COMITÉ FRANÇAIS DE MÉCANIQUE DES ROCHES

CFMR_JEUNES

Séance technique CFMR

Caractérisation et modélisation des discontinuités dans les massifs rocheux

Organisée par le groupe CFMR_Jeunes

Jeudi 3 mars 2022 à 14h00

Séance organisée en mode hybride :
Ecoles des Mines de Paris (60 Bd Saint-Michel, Paris), Amphi V107
Pour rejoindre la salle virtuelle : https://salles-zoom.mines-paristech.fr (login=mpt-zoom, mot de passe=kM2sE!UnD6Jw), chercher « Salle V-107 » dans le menu à gauche et cliquer sur le lien zoom en bleu.

14h00 Accueil et informations du CFMR par Philippe Cosenza, Président du CFMR.

14h10 Présentation de la Commission CFMR_Jeunes et introduction à la séance.

14h25 Investigation of the creep slip of a fracture in Callovo-Oxfordian claystone with Digital Image Correlation.
Sophie Jung (Laboratoire Navier, Ecole des Ponts ParisTech).

14h55 Fault friction under thermal pressurization during large coseismic slip.
Alexandros Stathas (Institut de Recherche en Génie Civil et Mécanique, Ecole Centrale de Nantes).

Pause

15h40 Numerical modelling of fluid-induced fault slip reactivation, application to Geo-Energy systems.
Jinlin Jiang (Centre de Géosciences, MINES ParisTech).

16h10 Modélisation Physique et numérique de la stabilité d'une exploitation minière souterraine dans un massif rocheux.
Emilio Abi Aad (Université de Lorraine, CNRS, GeoRessources, Ecole des Mines de Nancy).

16h40 Modelling the effective elastic moduli of partially saturated porous rocks.
Santiago G. Solazzi (Institute of Earth Sciences (ISTE), University de Lausanne (UNIL), Switzerland).

17h10 Discussion

17h30 Fin de la séance

Investigation of the creep slip of a fracture in Callovo-Oxfordian claystone with Digital Image Correlation

Sophie Jung[1,2], Siavash Ghabezloo[1], Michel Bornert[1], Amade Pouya[1], Mathias Lebihain[1], Julien Archez[1], Marine Lemaire[1], Baptiste Chabot[1] and Minh Ngoc Vu[2]

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In the context of nuclear waste management project Cigeo, the behavior of the fractured Callovo Oxfordian claystone (COx) is studied for its time dependent effect on the long term convergences of the drifts. We present an experimental setup designed to investigate the viscous behavior of a fracture. While few experimental setup already exist with the purpose of studying the time dependent deformation of a rock joint, all of them measure the displacement in the direction of the sheared discontinuities in one point of the sample with devices such as a linear variable displacement transducers (lvdt). The information provided by this sensor comes to measuring the average displacement of the fracture slip. Depending on the configuration of the experimental device, the lvdt sometimes also measures the deformation of the rock medium which cannot always be considered as a rigid body. Which is why we propose to set a camera up in order to use Digital Image Correlation to get an information of the slip along the fracture.

Fault friction under thermal pressurization during large coseismic slip

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We study the role of thermal pressurization in the frictional response of a fault under large coseismic slip. We consider the effect of seismic slip velocity, mixture compressibility, characteristic grain size and viscosity in the frictional response of the coupled thermo- hydro- mechanical problem. We investigate both the rate independent as well as the rate dependent frictional response and compare with the rate and state friction law.
We show that our model is capable of predicting strain rate hardening and velocity softening without the assumption of a state variable.
Inside the fault gouge a traveling strain localization develops resulting in oscillatory frictional response (see Figure 1), a phenomenon similar to the case of Portevin Le Chatelier (PLC, see Mazière et al 2010). Current models of uniform shear (see Lachenbruch, 1980) and shear on a mathematical plane (Rice, 2006), capture only monotonous frictional decrease, however, experiments, which insulate thermal pressurization from other weakening mechanisms (see Badt et al., 2020) agree with our numerical results. We expand then the analytical model in Rice, 2006 by considering realistic boundary conditions at the fault's Principal Slip Zone (PSZ) and applying a traveling mode of strain localization (see Figure 1).

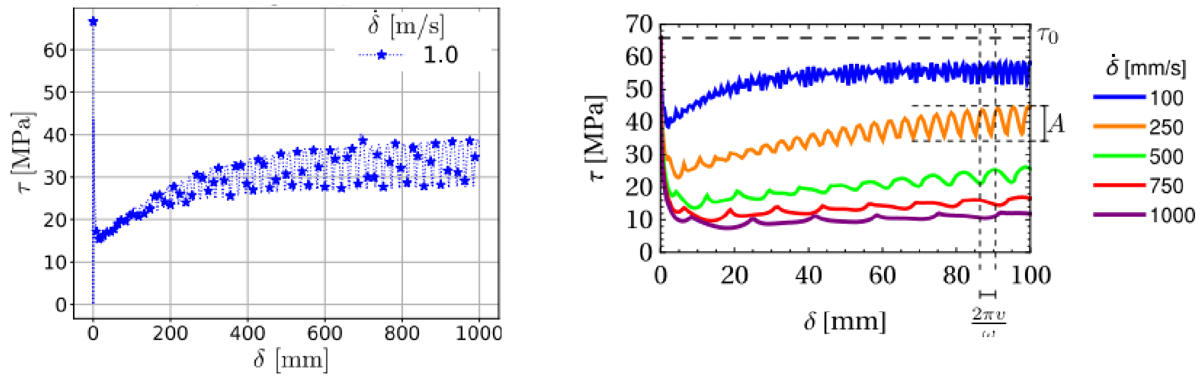

Figure 1 : *Figure on the left: Fully nonlinear numerical solution for large seismic slip and coseismic slip rate. Figure on the right: Numerical solution from the expansion of the model in Rice, 2006, detail close to the initiation of slip for different rates of coseismic slip .*

References:

Badt, N. Z., Tullis, T. E., Hirth, G., & Goldsby, D. L. (2020). Thermal pressurization weakening in laboratory experiments. Journal of Geophysical Research: Solid Earth, 125(5), e2019JB018872.

