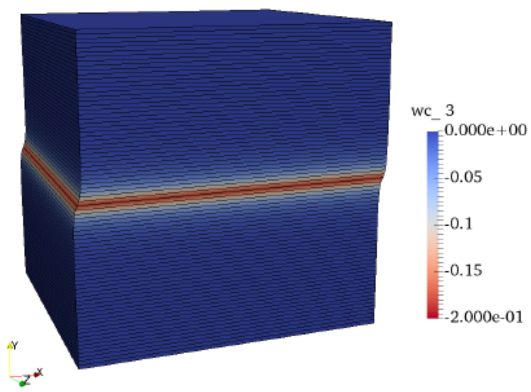
Going beyond failure in geomechanics:
From bifurcation theory to strain localization and earthquake control

Abstract:

“Failure” is an application-wise term. For instance, the failure of a car part is many times defined by the maximum applied force before the onset of permanent deformation, the failure of a metal beam is usually connected to the development of plastic hinges, while the failure of a foundation is related to its ultimate limit load and collapse. Many definitions can be given for failure, but there is always a close relation between “failure” and “(in-)stability”.

After the pioneer work of Lyapunov, instability takes a precise and rigorous meaning in mathematical modeling and it is nowadays a basic ingredient of the so-called bifurcation theory. The latter studies the existence, stability and evolution of the steady states of non-linear systems. Buckling is an example of the application of bifurcation theory, when large displacements and/or deformations are taken into account. Another important application of bifurcation theory is strain localization, which can be seen as a bifurcation of the solution from the homogeneous state of deformation to a localized one. Strain localization is favored by softening behavior.

In this seminar some recent results are presented focusing mainly on strain localization and fault-mechanics. As softening plays a central role in strain localization and energy dissipation, the advantage of higher order continuum theories (e.g. Cosserat) is illustrated for regularizing the ill-posed mathematical problem of Cauchy continuum. Finally, the importance of thermo-hydro-mechanical couplings in the post-bifurcation, beyond failure regime is shown through the numerical integration of the governing non-linear equations. These theoretical and numerical developments are expected to cover ground for answering several open questions related to earthquake nucleation and eventually earthquake control.



Strain localization inside a fault gouge (colours represent Cosserat rotations).

References:

Rattez, H., Stefanou, I., & Sulem, J. (2018). The importance of Thermo-Hydro-Mechanical couplings and microstructure to strain localization in 3D continua with application to seismic faults. Part I: Theory and linear stability analysis. *Journal of the Mechanics and Physics of Solids, 115, 54-76.*

Rattez, H., Stefanou, I., Sulem, J., Veveakis, M., & Poulet, T. (2018). The importance of Thermo-Hydro-Mechanical couplings and microstructure to strain localization in 3D continua with application to seismic faults. Part II: Numerical implementation and post-bifurcation analysis. *Journal of the Mechanics and Physics of Solids, 115, 1–29.*

Short bio:

Dr Ioannis Stefanou, is Researcher at Navier Laboratory (UMR 8205, CNRS, ENPC, IFSTTAR) and Assistant Professor at the Ecole des Ponts ParisTech (ENPC). He holds a Diploma in Civil Engineering from the National Technical University of Athens (NTUA) and a Master Degree in Applied Mechanics from the School of Applied Mathematical and Physical Sciences (NTUA). He did his Thesis on upscaling procedures in Micromorphic Continua with the late Professor Ioannis Vardoulakis. His research activities involve homogenization of heterogeneous (geo)materials in the frame of higher order continuum theories, such as Cosserat continuum, bifurcation theory and strain localization, (multisurface) plasticity theory, finite and discrete element methods (development of higher order FE and applications). The applications of his research span from deep down into the earth, where challenging questions arise regarding earthquake nucleation and control, to the dynamic behavior of modern and historic structures. He teaches Finite Elements, Mechanics of structures and Soil Dynamics at undergraduate and postgraduate level at the ENPC. He was recently awarded with an ERC Starting Grant for his project "Controlling eartQuakes - CoQuake".