Position 1. Effect of temperature on the engineering behaviour of geomaterials

Supervisor: Dr. Gianvito Scaringi

Required experience/skills: coding of constitutive models of geomaterials, and/or thermo-hydromechanical numerical modelling of geomaterials (e.g., Plaxis, Comsol, Geostudio), and/or experience in a soil mechanics laboratory conducting advanced experiments (e.g., unsaturated and/or cyclic/dynamic triaxial, thermal oedometer or triaxial, CRS oedometer, ring shear), and/or fieldwork experience with energy geostructures.

Project description: Temperature and its changes significantly affect the mechanical and hydraulic behaviour of geomaterials. In soils, temperature controls compressibility and shear strength, swelling potential, and hydraulic conductivity, among other characteristics. Heating-cooling cycles can lead to permanent deformation and stiffening. In rocks, temperature affects permeability and stiffness, and temperature fluctuations can significantly enhance the mechanical and chemical degradation of rock masses.

This dependence on temperature, often understudied, is relevant to several engineering geological problems, from slope stability and geohazard propagation to the design of waste repositories, underground heat storage, and energy geostructures.

The proposed work aims to provide insights into the thermo-hydro-mechanically coupled behaviour of geomaterials via advanced laboratory experiments and the development of modelling tools through constitutive modelling. Depending on the student's inclinations, the work will also include the development of field data acquisition and monitoring strategies, the set up of proof-of-concept demonstrations (physical models, mock-ups), or the numerical simulation of case studies to validate the gained knowledge.

Position 2. Numerical modelling of soil cyclic behaviour

Supervisor: Prof. David Masin

Required experience/skills: deep understanding of advanced constitutive models of soils (ideally, knowledge of hypoplasticity) as well as programming skills (mainly C++ and Fortran) and knowledge of ABAQUS, OpenGeoSys, and Plaxis.

Project description: This thesis investigates the numerical modelling of soil behaviour under cyclic loading, a phenomenon critical in geotechnical engineering applications such as earthquake engineering, offshore structures, and foundation dynamics. The research focuses on developing and validating advanced constitutive models capable of accurately predicting soil responses to cyclic loading conditions, including stiffness degradation, accumulation of permanent strains, and pore pressure evolution.

The study builds on the hypoplasticity framework, enhancing its formulation to capture the complex mechanical behaviour of soils subjected to repeated loading and unloading cycles.

The research introduces novel extensions to existing models, incorporating key features such as strain-rate dependency, anisotropy, and memory effects in cyclic behaviour. These extensions are calibrated using experimental data from cyclic triaxial and simple shear tests on various soil types, ensuring the model's applicability across a broad spectrum of geotechnical scenarios.

The numerical models developed are implemented within finite element frameworks to simulate real-world geotechnical problems. Case studies include the dynamic response of foundations under machine-induced vibrations and the liquefaction potential of saturated sands during seismic events. These simulations demonstrate the model's robustness and provide insights into the interaction between soil mechanics and structural performance under cyclic loading.

The findings contribute to the advancement of soil constitutive modelling, offering a practical tool for engineers and researchers in the prediction and mitigation of cyclic loading effects in soil-structure interaction problems. This work underscores the importance of rigorous model validation and highlights the potential for future extensions to address multiscale and multiphysical aspects of soil behaviour.