Thermal stresses in concrete as a function of internal relative humidity: a multiscale analysis

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ABSTRACT

Concrete structures are typically exposed to the ambient environment. Therefore, they are subjected to many temperature cycles during their service life. Temperature changes, in turn, result in thermal eigenstrains of concrete constituents. Notably, there is a mismatch of the thermal expansion coefficients of cement paste, sand, and aggregates. Therefore, temperature changes result in thermal stresses at the microstructure of concrete, even if the concrete volume is free of macroscopic stresses. In this context, it is noteworthy that the thermal expansion coefficient of mature cement paste is a nonlinear function of the relative humidity prevailing, at the time instant of a sudden temperature change, inside the air-filled capillary and gel pores [1]. In other words, the mismatch of microscopic thermal expansion coefficients and, hence, the resulting microscopic stresses are functions of the internal relative humidity. This work contains a report on a multiscale model, developed in the framework of homogenization of eigenstressed heterogeneous materials [2], in order to predict the thermal expansion coefficient of concrete and the corresponding self-equilibrated microstresses, as a function of the internal relative humidity.

In statically indeterminate structures, macroscopic thermal strains of concrete are restrained by kinematic constraints. This gives rise to another source of macroscopic concrete stresses. The aforementioned multiscale model is involved in corresponding structural analyses, in order to provide the scale transition to microscopic average stresses in cement paste, sand, and aggregates. This results in multiscale structural analysis.

During their long service life, concrete structures may be exposed to moderate thermal shocks, as may result from nearby fires or from accidental spilling of cooled fluids. The associated instationary heat conduction process can be shown to activate a third source of macroscopic concrete stresses, even if the concrete structure is supported in a statically determinate fashion. This situation is also investigated in the context of multiscale structural analysis. Results from sensitivity analyses with respect to the internal relative humidity will be presented.

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