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Thermal Proprieties of Concrete Lightened by Wood Aggregates

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Abstract: It is about an experimental study of the thermal proprieties of a concrete lightened by wood aggregates stemming from waste products of the carpentry work. We were especially interested in the comparison between the proprieties of concretes lightened by sawdust and those lightened by wood shavings. The determination of the thermal conductivity and diffusivity of various samples allowed us to demonstrate that the incorporation of wood aggregates in the concrete increases considerably its thermal insulation capacity. Also, we found that, at equal mass percentage of wood aggregates, the concretes elaborated from shavings present thermal insulation capacities better than those obtained from sawdust. On other hand, we have examined the influence of the water content on the thermophysical properties of the studied concretes. So, we have demonstrated and confirmed that the thermal conductivity and diffusivity of the studied materials are strongly dependent on the water content.

Key words: Lightweight concrete, thermal conductivity, thermal diffusivity, water content, wood waste

INTRODUCTION

The wood is used in the industry, the carpentry work or the heating. In every case, it generates a big quantity of waste. Which materials cannot be dumped directly because of the pollution it would engender. That is why; the use of wood shavings in the manufacturing of lightweight concretes contributes to valorize some by-products of the wood industry.

Several studies have focused on the use of wood as ash in concrete (Campbell, 1990; Fehrs, 1996; Naik and Kraus, 1999). Other researches use wood in form of shavings in a matrix of cement (Mimoune *et al*., 1999) or in a matrix of cement and clay (Bouguerra *et al*., 1999).

In this context, this work has been conducted to study the thermal proprieties of a concrete lightened by wood aggregates stemming from waste products of the carpentry work. For this purpose, after presenting the protocol for samples preparation and the measurement techniques, we present and discuss the main results.

MATERIALS AND METHODS

This study was led between 2006 and 2010, in the Energetic Laboratory of the Faculty of Sciences of Tetuan, Abdelmalek Essaadi University, Morocco.

Used materials: In this study, we used CPJ35 Portland cement and sand (0/5 mm). The wood aggregates used are a sawmill waste. They correspond to the species generally used in the carpentry work in Morocco.

Operating mode: A dry mixing of the constituents is performed before the addition of water. The homogenized mixture is then introduced into moulds of dimensions (27×27×2) cm^3; the specimens are preserved before and after turning out into the room test at a controlled temperature and humidity (T_a = 20ºC, R.H. = 60%).

Formulation: The concrete intended for this study is based on 2/3 of sand and 1/3 of cement. The specimens are made with a mass ratio of water to cement (W/C) of 0.6.

Two categories of the lightened concrete are studied:

- Concrete-Sawdust: concrete lightened by sawdust of aggregate size lower than 0.8 mm. The apparent density of the sawdust is on the order of 174.49 kg/m^3.
- Concrete-Shavings: concrete lightened by wood shavings of aggregate size between 8 mm and 2 cm. The apparent density of the shavings is on the order of 73.82 kg/m^3.

The material was lightened by incorporating wood aggregates with a mass ratios of wood aggregates to (cement+sand) varying from 0 to 10%.

Measurement techniques: For measuring the thermal conductivity we have used the "Boxes method" (Mourtada, 1988). The sample of area *A* and thickness *e*, is placed between a cold isothermal capacity and a heat source at constant flux *q*, it established a heat flux

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Table 1: Bulk density and porosity of the studied samples

	Concrete	Concrete-sawdust				Concrete-shavings			
Reference	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
Wd/Crt[1] (%)	0	2	5	8	10	2	5	8	10
Bulk density (kg/m^3)	2142.66	1882.03	1619.34	1483.54	1427.30	1914.27	1779.15	1547.33	1495.20
Porosity (%)	20.54	25.50	31.70	44.86	56.77	24.22	30.80	43.74	55.01

[1]: The mass percentage of wood aggregates to (cement+sand)

supposed unidirectional, through the test sample. When the permanent regime is established, the thermal conductivity is given by:

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

ΔT : Temperature difference between the hot face and the cold face of the sample.
$\Delta T'$: Temperature difference between the outside ambiance and the internal ambiance of the box carrying the sample.
C : Coefficient of thermal loss from the box (W/ºC).

The thermal diffusivity is directly measured in the transition regime. The Flash method is used (Parker and Jenkins, 1961). Its principle consists in applying a short thermal impulse, from a heat source radiation with constant flux (1000 W), on one face of the sample. The analysis of the thermogram recorded on the non irradiated face of sample can be achieved, using existing counting techniques (Yezou, 1978), the thermal diffusivity *a*.

RESULTS AND DISCUSSION

Density and porosity: Before proceeding to the study of the thermophysical properties of our materials, we considered it necessary to examine its bulk densities and porosities.

The measures of the porosity and the bulk density of the various samples are grouped in the Table 1.

It is clear that the incorporation of wood aggregates in the matrix is translated by a gain of the porosity, accompanied by losses on the density. This result is similar to those obtained by some authors concerning wood concretes (Aouadja *et al*., 1995).

