11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Methods (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
Barcelona, July 20-25, 2014

A MULTILEVEL MODEL FOR ION AND MOISTURE TRANSPORT IN INTACT, MICRO-CRACKED AND FRACTURING POROUS MATERIALS: APPLICATION TO ASR IN CONCRETE

JITHENDER J. TIMOTHY*, MINH N. NGUYEN AND GÜNTHER MESCHKE

Institute for Structural Mechanics
Ruhr University Bochum
Universitätsstraße 150
44801 Bochum, Germany
{timothy.jithenderjaswant, nguyenmy, guenther.meschke}@rub.de

Key words: Multiphysics modeling, Concrete, Alkali-silica reaction, Continuum Cascade Model

ABSTRACT

A multi-level model for the description of ion diffusion, moisture transport and ASR induced damage is presented. Concrete is modelled as a fully saturated deformable porous medium with interacting constituents such as the solid skeleton and ions in the pore fluid. Ion diffusion is assumed to be governed by the NERNST-PLANCK-POISSON system of equations [3], where the NERNST-PLANCK equation describes the diffusion of multiple ion species, and the POISSON equation describes the variation of the electric potential according to the spatial distribution of the electric charges. The influence of the topology of the pore space and the presence of oriented micro-cracks on ion diffusion is taken into account through a novel continuum micromechanics based homogenization model [2]. For modelling of fluid flow in unsaturated concrete, an extension of DARCY law, i.e. the RICHARDS equation [1], is used. The hydraulic property of moisture transport in concrete is assumed to satisfy the non-linear VAN GENUCHTEN model [4]. Alkali-silica reaction occurs when diffusing ions in the pore fluid such as the alkalis and hydroxyl ions break the silanol and siloxane bonds in reactive aggregates in the solid skeleton, forming an alkali-silica gel. The gel expands and its volume is assumed to be a function of the amount of ions involved in the alkali-silica reaction process. Once the volume of the gel exceeds the available volume of the pore space, stresses and swelling occur, leading to micro-crack nucleation and micro-crack propagation in and around the aggregates, causing overall deterioration of the material. Damage, crack propagation and effects of induced topological changes on the fluid and ion transport are taken into account using a phase-field model [2] based on isogeometric analysis.

REFERENCES

[1] CELIA, M. A.; BOULOUTAS E. T; ZARBA R. L.: A general mass-conservative numerical solution for the unsaturated flow equation. In *Water resources research* **26** (1990), p. 1483-1496

[2] TIMOTHY, J. J.; MESCHKE, G.: Diffusion in Fracturing Porous Materials: Characterizing Topological Effects using Cascade Micromechanics and Phase-Field Models. Poromechanics V: pp. 2250-2259. July 2013. doi: 10.1061/9780784412992.264

[3] SAMSON, E; J. MARCHAND; SNYDER, K. A.; BEAUDOIN J. J.: Modeling ion and fluid transport in unsaturated cement system in isothermal conditions. In: *Cement and Concrete Research* **35** (2005), p. 141-153

[4] VAN GENUCHTEN, M. T.: A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. In *Soil Science Society of America Journal* 44 (1980), p. 892-898