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Impact of ratio of the solid and liquid phase, and the humidity on the apparent thermal conductivity of concretepozzolan

M.Z Bessenouci[1], N.Bibi-Triki[2], S.Khélladi[3]

[1]*Unité de recherché des matériaux et énergies renouvelables (URMER)*
Université Abou-BekrBelkaid, B.P. 119, Tlemcen, Algérie
[1]*Dept des sciences techniques*
CtrunivNaama, B.P 66, Naama, Algérie
mzbessenouci@yahoo.fr

[2]*Dept de physique*
Unité de recherché des matériaux et énergies renouvelables (URMER)
Université Abou-BekrBelkaid, B.P. 119, Tlemcen, Algérie
[3]*Ecole préparatoire des sciences techniques Tlemcen, Algérie (EPSTT)*
Unité de recherché des matériaux et énergies renouvelables (URMER)
Université Abou-BekrBelkaid, B.P. 119, Tlemcen, Algérie

***Abstract*-The use of natural pozzolan as a mixture of aggregates for the formulation of a lightweight concrete which provides mechanical strength, conform to standards.**
Thermal modeling, apparent To That commonly used for porous materials, has-beens Applied to pozzolana concrete.
The impact of humidity and the quotient of the conductivity of the solid phase and the liquid phaseon the apparent thermal conductivity of concrete pozzolan considered as a porous material requires the best description of the phenomena which surrounds the heat transfer of different phases (liquid-solid-and air).
The use of mixed model extended to three phases as a prediction of the thermal conductivity, highlights the importance of the liquid phase

Keywords: Lightweight concrete Pozzolana-concrete – Porous materials – Thermal insulation Modeling – Building-humidity

I. Introduction

The development of models representing the heat transfer in porous materials intended to interpret the apparent thermal conductivity by considering the material formed of a solid phase and one or more phases (liquid phase, gas phase).

The porous material may consist essentially of:

In a solid phase and a liquid phase (water)
In a solid phase and a gas phase (air)
In a solid phase and two phase gas (air) and liquid (water)

On the one hand, we can conceive the concrete as a porous material composed of a solid phase and water or a solid phase and air. In the first combination the water is present in various forms; absorbed by the granules with open porosity, combined in the cement hydrates, absorbed to the surfaces of solid and free components in the capillaries.

II. Definition

Pozzolana is a non-binding aluminosilicate material, and in the presence of moisture, at room temperature, reacts chemically with calcium hydroxide (Ca (OH) 2) to form compounds with binding properties [2]. It is of two kinds: natural pozzolana (sedimentary, volcanic and metamorphic rocks) and artificial pozzolana, found in the form of industrial by-products (blast furnace slag, fly ash, silica fume).

III. Thermal conductivity measurement

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The measurement technique, used by [1], to determine the thermal conductivity is called the "boxes" method [5] (fig.1). It was developed in the Solar and Thermal Studies Laboratory at Claude Bernard University -Lyon 1

The method of "boxes" is a method for measuring thermal conductivity under a steady state condition. It consists in keeping enclosure A at a lower temperature than the boxes, using the heat exchanger R.

The heater creates a temperature gradient across the sample.

Temperature sensors are resistive thermal sensors for measuring surface and atmosphere temperatures

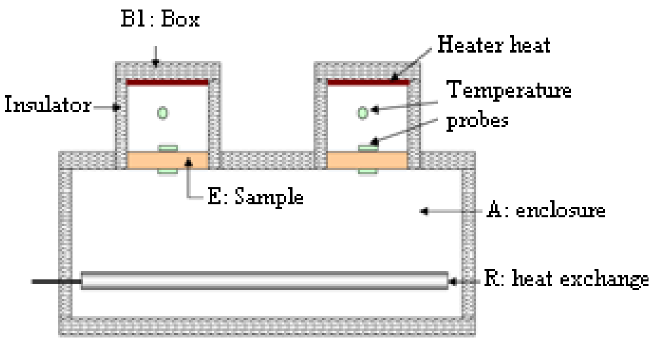

Figure1: The "boxes" apparatus

IV. THEORETICAL APPROACHES TORESULTSOF THERMAL CONDUCTIVITY MEASUREMENTS.

We consider that the material consists of a solid phase and two phases; the gaseous phase (air) and liquid phase (water) so we can determine and interpret the apparent thermal conductivity of pozzolana concrete. Considering that pozzolana concrete is a porous material, we can say that:

- Heat transfer by pure conduction takes place in gases enclosed in pores in the solid structure as well as in the liquid phase.
- The convective movement inside the cells is negligible for the range of pore size <100 microns.
- The fraction of radiation transmitted is zero because the wall temperatures are generally close to room temperature.

