Characterization of cork lightweight material used in building thermal insulation

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Abstract: An experimental study was carried out in order to determine the thermal properties of new materials used in building insulation .We are particularly interested in cork lightweight concrete. In this work, the thermal conductivity of the tested samples is determined in terms of moisture, density and fibers dosage. The thermal conductivity is measured in the similar conditions as those of utilisation. The thermal resistance is obtained by calculation. The obtained results allow us to specify the optimal use conditions of the tested materials.

Key words: Thermal properties, thermal conductivity, thermal resistance, insulation material, cork, boxes method.

Introduction

For the buildings thermal design, two criteria are necessary; the first one is the user's comfort and second one is the energy efficiency. To achieve these objectives, we lead to reflect in particular on the materials choice used for building shielding, which has to prevent heat loss to the outside. This explains the recent development of new building materials, among these materials the lightweight concretes. They can play a role as an insulator, while maintaining adequate levels of performance. The thermal conductivity and the resistance are the most important thermophysical features for the thermal insulation material choice.

This work is a contribution to the experimental study of cork lightweight concrete thermal behaviour. This material is intended to be used for roof insulation and other building components (Kabbazi & al., 2003). Regarding the experimental measurements, in steady regime for the thermal conductivity, we have used the Boxes method.

Studied Materials

We have chosen to make mixtures with an identical matrix and different dosages of cork aggregates, by replacing a portion volume of cement paste with cork aggregates. Then we stopped when the volume occupied by the cork became so important that it became difficult for the mixer to mix everything. The amount of cork aggregates inserted is a mass fraction of the cement mass. The fiber dosages (L/B) studied are: 0, 2, 4, and 6 %. The used matrix consists of Portland cement (CPJ45, CMII), sand (0/4), and water. Table 1 lists the various mixtures studied.

Table 1: Studied compositions.

Cement (Kg) 450	450			
Sand (0/4) (Kg)	1350			
Water (l)	225			
E/C	0.5			
Cork mass (Kg)	0	9	18	27
Designation	B	BL2	BL4	BL6

Thermal Conductivity Measurements

Several methods are used for measuring the materials thermal conductivity: the guarded hot box method (Fournol, 1955), the guarded hot plate method (Tye, 1969), boxes method (Azizi, & al., 1989 ; Boukhattem & al., 2007; Chaker & Hamida, 2010), the method of radial flow (Crausse, 1983), among them we chose the boxes method, this last method was developed in the Thermal and Solar Studies Laboratory, Claude Bernard University in France ((Azizi, & al., 1989). It's of substantial precision, because the relative error of the measurement is evaluated to 5 %. This method made the object of several publications (Boukhattem, Kourchi & Bendou, 2007). It uses parallelepiped samples with sizes of (27 cm×27 cm) and thickness varies from 2 to 7 cm. The thermal conductivity measurements are based upon steady the heat conduction. The sample is set between two atmospheres (see Figure1).

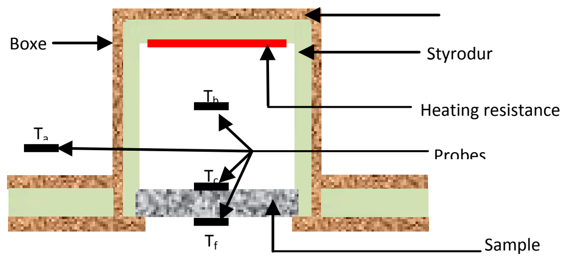

Figure 1: Box measurements

Their temperature corresponds to real cases. As surroundings are at the same temperature as upper boxes, the power q supplied by the electrical resistance goes through the sample and the thermal conductivity is given by the following formula (Menguy & al., 1986):

$$\lambda = \frac{e}{S\Delta T}(q + C\Delta T') \qquad (1)$$

with:

λ: is the thermal conductivity in w m^{-1} K^{-1}, e: is the sample thickness in m, S: is the sample area in m^2, C: is the depredation thermal coefficient in W K^{-1}, q: is the unidirectional heat flow in W m^{-2}, ΔT: is the temperature variation between cold and heated sample faces in °C and ΔT': is the temperature variation between external and internal environments in °C.

