École des Ponts
ParisTech

PhD Position

Investigating the mechanical behaviour of frozen soils by particle- and meso-scale observations

Naturally frozen soils (permafrost and seasonally frozen soils) cover around 20% of the land surface on Earth. Over the past decades, these areas have been subjected to warming, which affects the equilibrium conditions of frozen soils, causing major ground perturbations compared to other regions. These changes pose a threat in terms of natural hazards affecting infrastructure in the periglacial, high altitude environment around the globe (e.g. warming induced progressive failure of frozen slopes) or in high latitude regions such as areas of Canada, Alaska, Russia or China, to name but a few. A thawing permafrost has critical impact on the stability of overlying structures in inhabited regions or areas exploited for mineral and energy resources. Despite their prevalence and growing importance, to date, most approaches to explain frozen soil mechanical behaviour have focussed on phenomenological models that cover its macroscopic behaviour. However, it is known that the microstructure of frozen soil changes during loading and with temperature variations but the processes underpinning these microstructural changes are not fully explained yet and thus not included in predictive models. Hence, an approach considering ice-particle interaction at the solid particle scale can help providing better and novel tools to understand and predict the behaviour of frozen soils. Such a revolution has been recently happening for cemented soils, where the cementation agent is not ice, but a mineral precipitation or cohesive material that bond particles together.

This PhD thesis aims at investigating the behaviour of frozen soils under mechanical loading and freezing/thawing processes by using laboratory soil microstructural observations. The test programme will focus on sandy soils with various fines contents. First, the freezing and thawing characteristics of frozen soils will be investigated by using Nuclear Magnetic Resonance (NMR) relaxometry. Second, frost heave tests combined with Magnetic Resonance Imaging technique will be performed. Third, the freezing and thawing processes will be further investigated at the particle scale via observations by X-ray microtomography (XRμCT). Finally, the microstructural change of frozen soil at particle scale under thawing will be investigated in using an XRμCT-based triaxial apparatus. 3D image processing of the XRμCT tests will be performed to quantitatively investigate the behaviour of frozen soils, using volumetric digital image correlation.

This PhD thesis is part of REFROZEN project, a collaboration between Ecole des Ponts ParisTech (France) RWTH Aachen University (Germany). The work will be performed at the Navier Laboratory (https://navier-lab.fr/en/).

- *Funding: French National Research Agency*
- *Net salary: ≅ 1,700 € /month (36 months)*
- *Supervision: A.M. Tang, M. Bornert, J.M. Pereira, P. Aimedieu, R. Sidi Boulenouar, B. Maillet.*
- *Candidate profile: MSc degree in Civil Engineering or Geotechnical Engineering*

Application (CV, letter of motivation, letters of recommendation) to be sent to Dr. A.M. Tang (anh-minh.tang@enpc.fr) before April 1, 2023.

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