MODELING OF AGING EFFECTS ON CONCRETE CREEP/SHRINKAGE BEHAVIOR: A LATTICE DISCRETE PARTICLE MODELING APPROACH

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ABSTRACT

The currently aging and deteriorating infrastructures both in the US and all around the world have been a major cause to extend the current design provisions for concrete structures to 100 years of design lifetime. During such a long period, concrete exhibits a well-known time dependent behavior that is a function of multiple factors including both rheological aspects of the concrete mix as well as the effect of environmental conditions, which contribute to its time dependent aging. While initial conditions (e.g. concrete mix design parameters) can be well controlled, much less knowledge is available on the type and extent of the environmental conditions that will affect the structure.

Using macroscopic homogeneous models results in an averaged creep deformation that neglects internal creep/relaxation at lower scales due to internal self equilibrated stresses. Such a short-coming of all continuum based creep models is naturally over come by the explicit implementation of the previously formulated solidification-microprestress (SM) theory within the Lattice Discrete Particle Model (LDPM). LDPM is a discrete model capturing various features of concrete internal heterogeneity and it has demonstrated superior modeling and predictive capabilities under a large variety of loading conditions, both quasi-static and dynamic.

The new model entitled Solidification-Microprestress Lattice Discrete Particle Model (SM-LDPM) is uniquely capable of representing creep due to nonuniform shrinkage or thermal strains even under zero external loading. This is thanks to the formulation of creep deformations at the aggregate interface as a function of the inter-aggregate stresses.

In this work, the SM theory is numerically approximated through an aging Kelvin chain and the resulting rate-type constitutive equations are integrated with an explicit time integrator. Temperature, humidity and reaction degree of concrete are obtained through a multi physics model evolving temperature, humidity and cement degree of reaction in full coupling over time and space. This leads to an elegant and simple implementation within the LDPM framework through an imposed eigenstrain, which leaves the features of the LDPM constitutive equation simulating material strength and toughness completely unaltered.

Aging of the Kelvin chain is formulated as a function of a global aging degree of concrete. Simulations of elastic stiffness evolution over time are perused using different aging functions and the results are compared to the engineering code provisions. The presentation is completed with multiple numerical simulations of experimental data from literature to show the superiority of the proposed model.