Numerical modeling of the hydro-mechanical behavior of the fractured excavation zone in deep nuclear waste disposal schemes

UNIVERSITE DE PAU ET DES PAYS DE L'ADOUR
Laboratoire SIAME, Anglet, France (Côte Basque Campus http://goo.gl/maps/OqJoM)

36-months PhD studentship

POST DESCRIPTION:

The Université de Pau et des Pays de l'Adour seeks to recruit a PhD student for a period of 36 months in the framework of a research collaboration with the National Radioactive Waste Management Agency of France (ANDRA). The PhD student will work at the Université de Pau et des Pays de l'Adour under the direction of Prof. Christian La Borderie, Prof. Domenico Gallipoli and Dr. Olivier Maurel. He will be affiliated to the Laboratoire des Sciences de l'Ingénieur Appliquées à la Mécanique et au génie Electrique (SIAME). Further details on the Université de Pau et des Pays de l'Adour and the Laboratoire SIAME can be found at http://www.univ-pau.fr/live and http://siame.univ-pau.fr/live/ , respectively.

Candidates must be less than 26 years of age and of European nationality. The scholarship will be paid at the standard rate of 1990€ gross/month. Tuition fees are relatively low (390€/year) but they will have to be covered by the candidate.

Candidates should have a good first degree in Engineering or Mathematics or Physics or a related discipline. The project will involve advanced numerical modelling and previous programming experience is desirable. Applications consisting of:

a) a full CV (including transcript of marks from their first degree)
b) a letter of motivation stating the reasons why the applicant is interested in this position
c) the names, addresses and emails of two referees, to be contacted if necessary

should be emailed to Prof. Christian La Borderie (christian.laborderie@univ-pau.fr) and to Prof. Domenico Gallipoli (domenico.gallipoli@univ-pau.fr) before Friday 11 April 2014. The expected start date of the post will be September or October 2014.

CONTEXT:

Deep disposal of radioactive waste involves the construction of underground galleries (usually in rocks or stiff soils), in which the waste is stored for the long term. During excavation and operation of deep disposal schemes, important hydro-thermal-mechanical changes take place in the host rock.

In this project, these changes will be studied with reference to a specific host rock, i.e. the Callovian-oxfordian mudstone. The permeability of the the Callovian-oxfordian mudstone is generally very low

but can increase significantly during excavation, due to the formation of a network of fractures close to the gallery wall, as it has been identified in the Meuse/Haute-Marne underground laboratory in Bure. Moreover, the presence of water in these fractures can cause swelling of the mudstone that leads to sealing of the cracks and can, in turn, reduce the permeability of the soil back to its original value.

PROJECT DESCRIPTION:

This project will develop a finite element code to simulate the hydro-mechanical behavior of the fractured soil region around galleries for the underground disposal of nuclear waste. Laboratory experiments have shown that the fractured region around galleries can, after some time, recover its original low permeability (but not its original strength) due to auto-sealing of the fractures. This is an important design aspect for a deep disposal scheme and will be studied in details during the present project.

When a crack propagates through a finite element, the fracture toughness of the material translates into a crack cohesion, which is governed by the fracture energy. The displacements of the finite element nodes can thus be decomposed into two parts: the first part relates to the opening and slippage of the crack lips while the second part relates to the elastic deformation of the intact material on both sides of the crack. Although the fracture is not explicitly represented in the mesh, the damage of the material can be modelled by means of energy regularization. The present project will extend this approach to take into account hydro-thermal and time-dependent deformations.

The information about cracks opening will also be used to calculate the permeability tensor around the excavation. This tensor depends on the preferential orientation of the fractures and can therefore be anisotropic, even if the mechanical model is isotropic. By taking into account the anisotropy of permeability, as well as capillary effects, it will be possible to achieve an improved description of water flow and, hence, of the auto-sealing of fractures around the gallery. The presence of water will induce swelling of the soil that will in turn close the cracks and reduce permeability, thus resulting in a coupling of mechanical and hydraulic behaviour.

The method will be validated on experiments at laboratory scale and on the CDZ. At least one of the following two objectives will be achieved by the end of the PhD:

- Evaluation of the hydro-mechanical regime and permeability properties of a soil continuum whose cracking pattern is known based on applied boundary conditions (i.e. hydraulic and/or mechanical boundary conditions).
- Determination of the cracking pattern, hydro-mechanical regime and permeability properties of the soil continuum. This will require the adoption and implementation of a damage model, coupled with plasticity, which will be taken from the literature. Additional experiments to evaluate the cracking energy of the soil will also be necessary.

The project is essentially computational and the proposed methods will be implemented in the finite element code Cast3M and then transferred to the code Aster. Particular care will be taken to ensure the robustness of the numerical formulation to make it usable in calculations of larger structures. If needed, small experiments will be performed in the laboratory.