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Thermal and mechanical performance of natural mortar reinforced with date palm fibers for use as insulating materials in building

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ABSTRACT

This paper presents an investigation on the use of a new material, composed with natural cement, sand and date palm fibers (DPF). The main goal is to evaluate the possibility of using this new material as insulating building materials. Several composites were prepared for different weight concentrations (from 0% to 30%) and for three sizes of fibers. Water absorption, thermal conductivity and compressive strength were experimentally investigated. The results reveal that the incorporation of DPF reduces the thermal conductivity and the compressive strength of the composite while reducing the weight. For a DPF loading lower than 15%, the composite satisfies both thermal and mechanical requirements of construction materials, and they could be used for wall structures. Thus, utilization of DPF as filler in mortar seems to be a very promising option which allows to be applied as thermal insulation materials in buildings.

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1. Introduction

Composite materials are widely used today in numerous applications in many engineering fields. One of the most attractive features of composites is the wide scope for physical property applications through constitutional design [1].

The building sector is a large consumer of resources (materials and energy), highly polluting (emission of CO_2), and a generator of residues. Therefore, in the search of a sustainable building construction, attentions turn to research the adequate use of industrial and agro-industrial material [2].

Thus, the new approaches to energy-efficient design are the development and use of natural and local building materials. Several investigations were carried out with natural materials and have shown that they are comparable with standard building materials [3]. Indeed Agoudjil et al. have shown that the date palm wood is a good candidate for the development of efficient insulating green materials when compared to the other materials [4].

In that way, good natural materials insulation becomes the key tool in designing and construction energy thrifty buildings using green materials. In this context, several kind of vegetable materials (hemp, straw, flax, bamboo, animal hairs, cork, *etc.*) have been used as fillers by blending with other compounds (cement, clay, sand, gypsum, mortar, concrete, *etc.*) to make composite materials [5–10].

Many factors affect the properties of composite materials reinforced by natural fibers, include the geometry, the properties of the different phases (matrix, fibers), the distribution and orientation of fibers within the medium, the contact between the fibers and matrix [11], the shape, size of the fibers, mix design, mixing and processing methods, *etc.* Many studies on the composites used only a few significant parameters (fiber content, length fiber, type fiber) for the performance predictions of composites [12].

Hernandez-Olivares et al. have examined the feasibility of using composites based on cork–gypsum [13]. The results indicated that these composites (cork–gypsum) have potential to be used as a partition wall owing to their thermal insulation properties and sound reflecting and absorption ability. More recently, Panesar and Shindman indicated as a general consensus, that incorporation of cork fibers in concrete improves its thermal resistance but reduces the mechanical properties [14].

Bouguerra et al. included wood chippings (3–8 mm) in cement-clay matrix and have studied the water sorptivity effect, they concluded that the macroporous wood aggregates reduced the capillary absorption inside the material [15]. This composite material

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Fig. 1. Date palm wood in different sizes: DPF_3, DPF_6.

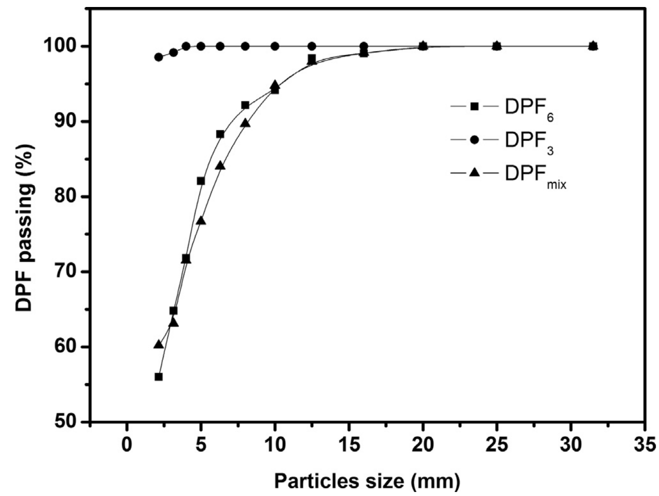

Fig. 2. Size distribution of various DPF.

also displays low thermal conductivity. Pinto et al. studied the use of corn's cob as sustainable building material for thermal insulation [16]. They revealed that the corn's cob may have adequate thermal properties for building purpose. Further, in the study of Jiří Zach et al., the thermal and acoustic insulation from sheep wool has been tested under various conditions [17]. Theirs results show that the sheep wool is an excellent acoustic and thermal insulating.

