RÉPUBLIQUE FRANÇAISE
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maîtriser le risque pour un développement durable

PhD POSITION IN GEOMECHANICS

A discontinuous approach to study the spatio-temporal evolution of the EDZ subjected to hydraulic (H) or gaseous (G) and mechanical (M) loadings: Application to the structures of the French Cigéo storage facility

Our Ref.: Ineris 228203 - ID 2790180

BACKGROUND AND MOTIVATIONS OF THESIS

The induced and/or pre-existing fracturing of rock media raises major issues of integrity, performance, and safety in many underground and subsurface operations, such as mining, underground storages, and deep geothermal energy. This research will focus on the closure structures constructed by Andra at the Meuse/Haute-Marne underground laboratory (M-HM URL) in the Callovo-Oxfordian (COx) clay formation. The research will be built on the many in situ observations and measurements (pore pressure, convergence, rock expansion, induced fracturing commonly known as **EDZ** or **E**xtent of **D**amaged **Z**one, wave velocities, etc.) continuously carried out for more than 20 years at the M-HM URL. Numerous numerical modellings (mainly using a continuous approach with coupled thermo-hydro-mechanical models for the COx claystone behaviour), which have been constantly enriched since 2000 to integrate scientific advances relating to the behaviour of this host rock, have helped to reproduce some of these observations in situ (Manica et al. 2022, Souley et al. 2023, for example). However, they do not yet provide a satisfactory reproduction of the geometry and topology of the observed induced fracturation around the M-HM URL structures (a conceptual model of which has been proposed by Armand et al. 2014, see Fig. 1), its evolution with time, and consequently the transport mechanisms expected to occur within the EDZ in the mid and long terms. In addition, the response and the temporal evolution of this EDZ govern, on the one hand, the performance of the other components of the repository (support, lining, etc.) and, on the other hand, the hydromechanical response in time of the near-field and the circulation of a given fluid (liquid and/or gaseous).

AIM OF THE RESEARCH

As an alternative to these modellings, the approach of pre-fracturing around the galleries with fractures activated from the wall towards the intact massif has been explored and its application to certain M-HM URL structures seems promising (Camusso et al. 2022, Thoraval 2023). The aim of this thesis is to extend this methodology and conduct 3D numerical modellings to characterise this induced fracturation and its evolution in time under the effect of HG-M solicitations. The main aim is to consolidate the preliminary results of the pre-fracturing approach, and to validate a developed methodology on standard M-HM URL structures. Within the framework of this thesis, the modelling methodology will employ a discontinuous or mixed (combining discontinuous and continuous) approach if necessary. The impact of this fracturation on the induced stresses in the cementitious components of the Cigéo structures in the short and medium term, will be assessed. Secondly, the impact of hydraulic and/or gaseous loadings on the activation and propagation of these fractures will be researched using the experimental data available from Andra database. At each step, the modelling results will be compared with the in situ observations and measurements of M-HM URL. From a rheological point of view, the thesis research will focus on the highly non-linear short- and long-term behaviour of both intact rock and induced (activated) fractures. The applicant will be asked to improve certain constitutive relationships and implement them in the selected computing software. These include the regularisation of the

softening elastoplastic behaviour of the intact matrix, for which the Hoek-Brown criterion is well suited to approach the elastic limit, peak and residual strengths of COx claystone (Andra's geological database, Souley et al. 2017, Itasca900).

N.B. A Master 2 internship is also available in preparation for the subject.

