Homogenized mesoscale discrete model for coupled mechanics and mass transport

J. Eliáš[1]*, G. Cusatis[2],

[1] Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, 602 00, Czechia, jan.elias@vut.cz

[2] Department of Civil and Environmental Engineering, Northwestern University, 2145 Sheridan Road, Tech A134, Evanston, IL 60208-3109, USA

Mesoscale discrete models of heterogeneous quasibrittle materials have been are under development for several decades [1]. They are often used for simulations of fracture processes, because the discrete nature of the model allows for direct representation of oriented discontinuity. The mesoscale character of the model brings detailed information about the creation of microcracks, transition from diffused to localized cracking process, and/or propagation of the macrocrack. For these reasons they are perfectly suited for coupling with the mass transport phenomenon. The original isotropic permeability tensor rapidly changes by several orders of magnitudes with the development of cracks and becomes highly anisotropic. The coupling scheme is typically adopted according to Refs. [5], where the primary geometrical network is used for mechanics and the dual network solves the mass transport.

The mechanical model is adopted from Ref. [2] and is slightly modified. The coupling with the mass transport in saturated medium is provided by four components: the Biot's theory where (i) the effective traction at the discrete contacts is composed of the traction in the solid and the fluid pressure contribution and (ii) the rate of the volumetric deformation is linked to the fluid pressure; (iii) the cracking which enhances the permeability coefficient of the associated conduit elements; (iv) the open cracks create storage space for the fluid.

There is, however, one disadvantage associated with the mesoscale character of the model – a large computational burden. To address this issue Rezekhani and Cusatis [6] developed an asymptotic expansion homogenization capable to separate the macroscopic trends and mesoscale fluctuations. The macroscopic model becomes homogeneous Cosserat continuum solved by the finite element method. Every integration point of the macroscale contains, instead of the constitutive routine, an embedded sub-scale model of periodic unit cell, so called RVE. The same approach is taken in Ref. [4] to homogenize discrete problem of mass transport (or diffusion or conduction as they have an identical mathematical structure).

The contribution extends previous separate homogenizations of the mechanics and mass transport to account for the coupling effects. It as a brief summarization of the recent article [3] of the authors.

References

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