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 s are relatively low (390€/year) they will have to be covered by the candidate.

Candidates should have a good 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 degree)
b) a letter of motivation stating the reasons why the applicant is interested in this position
c) the names and emails of two referees to be contacted, if necessary

should be sent in a single email addressed to both Prof. Christian La Borderie (christian.laborderie@univ-pau.fr) and Prof. Domenico Gallipoli (domenico.gallipoli@univ-pau.fr) before 20March 2015 . The expected start date of the post will be September 2015 (some flexibility exists to change the start date if necessary).

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 intact Callovian-oxfordian mudstone is generally very low but can increase significantly due to the formation of a network of fractures around the gallery wall because of the disturbance produced by the excavation process. This has been observed, for example, in the Meuse/Haute-Marne underground laboratory in Bure. Nevertheless, the subsequent infiltration of water in these fractures can cause swelling of the surrounding mudstone which leads to the subsequent sealing of the fractures and, in turn, to the reduction of permeability back to the 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 the 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 this anisotropy of permeability as well as the capillary effects due to the presence of very small fissures, it will be possible to achieve an improved description of water flow into the soil. The increase of water content will also induce swelling of the intact soil that will in turn seal the fractures around the gallery and hence reduce permeability, thus resulting in the coupling of mechanical and hydraulic behaviour.

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

- Determination of the changes in the hydro-mechanical regime and permeability properties of a soil continuum, whose cracking pattern is known, due to the application of hydraulic and/or mechanical boundary conditions.
- Determination of the changes in cracking pattern, hydro-mechanical regime and permeability properties of the soil continuum due to the application of hydraulic and/or mechanical boundary conditions. This will require the adoption and implementation of a damage-plasticity model, 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.