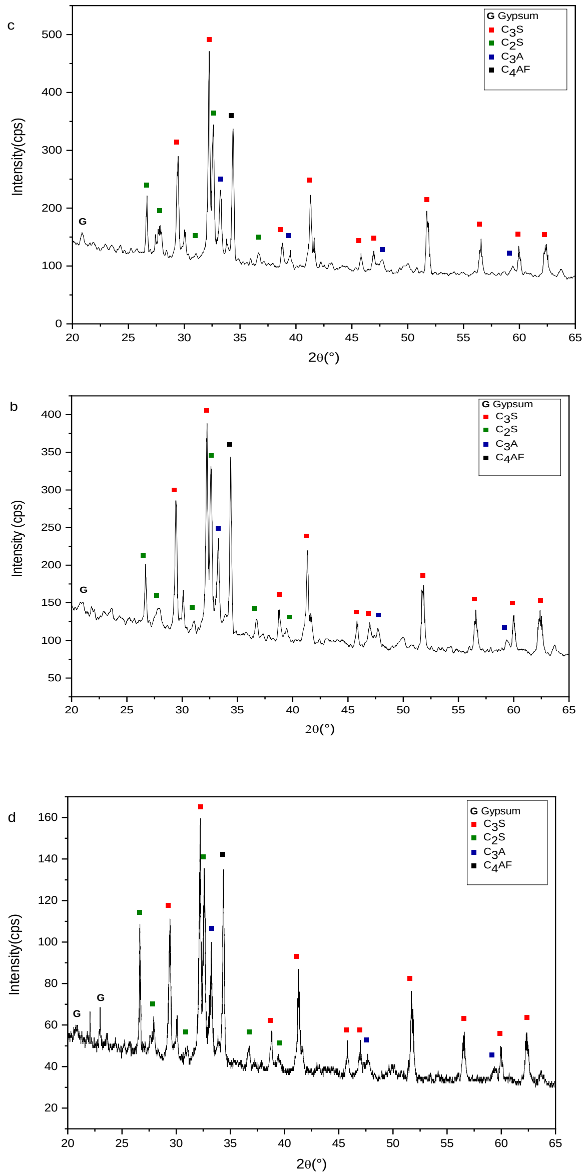


Figure 3. X-ray diffraction analysis (XRD): (a) CB0, (b) CB1, (c) CB3 and (d) CB5.

Figure 3 shows the results of the XRD analysis of the samples CB0, CB1, CB3 and CB5. (Figure.3a) comprises four different mineral phases defined in Table 2.

The XRD results of the samples CB1 (Figure.3b), CB3 (Figure. 3c) and CB5 (Figure. 3d) show that the Portland cement retains its mineral phases after the addition of DPF, which indicates that the addition of DPF masse fractions in the matrix has no influence on the crystalline form of the matrix. The identification of the XRD peaks illustrated in Figure 3 was based on reported work [10].

4.2. Differential scanning calorimetry (DSC) and Thermogravimetric analysis (TGA)

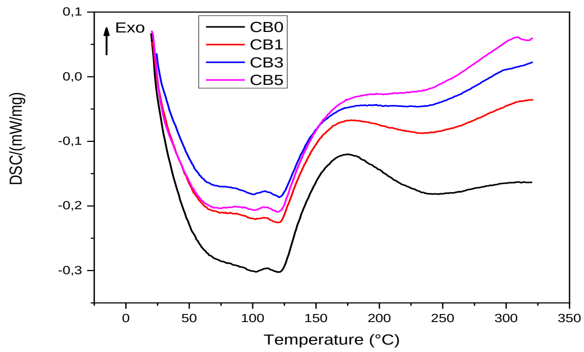


Figure 4. Variation of DSC graphs

Figure 4 shows the differential scanning calorimetry (DSC) curves of the different samples.

The DSC analysis of the CB0 sample shows that there is an endothermic peak between 100 and 150 ° C due to the decomposition of CSH calcium silicate hydrates and the evaporation of free water [11]. The same phenomenon can be observed for samples CB1, CB3, CB5.

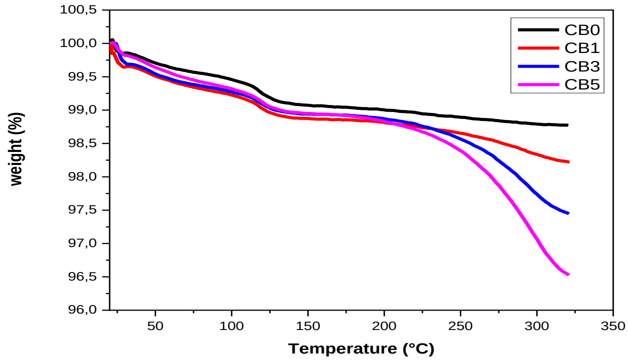


Figure 5. Weight loss of different samples as a function of temperature

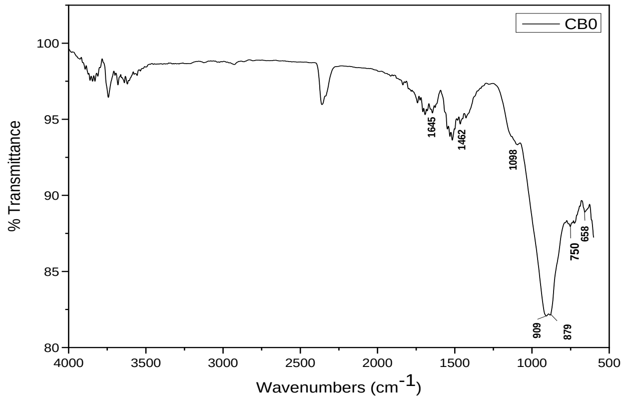
Table 2: The mineral phases of Portland cement

