A NOVEL SYSTEM FOR THE STUDY OF STRUCTURES IN FIRE

Moving Away from the Status Quo

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Rapid growth in the use of new construction techniques and innovative materials in building construction is being driven by the need for optimization, energy efficiency, sustainability, and architectural creativity. Advances in fire protection engineering of buildings, from both practitioners and researchers, have thus far allowed the industry to keep up with the evolving modern building construction environment. In contrast to this progress, the structural fire testing community has mainly relied in the use of the standard fire resistance test (i.e. furnace test) for assuring regulatory compliance testing but also for scientific understanding of material and structures response to fire. Developed in the early 1900s and fundamentally unchanged since then, the pass/fail standard testing procedure is characterized by its high cost, low repeatability, and unrealistic thermal and mechanical conditions. More than half a century of enhancements, essentially in line with additional standardisation mechanisms, have been unsuccessful in addressing the inherent problems with the standard fire resistance test.

Developed at The University of Edinburgh and named the H-TRIS (Heat-Transfer Rate Inducing System), the novel testing methodology uses a mobile array of propane-fired high performance radiant panels, along with a mechanical linear motion system. Whilst this is not the first time that mobile radiant panels have been used for thermal testing of construction materials, H-TRIS is the result of a mental shift associated with controlling the thermal exposure not by gas temperature but rather by the time-history of thermal energy absorbed, never before done, at this scale, for the study of structures in fire. The thermal loading imposed by the H-TRIS is defined by a numerical inverse heat transfer model which uses through-thickness temperature measurements (thermal gradients) taken from control specimens exposed to the actual fire conditions intended to be replicated (e.g. a standard furnace exposure in a specific fire testing furnace). Alternatively, a time-history of thermal energy absorbed can be specified using outputs from a fire dynamics model.

Thermal loading of test specimens, is controlled using incident heat flux (i.e. flow of thermal energy) measurements, rather than temperatures, taken during a pre-programmed calibration procedure. Recalibration can thus be performed before each new test, relevant to the specific conditions of the material or structure being tested, as well as to the ambient laboratory conditions on any given day. This allows a previously unachievable level of repeatability between tests. During a test, the computer-controlled linear motion system adjusts the radiant panels' location (i.e. distance from the specimen) so as to follow any pre-defined time-history of thermal energy absorbed. H-TRIS thus allows accurate quantification of the thermal energy flow absorbed by a tested element with good repeatability; all at negligible economic and temporal costs in comparison to furnace tests. Potentially, it also allows rational simulation of any real fire or furnace exposure condition.

The first research project based on application of the H-TRIS methodology has evaluated the occurrence of heat induced concrete spalling in high performance structural concrete under standard heating regimes. Since then, due to the multiple benefits of the H-TRIS, a number of diverse projects have been executed or are scheduled, including studies on the performance of intumescent coatings under non-standard heating regimes, the thermo-mechanical incompatibility between concrete and polymer based reinforcements, through-thickness temperature predictions relevant to the fire performance of post-tensioned concrete slabs, and the performance in fire of phase change materials used to insulate energy efficient buildings.