Course offered for the PhD program
in Civil, Chemical and Environmental Engineering
Curriculum in Structural and Geotechnical Engineering, Mechanics and Materials
Curriculum in Geotechnical Engineering
A.Y. 2022/2023 (XXXVIII cycle)

(course is open for participation of students from other PhD cycles or programs)

1. Title

Unsaturated soils: theory and practice

2. Course Description

The aim of the Course is to provide basic knowledge on the theory of unsaturated soils including applications to engineering design cases.
The first part of the course is devoted to the introducing unsaturated soil mechanics to highlight the main difference with classical saturated soil mechanics. Initially, the role of surface tension and intergranular capillary menisci will be discussed before introducing the stress variables for unsaturated soils. Then, one of the best-known constitutive models for unsaturated soils, the BBM (Barcelona Basic Model), will be described.
The soil-water retention behaviour and its applications to the monitoring of unsaturated slopes stability and the management of agricultural soils will be also addressed. A particular focus will be placed on the modelling of the influence of both soil deformation and hydraulic hysteresis on the retention behaviour of unsaturated soils.
Several examples of the importance to incorporate unsaturated soil framework into traditional engineering problems will be presented. The effects of the degree of saturation on the response of laterally loaded piles, settlements induced by water table oscillation, effects of artificial/natural ground freezing and evaporation/infiltration processes will be analysed in detail, exploring the available experimental data, the numerical results and the theoretical framework. A practical module on numerical modelling aims on providing the tools to set the governing equations and the proper initial/boundary conditions of selected case studies that involve unsaturated soils, then going to the implementation via the Finite Element software Comsol Multiphysics®.

3. Course Organization

The course consists of lectures and exercises articulated in four modules:
1) Introduction to unsaturated soils and the BBM (Domenico Gallipoli - 3h in total)
- 1 hour – From Terzaghi to unsaturated soil mechanics: bulk water vs meniscus water and the justification for overcoming a single tensorial effective stress variable
- 1 hour – Definition of tensorial and scalar stress variables for describing the mechanical behaviour of unsaturated soils
- 1 hours – Main features of unsaturated soil behaviour captured by BBM. Description of the isotropic and deviatoric parts of BBM. Advantages and limitations of BBM

2) Soil-water retention behaviour (Agostino Walter Bruno - 5h in total)
- 1 hour – Introduction to relevant variables (*e.g.,* degree of saturation, gravimetric or volumetric content, soil suction) and their relationships, *i.e.,* soil-water retention curves
- 1 hour – Experimental techniques for measuring soil water content and suction, *e.g.,* high-capacity tensiometers, soil moisture sensors, *etc.*
- 2 hours – Influence of soil deformation and hydraulic hysteresis on the retention behaviour of unsaturated soils and its analytical modelling
- 1 hour – Application: an automated data-quality control method based on the soil-water retention curve

3) Laterally loaded piles in unsaturated soils (Leonardo Maria Lalicata - 6h in total).

- 1 hour – Position of the problem: behaviour of laterally loaded piles, strength and stiffness of unsaturated soils, SWRC.
- 1 hour – Experimental observations: centrifuge tests, principles of physical modelling, analysis of the results
- 1 hour – Numerical analysis: introduction to FEM, numerical modelling of soil-structure interaction problems, critical analysis of the results
- 1 hour – Theoretical framework: how to account for unsaturated soils within traditional design methods
- 2 hours – Exercises: application to the proposed method to the design of a pile.

4) Modelling coupled phenomena in Comsol Multiphysics® (Giulia Guida – 11 h in total)

- 1 hours – Case studies of coupled phenomena that involves partially saturated soils
- 2 hours – Derivation of the governing balance equations, mass and energy balances
- 2 hours – Practical's on Settlements induced by the water table oscillation. Framing of the problem and practical implementation and analysis
- 3 hours – Practical's on Evaporation and Infiltration process. Framing of the problem and practical implementation and analysis
- 3 hours – Practical's on Artificial Ground Freezing. Framing of the problem and practical implementation and analysis

4. Lecturers

Prof. Dr. Domenico Gallipoli
Dr. Agostino Walter Bruno
Dr. Leonardo Maria Lalicata
Dr. Giulia Guida

5. Duration and credits

25 hours (5 credits)

6. Activation mode and teaching period

The course will take place from the 28th of November to the 2nd of December 2022 (5 lectures of 3 hours each and 5 lectures of 2 hours each). The minimum number of participants to activate the course is 3.

7. Registration

The deadline for registration is November 15th, 2022. Please send an e-mail simultaneously to: Domenico Gallipoli (domenico.gallipoli@unige.it), Agostino Walter Bruno (agostinowalter.bruno@unige.it), Leonardo Lalicata (leonardo.lalicata@unige.it) and Giulia Guida (giulia.guida@uniroma2.it).

8. Final exam

Test examination at the end of the course