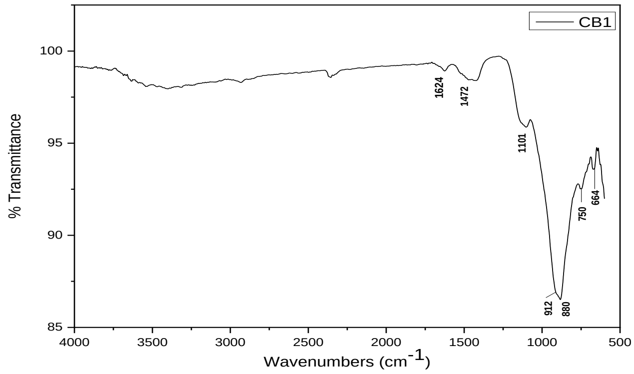
Name	Mineral phase	Abbreviation	Chemical formula
Tetracalciumalumino ferrite	Ferrite	C_4AF	$(CaO)_4(Al_2O_3)(Fe_2O_3)$
Tricalcium aluminate	Celite	C_3A	$(CaO)_3(Al_2O_3)$
Dicalcium silicate	Belite	C_2S	Ca_2SiO_4
Tricalcium silicate	Alite	C_3S	Ca_3SiO_5

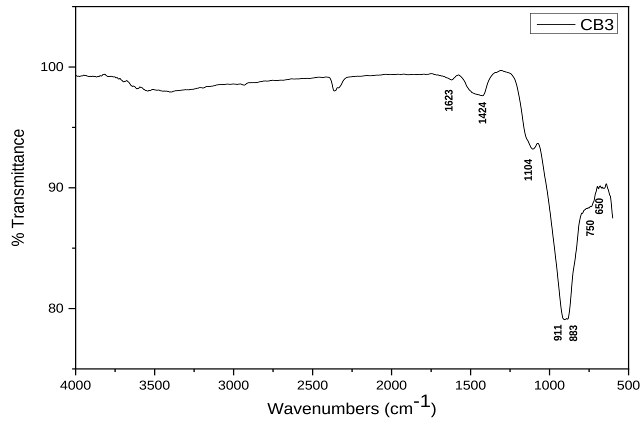
Mass loss measurements of different samples as a function of temperature are presented in Figure 5. The TGA curves of FIG. 5 show a mass loss of the samples CB0, CB1, CB3, CB5 with the increase of the temperature corresponding to the dehydration of the CSH hydrated calcium silicate and the evaporation of the free water. By comparing different samples curves, there is a slight difference in mass loss which confirms that the addition of date palm fibers affects the thermal properties of the matrix.

4.3. FT-IR analysis

The chemical composition characterization of the samples was performed using the Fourier Transform Infrared Spectrometer. The results obtained are shown in Figure 6.







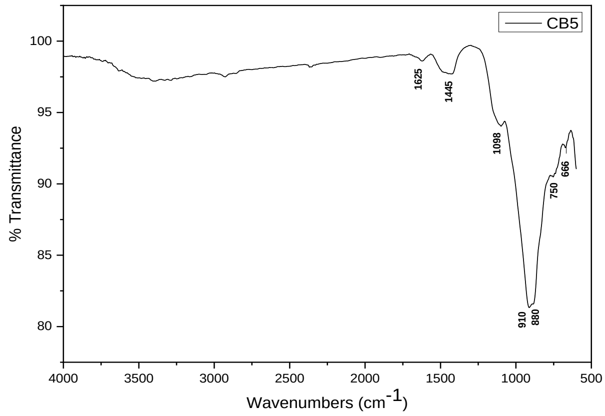


Figure 6. Comparison betweenFTIR spectrums of different samples

The CB0 sample FTIR spectrum show a CO3 uptake peaks located at about 879 cm^{-1} and 1462 cm^{-1} [12]. These absorption bands indicate the presence of calcium carbonate ($CaCO_3$) [13]. An absorption band around 909 cm^{-1} (ν Si-O), corresponds to the valence vibration modes of the Si-O bond of the C_2S and C_3S siliceous phases [13]. In addition, two characteristic water bands appearing at 1645 cm^{-1} and 750 cm^{-1} can be observed [14].

Indeed, two bands at 1098 cm^{-1} and 658 cm^{-1} are observed which correspond to the extension of the S-O bond of sulphates (SO_4^{2-}), characteristic of the presence of gypsum ($CaSO_4$) [13]. The FTIR analysis of CB1, CB3, CB5 shows that the different samples peaks are almost identical, indicating that the addition of date palm fibers has no influence on the chemical composition of the matrix.

5. Conclusion

The study of the DPF addition to Portland cement effects on their physicochemical properties and their comparison with those of the pure matrix was the main objective of this work. The characterization shows that:

- The FTIR and XRD results confirmed that the presence of date palm fibers in Portland cement was only physical, indicating that DPFs were successfully integrated into the microstructure of the matrix and that the materials prepared were chemically stable.
- The DSC and TGA results showed that for an application in building coatings, the thermal properties remain acceptable.
- The addition of date palm fibers in Portland cement can be used as a low-cost insulating material (thermal efficiency) in wallcoverings.

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