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Effects of moisture on thermal conductivity of the lightened construction material

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ABSTRACT

The major objective of this study is the determination of the physical and mechanical properties of building materials lightened by vegetable fibers, used as heat insulator. An experimental work was set up in order to include/understand and to evaluate the thermo-physical and mechanical characteristics of these materials according to the water content. The experimental results show a significant decrease in the material density and in the thermal parameters with the increase in the percentage of vegetable fibers in the concrete. The results also show the effect of humidity on the thermal conductivity. The composite material studied offers interesting thermal insulation, and consequently an optimal gain of energy in comparison to common construction materials.

Introduction

To improve the thermal comfort in a building and save energy, it is important to use high-performance materials with good thermal insulation. Mixing an isolation material with a construction material is one of the most known procedures to improve thermal insulation properties. This technique is traditionally used in Algeria since times immemorial, and the best example to give in this context is that of the bricks made from a mixture of clay and vegetable fibers (straws ...). Many researchers have been interested in the study of vegetable fiber-based construction materials. Bouguerra et al. [1] carried out an experimental and theoretical study to evaluate the thermo-physical properties of a construction material based on wood and concrete, using the transient plane source technical measure and developing a new model to predict the thermal diffusivity of composite materials. Their results show a good correlation between the experimental measures and the theoretical approach and the authors concluded that wooden composite materials provide heat storage ability with good thermal insulation. Khedari et al. [2] studied the inclusion of coconut fibers in stabilized earth, without taking into account the humidity effect. They concluded that the use of coconut fibers can reduce the thermal conductivity and give a light weight material but at the expense of its compression Strength. Kriker et al. [3] studied the mechanical and hygroscopic properties of a date palm fiber concrete without taking into account the effect of thermal transfer. The Results show low performance in terms of durability of fibers after their immersion in alkaline solutions. Harrouna et al. [4] determined the thermo-physical and water-related characteristics of laterite based bricks with millet waste additive using an asymmetrical hot plate device and a new model based on a

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physical approach consisting of distributing air and water inside the solid matrix. This new model provides more precision in comparison to the classical models which measure the thermal conductivity variation according to water and fiber content. The effect of adding millet on the mechanical resistance of the material is not taken into account. Abou-Bakr Cherki et al. [5] carried out an experimental study about the thermal properties of a cork-gypsum composite, by using the asymmetrical Hot Plate method. They demonstrated that the composite material is three times more insulating and twice lighter than cork-free gypsum. All the preceding studies show the beneficial effect of adding plant fibers on the thermal properties of the studied materials.

On the other hand, using the boxes method, many studies on porous materials is published, Meukam et al. [6] carried out a study on the effect of additives on the thermo-physical properties of cheap construction materials (such as stabilized earth). The authors found that the thermo-physical properties depend on the water content of the samples. Also using the box method, P.S.Ngohe et al. [7] determined experimentally the thermal conductivity in the steady regime and the thermal diffusivity in the transient regime through the flash method for tropical wood with different densities, where the specific heat values and the thermal effusivity are calculated. The results show that the thermal conductivity and thermal effusivity increase and the thermal diffusivity decreases with the increase in the humidity rate. Taoukil et al. [8] demonstrate the effect of humidity on the thermal conductivity and the thermal diffusivity of a wood–concrete composite using the boxes method and the flash method respectively. The results reveal that the thermal conductivity considerably increases with the water content rate, and the thermal diffusivity values depend on the calculation model used.

Materials

Basic materials

After a thorough investigation of the different local materials existing in Algeria, taking into account cost and its availability, we selected vegetable fibers, should make it possible to design new and competitively priced materials that can be used as structural insulators. The vegetable fibers used are the olive pomace (Fig. 1) obtained from oil extraction by the "super – presses" in the region of Oum Etob (Skikda, East of Algeria). The granulometric analysis by sieving, established by a method identical to that proposed by the French standard NF P18-560 [9] demonstrates that the used olive pomaces have a particle size between 4 mm and 12 mm. The olive pomace is incorporated, without any preliminary treatment, into a cement mixture. According to standards NFP 15-301 [10] the Portland cement (CPJ45) is used, produced at an industrial plant in Hamma Bouziane (Constantine, East of Algeria). Table 1 gives chemical and physical properties of the cement.

Two aggregates with maximum size 10 mm and minimum size 5 mm are used:

Fig. 1 – Olive pomace.

- Aggregate 1: A crushed slice-lime stone with bulk density 1600 kg/m3,
- Aggregate 2: Natural, with bulk density 1610 kg/m3.

The sand used is quarries one corrected by incorporating a fine sea sand, the test of sand equivalent made according to the standard NF EN 933-8 [12] gives the value 85% quarries sand and 15% sea sand. Its granulometry is 0/5 and a bulk density on the order of 1600 kg/m^3.

Preparation of specimens

Specimens of concrete with two dimensions are made according to the type of tests to be realized. As regards the thermal aspects, the molds of dimension $(27 \times 27 \times 6)$ cm^3 are used. For mechanical strength, the cylindrical molds (16×32) cm3 are used see Fig. 2. These different sizes are related to measuring devices (thermal box, mechanical press) whose dimensions are imposed. The specimens are preserved before and after demoulding into the room test at a controlled temperature and humidity (Ta = 20 ± 2C, RH = 65 ± 5%). These conditions correspond to a standard climate and allow reproducing real conditions of the use of the material [3].

Implementation of fresh concrete

For the mix design of concrete without fibers, the experimental method recommended by Baron–Lesage [11] and Gorisse [12] is used to obtain the optimum sand/aggregate ratio [13,14]. For a given minimal W/C (water over cement) rate, these methods aim to optimize the S/G (sand over gravel) rate to obtain a better workability.

- The density of the fresh (before curing) concrete is 2350 kg/m^3
- Good workability is obtained for a concrete with an S/G rate between 0.58 and 0.89.

To improve the thermal properties of the material, fibers (olive pomace) are incorporated to the concrete with rates varying from 0% to 3%.

For all mixes of fiber concretes, masses of cement and sand are kept equal to that of concrete without fibers. The volume