OZ Doctoral course, ALERT Geomaterials, ED353, Aix-en-Provence, France, 22-26 April 2024

Hydro-mechanical behavior of geomaterials for civil engineering structures

Theoretical models, simulations, lab testing and risk analysis

Objectives: How to characterize and model the hydro-mechanical behavior of geomaterials from the microscale to the structure scale?

Monday April 22nd		
	13h30-14h	Welcome coffee
	14h-16h	**Hydraulic actions on soil: erosion, hydro-mechanical instabilities (P. Philippe)**
	16h-16h30	Coffee break
	16h30-18h30	**Mechanical behavior of granular materials (N. Benahmed)**
	19h-21h	Poster session from participants and cocktail
Tuesday April 23rd	9h-11h	**Mechanical instabilities and failure in granular materials** (A. Wautier)
	11h-11h30	Coffee break
	11h30-13h30	**Mixing properties in granular media (M. Souzy)**
	13h30-14h30	Lunch
	14h30-17h30	**The Discrete Element Method (DEM): a numerical modeling approach adapted to geomaterials** (J. Duriez)
Wednesday April 24th	9h-12h	**Practice of DEM** (A. Wautier)
	12h-13h	Lunch
	13h-15h	**Multi-phase Lattice Boltzmann Method (LBM) and its Application to Partially Saturated Granular Soils (Theory and Practice)** (N. Younes)
	15h-15h30	Coffee break
	15h30-18h	**Simulating large displacement problems in Continuum Mechanics with the Material Point Method (MPM)** (J. Duriez)
Thursday April 25th	10h-12h	**Risk assessment of civil engineering structures** (L. Peyras)
	12h-13h	Lunch
	13h-15h	**Uncertainty propagation and reliability analysis** (C. Carvajal)
	15h-15h30	Coffee break
	15h30-17h30	**Practical session on dam failure assessment** (L. Peyras et C. Carvajal)
Friday April 26th	9h30-11h	Lab tour (geomechanics and geosynthetics)
	11h-15h	Hike tour to Zola and Bimont Dams

Detailed content of the course

1- Hydraulic actions on soil: erosion, hydro-mechanical instabilities (P. Philippe, 2h)
General context: flood risk, protective structures, external and internal erosion
Surface erosion: local law(s), erosion lab tests and interpretation models
Example for piping erosion and contact erosion
Hydro-mechanical instabilities: fluidization, gravity collapse

2- Mechanical behavior of granular materials (N. Benahmed, 2h)
General concepts: strain, stress-strain relationship, effective stresse
Experimental characterization of geomaterials: different types of tests, drained/undrained behaviors; Volumetric strain behavior (contracting/dilatation), triaxial shear strength, relationship with constitutive soil properties
Instability and failure of geomaterials: instability line, characteristic line, critical state (Mohr-Coulomb criterion)
Examples of instability-related disorders

3- Mechanical instabilities and failure in granular materials (A. Wautier, 2h)
Definitions: instability, bifurcation, failure
Granular plasticity: interlocking between elasticity and plasticity, plasticity-non-association, incrementally non-linear plasticity
Failure modes: diffuse or localized failure, material or structural softening
Instability criteria: plastic limit surface, localization criterion, second-order work criterion
criterion

4- Mixing properties in granular media (M. Souzy, 2h)
General concepts: mixing, dispersion, molecular diffusion, stretching laws
Mixing in dry granular media, segregation, rotating drum, fluidized bed, vibrations
Mixing of particle suspensions, interstitial flow, lamellar approach, Diffusive Strip Method, coalescence
Mixing in porous media, experimental characterization of stretching laws, 3D velocity fields in porous medium, anomalous dispersion
Example of particle suspension flow in a constriction: risk of clogging and intermittent flow

5- The Discrete Element Method (DEM): a numerical modeling approach adapted to geomaterials (J. Duriez, 2h)
Presentation of the DEM calculation cycle
Contact laws, particle shape, numerical damping, parallel calculation concepts
DEM as a tool for virtual experiments providing continuum stress and strain quantities
Overview of hydro-mechanical couplings

6- Practical session: Implementation of a 1D minimal DEM code and introduction to YADE (A. Wautier, 3h)
This session requires that students have a computer (loan possibilities to be discussed with the teacher) Python (https://www.python.org/) installed, and know how to use classes.
For the YADE part: Ubuntu desktop with sudo apt install permission or any other Operating System with Docker installed.

7- Multi-phase Lattice Boltzmann Method (LBM) and its Application to Partially Saturated Granular Soils (Theory and Practice) (N. Younes, 2h)
Origins, Background, and Theory
Benchmarks (Real-time Tutorial)

Coupling with the Discrete Element Method (DEM) for simulating partially saturated granular assemblies at the Representative Elementary Volume (REV)
Modeling Partially Saturated Granular Assemblies: Investigating various aspects at the REV scale, including suction, capillary stress, and more.