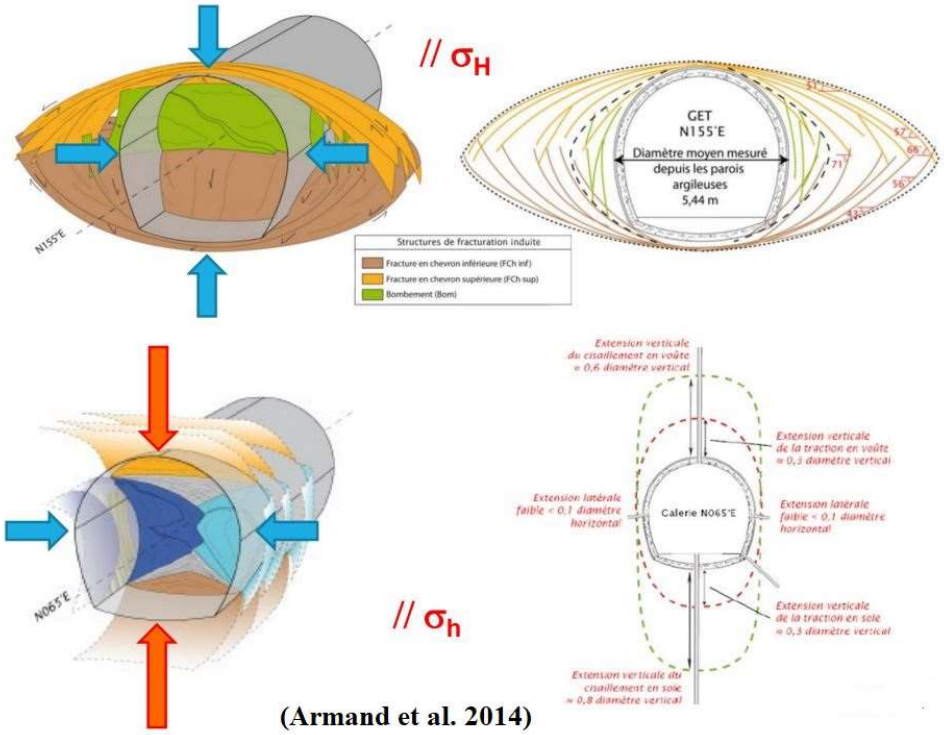

Fig. 1 – Geometry of the induced fracturing around the M-HM URL structures: Left = fracturation observed in situ; Right = conceptual model proposed by Armand et al. (2014); Top = galleries parallel to the major horizontal stress; Bottom = galleries parallel to the minor horizontal stress.

REFERENCES

Armand G, Leveau F, Nussbaum C, de La Vaissiere R, Noiret A, Jaeggi D, Landrein P, Righini C (2014) Geometry and properties of the excavation induced fractures at the Meuse/Haute-Marne URL drifts. Rock Mech Rock Eng 47(1):21–41. https://doi.org/ 10.1007/s00603-012-0339-6

Camusso M., H. Tran-Manh, D. Billaux, M.N. Vu, O. Ozanam (2022) - CIGEO project - Analysis of ILW-LL repository tunnel long term behavior. Clay2022 Conf. Nancy, June 2022

Itasca900 - Itasca Software 9.0 - documentation

Mánica MA, Gens A, Vaunat J, Armand G, Vu MN (2022) Numerical simulation of underground excavations in an indurated clay using non-local regularisation. Part 1: formulation and base case. Geotechnique 72(12):1092–1112

Souley M, Armand G, Kazmierczak J-B (2017) Hydro-elastoviscoplastic modeling of a drift at the Meuse/Haute-Marne underground research laboratoratory (URL). Comput Geotech 85(2017):306–320

Souley, M, E.-D. Coarita-Tintaya, M.-N. Vu, F. Golfier, G. Armand, M. Laviña, A. Idiart (2023). A regularised anisotropic elastoplastic, damage and viscoplastic model and its hydromechanical application to a Meuse/Haute-Marne URL drift. Rock Mech Rock Eng. https://doi.org/10.1007/s00603-023-03563-1

Thoraval A. (2023) Modélisation discontinue préliminaire du comportement de l'argilite à Court et Moyen/Long Terme. Rapport d'Etude, Ref. Ineris-208805-277018

LOCATION

The thesis project is built and managed by four entities: Ineris, PhD department (University), Andra and Itasca. The PhD student will be located at Ineris, Nancy (School of Mines), and will work in the university partner about 15% of its time. Work trips to Andra (LS M-HM) and Itasca (France) are scheduled.

Ineris was created in 1990 as a result of the merger between the French Centre for Studies and Research into Collieries (Cerchar) and the Institute of Applied Chemical Research (Ircha). The Institute's mission is to contribute to the prevention of risks caused by economic activities to health, environment, and the safety of people and goods.

The thesis research will be carried out at Ineris' Natural Hazards, Facilities and Storage department, within a THMC modelling team dealing with geomaterial constitutive laws up to applications to the design of structures, in continuous and discontinuous media.

CANDIDATE PROFILE

The candidate will hold a Master 2 and/or an Engineering degree in Geosciences, with a mention and a solid background in continuous media mechanics, geomechanics and transfers in porous and fractured media. He/she will enjoy modelling and numerical developments to provide an in-depth understanding of the mechanisms involved in the EDZ under numerous solicitations. He/she has a very good English level. He/she has an ability to take initiative, to work in a collaborative team and to exchange results with partners involved in the project, both orally and in writing.

GENERAL INFORMATION

Thesis start: September/October 2024
Duration: 3 years
Gross salary (Andra thesis): around 2200 € / month
Type of contract: Limited term contract
Subject to acceptance of the application by Andra (scheduled hearing in May 2024).

APPLICATION FORM

The application must include: a curriculum vitae, copies of certificates for each university degree and obtained scores, a letter describing your motivation and interest in working on the proposed subject and any letters of recommendation from your teaching researchers and/or supervisors. The application must be received before April 1, 2024.

SUPERVISION / CONTACT

Co-supervision: University of Lorraine (GeoRessources Laboratory), Andra and Itasca
Contact: M. Souley
Ineris - Campus ARTEM – School of Mines - Nancy,
CS 14234 F-54042 Nancy Cedex
Tel: +33 (0)3 54 40 66 33, Email: Mountaka.Souley@ineris.fr

This position is open to people with handicaps.