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

A TWO-SCALE COMPUTATIONAL FRAMEWORK FOR HYDRO-MECHANICAL COUPLINGS IN QUASI-BRITTLE HETEROGENEOUS POROUS MEDIA INCLUDING TRANSIENT AND DAMAGING EFFECTS

B.C.N. Mercatoris[1], L.J. Sluys[2] and T.J. Massart[3]

[1] University of Liège, Department of Environmental Sciences and Technologies, Passage des Déportés 2, 5030 Gembloux, Belgium, benoit.mercatoris@ulg.ac.be, http://www.gembloux.ulg.ac.be
[2] Delft University of Technology, Faculty of Civil Engineering and Geosciences, P.O. Box 5048, 2600 GA Delft, The Netherlands, l.j.sluys@tudelft.nl, http://citg.tudelft.nl
[3] Université Libre de Bruxelles, Department of Building, Architecture and Town Planning, Av. F.D. Roosevelt 50 CP 194/2, 1050 Brussels, Belgium, thmassar@ulb.ac.be, http://batir.ulb.ac.be

Key words: *Computational Homogenisation, Hydro-mechanical Couplings, Damage, Anisotropic Properties, Porous Materials.*

A coupled two-scale framework based on computational homogenisation is proposed for problems combining damage processes and moisture flow in saturated heterogeneous porous geomaterials such as masonry, concrete, soil or rock. Due to their texture and the quasi-brittle nature of their constituents, complex hydro-mechanical behaviours such as damage-induced permeability and anisotropic properties may occur. This results in preferential directions for cracking and moisture transport. The characterisation of hydro-mechanical behaviour of heterogeneous porous geomaterials by means of macroscopic closed-form constitutive laws is complex. As a complementary approach, multi-scale computational strategies aim at solving this issue by bridging both the constituents and macroscopic scales. Based on postulated constituent properties and averaging theorems, computational homogenisation allows for extraction of an average structural response from a representative volume element (RVE). The constituents inside the RVE may be modelled using a closed-form formulation, depending on the multi-physical phenomena to be represented. Such methods were developed for thermo-mechanical problems in [1] using a staggered approach, a fine-scale steady-state assumption and periodic constraints applied at the boundary of the RVE. A variational homogenisation procedure, taking into account fine-scale transient phenomena and based on (strong) uniform boundary conditions applied to the fine-scale RVE, was recently proposed for consolidation problems in [2]. In this contribution, a monolithic computational homogenisation procedure is proposed for the non-linear coupled hydro-mechanical behaviour of saturated heterogeneous porous media. The procedure involves the application of macroscopic strains, pressure gradients and pressure in an average sense to an RVE; and to deduce the corresponding stresses, fluxes and fluid storage, as well as the hydro-mechanical coefficients by solving a mesostructural boundary value problem. The scale transitions are adapted to take the transient effects at the fine scale into account. The periodicity argument is addressed. A damage model including hydro-mechanical couplings is incorporated at the RVE level in order to capture damage-induced anisotropy with fracture processes and fluid flow inside cracks [3]. Using the proposed multi-scale framework and parallel computation tools, simulations are performed for heterogeneous porous materials under hydraulic and mechanical loadings. The multi-scale solutions are compared to direct numerical simulations.

REFERENCES

[1] I. Ozdemir, W.A.M. Brekelmans and M.G.D. Geers. FE2 computational homogenization for the thermo-mechanical analysis of heterogeneous solids. *Int. J. Num. Meth. Engng.*, Vol. **73**, 185–204, 2008.

[2] F. Su, F. Larsson and K. Runesson. Computational homogenization of coupled consolidation problems in micro-heterogeneous porous media. *Int. J. Num. Meth. Engng.*, Vol. **88**, 1119–1218, 2011.

[3] J.M. Segura and I. Carol. Coupled HM analysis using zero-thickness interface elements with double nodes. Part I: Theoretical model. *Int. J. Num. Ana. Meth. Geo.*, Vol. **32**, 2083–2101, 2008.