The comparison between the two types of lightened concretes allowed us to notice that the concrete-shavings present less porosity and are consequently denser than the concrete-sawdust. Indeed, wood shavings are more compressible in the mortar compared to sawdust, which allows, reducing the porosity easily.

Thermal conductivity and diffusivity in the dry state: Figure 1 and 2 represent the evolution of the dry thermal conductivity and diffusivity, respectively, with the mass proportion of wood aggregates.

Table 2: Thermal proprieties of the sawdust and wood shavings in the dry state

	Wood sawdust	Wood shavings
λ (W/mºC)	0.098	0.085
a (.10^{-7} m^2/s)	0.78	0.69

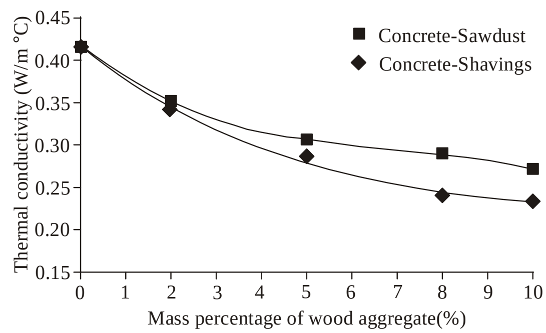

Fig. 1: Dry thermal conductivity variation with the mass proportion of wood aggregates

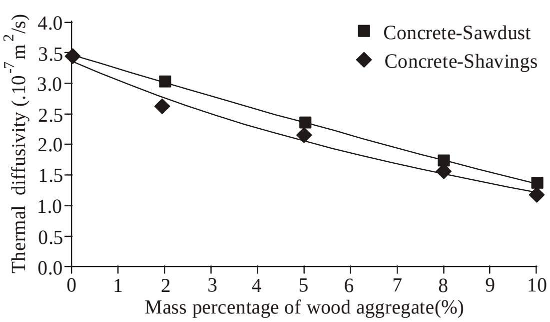

Fig. 2: Dry thermal diffusivity variation with the mass proportion of wood aggregates

Thanks to its low thermal proprieties (Table 2) and its stronger porosity, the incorporation of wood aggregates in concrete decreases its thermal proprieties. For a mass percentage of wood aggregates ranging from 0 to 10%, the reduction in the thermal conductivity increases until 35% for the concrete-sawdust and 44% for the concrete-shavings. The corresponding thermal diffusivities decrease untill 60% for the concrete-sawdust and 66% for the concreate-shavings. Similar results were found by Bederina *et al*. (2007).

Figure 3 and 4 show the evolution in thermal conductivity and diffusivity, respectively, versus the bulk density. It may be noted that, at equal densities, the concretes elaborated from shavings present thermal

Table 3: Mass water content in the saturation state and report of the thermal conductivities $\lambda_{sat} / \lambda_d$ of the studied samples

Reference	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
W_{sat}(%)	9.28	12.46	17.92	25.38	28.93	11.29	16.31	27.30	35.18
λ_{sat}/λ_d	2.76	2.51	2.31	2.01	1.87	2.31	2.20	2.54	2.44

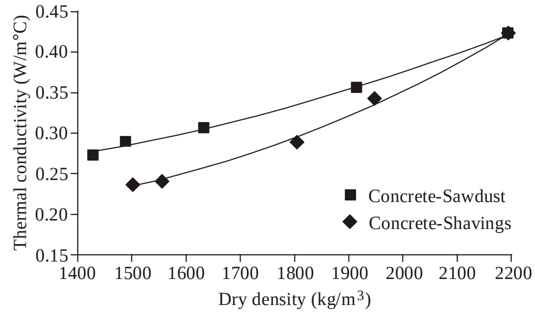

Fig. 3: Dry thermal conductivity variation with the bulk density

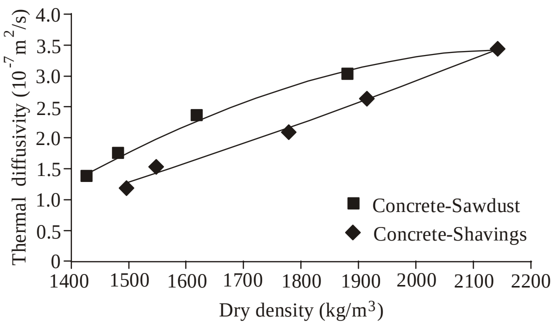

Fig. 4: Dry thermal diffusivity variation with the bulk density

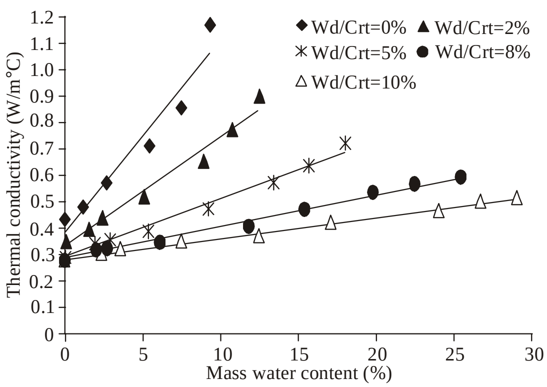

Fig. 5: Thermal conductivity variation with the mass water content: Case of concrete-sawdust.

conductivity and diffusivity less than those obtained from sawdust. This phenomenon can be explained by the fact that shavings are better insulators than sawdust.