V. APPARENT THERMAL CONDUCTIVITY OF CONCRETE ACCORDING TO THE SERIES, PARALLEL AND MIXED MODELS EXTENDED TO THREE-PHASE SOLID-LIQUID-GAS

In this approach, we consider that pozzolana concrete consists of a solid phase (cement paste + aggregate) and a two phases; the gaseous phase (air) and liquid phase (water). So we introduce the concept of the thermal conductivity of a solid matrix λs and that of a fluid phase (air) λf and liquid phase λl. The thermal conductivity of a granular medium depends strongly on the thermal conductivity of the solid phase. In order to estimate its influence on the apparent thermal conductivity, some values of thermal conductivity of the solid phase are introduced in the models.

The binding matrix (hydrated cement paste) and the entire aggregate is assumed to be a juxtaposition of plates in a parallel and series. The mixed model is inspired by models of Krischer and Willy Soutwik [6].

The mixed model extended to three phases Figure 2 (b), is described by the relationship that looks to the globally mixed model two-phase, formula (1).

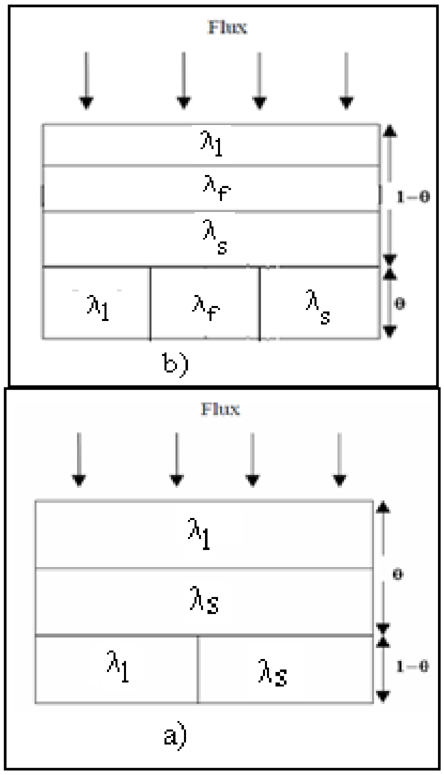

Figure 2: a)The mixed model two-phase; b) The mixed model extended to three phases

$$\lambda_{appthree\ phase} = \frac{\lambda_{series}\lambda_{parallel}}{\theta\lambda_{series} + (1-\theta)\lambda_{parallel}} \qquad (1)$$

Withθ=volume fraction of theportionarranged inparallel

$$\theta = \frac{\lambda_{parallel}(\lambda_m - \lambda_{series})}{\lambda_m(\lambda_{parallel} - \lambda_{series})}$$

λ_{series} *and* $\lambda_{paralel}$, represent respectively the thermal conductivity of layers arranged in series and arranged in the parallel which are determined by relations (1) and (2). [4]

$$\lambda_{serie} = \frac{1}{\frac{\alpha}{\lambda_s} + \frac{(1-S)\varepsilon}{\lambda_f} + \frac{S\varepsilon}{\lambda_l}} \qquad (2)$$

$$\lambda_{parallel} = \alpha\lambda_s + (1-S)\varepsilon\lambda_f + S\varepsilon\lambda_l \qquad (3)$$

Porosity is a very important physical parameter to determine properties at the macroscopic level. It can be calculated from formula (4), [7]:

$$\varepsilon = 1 - \frac{\rho_{app}}{\rho_{ag}} \qquad (4)$$

The results for the model series, parallel and mixed model extended to three phases are represented in figures 3 to 5, for some typical values of conductivity solid introduced, showing the evolution of the apparent thermal conductivity of concrete to saturated state in comparison with the measured values.

The calculated and measured thermal conductivities are located between the limits of simple series and parallel models.

The apparent thermal conductivities measured in the wet state at 28 days, slightly higher than those of dry concrete [3]. Liquid water is an unfavorable element vis-à-vis the insulation. The results of the extended model confirm this hypothesis because the calculated values are also slightly higher.