The thermal resistance value R_{th} in m^2 K W^{-1} is expressed as:

$$R_{th} = \frac{e}{\lambda} \qquad (2)$$

Results and Discussion

The apparent thermal conductivity measurements of the studied materials were carried out in the dry state, in the saturated state, and in the different moisture degrees. The levels of successive moisture contents were obtained by first saturating the samples tested, then the desaturated by drying in a ventilated oven. We noted that this technique allows to obtain a distribution as uniform as possible from the water within samples (Horton & al., 1982)

Moisture Influence

The obtained results of measuring the thermal conductivity as function of the water content are summarized in Figure 2.

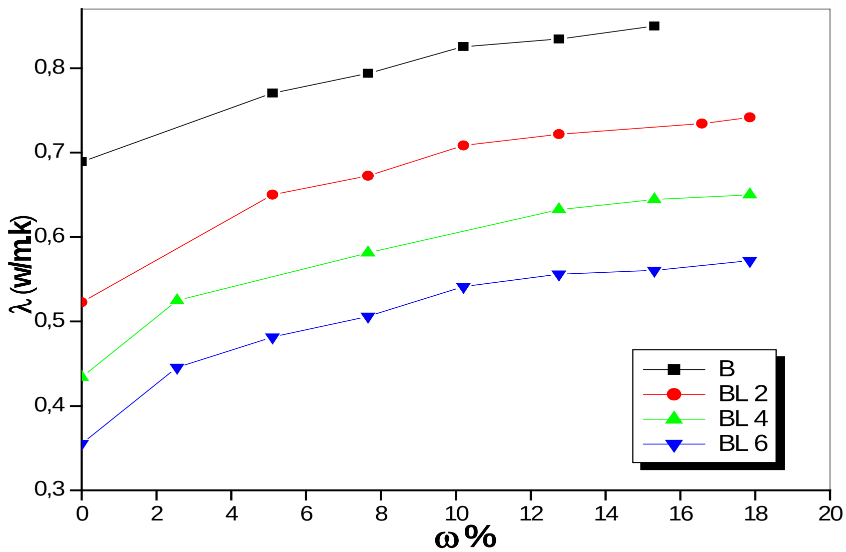

Figure 2: Thermal conductivity in terms of water content of cork lightweight concrete

As can be seen in Fig. 2, the thermal conductivity is an increasing function of the water content. This is explained by the fact that the materials under study are porous, the thermal conductivity depends only on that of the solid matrix and that of air about 0.26 W m^{-1} K^{-1} at 20 ° C, the latter is much lower than that of the water (about 0.60 W m^{-1} K^{-1} at 20 ° C), which partially replaces the air in the pores during the wetting, and thermal conductivity will depend on that of the water. Thus a water high concentration increases the thermal conductivity. This result has been observed on the other materials such as mortar based cement (Chaker & Hamida, 2010), brick hollow of earth stabilized with cement (Meukam & al., 2003) and cellular concrete (Laurent & Guerre-Chaley, 1995).

The evolution of the thermal resistance versus the water content is represented in Figure 3.

