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Hygro-thermal behavior of raw earth concrete

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ABSTRACT: Raw earth materials represent an alternative to the traditional building materials since a lot of time. It is a material available in large quantities, ecological, economic and environmental. This material can be compacted or stabilized by small quantities of binders to improve its mechanical behavior. For its hygro-thermal behavior, several studies have shown that the raw earth is characterized by a very interesting and encouraging temperature-humidity regulating power for comfort and well-being. In this study, we are interested in the hygro-thermal characterization of raw earth concrete. Different complementary techniques were used on the one hand for the thermal properties and on the other hand for the water vapor permeability. For the measurement of thermal conductivity, the device KD2 Pro was used to determine. For the measurement of water vapor permeability, the cup method was used (Ferroukhi, 2016; Hibouche, 2013). The results were analyzed and compared with those of traditional building materials which highlighted the interesting hygrothermal behavior of the studied raw earth concrete.

Keywords: Raw earth, thermal conductivity, water vapor permeability

I. INTRODUCTION

Raw earth materials are able to contribute to moisture and heat control in constructions, and this is due to its capacity to absorb the water vapor. This allows it to stock up water vapor until reaching a hygroscopic equilibrium between the material and the air. In addition, its thermophysical properties allows it to contribute significantly to the thermal comfort in the building. In this study, we will evaluate the hygrothermal behavior of raw earth materials called "Cématerre", a new concrete based on raw earth material. This earthen material is stabilized with flax fibers, 3% of lime and 8% of cement which ameliorate the mechanical behavior.

II. Hygrothermal characterization of raw earth concrete

A. Raw earth concrete

The studied material is an earthen concrete called "Cématerre", composed of 78% of natural silt, and stabilized with hydraulic binders and flax fibers. Its formulation is given by the following table (TABLE 1). It is a basic formulation initially prepared by the company "Cématerre" in accordance with a precise specification for building materials designed for structural elements in buildings. The earth concrete samples were cast directly into cylindrical and parallelepipedal molds and were kept to be cured for 90 days under normal laboratory conditions ($T=20^{\circ}\text{C}\pm 3^{\circ}\text{C}$ and $\text{RH}\approx 50\%$) before testing.

TABLE 1: Percentage of different components of raw earth material

Limon GO (%)	Chaux (%)	Ciment (%)	Fibres de lin (%)	Eau (%)	Plastifiant réducteur d'eau (%)
78	3	7	0,4	11	0,3

B. Thermal and hygric methods

1. Thermal method

The measurements were carried out, using the device "KD2 Pro", on an initially unsaturated "Cematerre" earth concrete sample, parallelepipedal in shape ($270\times 270\times 60$) mm³. In fact, the method used to measure thermal conductivity is the heat dissipation method. The measuring device KD2 Pro, is accompanied by a SH-1 sensor which is both a source of heat and a sensor for monitoring the evolution of the temperature during the test. Using the data of the test, the KD2 Pro calculate the thermal conductivity and heat capacity of "Cematerre".

The sample is immersed in a container filled with water and left immersed until its complete saturation, controlled by weighing. After saturation, the sample was exposed to the air on a scale. This scale measures the water loss during drying as a function of time. The different thermal properties (thermal conductivity and the volumetric heat capacity) were measured as a function of the water content of the sample (FIGURE 1).

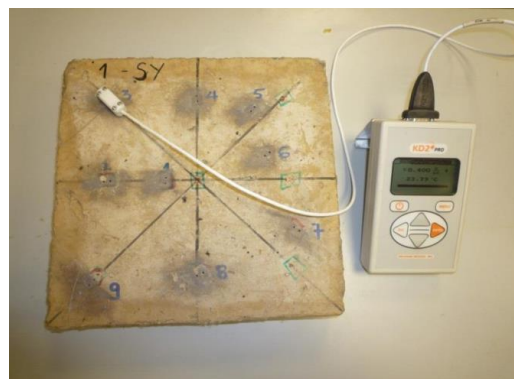


FIGURE 1. Measurement of the thermal conductivity of raw earth material "Cematerre" using the apparatus KD2 Pro

2. Hygric method

It is a gravimetric method called "cup method" (FIGURE 2) (Hibouche, 2013; Galbraith et al. 1998; Bennai et al., 2016). This method consists in placing a cylindrical sample of "C  materre" (Thickness $e = 15 \text{ mm}$ and diameter $\phi = 100 \text{ mm}$) under a constant and unidirectional vapor gradient in isothermal conditions. Knowing the flow of vapor through the material, determined by weighing, we can calculate the water vapor permeability δ_v [kg/ (m. s. Pa)] using Fick's law:

$$\delta_v = e \frac{j_v}{\Delta p_v}$$

e : sample 's thickness [m]; j_v : vapor flux density [kg/ (m². s)]; p_v : vapor pressure [Pa].