For cavernous concrete values of conductivity are quite similar. These results are explained by the presence of air voids and inter granular and significant closed porosity rate.

For concretes full evolution model values and measured values are almost parallel lines, those of the model are lower than the measured conductivities. The higher values of wet conductivity, from the dry conductivity, may be due to the absence of air voids between the grains, and between the binding matrix and grains.

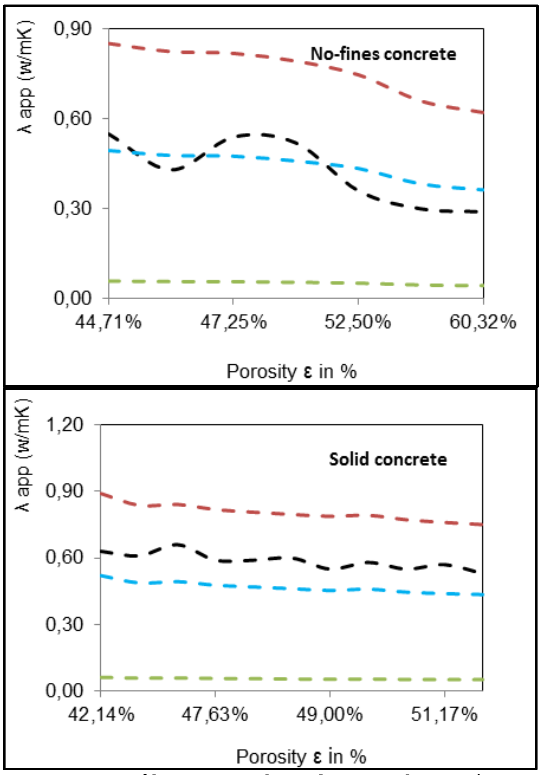

Figure 3: Variationofthe apparent thermal wet conductivityλ_{app}measured and calculated using the three modelsas a function ofconcrete porosity(ε), λmeasured, parallelmodel, seriesmodel, mixedmodel extended to three phases (λs =1,5 W/m.K), with $\frac{\lambda_S}{\lambda_l}$ = 2,5

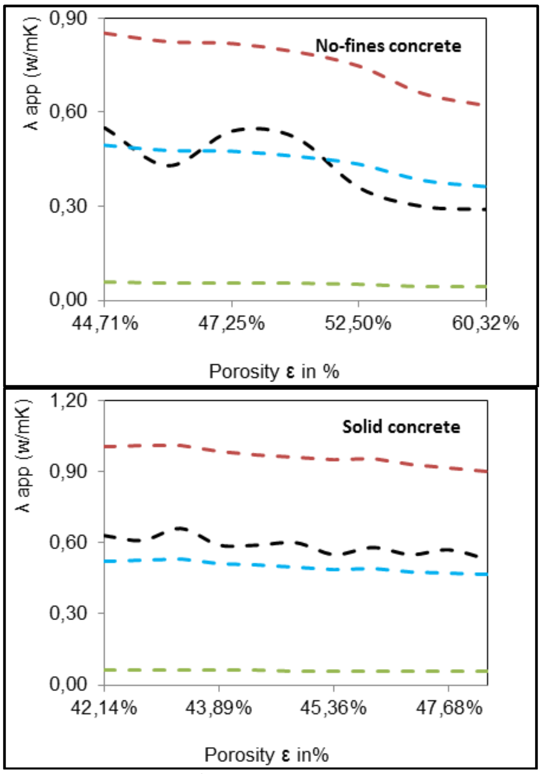

Figure 4: Variationofthe apparent thermal wet conductivityλapp,measured and calculated using the three modelsas a function ofconcrete porosity(ε), λ measured, parallelmodel, seriesmodel, mixedmodel extended to three phases (λs =1,7 W/m.K) with $\frac{\lambda_S}{\lambda_l}$ = 2,83

