Proposition de thèse de doctorat

Début: 2018-2019

Titre de la thèse:

Numerical modeling of localization in (partially) saturated low permeability geomaterials

Laboratoire: GeM

Equipe: MEO

Localisation de la thèse en cotutelle: Ecole Centrale Nantes/Université de Liège

Directeur de thèse	Co-Directeur de thèse
Sciarra Giulio Tél: +33 (0) 2 40 37 16 66 Mail: giulio.sciarra@ec-nantes.fr	**Frédéric Collin** Tél: +32 4 3669142 Mail: f.collin@uliege.be **Co-Encadrant** **Panagiotis Kotronis** Tél: +33 (0) 2 40 37 68 93 Mail: panagiotis.kotronis@ec-nantes.fr

Description du sujet

This thesis deals with the constitutive modeling of low permeability partially saturated geomaterials, in the framework of enhanced poromechanics. Partial saturation means in this context that the porous network is occupied at least by two different fluid phases, having their own wetting properties. The classical poromechanical model, based on Biot's theory, will be therefore generalized in order to account for stress/strain localization, within the solid phase, and fluid fingering, within the fluid phases. Strain localization will be treated making use of strain gradient theory and plasticity whilst partial saturation following a phase-field modeling approach to multi-phase fluid flow. To this aim, on the one hand, a fully coupled gradient constitutive law of the porous skeleton and the saturating (mixture of) fluid(s) will be assumed, which means that the free energy of the overall continuum will be a function not only of strain and mass concentrations of the fluid components, but also of their gradients. On the other hand, irreversible deformations of the solid skeleton will be modeled adopting a suitable plasticity model. This approach stems from previous results published by the coordinator of the project [1-2] and can be partly retrieved in a line of research pursued by Collin and Kotronis, see e.g. [3-4], for what concerns the gradient approach to (un)saturated poromechanics.

The numerical implementation of the model will be initially coded within matlab and later within the FE code LAGAMINE. The most relevant aspects, concerning the numerical implementation, reside in the approach which will be adopted to solve the problem relative to the multi-phase fluid. As the enriched model involves energy contributions related to gradients of the state parameters, in particular gradient of concentrations, a mixed FE approach will be formulated so as to avoid C1 regularity of the shape functions. Additional state (nodal) variables should be therefore introduced, for instance the saturation degree and the pore water pressure (or better the chemical potential of the mixture) in the case of a partially saturated soil. The number of degrees of freedom of each finite element will be therefore increased.

The results of the laboratory scale experimental campaign, under biaxial loading conditions and wetting/drying cycles, will be used to validate the phase-field model and to calibrate the constitutive parameters relative to gradient effects. The experimental measures of the thickness of the (shear) deformation bands and of the transition zone from a fluid phase to another will be used to characterize the intrinsic lengths of the model.

References

[1] Sciarra G. (2016) Phase field modeling of partially saturated deformable porous media. *Journal of the Mechanics and Physics of Solids* 94, pp. 230-256.

[2] Casini F., Sciarra G., Vaunat J. (2017) Modeling gravity-driven segregation in porous media by a phase-field approach to unsaturated poromechanics. Poromechanics 2017 Proceedings of the 6th Biot Conference on Poromechanics, pp. 563–570.

[3] Collin F., Chambon R., Charlier R. (2006) A finite element method for poro mechanical modelling of geotechnical problems using local second gradient models. *International Journal for Numerical Methods in Engineering*, 65, pp. 1749-1772.
[4] Kotronis, P., AL Holo S., Bésuelle P., Chambon R. (2008) Shear softening and localization: Modelling the evolution of the width of the shear zone. *Acta Geotechnica* 3.2: 85-97

Required competences

Strong competences in continuum mechanics are recommended together with non-elementary skills in numerical modeling and programming.

Additional remarks

The thesis will be «en cotutelle» between l'Ecole Centrale de Nantes et l'Université de Liège. The doctorant will therefore spend half the time in Nantes and half the time in Liège.

The study is developped within the framework of the ANR project «STOWENG» underground STOrage of reneWable ENergies in low permeability Geomaterials.