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A XFEM / LEVEL SET-BASED POROELASTIC FRAMEWORK FOR HETEROGENEOUS GEOMATERIALS

B. Sonon[1], S. Amalou[1], B.C.N. Mercatoris[2], B. François[1], T.J. Massart[1]

[1] Building, Architecture & Town Planning CP 194/2, Université Libre de Bruxelles (ULB), Avenue F.D. Roosevelt 50, 1050 Brussels, Belgium, thmassar@ulb.ac.be, http://batir.ulb.ac.be
[2] Environmental Sciences and Technologies Dept., University of Liege - GemblouxAgro Bio Tech., Passage des déportés 2, 5030 Gembloux, Belgium, benoit.mercatoris@ulg.ac.be

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The mechanical behaviour of fluid-saturated porous media constitutes an important development in the study of geomaterials. The classical theory of poroelasticity models the coupling between the mechanics of the porous fabric of such materials and the behaviour of the fluid saturating the pore space.
This theory has been applied in many areas of research, in particular in the study of consolidation phenomena. Review articles can be consulted for more details on the potential application fields [1]. Such simulations are for instance central in studies related to the assessment of the long term behaviour of geological repositories of hazardous materials.

In many instances, the real nature of soils and rock materials is intrinsically heterogeneous, even at the macroscopic or regional scale of interest. This can manifest itself by spatial variations of mechanical properties, depending on the nature of the geological layer considered; as well as spatial variations of permeability, caused by the presence of faults [2]; or damage [3]. In spite of this, a frequent assumption in many simulation efforts using poromechanical simulation is related to the homogeneous nature of the geomaterial under consideration (recent ref needed), even if recent efforts have been devoted to the effect of permeability and modulus spatial random variations by means of multigrid/multiscale computational methodologies [4].

Numerical simulation techniques were developed for the representation of complex microstructures using the eXtended Finite Element Method (XFEM) in combination with level set functions [5]. For mechanical simulations, these techniques consist in incorporating an enrichment to the displacement field based on level set functions, in order to represent strain discontinuities at an interface between different materials. This allows using non conforming meshes, and thereby decrease the complexity and cost of the meshing operation when many material interfaces have to be considered. Next to these XFEM related efforts, recent development were centred on the generation of the geometry of representative volume elements by means of level set functions-based tools for their subsequent use in computational homogenization. The use of level set-related functions allows their subsequent integration in XFEM simulations [6].

The present contribution will integrate these level set-based microstructure generation tools with an XFEM implementation of poroelasticity. A geometrical generator for random geomaterials, as well as for layered geometries will be presented for its use in geomechanical applications, and the main features of the level set-based extended finite element formulation for poroelastic behaviour will be outlined. Both tools will be used to illustrate the versatility of the approach by means of consolidation simulations with a varying extent of the heterogeneous properties of the considered medium.

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