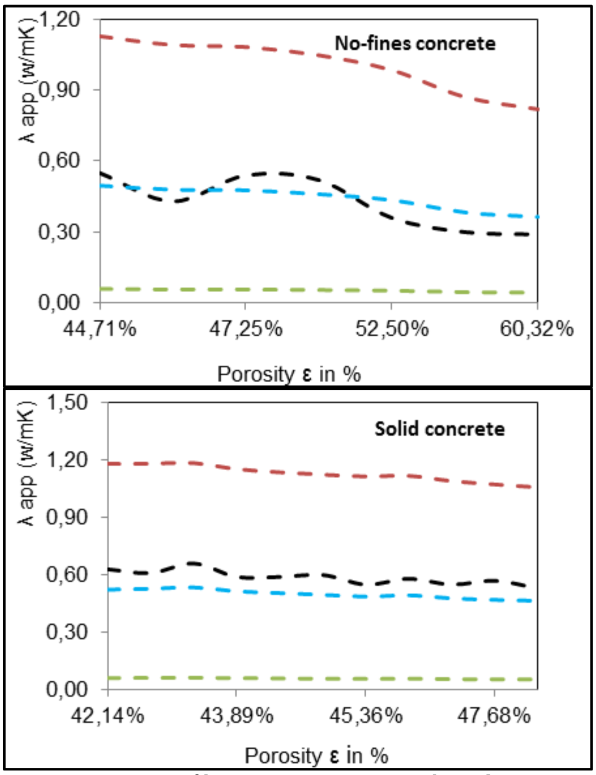

Figure 5:Variationofthe apparent thermal wet conductivityλapp,measured and calculated using the three modelsas a function ofconcrete porosity(ε), – – – λ measured, – – – parallelmodel, – – –seriesmodel, – – –mixedmodel extended to three phases (λs =2 W/m.K) with $\frac{\lambda s}{\lambda l} = 3{,}33$

Figures 6 to 8 represent the evolutions of the apparent thermal conductivity as a function of wet water content.

For no-fines concrete, when the water content increases, the thermal conductivity increases as well. This shows the negative role of the presence of water in insulating environments. Pozzolan concrete is considered a porous material; the type of porosity influences the water content.

For solid concrete, we note first, that the lines obtained are approximately parallel, and secondly, the water content does not have a direct influence on the evolution of the thermal conductivity.

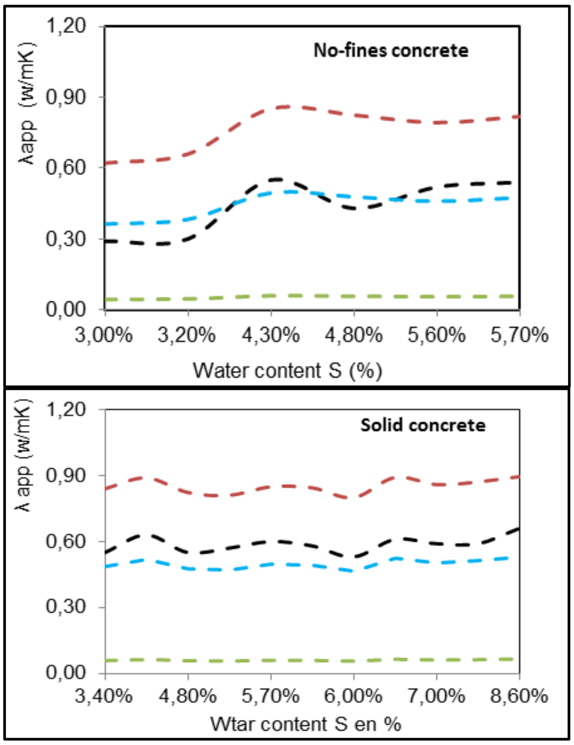

Figure 6: Variationofthe apparent thermal wet conductivityλappmeasured and calculated using the three modelsas a function ofwater content (S), – – – λ measured, – – – parallelmodel, – – –seriesmodel, – – –mixedmodel extended to three phases (λs =1,5 W/m.K)with $\frac{\lambda s}{\lambda l} = 2{,}5$

