Experiments-based multi-scale modeling of the alkali-silica reaction in concrete

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ABSTRACT

In this study, we investigate the mechanical behavior of large concrete structures affected by the alkali-silica reaction. Particularly, concrete dams are explored. Their permanent contact with water, and thus increased humidity, promotes the ASR. Seasonal variation of the environmental temperature causes different levels of concrete damage in "cold" and "warm" zones. In order to study the behavior of such structures, a thermo-mechanical multi-scale numerical model is developed. It is based on the algorithm proposed by Cuba Ramos [1]. Simulations are performed at the macro- and meso-scales, both of which are handled by the finite element method. An elastic thermo-mechanical simulation, performed at the macro-scale, results in a temperature and displacement field. This information at every integration point of the macro-scale is communicated to a corresponding representative volume element (RVE) at the meso-scale. The temperature value is used to determine the gel expansion rate for the following time step. Advancement of the ASR at the level of RVEs leads to gel expansion, deformation of the matrix, and growth of cracks. Given the solution of an RVE problem, homogenized material properties are extracted and communicated to the corresponding integration point of the macro-structure. In the next loading step, the latter behaves according to local states of material throughout a structure.

Concrete damaging process is locally driven by gel volume increase, which in its turn depends on the rate of alkali-silica reaction. An equation used to relate the ambient temperature and the amount of available reactants to the gel strain rate is inspired by the Arrhenius law. Parameters of this equation are calibrated based on the experiments by Gautam & Panesar [2].

Cracks in concrete are handled by a continuum damage model. Convergence of the static solution in the presence of multiple cracks is achieved by modification of the sequential linear analysis proposed by Rots and Invernizzi [3]. The cement paste at the meso-scale behaves viscoelastically, which causes relaxation of stresses and reduction in the level of damage. For this purpose, an algorithm coupling the SLA with the general viscoelastic model is developed.

REFERENCES

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