Title: On modeling the effects of polypropylene fibers on preventing spalling hazard for high and ultra-high performance concretes when exposed to fast development fires.

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Project details:

Concrete spalling due to re exposure may be a vulnerability of concrete structures. The phenomenon manifests as a breakdown of concrete layers which flake into small pebble-like pieces at the material surface exposed to fire. Besides the reduction of the concrete resistant cross section, spalling may also lead to a direct exposure to flames of steel rebars which increases the risk of precocious failure of the structure.

It is well established now that adding polypropylene fibers (PPF) to concrete (PPF-concrete) is an embedded solution that may reduce spalling occurrence by conferring to the material self-protection features against fire hazard. High temperature induced degradation of PPF gives progressively rise to a network of micro-channels (corresponding to the space initially filled by PPF: fiber beds) whose connectivity contributes to the increase of hot permeability of PPF-concrete. This evolution (on demand) of the microstructure allows reducing pore pressures which are a major driving mechanism of fire induced spalling.

Nevertheless, adding PPF affects other concrete performances required by design. Therefore, it is crucial to be able to design PPF-concretes with optimal contents of PPF fibers in order to satisfy all design requirements: workability during concrete pouring, mechanical performance and durability during service-time and stability during a fire.

The present PhD thesis research work aims to elaborate a design support tool of PPF-concretes with regard to fire induced spalling hazard. In particular, the work will focus on high and ultra-high performance concretes (HPC, UHCP: experiencing very low permeability of their porous networks) when exposed to fast development fires as a hydrocarbon fire in tunnels.

In this context, a modeling approach will be followed with three major stages:

- A first stage deal with the estimation of the connectivity of the network of fiber beds based on standard design parameters: fiber content of concrete, fiber physical characteristics (geometry, melting and gasification temperatures) and grading of aggregates. The estimation will be performed by determining the percolation probability of the micro-channels released by fibers in concrete considered as a heterogeneous material at the mesoscale, that is, aggregates with distributed sizes embedded in a porous matrix containing PPF.

- The next step aims to estimating the hot permeability of PPF-concrete. The estimation will be performed for continuous descriptions of representative elementary volumes (REV) and will be based on a homogenization approach that uses the percolation probability as an input parameter. A focus will concern the interaction between the distribution of aggregates and the micro-channels released in the cement paste due the high temperature.

- The last stage will consist of implementing the estimation tool of the permeability of heated PPF-concretes in an already existing finite element thermo-hygro-mechanical model specifically developed for investigating the occurrence spalling of concrete when exposed to fast development fires. Then, numerical simulations will be performed in order to determine the correlation between material microstructure, PPF features and contents and the prevention of fire induced spalling.

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