Modelling of Heat and Moisture Transport in Concrete since Its Early Ages Using Hybrid Finite Elements

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Abstract: A hybrid finite element formulation is used to model the coupled process of heat and moisture transport in concrete structures considering the effect of cement hydration. Temperature, relative humidity and hydration degree fields are directly approximated in the domain of the element using naturally hierarchical bases independent of the mapping used to define its geometry. This added flexibility in modelling implies the independent approximation of the heat and moisture flux fields on the boundary of the element, the typical feature of hybrid finite element formulations. The formulation can be implemented using coarse and, eventually, unstructured meshes, which may contain elements with high aspect ratios, an option that can be advantageously used in the simulation of the casting of concrete structural elements. The resulting solving system is highly sparse and well suited to adaptive p-refinement and parallel processing. It is solved coupling a trapezoidal time integration rule with an adaptation of the Newton-Raphson method designed to preserve symmetry. The relative performance of the formulation is assessed using a set of testing problems supported by experimental data and results obtained with conventional (conform) finite elements. The model can be used to simulate the hygro-thermo-chemical response of both hardening and hardened concrete and is valid for normal strength concrete and high-performance concrete. Moreover, the model is also able to simulate the boundary layers (high moisture gradient) caused by drying in the vicinity of element surfaces.

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