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SIMULATING CONCRETE BEHAVIOUR SUBJECTED TO HIGH SPEED HEATING REACHING ELEVATED TEMPERATURES

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ABSTRACT

The behaviour of concrete when exposed to high temperatures (instability, risk of explosive spalling…) is known to be of great interest in civil engineering. Its porous multiphase structure (where the hydrated solid mixture contains pores filled with water and gas) makes it difficult to predict its real behaviour. That's why, modelling concrete behaviour at high temperatures requires a fully coupled thermo-hydro-mechanical model (THM) that could take into consideration most of the physical phenomena taking place inside the concrete structure.

In the present study, a THM model based on the mechanics of unsaturated porous material [1][5][7] is used. The mathematical formulation of this model consists of a series of balance equations: solid mass, dry air mass, water mass in both liquid and gaseous state, taking into consideration phase changes and cement paste dehydration. In this approach, the THM model is coupled to a damage model developed at CSTB[4]. The thermo-chemical damage is also taken into account. Isotherm adsorption curves, concrete permeability, parameters linked to mass transfer and fluid properties are supposed to depend upon temperature [3].

This model is used to simulate the behaviour of an ordinary concrete block (F_{c28}= 41 MPa) subjected to a high speed heating (600°C in 10 minutes)[6]. The concrete block has a thickness of 12 cm, and a height and a width of 30 cm. It was simulated in the finite element code SYMPHONIE of CSTB, using the THM model recently developed and updated [1].

The analysis of the simulation results allows a deeper understanding of concrete behaviour at high temperatures. Gas pressure profile at 10 mm from the surface exposed to fire reaches its maximum after half an hour, and then it begins to decrease (fig.1). Meanwhile it increases at 30 mm (maximum at 90 min) and 50 mm (maximum at 150 min). This is explained by a migration of the pore gas (water vapour and dry air) from the heated surface to the cooler one. This migration is slowed down by the low permeability of concrete, and the water vapour accumulates for a certain time, which increases the relative humidity (up to 0.73 at 10 mm). Then the latter decreases due to high temperature and the concrete block becomes dryer at the exposed face (fig. 2). At the same time, concrete damage increases with temperature, which causes an increase of

the pore volume and of the concrete permeability. This phenomenon contributes also in reducing the pore pressure at the most damaged parts of the concrete sample. Gas pressure and temperature simulation profiles, compared to experimental ones, show good correlation (fig.1). Further simulations will be done on different types of concretes in order to validate the model. Some refinements were made to take into account the polypropylene fibres effect on the concrete behaviour [2].

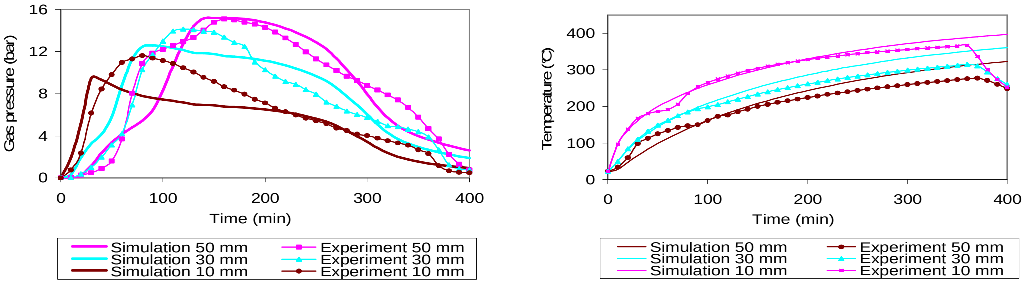

Figure 1. Numerical and experimental gas pressure and temperature vs time, at 5 cm, 3 cm and 1 cm from heated surface

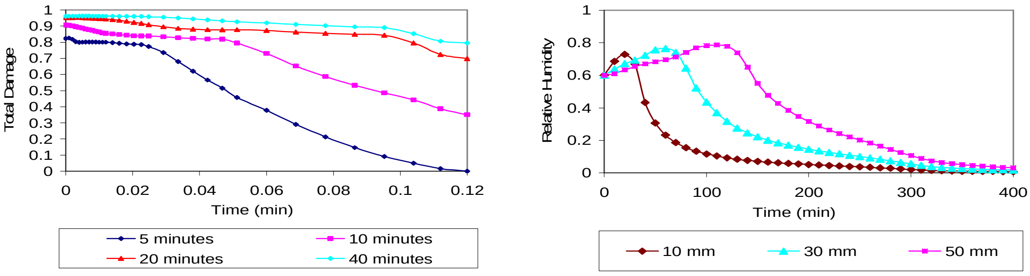

Figure 2. Total damage profile at 5,10,20 and 40 min, and relative humidity vs time at 5, 3 and 1 cm

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