Department of Civil Engineering and Engineering Mechanics
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A MULTISCALE MODEL FOR HYDRATING CONCRETE AND ITS APPLICATION FOR STRUCTURES

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Hydrating concrete generates a significant amount of heat which leads to temperature increase, induction of stresses, microcracking and changes in chemical products of hydration. These phenomena are perceived on two scales with different solution strategies; the microscale captures hydrating cement paste while the structural scale simulates concrete performance. Both scales are coupled and exchange heat and temperature variables.

The finite element method is used on the structural scale to solve the heat conduction problem and stress-strain analysis. A staggered solution strategy allows to decouple both problems and non-linear constitutive laws are introduced. The heat source origins from cement hydration model which has been developed at NIST and further extended by the authors. The model is formulated on the basis of cellular automata simulating cement chemistry in a voxelized representation of cement paste. The hydration model captures further water/cement ratio, cement fineness and capillary water effects.

The multiscale simulation is validated on several examples; a calorimetry experiment, hydrating cube of self-compacting concrete, sequential erection of railway concrete bridge with varying boundary conditions. The most beneficial application occurred for an arch-bridge spanning 135 m where the massive concrete arch had to be cooled by water pipes to maintain a maximum temperature below 70^{o}C. The position of pipes, regime of cooling water, temperature peaks, temperature gradients, and stress field had to be optimized in order to minimize concrete cracking and to increase durability of the arch. The multiscale simulation helped to arrive to much more advanced design than that originally proposed by the contractor.

The beneficial role of coupled model is demonstrated on several examples from the world of civil engineers. The variability of input parameters allows to capture details in material base and to engineer several properties on the structural scale.