Research Project Highlight

How the Water/Binder Ratio and Voids Affect the Performances of Hardened Concrete Subjected to Fire

Project # NCTRKN

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Start-End Dates:
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Abstract
Post-earthquake fire (PEF) is a relatively frequent disaster, but its damage on concrete is complicated and is usually affected by uncertain factors. Considering the risk of fire either locally within buildings or conflagrations after an earthquake, the effects of seismic damage on the fire resistance of structural members need to be better understood for resilient structural design. To increase the efficiency of concrete structures, the use of high-strength concrete is desirable, especially in bridges, tall buildings, and concrete tunnel linings. However, high-strength concrete shows very brittle behavior in compression and is prone to spalling in case of fire. The presence of fibers can increase the fracture toughness (or the ductility) in compression and reduce the risk of fire spalling. Several types of concrete, having different water/binder ratio and porosity, have been investigated in the past decades. In this research, we concluded from the experiments that the concrete strength (i.e., the quality of concrete) increases when air content and/or w/c decreases, regardless of the fiber content. Conversely, material ductility decreases with air content, but increase with w/c. Contrary to the common opinion, mass loss does not decrease as air voids increases, and the lower w/c, the lower the mass loss. Mass loss in concrete subjected to fire can be predicted only by means of uniaxial compression test, as the experiments clearly indicate that mass loss decreases with increasing strength and increases with ductility, and both of these parameters are measured through the uniaxial compression test. Artificial voids can substitute the polypropylene fiber in reducing the mass loss after fire. Mass loss is mainly related the mechanical properties of concrete rather than the content of polypropylene fibers. A concrete with the highest strength and the lowest ductility will best perform if subjected to fire.

Deliverables
A PEER report and several conference and journal papers describing the effect of fire on twelve different mix designs.

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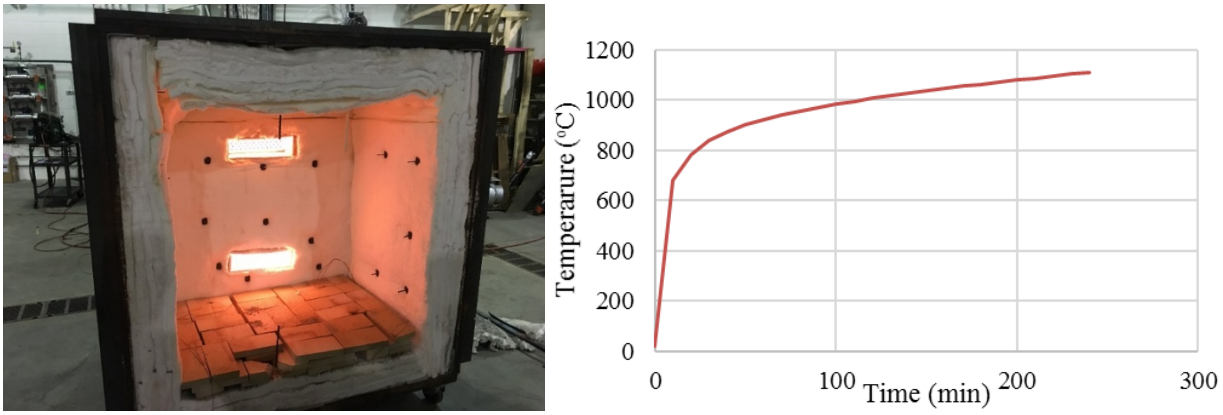
Research Impact

In the past, most of the experimental campaigns were carried out to judge the strength of concrete, or, separately, the fire spalling resistance. Studies on both these properties, and on the fracture toughness in compression as well, are very scarce in the technical literatures. We believe that this detailed study, dealing with the effect produced by the water/binder ratio and by porosity on the mechanical performances in compression and fire spalling, was carried out for the first time and will be very useful to concrete technology. Indeed, the prediction of the fire spalling is possible by means of the sole uniaxial compression tests, and the amounts of artificial voids and polypropylene fibers can be optimized to prevent fire spalling (also in the case of the lower water/binder ratio).

Project Images



a) Fire simulation temperature

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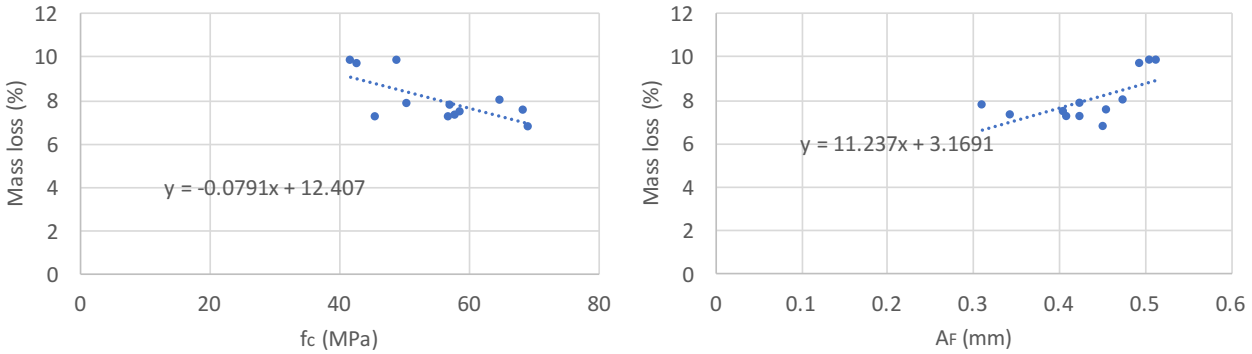
b) The test set up and samples configuration and data collection, before and after the fire test



c) Results showing mass loss decreases with strength (f_c) but increases with ductility (A_F)

Main results

Contrary to the common opinion, mass loss does not decrease as air voids increases. Hence, the better the quality of concrete (i.e., the lower w/c), the lower the mass loss. As it clearly appears in figure c, mass loss decreases with increasing f_c and increases with the material ductility A_F. Both these two parameters are simply measured through the uniaxial compression test.

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