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Study of thermo-hydraulic transfers in concrete in fire situations: effect of mechanical loading, simulations and experiments

Abstract:

Fire and elevated temperatures impose severe loading conditions, in particular, on the strategic infrastructures such as tunnels, as very high maximum temperatures, e.g. higher than 1000 ℃, were hit in the most severe fire scenarios. Owing to the thermal insulation capability, concrete elements will be able to retain sophisticated mechanical performance and hold their integrity even at such high-temperature conditions; nevertheless, fire-induced spalling is the most unfavorable phenomenon occurring at elevated temperatures. Non-violent and/or violent dislodgments of concrete pieces or chunks from the heated surface of concrete define fire-induced spalling. Spalling leads to the loss of concrete cross section, reduction in the load-bearing capacity of concrete elements, and subsequently, plunging fire-performance of the structure. Spalling is a complex thermo-hygro-chemo-mechanical phenomenon, taking place in the presence of a transverse force adjacent to the concrete surface, which is equal or higher than the tensile strength of the concrete surface. In fire condition, two main driving forces entailing occurrence of spalling are: (i) stress originated from external forces and thermal gradients, known as thermo-mechanical mechanism, and (ii) pore pressure build-up due to water vaporization at high temperatures, the so-called thermo-hygral mechanism. As shown by various researchers, combination of both pore pressure build-up and stress is required to trigger spalling. Application of fibers has shown the potential to be considered as the most efficient, cost-effective and practical method to prevent or decrease magnitude of spalling. Polypropylene (PP) fibers have been received global attention, in particular, to reduce risk of explosive spalling in high-strength concrete (HSC).In this research, the spalling behavior of concrete and the thermo-hydro/thermo-hydro-mechanical (TH/THM) transfers occurring within the unloaded/loaded concrete at fire situation will be studied both experimentally and numerically.

Results and Discussion:

Experimental results will be collected from characterization tests in terms of thermal and mechanical properties. Moreover, tests to study coupling between permeability and thermal and/or mechanical loadings will be also performed. Thereafter, a numerically TH/THM model will be implemented in the finite element software Cast3M for understanding and predicting the complex thermo-hygro-mechanical nature of fire-induced spalling of concrete exposing to elevated temperatures.