Numerical modelling of the behaviour of concrete at high temperature: from continuum towards a mesoscopic approach

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ABSTRACT

The safety of concrete structures is often put at risk due to the fire exposure of structural elements. At high temperatures, concrete is prone to spalling. The latter exposes the reinforcement and may lead to premature failure of concrete members. Thus, a quantitative explanation of spalling is of high concern for the fire safety of concrete structures.

Numerical models found in literature [1] for studying the behavior of concrete at high temperature follow the theory of heat and mass transfer in porous media. The validation of these numerical models is usually based on experiments as in [2] measuring temperature and pressure inside a heated concrete specimen. In this study, a thermo-hydro-mechanical model is used to simulate an experiment from literature [3]. In that experiment, a combination of measurements was performed simultaneously on the same sample: moisture profiles via neutron radiography, temperature profiles with embedded thermocouples and pore pressure evolution with embedded pressure sensors. In addition to temperature and pressure comparison, numerical results are compared with experimental results in terms of moisture content as well.

We also present a mesoscopic approach that explicitly takes into account the heterogeneous structure of concrete to allow an in-depth view of the material. While concrete is usually treated as a homogenous porous material, it is modelled as a bi-phase material in this approach: solid intrusions (aggregates) and porous matrix (cement paste). Using the mesoscopic approach, we perform a numerical simulation of neutron tomography experiments on heated concrete specimens which are planned at the ILL institute in Grenoble.

The numerical model is implemented in the finite element code Cast3M. In contrast to the previous models in Cast3M, the problem is solved using a monolithic approach. The computational time using the new solution strategy is 20-30 times faster.

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