Influence of water content on thermal conductivity and diffusivity: The evolution of the thermal conductivity with the mass water content of the various samples is illustrated on the Fig. 5 and 6, respectively for the concrete-sawdust and the concrete-shavings.

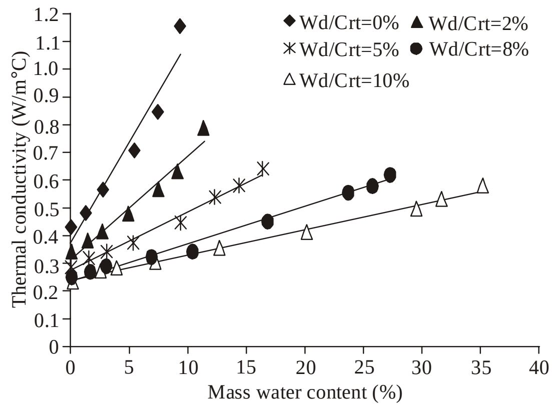

Fig. 6: Thermal conductivity variation with the mass water content: Case of concrete-shavings

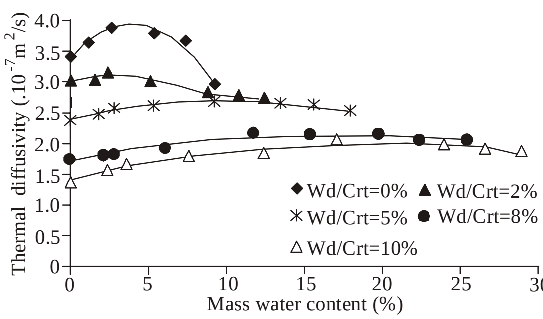

Fig. 7: Thermal diffusivity variation with the mass water content: Case of concrete-sawdust

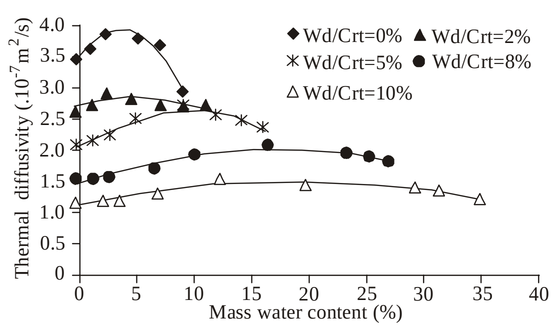

Fig. 8: Thermal diffusivity variation with the mass water content: Case of concrete-shavings

We notice according to these results an important increase of the thermal conductivity with the mass water content; indeed, we replace middle with low conductivity (air) by middle with stronger conductivity (liquid water). Numerous works (Krischer and Kroll, 1978;

El-bouardi, 1991; Laurent and Guerre-chaley, 1995) bring to light this dependence (conductivity/water content) on other building materials.

This hygrothermal behaviour is better visualized on the Table 3 which gives, for every sample, the mass water content in the saturation state W_{sat} and the report thermal conductivity in the saturation state λ_{sat} than in the dry state λ_d.

The curves of the variation of the thermal diffusivity in function of the mass water content for the both types of the lightened materials are shown in Fig. 7 and 8.

The results bring to light a maximum of thermal diffusivity corresponding to a mass water content W_m. We note that this phenomenon has been observed on other materials (Foures *et al*., 1981; Meukam *et al*., 2004). The presence of this maximum is explained by the fact that the volumetric heat capacity (ρc) varies linearly with the water content, while the thermal conductivity presents an unmonotonous variation.

CONCLUSION

The lightening of concrete by wood aggregates engenders a significant increase of the thermal insulation capacity. Otherwise, we saw that the concretes elaborated from shavings present thermal insulation capacities better than those obtained from sawdust.

The hygrothermal study allowed us to demonstrate the important approximation made when only the dry thermal characteristics of the studied lightweight concretes are considered independently of their hydrous states. Indeed, the presence of the water within the studied materials modifies considerably their thermophysical characteristics. The differences observed, especially between the thermal conductivity of a dry material and that of a wet one, imply consequences which can be very significant during the establishment of the thermal balances of buildings. However, the measure of the thermal properties in the wet state presents difficulties related to the preservation of the hydrous state of the material. It is necessary to verify that the water absorbed by the concrete does not disappear during measurement. Copper plates were used to isolate the material of the ambient air and audits by weighing before and after measurement were made.

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