PhD proposal:

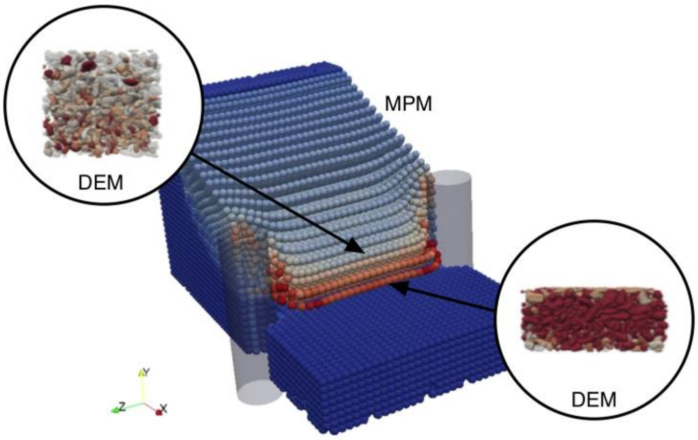
MPMxDEM double-scale modelling of slab avalanche release

Project description

Snow is a fascinating material with a complex and evolving microstructure. Snow avalanches, notably slab avalanches, are generally initiated by failure and collapse in the snowpack of a so-called weak layer, whose thickness can be very small (a few mm). This phenomenon, in which the instability of a whole slope is ultimately controlled by rupture mechanisms at the scale of the microstructure of the weak layer, is intrinsically multiscale.

Recent studies in our group explored snow mechanical behavior through discrete element (DEM) simulations based on 3D microstructure data obtained from X-ray microtomography *[Mede et al., 2018]*. Do to the heavy computational costs, such simulations currently remain limited to the scale of representative elementary volumes (REV).

In this PhD, we want to tackle the scale of the snowpack and of the slope, by coupling these microstructure-based discrete simulations with a continuous model. We will build upon recent numerical homogenization approaches developed in geomechanics, notably in Grenoble *[Desrues et al., 2019]*. These coupled double-scale approaches have the advantage of "naturally" transmitting to the macroscale all the specificities inherited from the complex microstructure of the material (non-coaxiality betwwen stresses and strains, softening, collapse, etc.). In the frame of this project, the macroscopic model will be based on MPM (*Material Point Method*), which is well suited to modelling large deformations and transition towards flow.



Left: Slab avalanche release. Right: Principle of a double-scale MPMxDEM simulation. At each MPM Gauss point, the constitutive model is obtained through DEM simulation of a REV.

The first stage of the work will be dedicated to the development of the coupled MPMxDEM tool, based on preexisting MPM and DEM engines. Particular emphasis will be put on the development of efficient parallelization strategies. To further reduce computing times, efforts shall also be devoted to simplifying the microstructure of the material while preserving the main features of its mechanical response. The code will first be tested and validated in canonical configurations through comparisons with experimental data, both at the scale of the REV (shear and compression tests) and of the snowpack (stability tests). The tool will then be exploited at the scale of the slope to investigate important issues for the forecast and evaluation of natural hazards, such as the influence of topography and snowpack heterogeneity on avalanche release.

This PhD is part of ANR project MiMESis-3D (2020-2024), which aims at a better understanding of the metamorphism and mechanical, thermal, and optical properties of snow based on microstructure data. The project brings together a consortium of partners specialized in snow science, geosciences, mechanics, and applied mathematics.

→ Key points of the PhD:

- Development of an innovative numerical approach
- Applications to natural hazards (snow avalanches)
- Stimulating and multidisciplinary work team

Location and practical aspects

The PhD student will share its time between the research unit ETNA of INRAE (Torrent control, Snow and Avalanches) and 3SR laboratory (Soils, Solids, Structures, Risks; Grenoble INP – UGA – CNRS). The two laboratories are located in neighboring buildings on Grenoble Alpes University campus. A close collaboration with CEN (Snow Study Center; Meteo-France – CNRS) will also be established.

Required profile

This PhD requires a solid background (Master 2 or equivalent) in mechanics and/or numerical methods, as well as a keen interest for software development and programming. A previous experience in advanced mechanical modelling (DEM, FEM, SPH, MPM, etc.) will be appreciated.

Applications

Candidates shall send their CV and motivation letter to Guillaume Chambon (guillaume.chambon@inrae.fr) et Vincent Richefeu (Vincent.Richefeu@3sr-grenoble.fr).

Application deadline : 15 July 2020.

References:

Desrues, J, Argilaga, A, Caillerie, D, et al. From discrete to continuum modelling of boundary value problems in geomechanics: An integrated FEM-DEM approach. *Int J Numer Anal Methods Geomech*., 43, 919– 955, 2019.

Mede T., Chambon G., Hagenmuller P., Nicot F. Snow failure modes under mixed loading. *Geophys. Res. Lett.*, 45, 13351-13358, 2018.