PhD Thesis Proposal

Influence of Freeze-Thaw Cycles on Geomaterial Damage

Start date: 01/10/2025
Duration: 36 mois
Funding: 100 % École Doctorale STEP - https://edstep.univ-grenoble-alpes.fr/l-ecole-doctorale/

Summary

The climate crisis is driving rapid transformations in mountainous regions, particularly in areas where rocks and soils have remained in a negative thermal state for millions of years without disruption. Global warming, intensified freeze-thaw cycles, and daily temperature fluctuations lead to the degradation (through melting processes and fluid overpressure) and failure of these geomaterials, with significant societal impacts (e.g., road closures, ski lift disruptions, and damage to mountain refuges).
Until now, research on ice melting and permafrost degradation has primarily focused on large-scale field studies using geophysical and in situ measurement approaches. However, the early stages of permafrost melting involve complex micromechanical processes that ultimately lead to large-scale failure. Unlike pure ice mechanics, which has been well-documented since the late 20th century, the mechanics of heterogeneous and multiphase geomaterials, particularly under freeze-thaw cycles, remains less understood. This PhD project aims to investigate the influence of freeze-thaw cycles on geomaterial damage through an experimental and numerical approach.

Research environment

The University Savoie Mont-Blanc (USMB) is a dynamic learning and research institution set in an exceptional natural environment between lakes and mountains. With campuses in Chambéry, Annecy, and Le Bourget-du-Lac, USMB offers a unique working environment that combines high quality of life, proximity to nature, and academic excellence. Since its establishment in 1979, the university has become a major player in higher education and research in France and internationally. With a dedicated community of over 1,000 faculty members and administrative staff, USMB is known for its collaborative spirit, commitment to innovation, and focus on scientific and societal challenges, particularly those related to ecological transition and sustainable development. Working at USMB means joining a human-scale university where mutual support and a friendly atmosphere are central to everyday life. It also means benefiting from modern infrastructure, state-of-the-art laboratories, and numerous academic and industrial partnerships in France and abroad.

The PhD will take place at the Institute of Earth Sciences (ISTerre), on the Bourget-du-Lac campus. It is part of an ongoing effort to establish an experimental platform dedicated to the mechanics of frozen rocks and soils. The PhD will be supervised by Jérôme Aubry (Associate Professor, USMB/ISTerre) and directed by François Nicot (Professor, USMB/ISTerre). Regular interactions with researchers based in Chambéry, Lyon, Paris, Grenoble, and Switzerland are expected.

Main objectives and expected outcomes

This project is based on a multi-scale approach, combining mechanical testing in a cold room laboratory, discrete element numerical modeling incorporating thermo-hydro-mechanical coupling and modeling development to better account for the thermal evolution of interstitial ice

The expected outcomes include experimental data illustrating the effect of freeze-thaw cycles on geomaterial strength, a better understanding of the micromechanical processes driving permafrost degradation, together with the development of a multi-scale model integrating freeze-thaw processes.

Candidate Profile – required skills and qualifications

- Master's or Engineering degree in material mechanics, soil mechanics, or rock mechanics
- Technical skills: Experience in laboratory experimentation and/or numerical modeling (Python/Matlab, discrete elements) and data analysis
- Scientific writing and communication skills
- Proficiency in both French and English

Our institution is committed to promoting equality, diversity, and inclusion within its communities. We encourage applications from diverse backgrounds and will ensure a fair and transparent recruitment process.

Application: Please submit your complete application (CV + cover letter) via the **ADUM platform** and by email to: jerome.aubry@univ-smb.fr / francois.nicot@univ-smb.fr

Application deadline: **May 18th, 2025**

Some relevant references:

1. **Aubry, J.**, Passelègue, F. X., Escartín, J., Gasc, J., Deldicque, D., & Schubnel, A. (2020). Fault stability across the seismogenic zone. Journal of Geophysical Research: Solid Earth, 125(8), e2020JB019670.
2. Arenson, L. U., & Springman, S. M. (2005). Mathematical descriptions for the behaviour of ice-rich frozen soils at temperatures close to 0 C. Canadian Geotechnical Journal, 42(2), 431-442. https://doi.org/10.1139/t04-109.
3. Liu, Z., **Nicot, F.**, Wautier, A., and Darve, F. (2024): Multiscale investigation of bonded granular materials: the H-bond model. Computers and Geotechnics, Vol. 172, 106481.
4. Ravanel, L.,Deline, P., Lambiel, C., & Vincent, C. (2013). Instability of a High Alpine Rock Ridge: the Lower Arête Des Cosmiques, Mont B lanc Massif, F rance. Geografiska Annaler: Series A, Physical Geography, 95(1), 51-66.
5. Schulson, E. M. (1990). The brittle compressive fracture of ice. *Acta Metallurgica et Materialia*, *38*(10), 1963-1976. https://doi.org/10.1016/0956-7151(90)90308-4.
6. Guillemot, A., Helmstetter, A., Larose, É., Baillet, L., Garambois, S., Mayoraz, R., & Delaloye, R. (2020). Seismic monitoring in the Gugla rock glacier (Switzerland): ambient noise correlation, microseismicity and modelling.Geophysical Journal International, 221(3), 1719-1735. https://doi.org/10.1093/gji/ggaa097.
7. Weiss, J., & Marsan, D. (2004). Scale properties of sea ice deformation and fracturing. Comptes rendus. Physique, Vol. 5(7), pp. 735-751.