Multiphysical failure processes in concrete: a thermodynamically consistent multiscale homogenization procedure

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ABSTRACT

Durability and strength capabilities of concrete materials are vastly affected by the combined action of temperature and mechanical loading, which give rise to multiphysical failure processes. Such a phenomenon involves complex cracking, degradation and transport mechanisms on different scale lengths of concrete mixtures which, in turn, depend on the particular properties of the different constituents. Thus, the macroscopic observation of relevant concrete mechanical features such as strength, ductility and durability is the result of several different properties, processes and mechanisms which are not only coupled but moreover, depend on multiple scales. Particularly and regarding the pore pressure and thermal actions, most of the degradation processes in concrete are controlled by the heterogeneities of the microscopic scale, while in case of the mechanical actions both the micro and mesoscales play a relevant role.

In this context, multiphysical failure processes in cementitious material-based mixtures like concrete can only and fully be understood and accurately described when considering its multiscale and multi-constituent features. In the realm of the theoretical and computational solid mechanics many relevant proposals were made to model the complex and coupled thermo-hydro-mechanical response behavior of concrete. Most of them are related to macroscopic formulations which account for the different mechanisms and transport phenomena through empirical, dissipative, poromechanical theories. Moreover, although relevant progress was made regarding the formulation of multiscale theories and approaches, none of the existing proposals deals with multiphysical failure processes in concrete. It should be said in this sense that, among the different multiscale approaches for material modeling proposed so far, those based on computational homogenization methods have demonstrated to be the most effective ones due to the involved versatility and accuracy.

In this work a thermodynamically consistent semi-concurrent multiscale approach is formulated for modeling the thermo-poro-plastic failure behavior of concrete materials. Thereby, a discrete approach is considered to represent the RVE material response, while a continuous, smeared-crack approach is followed for the macroscopic scale. After formulating the fundamental equations describing the proposed homogenizations of the thermodynamical variables, the dissipation and the free energy, the constitutive models for both the skeleton and porous phases are described. Then, numerical analyses are presented to demonstrate the predictive capabilities of the proposed thermodynamically consistent multiscale homogenization procedure for thermo-hydro-mechanical failure processes in concrete mixtures.

REFERENCES

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