Date palm is usually cultivated either for fruit production, medical uses or many other purposes (religious, feed, brooms and wood) [18]. The wood of date palm is also an agro wastes and was widely used as reinforcement material in recycle thermoplastic composites [19,20].

Other natural fibers have also been studied (hemp [9], rice husks [21] or other vegetal fibers [10]); where the mortars containing these loadings display a good durability and are already used for insulating or coating applications.

This work is dedicated on the one hand to the investigation of the thermal and mechanical properties of mortars reinforced with date palm fibers (DPF) based on natural resources materials. On the other hand, the possibility of using this material as thermal insulating component in buildings is explored. Thereby, this work focuses on the experimental study of thermal conductivity and mechanical properties of mortar reinforced with natural DPF.

2. Experimental

2.1. Materials

The composites used are formed with sand, cement and date palm fibers (DPF). The cement used is natural cement (PROMT-VICAT) from AinTouta-Algeria. The used sand is from AinTouta-Algeria, with maximum size of 5 mm. Date palm fibers are used as inclusions. It was obtained from oasis of Biskra, Algeria, where the petiole and the rachis are dried under natural conditions. The various thermophysical characteristics of DPF are already presented in the previous work [4].

Two different fibers sizes are listed below and presented in Fig. 1:

The granulometric analysis of DPF is performed for three samples (DPF_3, DPF_6 and DPF_{mix}) to determine the different diameters and lengths of fibers. The granulometric analysis, established according to the French standard NF P18-304, is presented in Fig. 2.

The curve shows (i) fine fibers size distribution, with a mean diameter of 3 mm, noted (DPF_3), (ii) wide fibers size distribution with a mean diameter of 6 mm, noted (DPF_6), (iii) and mixture of two types of fibers (50% of fine fibers + 50% of large fibers), noted (DPF_{mix}).

Table 1
Weight concentrations of the materials used.

Cement (%)	Sand (%)	DPF (%)
69	26	5
66	24	10
62	23	15
58	22	20
55	20	25
51	19	30

2.2. Composites preparation

The composites are obtained by mixing natural cement prompt (VICAT), sand and water for several weight concentrations of DPF (5, 10, 15, 20, 25 and 30%). The composites are performed by mixing the fibers, cement and sand in a mixer (40 turn/min) during 5 min. Dry mixing is necessary to homogenize the mixture, so water is then added gradually. Then, the mixture is versed into cubic molds (15 cm × 15 cm × 15 cm). Drying of the samples was performed in the open air for 48 h in the molds and 28 days after demoulding. The proportions of the materials used in mixtures are presented in Table 1:

Three types of composites were obtained:

MDP_3: Sand + cement + DPF_3
MDP_6: Sand + cement + DPF_6
MDP_{mix}: Sand + cement + DPF_{mix}

2.3. Measurements methods

2.3.1. Water absorption of date palm fibers

For study the process of absorption, the two samples presented in Fig. 1 (DPF_3, DPF_6) are previously dried using an (moisture analyser balance) OHAUS MB200 at $T = 70\,^{\circ}C$ to reach constant weight. Then, the water is absorbed by the capillary effect.

The percentage of water absorption in the materials was calculated by weight difference between the samples after immersion in water and the dry samples using the following equation [22]:

$$\text{Absorption}\,(\%) = \frac{m(t) - m_s}{m_s} \qquad (1)$$

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