8- Simulating large displacement problems in Continuum Mechanics with the Material Point Method (MPM) and CB-Geo MPM – PyCBG softwares (J. Duriez, 2h30)
Overview of the MPM formulation for solving linear momentum balance equation in continua : capabilities and limitations of MPM
Hands-on activity on MPM simulations with the CB-Geo MPM code and its PyCBG interface
Ubuntu desktop with sudo apt install permission or any other Operating System with Docker installed

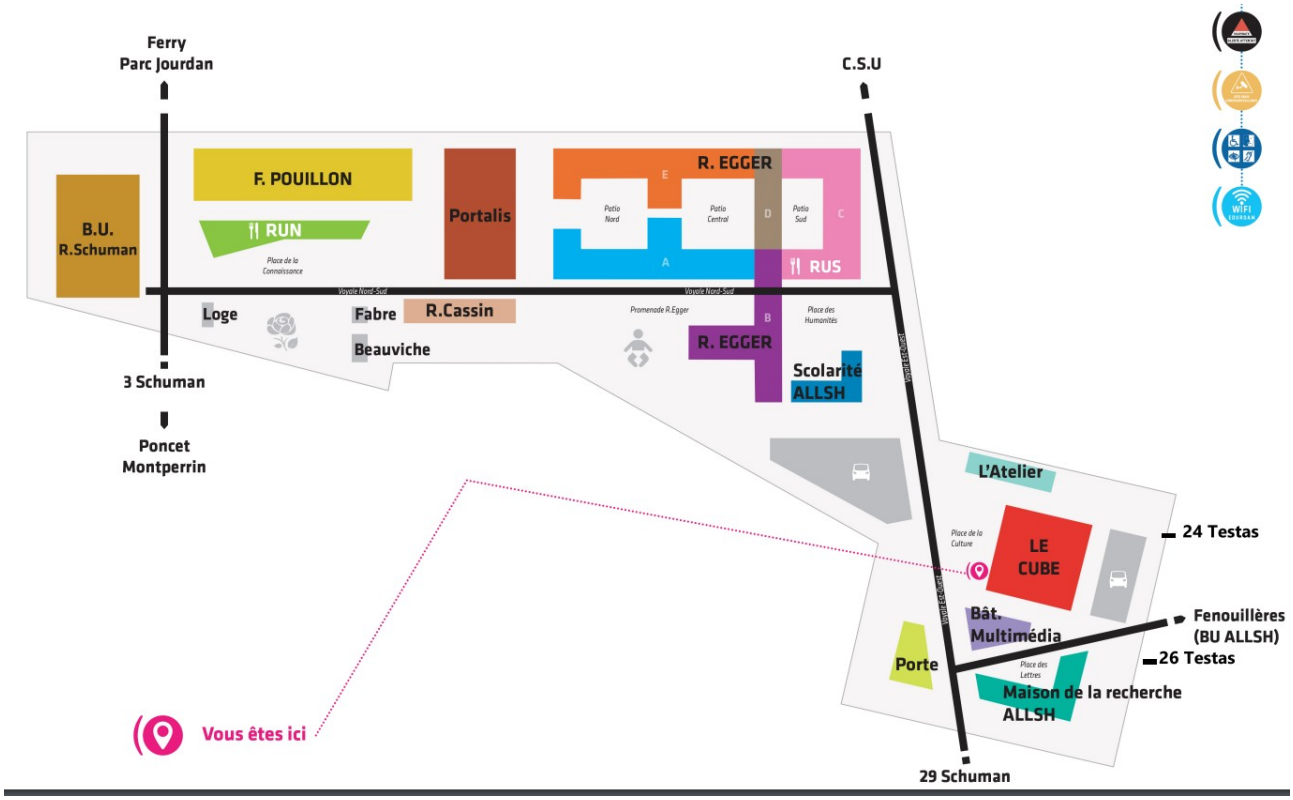
9- Safety assessment of civil engineering structures (L. Peyras, 2h)
Introduction to operational safety
Functional analysis
System failure mode analysis: overview of the existing methods (APR, APD, AMDE, AMEC, HAZOP)
System failure scenario analysis: overview of the existing methods (event trees, cause-trees, bow-tie)
System safety assessment: probabilistic, semi-probabilistic, expert
Illustrated examples on civil engineering systems

10- Uncertainty propagation and reliability analysis (C. Carvajal, 2h)
Introduction of uncertainties in mechanical modeling
Random variables and random fields
Mechano-fiabilistic coupling: First-Order Reliability Method, response surfaces, Monte-Carlo simulations

11- Practical session: Mechano-fiabilistic computations for the risk assesment of the rupture of a dam (L. Peyras et C. Carvajal, 2h)
Application of courses 9 and 10 on the real case of a dam

Practical information

The course will be held in Aix-en-Provence (France) from Monday April 22nd to Friday April 26th. The lecture room is located in "Le cube" on Aix-Marseille University campus. The address is 29 Av. Robert Schuman, 13100 Aix-en-Provence. Here is a map of the campus.



To reach Aix-en-Provence by train the most convenient is to stop at Aix-en-Provence TGV (note that there is also a train station in Aix-en-Provence city center but accissible only with regional trains) and then take the bus 40 to the city center. Participants coming by plane can land at Marseilles Airport and also reach Aix-en-Provence by bus 40.

To move around in Aix-en-Provence, you can check public transportation here : https://www.aixenbus.fr/fr/

On the Friday, we will propose to participants to come to visit the geomechanics and geosynthetics labs at INRAE and then take a tour in the mountain Sainte-Victoire. From Aix-en-Provence, to reach the premises, take bus 13 (or bus 110) to Le Tholonet (stop at Ferrageon).

On the Monday evening, a poster session will be organize for the participants to share their research work. A cocktail will be served during the poster session in the spirit of ALERT famous poster session.

There will be no registration fee for the course. Lunches and coffee breaks should be included. The participants will need to cover travel, hotel and diner costs.
For any question, please feel free to contact Antoine Wautier (antoine.wautier@inrae.fr) or Nadia Benahmed (nadia.benahmed@inrae.fr).

To attend the course, please register before March 15th here:
https://evento.renater.fr/survey/course-ed353-et-oz-c...-m1opux05