PhD Proposal 2017

School: Ecole Centrale de Nantes	
Laboratory: GeM	**Web site:** http://gem.ec-nantes.fr/
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Collaboration with other partner during this PhD: **In Belgium:** University of Liège (Argenco department) In Italy University of Rome TorVergata	**In China:**

Title: Modeling and testing coupling effects between strain and flow localization in partially saturated porous media using second gradient theory.
Scientific field: Civil Engineering, Continuum Mechanics
Key words: Strain & flow localization, gradient theory, microstructure, coupled phenomena, fracture

Details for the subject:

Background, Context:
Strain localization and fracture of porous materials, as soils, concrete or rocks, is a typical phenomenon due to the intrinsic heterogeneity of their response to complex loading conditions. Analogously flow localization or fingering is a typical occurrence in such kind of materials due, in this case, to the intrinsic heterogeneity of their permeability. What generally happens in real materials is that these two kinds of localization processes are definitely coupled. Examples are ubiquitous in natural and artificial structures as for instance the formation of cracks in desiccating soils or in concrete, and their response to successive wetting-drying cycles, local collapse induced by wetting in granular geomaterials, hydraulic fracturing or capillary fracturing. At the same way implications of such phenomena are of main relevance in civil and industrial engineering applications, as for instance underground storage of hydrocarbons or waste disposals. On the other hand an univocal approach to such problems accounting for micro-scale couplings between localization in the solid and the fluid phases is still missing.

In order to face this problem the use of a higher gradient theory of poromechanics has been recently proposed [1,2] in which both the solid and the fluid phase(s) are regarded as continua endowed with microstructure, in particular strain gradient solids and second gradient fluids, using the nomenclature reported for instance in [3] and [4]. In the case of partially saturated porous media, say porous materials in which the pore space is occupied by a liquid (i.e. water) and a gaseous (i.e. air) phase, modeling the response of the saturating mixture could be achieved adopting a phase field approach. The main advantage of higher gradient modeling of localization is the natural way in which intrinsic characteristic lengths of the constituents are imported into the model: it is the dependance of the free energy of the overall porous continuum on these higher order gradients which naturally allows the model to account for non-local effects, see also [5].

The subject of this PhD thesis mainly concerns the numerical implementation of this advanced model within existent FE codes (Lagamine and/or CODE_BRIGHT) and secondly in the validation of the obtained results against experimental study, to be developed for prototype material. Considering the numerical implementation of the model a change of point of view will be required in order to implement the proposed higher gradient model of the fluid mixture within exixsting FE codes. In particular a mixed FE approach will be developped. On the other hand, say concerning experimental validation, specific loading conditions should be envisaged in order to strengthen gradient effects. Attepting at validating at least the response of the liquid-gas mixture, one can think of those conditions which could enhance triggering of fingering through glass ballotini granular media.

A background in continuum mechanics is highly recommended, together with non elementary skills in computer programming.

Research subject, work plan:
The research mainly concerns the characterization of complex coupling phenomena in partially saturated porous media, in particular strain and flow localization. The numerical implementation of the an enhanced gradient model is the main subject of the research.

A work planning will be established at the beginning of the three years in order to provide a clear temporal scheduling of the activities of the student. In principle the first six month will be devoted to the understanding and statement of the problem and the mounting the experimental set up, the successive two years to the numerical implementation of the finite element code and the development of the experimental analysis. The residual half year will be devoted to the redaction of the thesis.

References:

[1] Sciarra G., dell'Isola F., Coussy O. (2007) Second gradient poromechanics. *International Journal of Solids and Structures* 44 (20), pp. 6607-6629.

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

[3] Mindlin R.D. (1964) Micro-structure in Linear Elasticity. *Archive for Rational Mechanics and Analysis* 16(1), pp. 51-78.

[4] Gurtin, M.E., Vianello, M., Williams, W.O. (1986) On fluids of grade n. *Meccanica* 21(4), 179-183.

[5] 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.