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PhD POSITION IN GEOMECHANICS

Study of the spatio-temporal evolution of a damage zone subjected to hydraulic (H) or gaseous (G) and mechanical (M) loadings: Application to the structures of the French Cigéo storage facility

Our Ref. : Ineris - 231668 - ID 2824288

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Type of contract: Thesis
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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 thesis 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, etc.) continuously carried out for more than 20 years at the M-HM URL and numerical modellings constantly enriched since 2000 to integrate scientific advances relating to the behaviour of this host rock (Manica et al. 2022, Souley et al. 2023, for example). The latter, essentially continuous, do not yet provide a satisfactory reproduction of the geometry and topology of the observed induced fracturation (commonly known as **EDZ** or **E**xtent of **D**amaged **Z**one) around the M-HM URL structures (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

The discontinuous approach, which considers pre-fracturing around the galleries and an activation of fractures 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. If necessary, the candidate will contribute to the enrichment of these rheological models on the basis of scientific advances regarding the behaviour of COx and the temporal evolution of the EDZ.

Note that a Master 2 internship is also available in preparation for the subject.

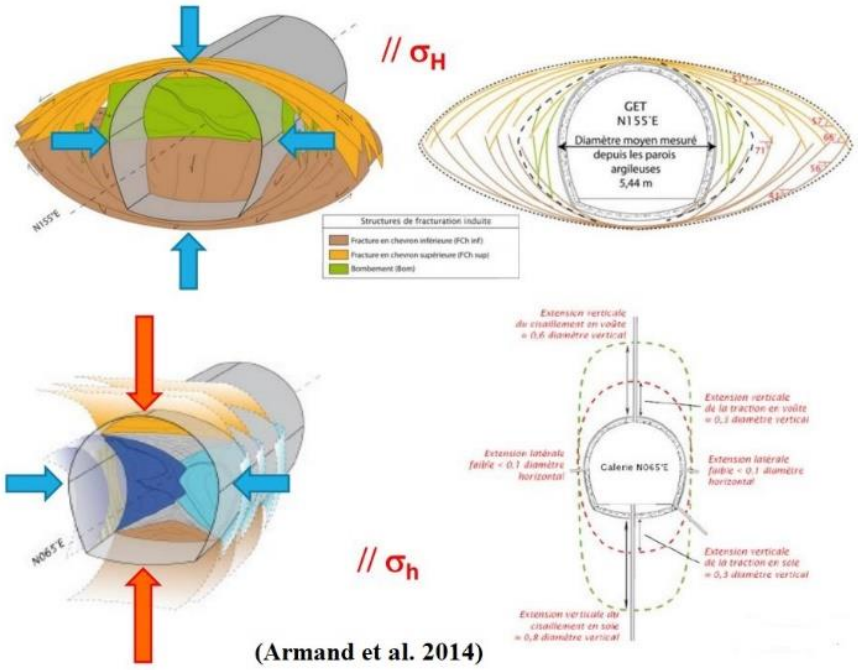

Fig. 1 – Geometry of the induced fracturing around the M-HM URL structures: Left = fracturation observed in situ; Right = conceptual model proposed by Armand et al. (2014); Top = galleries parallel to the major horizontal stress; Bottom = galleries parallel to the minor horizontal stress.

POSITIONING AND CAREER PROSPECTS WITHIN RESEARCH

The dual advantage of this exploratory and operational thesis is that the doctoral student will be able to pursue his or her career and apply the work and topics covered in this doctoral research. There are numerous career opportunities in both industry (in the field of storage engineering in the widest sense, including underground structures excavated in fractured or unfractured rock masses, civil engineering, etc.) and academia (more complex discontinuous and mixed approaches, constitutive modelling, post-doc in education and/or research in Geomechanics/Geosciences).

This fundamental (hydromechanical behaviour and constitutive modelling of geomaterials - couplings), numerical and applied research has the great advantage of being supported by a large amount of experimental data from numerous laboratory tests and in situ measurements carried out at the M-HM URL over several decades, and of comparing its results with measurements.

SUPERVISION AND LOCATION

The thesis project, under Andra contract, will be supervised by a joint Ineris/GeoRessources (UL-CNRS laboratory) team located at School of Mines and National Geology School of Nancy.

The thesis advisory committee will be composed of Andra and Itasca, a recognized consulting group in the field of geostructures modelling.

The PhD student (Andra employee) will be based at Ineris, in Nancy (School of Mines, Campus Artem), 1h30 from Paris, and will work with the University of Lorraine for about 15% of his/her time. Work visits to Andra (at the M-HM URL) and Itasca (France) are to be expected.

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, as part of a THMC modelling team (10 engineers including 3 HDRs, one PhD student) dealing with material constitutive laws and their application to the dimensioning of structures, in continuous and discontinuous media.

The thesis requires frequent visits in France (Ineris and Andra offices, Bure underground laboratory, Itasca) and internationally (selected conferences).

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 2025
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 2025).

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, 2025.

SUPERVISION / CONTACT

Co-supervision: University of Lorraine (GeoRessources Laboratory), Andra and Itasca
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REFERENCES

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This position is open to people with handicaps.