Lachenbruch, A. H. (1980). Frictional heating, fluid pressure, and the resistance to fault motion. Journal of Geophysical Research: Solid Earth, 85(B11), 6097-6112.

Mazière, M., Besson, J., Forest, S., Tanguy, B., Chalons, H., & Vogel, F. (2010). Numerical aspects in the finite element simulation of the Portevin–Le Chatelier effect. Computer Methods in Applied Mechanics and Engineering, 199(9-12), 734-754.

Rice, J. R. (2006). Heating and weakening of faults during earthquake slip. Journal of Geophysical Research: Solid Earth, 111(B5).

Numerical modelling of fluid-induced fault slip reactivation, application to Geo-Energy systems

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Geothermal energy is one of the most promising techniques to exploit renewable energy resources from the Earth and to limit emissions of greenhouse gas. Deep geothermal exploitations are associated with long term fluid circulation and pressure perturbations at great depth, in fractured and faulted zones and are likely associated with a risk of triggering earthquakes. Such earthquakes are usually interpreted as the reactivation of rapid (m/s) shear slip on critically stressed faults caused by fluid flow and poroelastic stress changes. In some cases, however, slow aseismic slip (m/d) can take place on faults in response to fluid flow. How fluid pressure perturbations reactivate aseismic or rapid slip still remains poorly understood. A better understanding of the hydro-mechanical processes controlling fault slip is therefore crucial to mitigate seismic hazards associated with geothermal exploitation.

In this framework, our study aims at constraining the influence of stress state, fluid injection rate, diffusivity and frictional failure criterion on the reactivation of slip on pre-existing faults through mechanical modelling of a set of laboratory experiments. The experiments consist of a fluid injection into a saw-cut rock sample loaded in a triaxial cell. Fault reactivation is triggered by injecting fluids through a borehole directly connected to the fault. This experimental setup is modelled by a 3D Finite Element Method (FEM) coupled with a solver of the fluid diffusion. The sample fault is modelled as a contact surface obeying slip-weakening Mohr-Coulomb friction law. This approach allows to compute slip and stress evolutions, as observed during the laboratory experiment. The FEM model is calibrated and is able to reproduce the experimental results. We show that fluid injection triggers a shear crack that propagates varying from 1 to 300 m/d along the fault. This approach can be used to investigate the relationship between fluid front and slip front during reactivation, which is an important issue to control the effects of fluid injections at depth.

Modélisation Physique et numérique de la stabilité d'une exploitation minière souterraine dans un massif rocheux

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Cette étude s'inscrit dans le cadre d'un projet de recherche, à long terme qui a pour objectif principal de comprendre le comportement mécanique d'un massif rocheux soumis à des sollicitations mécaniques. Notre objectif à terme est de modéliser une exploitation minière creusée dans un massif rocheux discontinu, en utilisant la méthode de modélisation physique. Ce type de modélisation permet d'obtenir des résultats quantitatifs en complément de la modélisation numérique. Néanmoins, la transposition des résultats de l'échelle réduite à l'échelle du prototype nécessite de respecter les facteurs d'échelle.
L'originalité de ce travail consiste à développer une méthode innovante, basée sur les techniques d'impression 3D combinant du sable et un liant phénolique, qui permet d'introduire explicitement des joints rocheux à propriétés mécaniques et géométriques contrôlées. L'utilisation de cette technique peut permettre la réalisation de modèles réduits discontinus de géométrie très précise et reproductibles.
Six sous-objectifs sont définis : (i) la caractérisation mécanique du matériau 3DP ; (ii) la description géométrique et la caractérisation mécanique des fractures imprimées en tenant compte des facteurs d'échelle ; (iii) la modélisation géométrique en 3D du modèle physique comprenant un réseau de fractures aléatoire (réaliste) ; (iv) l'intégration d'un système d'instrumentation avec des capteurs de contrainte encastrés et des fibres optiques ; (v) la réalisation des essais physiques comprenant l'excavation des galeries ; (vi) la comparaison avec la modélisation numérique.

Modelling the effective elastic moduli of partially saturated porous rocks.

Santiago G. Solazzi
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Geophysical surveys and engineering measurements consistently show that the elastic moduli of saturated porous rocks are dependent on the probing frequencies. Interestingly, this frequency-dependent behavior is largely non-existent in the corresponding dry saturated media, which points to the existence of coupling mechanisms between pore fluids and solid rock matrix. Given that, field, borehole, and laboratory estimations of the mechanical properties of rocks are performed at different frequencies, ranging from some Hz to the MHz, it is imperative to reconcile such data by means of modelization strategies. Several mechanisms are associated with fluid/matrix coupling processes in porous media, amongst which, we highlight: (i) Biot's intrinsic mechanism; (ii) mesoscopic fluid pressure diffusion (FPD); and (iii) microscopic squirt flow. Each of them operates at a particular frequency range and presents its own characteristics. However, to date, the corresponding effects in partially saturated scenarios are still a matter of debate. In this talk, we will review how fluid presence affects the effective elastic moduli, as well as seismic amplitudes and velocities, in saturated porous rocks. Subsequently, we will discuss how to extend existing models to partially saturated environments. Results are of particular interests for many leading-edge operations in geosciences, such as, aquifer remediation, monitoring of underground CO_2 storage operations, and hydrocarbon exploration.