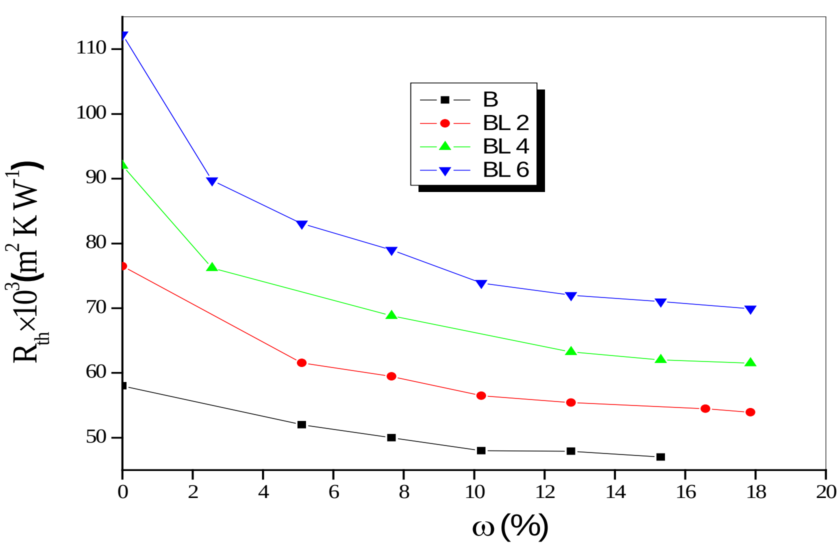

Figure 3: Thermal resistance in terms of water content of cork lightweight concrete

This figure shows a sharp decrease of thermal resistance with the water content, though the thermal conductivity increases slightly (see the Fig. 2). We can see that the thermal conductivity increasing and the thermal resistance decreasing are equal. Comparing the materials taking into account their thermal resistance, we announce that the cork lightweight concrete with L/B = 6 % in the dry state is more resistant to heat flow.

Density Effect

All the results from any action relating to the thermal conductivity evolution as function of the materials mass density are presented in Table 2 and plotted in Figure 4.

Table 2: The thermal conductivity of the studied samples in dry and saturated state.

Designation		B	BL2	BL4	BL6
ρ(Kg .m^{-3})		2168	2015	1862	1735
λ (W m^{-1} .K^{-1})	Dry state	0.689	0.523	0.434	0.355
	Saturated state	0.850	0.741	0.650	0.572

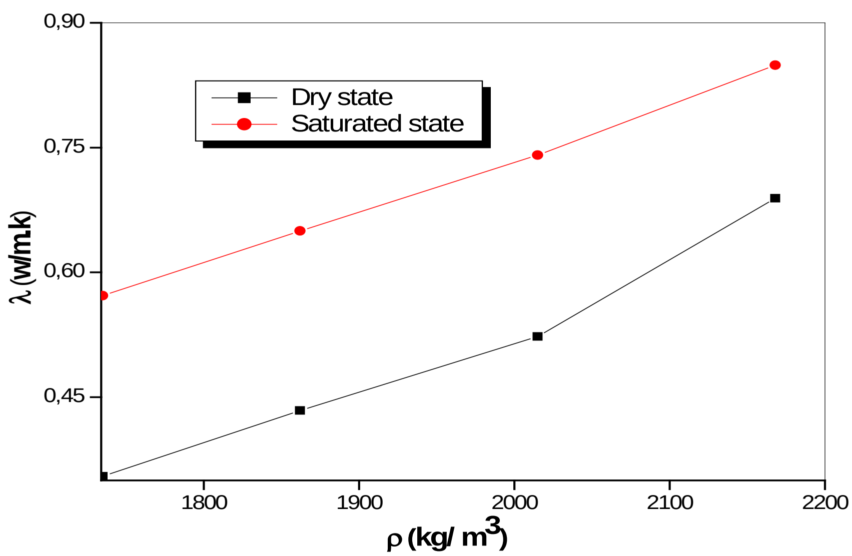

Figure 4: Thermal conductivity in terms of density in dry and saturated state

These results show that the concretes studied thermal conductivity increase linearly with the mass density. Indeed, the increasing densification of the material clogs the pores and removes the air inside, which its thermal conductivity is lower than that of the solid matrix.

The thermal resistance variation of cork lightweight concrete samples versus the density is represented in Figure 5. If we take a wall of about 4 cm thickness, the thermal resistance decreases from $112 \times 10^{-3}\ m^2\ K/\ W$ at the dry state to $70 \times 10^{-3}\ m^2\ K/\ W$ at the saturated state, this leads to say that the more the wall is dense, the more it is heat-resistant.

