Modelling of concrete behaviour using a novel DEM-based thermal-hydro-mechanical model

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The numerical investigations focus on two-dimensional simulations of the behavior of concrete under uniaxial compression and tension in both quasi-static and dynamic conditions. The influences of fluid migration, aggregate fragmentation, strain rate, and thermal conditions were examined. Concrete was characterized as a four-phase material, consisting of aggregate, mortar, interfacial transition zones (ITZs), and pores, derived from a micro-CT image. A comprehensive coupled DEM/CFD methodology, grounded in a pore-scale thermal-hydro-mechanical model [1], was employed for simulations. The method's concept established a network of channels among 3D discrete elements inside a continuous region to facilitate fluid flow. It was proposed that partly saturated material with low porosity exhibited a two-phase laminar fluid flow consisting of air and water. The fluid in the channels was both immiscible and incompressible across all flow regimes. In contrast to the channels, the fluid was compressible within the pores and fractures (grid elements). The locations and volumes of pores and fractures were ascertained to precisely monitor the liquid/gas content. Heat transport was regulated by fluid dynamics (diffusion and advection), particle interactions (conduction), and phase transitions. In multi-phase fluid flow, temperature was uniform, although enthalpy was exchanged. The heat transmission model was simplified in a manner analogous to the fluid flow model. Consequently, a homogenous heat transfer model was presumed in multiphase flow, disregarding mass transfer between phases. The multi-phase fluid was converted into a single-phase fluid. The effective fluid characteristics and velocity were determined using volume averaging over the phases. The numerical solution used the identical coarse mesh of both domains utilized to establish the fluid flow network for solving the governing equations. The model [1] was augmented by incorporating phase transitions at elevated temperatures. An technique known as clump breakage [2] was utilized to simulate intra-granular fragmentation of aggregate, employing clumps made of small spheres to represent particles of varying dimensions and shapes. Various aggregate strengths were expected.

Numerical computations were conducted with YADE, an open-source discrete element method (DEM) tool, employing the soft-particle methodology. Focus was directed towards the strength, brittleness, fracture mechanisms, free water pressures and velocities, and temperatures in concrete during simulations of uniaxial compression and tension at varying strain rates. The effects of fluid viscosity and fluid saturation were also examined. The numerical results were juxtaposed with the relevant experiments [3].

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