

# PhD course on Coupled hydro-mechanics of unsaturated soils

28 June – 1 July 2022  
Politecnico di Milano

## **COURSE COORDINATORS**

Cristina Jommi & Gabriele Della Vecchia, Politecnico di Milano

## **LECTURERS**

Cristina Jommi and Gabriele Della Vecchia, Politecnico di Milano

Guido Musso, Politecnico di Torino

Giulia Guida, Università degli Studi di Roma, Tor Vergata

## **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**

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Politecnico di Milano, Room 3.1.8/3.2.2

On-line (cisco-WebEx platform)

<https://politecnicomilano.webex.com/meet/cristina.jommi>

## Tuesday, 28 June: Fundamentals & Experimental Testing – Room 3.1.8

- 09.00-09.30: **Introduction**  
C. Jommi & G. Della Vecchia
- 09.30-11.00: **Fundamentals: processes and variables**  
G. Della Vecchia
- 11.00-11.30: 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, 29 June: Experimental evidence – Room 3.1.8

- 09.00-11.00: **Experimental evidence (1/2): hydraulic behaviour and micromechanical evidence**  
C. Jommi
- 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, 30 June: Constitutive modelling – Room 3.1.8

- 09.00-10.00: **Constitutive modelling (1/3): principles and approaches, state surfaces, elastic-plastic models**  
C. Jommi
- 10.00-10.30: Coffee Break
- 10.30-12.30: **Constitutive modelling (2/3): suction dependent elastic -plastic models, water retention 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**  
G. Della Vecchia

#### Friday, 1 July: Numerical Modelling – Room 3.2.2

- 09.00-11.00: **Numerical modelling (1/2): 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: **Numerical modelling (2/2): Engineering applications and case histories**  
C. Jommi, G. Guida
- 13.00-14.30: Lunch
- 14.30-16.00: **Practical on numerical modelling (1/2): simulating evaporation**  
G. Guida
- 16.00-16.30: Coffee Break
- 16.30-18.00: **Practical on numerical modelling (2/2): numerical implementation and analysis**  
G. Guida