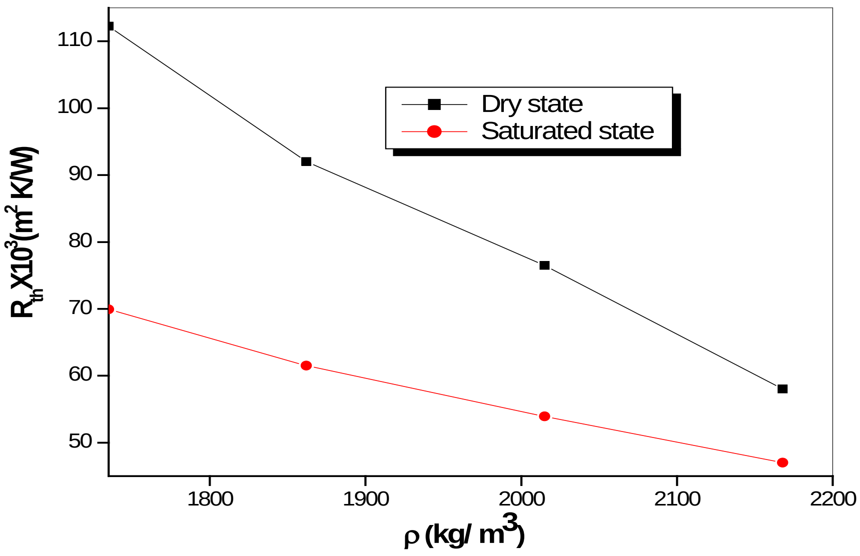

Figure 5: Thermal resistance terms of density in dry and saturated state

Cork Dosage Effect

The evolutions of the thermal conductivity and thermal resistance of lightweight concrete with the cork aggregates dosage have been shown in Figure.6.

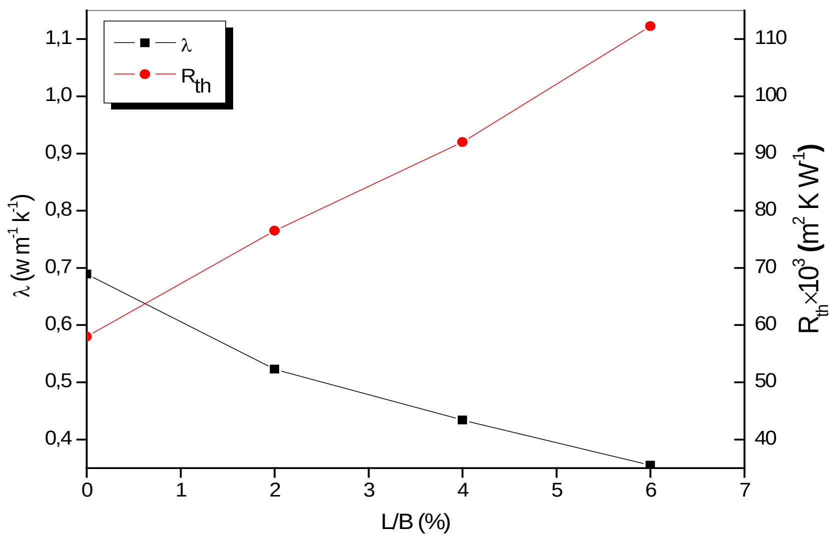

Figure 6: Variation of the thermal conductivity and thermal resistance in terms of cork aggregates dosage L / B.

From this figure, we found that the thermal resistance increases with the dosage increasing, but the thermal conductivity evolutions are in the opposite direction; this is explained by the fact that the cork aggregates thermal conductivity is very small compared to that of cement. So, the dosage increasing of these aggregates in concrete makes it more thermally insulated.

Conclusions

The results of measuring the thermal conductivity and resistance of cork lightweight concrete obtained using the boxes method it's in line (are in good agreement) with those presented by (Elbakkouri, 2004).
We have found that, the moisture influence on the thermal insulation materials is negative, the more the material is wet again its thermal conductivity is high, and thermal resistance is low.

We have also found that, the materials investigated thermal proprieties are strongly influenced by the density. The thermal conductivity increases and the thermal resistance decreases gradually as the material is dense.
The addition of cork granules in the initial material improves the thermal performance.

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