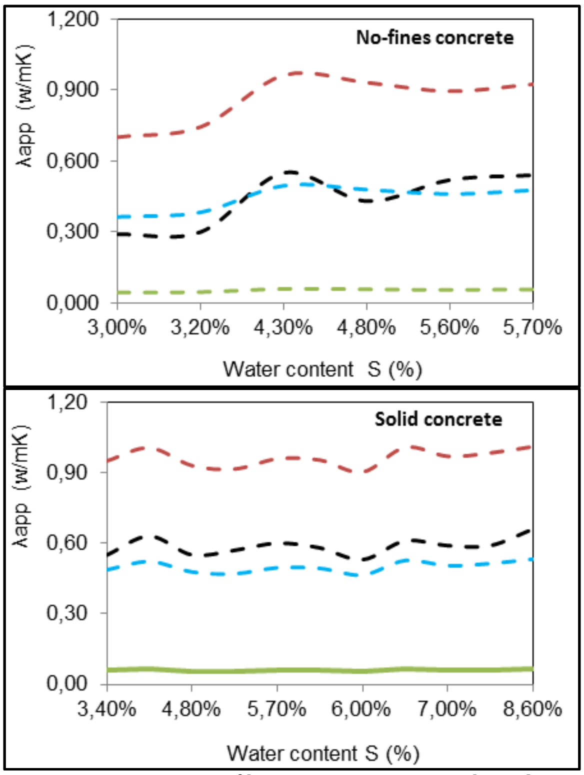

Figure 7 :Variationofthe apparent thermal wet conductivityλappmeasured and calculated using the three modelsas a function ofwater content (S), – – – λ measured, – – – parallelmodel, – – –seriesmodel, – – –mixedmodel extended to three phases (λs =1,7 W/m.K)with $\frac{\lambda s}{\lambda l} = 2{,}83$

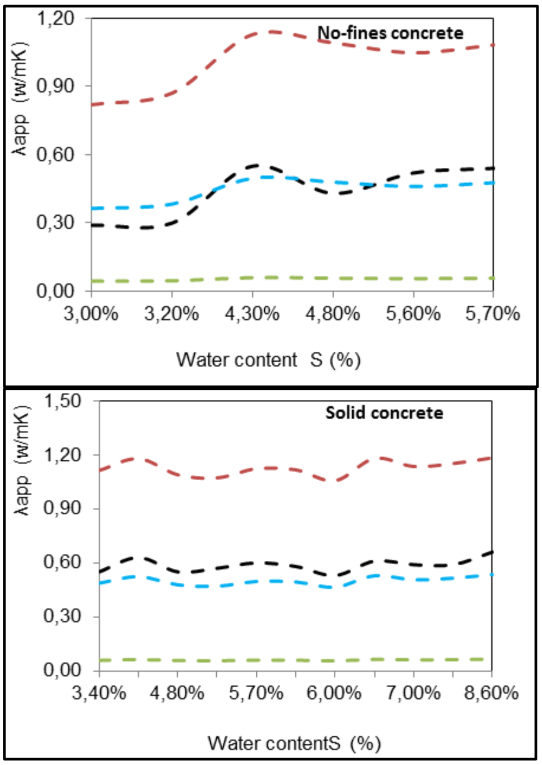

Figure 8: Variationofthe apparent thermal wet conductivityλapp,measured and calculated using the three modelsas a function ofwater content (S), — — — λ measured, — — — parallelmodel, — — —seriesmodel, — — —mixedmodel extended to three phases (λs =2 W/m.K)with $\frac{\lambda s}{\lambda l}=3{,}33$

VI. CONCLUSION

Our main objective was to study, evaluation of the thermal conductivity of humid concrete pozzolan.

We have observed that the pozzolan concrete in the wet state (28d) that the thermal conductivity is higher than that of dry concrete. [3].

The study of the influence of porosity and conductivity of the three phases carried out has shown that the thermal conductivity wasbased on comparisons between experimental results and predictions by analytical calculations using theoretical models.

The gap bounds for serial and parallel models is too important to be a predictive modeling of thermal conduction.

The mixed model extended to three phases, based on the hypothes stating that there is a uniform distribution of air in the material. Moreover, the experimental calibration represented by the part of the disposition of each model (serial and parallel) in the mixed model, ensures that this model depends strongly on the quality of experimental measurements.

We observe the evolution of values of mixed models in this approach, in Figures 4 to 9; the results obtained by comparing theory and experiment lead to good concordance in the case of no-fines concrete.

For solid concrete, the mixed model gives lower values of thermal conductivity compared with experimental results. We note that the no-fines concrete is less conductive than solid concrete.

The humidity has shown its influence on the thermal conductivity of the no-fines concrete as these curves increases when the humidity increases. Whereas, for solid concrete, the curves are approximately parallel with a relatively small change in values.

From the results obtained in this modeling study, we highlight the following points:

- The water content depends on the rate of apparent porosity of concrete.
- If the open porosity is significant enough, it may be necessary to take charge of the thermal approaches.
- We also note that for an interval of values of the ratio $\frac{\lambda_s}{\lambda_l}$ situated between [2.5 to 3.33], the theoretical conductivity is in agreement with measurements.

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