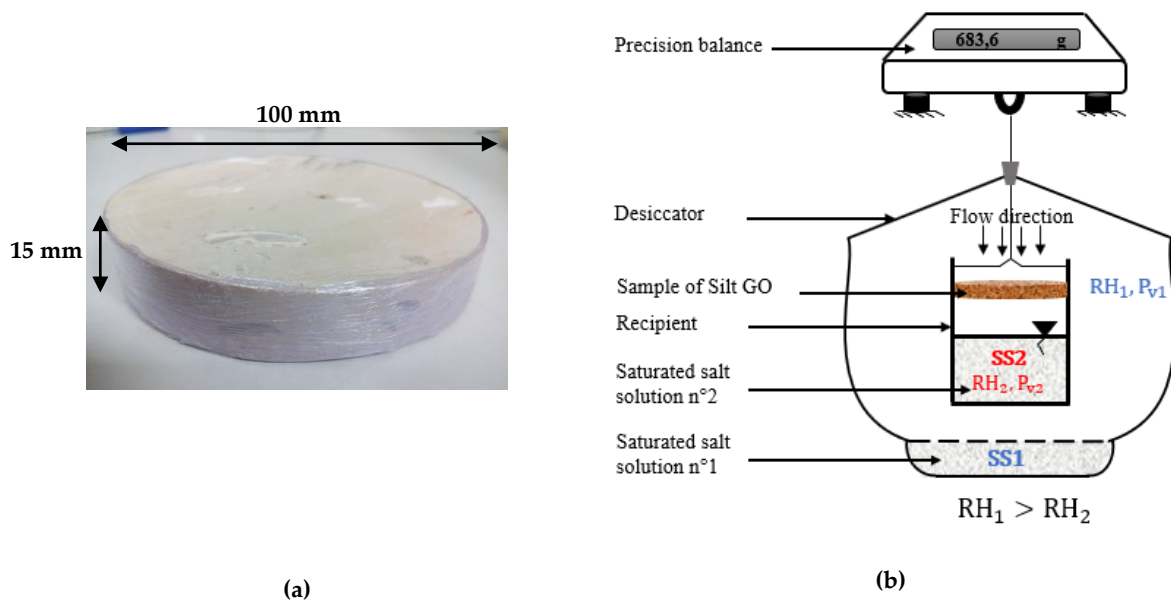


FIGURE 2. (a) and (b) are the cylindrical sample of raw earth concrete and the cup method respectively [Hibouche, 2013]

3. Results

The results have shown that the vapor permeability of raw earth concrete is about $7,64 \times 10^{-12} \text{ kg/ (m. s. Pa)}$. FIGURE 3 and FIGURE 4 show the evolution of the thermal conductivity and the heat capacity respectively as a function of time. Both of them, increase as the water content of the sample increase.

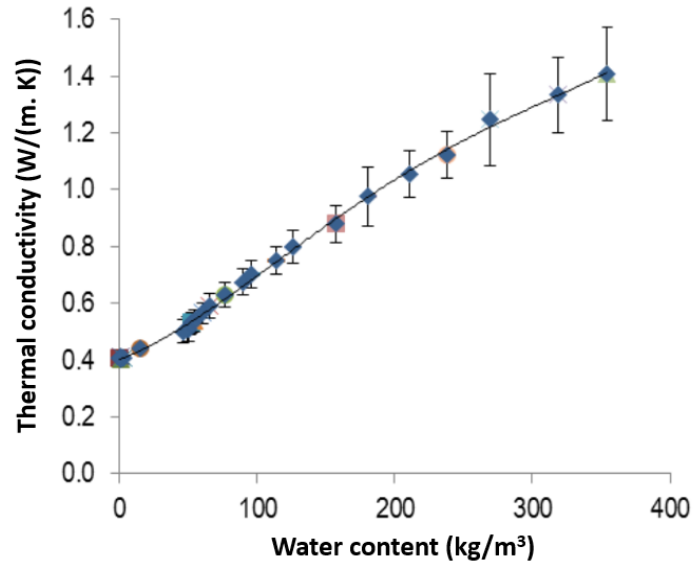


FIGURE 3. Thermal conductivity of raw earth concrete as a function of water content

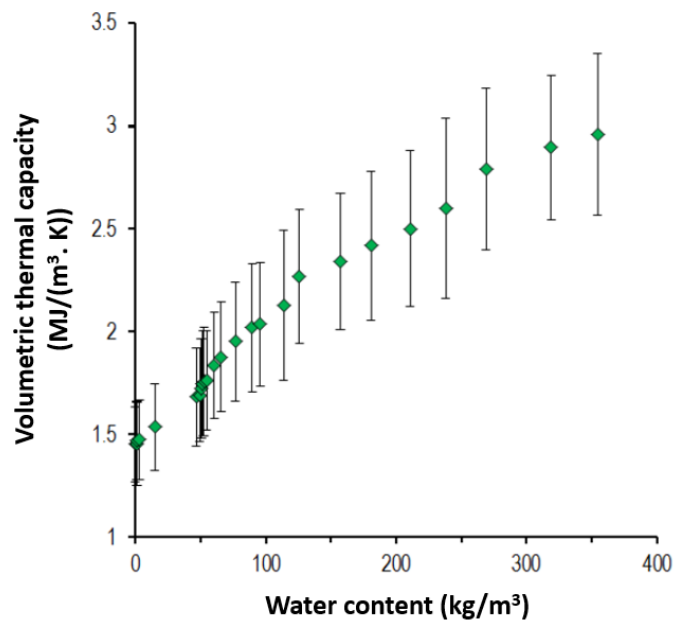


FIGURE 4. Evolution of heat capacity of raw earth concrete as a function of water content

4. Conclusion

The results highlight the remarkable hygrothermal properties of stabilized raw earth material “Cematerre”. The water vapor permeability of this material is $7,64 \times 10^{-12}$ kg/ (m. s. Pa). If we compare it to the water vapor permeability of traditional construction materials such as cement concrete, we find that Cematerre is 10 times more breathable to water vapor. Besides, the thermal conductivity of Cematerre, varies from 0.558 to 1.32 W/ (m. K) as a function of water content from 0 to 350 kg/m³ (saturation). If we compare it to the thermal conductivity of traditional

construction materials, we find that it is three times more insulating to heat (Hibouche, 2013; Zhang et al., 2015). We can conclude, that Cematerre is a good choice to guarantee an hygrothermal comfort inside the buildings.

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