PhD position 2026-2029 at University Grenoble Alpes / 3SR

Multiscale investigation of localized deformation around boreholes and galleries in heterogeneous and anisotropic rocks

Context: The PhD project aims to improve the understanding of initiation and evolution of failure by localized deformation around underground excavations in heterogeneous and anisotropic porous rocks, a key issue for the stability and integrity of deep boreholes and galleries in the context of the energy transition. Deep excavations in natural formations induce complex three-dimensional stress redistributions, and the resulting strain localization patterns depend strongly on multi-axial loading paths, as well as on natural rock anisotropy and heterogeneity. Despite their importance for engineering applications, these *in-situ* conditions remain insufficiently represented in existing laboratory datasets and are only partially accounted for in current modelling approaches.

This PhD research will investigate, through combined advanced experimental and numerical approaches, the mechanisms of localized deformation around boreholes and galleries in heterogeneous and anisotropic sedimentary rocks, under true triaxial stress paths representative of in-situ conditions.

Method: On the experimental side, the proposed project will combine highly innovative true-triaxial testing on hollow prismatic sandstone specimens with *in-operando* full-field imaging (DIC) to monitor the emergence and propagation of localized deformation during controlled cavity depressurization. A systematic evaluation of strain localization under realistic excavation stress paths will yield an unprecedented experimental dataset.

Numerically, the study will first benchmark classical elasto-plastic FEM models against the experimental results and assess the performance of classical constitutive laws in capturing the rock response during cavity depressurization under multi-axial loading. A second, multi-scale component will employ a hierarchical FEM×DEM framework that incorporates grain-scale mechanisms (cohesion loss, grain breakage, granular network rearrangement) and controlled heterogeneity distributions. The numerical study will provide new insights into the capabilities for advanced multi-scale models to capture the mechanisms governing damage development around deep excavations and support the development of predictive models, capable of accounting for realistic stress paths and microstructural complexity.

Objectives: Four key areas where progress is expected are outlined below:

- Identify the extent of localized zones and how they evolve around cavities, following stress paths inducing stress-field polarization and inhomogeneous unloading conditions, which remain largely unexplored in laboratory settings.
- Contribute to a more refined understanding of underlying damage mechanisms and risks of integrity loss in capable rock masses, during deep excavation operations.
- Propose a multi-scale numerical approach, accounting for realistic rock microstructure and grain scale deformation processes in the context of engineering scale deep excavations.
- Determine the role of material heterogeneities and the orientation of anisotropic bedding planes in controlling deformation localization around cavities.

Candidate: The candidate should hold a Master's degree (or equivalent) with a solid background in solid mechanics, some familiarity with geomechanics, and an enthusiasm for unconventional experimental methods and numerical simulations. The ideal candidate will have programming or code analysis experience in scientific programming languages such as Matlab/Python or Fortran/C/C++. In addition, experience in experimental data generation and analysis (e.g., imaging methods, instrumentation, sample preparation, etc.) is desirable. The candidate should have the ability to work in a research team, combining autonomy on individual tasks and strong interactions for collaborative work. Strong oral and written communication skills in English are essential.

Supervision: The PhD will be supervised by Pierre Bésuelle (senior researcher, CNRS), Cyrille Couture (associate professor, UGA) and Vincent Richefeu (associate professor, HDR, UGA).

The selected candidate will begin a 3-year doctoral contract in September 2026 funded by University Grenoble Alpes (UGA), and affiliated to the IMEP2 doctoral school. The thesis work will be performed at Laboratoire 3SR (Soils, Solids, Structures, Risks) in Grenoble, France.

Application: Interested students can contact the supervisory team. Applications should include a CV, copies of grades from recent diplomas, a covering letter and optional letters of recommendation. They should be sent by email to pierre.besuelle@3sr-grenoble.fr and cyrille.couture@3sr-grenoble.fr, before **March 1st 2026**.