PhD course on
Coupled hydro-mechanics of unsaturated soils

1 July – 4 July 2024 (total number of 4 days)
Politecnico di Milano

COURSE COORDINATORS
Gabriele Della Vecchia & Cristina Jommi, Politecnico di Milano

TEACHERS
Gabriele Della Vecchia and Cristina Jommi, Politecnico di Milano
Guido Musso, Politecnico di Torino
Marco Caruso and Chiara Rossignoli, Politecnico di Milano

COURSE DESCRIPTION
The course covers fundamental evidence and modelling approaches for soils in unsaturated states.
The lectures start from fundamental physical processes, including the choice for alternative variables to describe them. Experimental testing equipment and procedures are introduced, including microstructure investigation and non-destructive indirect testing. Paradigmatic experimental results are presented and discussed. Coupling between the hydraulic and the mechanical response is highlighted, together with the role played by the evolving microstructure. Modelling principles are introduced, discussing the choice for kinematic and static variables and alternative strategies to extend existing models to unsaturated states. The state surface approach will be introduced for both the hydraulic and the mechanical response, before diving into the framework of elastoplasticity with generalised hardening, which may include information on the microstructure. Uncoupled and coupled hydro-mechanical models are discussed. To address engineering problems, the fully coupled three-phase balance equations are formulated. Implications and shortcomings of simplified two-phase approaches are analysed with reference to paradigmatic applications. Setting initial conditions and boundary conditions is discussed, before going towards numerical implementation and analysis via Finite Element approximation.

LEARNING OBJECTIVES
- Evaluate the mutual influence of different physical-chemical processes on the response of soils in unsaturated states
- Assess proper experimental techniques to study the hydro-mechanical behaviour of unsaturated soils
- Compare advantages and shortcomings of different approaches to model the mechanical and hydraulic response of unsaturated states
- Design a FE analysis for an unsaturated soil system
- Develop a simple code for 1D analysis of evaporation and infiltration processes

PREREQUISITES
Basic soil mechanics, elastoplasticity and Finite Element knowledge is suggested as prerequisite.

EXAMINATION
A final examination will be arranged for the students who require it. It will consist in preparing and discussing a further in-depth presentation on one of the topics addressed during the course.

ECTS: 5

PhD course on

Coupled hydro-mechanics of unsaturated soils

1 July – 4 July 2025
Politecnico di Milano, Department of Civil and Environmental Engineering

Tuesday, 1st July: Fundamentals & Experimental Testing – Grandori Room

09.00-09.30: **Introduction**
C. Jommi & G. Della Vecchia

9.30-11.00: **Fundamentals: processes and variables**
G. Della Vecchia

11.0-11.30 Coffee Break

11.30-13.00: **Experimental testing 1/3: equipment and procedures**
G. Musso

13.00-14.30: Lunch

14.30-16.00: **Experimental testing 2/3: element testing**
G. Musso

16.00-16.30: Coffee Break

16.30-18.00: **Experimental testing 3/3: microstructure and advanced methods**
G. Musso

Wednesday, 2nd July: Experimental evidence – Grandori Room

09.00-11.00: **Experimental evidence (1/2): hydraulic behaviour, micromechanical evidence and water retention curve modelling**
G. Della Vecchia

11.00-11.30: Coffee Break

11.30-13.30: **Experimental evidence (2/2): mechanical behaviour: stiffness, strength, coupled response over hydro-mechanical stress paths**
C. Jommi

Thursday 3rd July: Constitutive modelling– Grandori Room

09.00-10.00: **Constitutive modelling (1/3): principles and approaches, state surfaces, elastic-plastic models**
C. Jommi

10.0-10.30: Coffee Break

10.30-12.30: **Constitutive modelling (2/3): suction dependent elastic -plastic models and BBM**
G. Della Vecchia

12.30-14.00: Lunch

14.00-16.00: **Constitutive modelling (3/3): fully coupled hydro-mechanical models including microstructure, modelling the role of pore-fluid chemistry in unsaturated conditions**
G. Della Vecchia

16.15-17.00: **Information and instruction on practical**
C. Rossignoli, M. Caruso

Friday 4th July: Numerical Modelling– Grandori Room

09.00-11.00: **Numerical modelling: fully coupled balance equations and discretisation. Simplified two-phase and one-phase approaches. Initial conditions, boundary conditions**
C. Jommi

11.00-11.30: Coffee Break

11.30-13.00: **Hands on soil-atmosphere interaction**
C. Jommi, C. Rossignoli, M. Caruso

13.00-14.30: Lunch

14.30-16.00: **Practical on numerical modelling (1/2): simulating evaporation and infiltration**
C. Rossignoli, M. Caruso

16.00-16.30: Coffee Break

16.30-18.00: **Practical on numerical modelling (2/2): simulating evaporation and infiltration**
C. Rossignoli, M. Caruso