Proposition de thèse de doctorat

Début: 2018-2019

Titre de la thèse : Hydro-mechanical instabilities in geomaterials

Laboratoire: GeM

Equipe: MEO

Localisation de la thèse: Ecole Centrale Nantes

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Subject

Strain location in geomaterials, particularly soils or concrete, is a common phenomenon due to the intrinsic heterogeneity of their response to complex loading conditions. Similarly, fluid flow localization, i.e. capillary or viscous fingering, is a common phenomenon in these materials due, in this case, to the intrinsic heterogeneity of their permeability. What usually happens in natural geomaterials is that these two types of localization processes are definitely coupled. Examples are ubiquitous in natural and artificial structures, as for instance the formation of cracks in drying soils or concrete, their behavior during wetting-drying cycles, the local volumetric collapse induced by wetting or the fracturing induced by drainage. The consequences of such phenomena are of great importance in civil and industrial applications, such as underground storage of hydrocarbons or waste disposal. However a comprehensive approach to these problems, capable of taking into account the micro-scale coupling between localization of the response in the solid and the fluid phases, is still missing.

In order to answer this problem, we recently proposed a gradient poro-mechanical theory [1,2] in which the solid and the fluid phases are considered as continuous and endowed with micro-structure, in particular a strain gradient solid and a second gradient fluid. In the case of partially saturated soils, where the porous space is occupied by a liquid phase (water) and a gaseous phase (air), modeling of the response of the saturating mixture can be obtained by adopting a phase field approach. The most important advantage of using a gradient approach to model the localization is the natural way in which the characteristic lengths of the constituents are imported into the model: it is the dependence of the free energy of the porous medium by these gradients which naturally allows the model to account for non-local effects [3].

The subject of this thesis concerns first of all the numerical implementation of this advanced model in existing Finite Element (FE) codes and secondly, the validation of the numerical results using innovative experimental studies to be developed for prototype materials. Regarding the numerical implementation of the model, a change of perspective will be required to introduce the proposed higher gradient model of the fluid mixture into existing FE codes. In particular, a mixed FE approach will be developed. For experimental validation, drainage/imbibition tests, under biaxial loading conditions, will be developed using model granular materials (glass beads, platelets, etc.); the purpose being to identify the triggering of the above-mentioned localization phenomena and to measure the average thickness of the phase transition region between a wetting and a non-wetting fluid phase.

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.

Required Skills

Knowledge of continuum mechanics is strongly recommended as well as non-basic skills in numerical analysis and numerical programming.

Additional remarks

Planned financing: Bourse du ministère