TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 11	**May 12**	**May 13**	**May 14**	**May 15**
9.00 - 9.45	Registration	dell'Isola	Millet	Li	Wan
9.45 - 10.30	Overview	dell'Isola	Millet	Li	Wan
11.00 - 11.45	Kruyt	Millet	Li	dell'Isola	Kruyt
11.45 - 12.30	Kruyt	Millet	Li	dell'Isola	Kruyt
14.00 - 14.45	Nicot	Li	Wan	Millet	
14.45 - 15.30	Nicot	Li	Wan	Millet	
16.00 - 16.45	Wan	Nicot	dell'Isola	Nicot	
16.45 - 17.30	Wan	Nicot	dell'Isola	Nicot	
18.00	Welcome Aperitif				

ADMISSION AND ACCOMMODATION

The registration fee is 600.00 Euro + VAT*, where applicable (bank charges are not included). The registration fee includes a complimentary bag, four fixed menu buffet lunches (on Friday upon request), hot beverages, downloadable lecture notes and wi-fi internet access.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through the following web site: http://www.cism.it. A message of confirmation will be sent to accepted participants. Applicants requiring assistance with the registration should contact the secretariat at the following email address: cism@cism.it.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email to cism@cism.it) no later than two weeks prior to the start of the course.

Cancellation requests received during the two weeks prior to the start of the course will be charged a 50.00 Euro handling fee. Incorrect payments are also subject to a 50.00 Euro handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered lodging and/or board, if available, in a reasonably priced hotel or student guest house.

Requests should be sent to CISM Secretariat by **March 11, 2020** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on the web site www.cism.it, or can be mailed upon request.

* Italian VAT is 22%.

For further information please contact:
CISM
Palazzo del Torso
Piazza Garibaldi 18
33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
fax +39 0432 248550

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2020
The Erwin Stein Session

MULTI-PHYSICS AND MULTISCALE COUPLINGS IN GEO-ENVIRONMENTAL MECHANICS

Advanced School
coordinated by

Niels Kruyt
University of Twente
Enschede, The Netherlands

Olivier Millet
University of La Rochelle, France

Udine ***May 11 - 15*** 2020

MULTI-PHYSICS AND MULTISCALE COUPLINGS IN GEO-ENVIRONMENTAL MECHANICS

This course focuses on complex phenomena in geo-environmental engineering, where a combination of physical phenomena occurs at different scales. In-depth understanding of such multi-physics and multi-scale approaches is increasingly becoming important in many novel applications, in particular in the understanding of the behavior of triggering mechanisms of landslides, avalanches, stability of granular soils.

This lecture series is aimed at academic and industrial researchers active in the fields of geo-environmental engineering, powder technology, chemical engineering, etc. The course gives a coherent view of the field, and hence is particularly suitable to researchers from various backgrounds that are in the initial and intermediate phases of their professional career.

Modern multi-physics and multi-scale approaches for geo-environmental problems frequently are based on three core competences: (1) continuum mechanics for large-scale problems, (2) Discrete Element Method simulations for detailed studies of small-scale systems and (3) multi-scale analyses for bridging the small-scale behavior to the large-scale, continuum level. These competences will be taught in the course. The basic concepts and tools of each competence will be explained. This will smoothly evolve to expositions of recent research findings. The international team of lecturers is active in academic teaching as well as research.

The course will start with recapitulating basic knowledge (continuum mechanics, Discrete Element Method, multi-scale analysis) to the wide target audience and then progress to highlight the latest research findings (homogenization of dry and partially-saturated granular assemblies, associated mean strain and stresses, multi-physics description at microscopic scale, stability analyses of granular assemblies, solutions of Young-Laplace equation).

The topics that will be addressed include the multi-physics description at the small scales of capillary effects that result in cohesive forces at a larger scale which ultimately determine the (in) stability of granular assemblies. For such partially-saturated granular materials, it is shown how the behavior at the small-scale (capillary bridge properties that are determined by the Young-Laplace equation) can explain the macro-scale behavior, through suitable homogenization techniques (requiring a capillary stress and a statistical description of the micro-scale structure). Such analyses are complemented with Discrete Element Method simulations.

The background and relevance of extended continuum-mechanical theories (higher-order, Cosserat) to the behavior of granular materials will be explained, in connection to the latest research findings.

For the prediction of the avalanches and stability of granular soils in geo-environmental problems, the latest developments in the use of the second-order work approach are taught. This is connected to micro-scale modeling of granular soils.

PRELIMINARY SUGGESTED READINGS

E. Turco, F. dell'Isola, A. Misra: A nonlinear Lagrangian particle model for grains assemblies including grain relative rotations. International Journal for Numerical and Analytical Methods in Geomechanics 43: 1051-1079 (2019).

F. dell'Isola, D. Steigmann (Eds.). Discrete and Continuum Models for Complex Metamaterials. Cambridge University Press (2020).

N.P. Kruyt: Statics and kinematics of discrete Cosserat-type granular materials. International Journal of Solids and Structures 40: 511-534 (2003).

N.P. Kruyt, L. Rothenburg: A micromechanical study of dilatancy of granular materials. Journal of the Mechanics and Physics of Solids 56: 411-427 (2016).

G. Gagneux, O. Millet: Analytic calculation of capillary bridges properties deduced as an inverse problem from experimental data. Transport in Porous Media 105: 117-139 (2014).

H.-N.-G. Nguyen, O. Millet, G. Gagneux: Exact calculation of axisymmetric capillary bridge properties between two unequal-sized spherical particles. Mathematics and Mechanics of Solids, 24(9): 2767-2784 (2019).

R. Wan, F. Nicot, F. Darve: Failure in Geomaterials. ISTE Press – Elsevier (2017).

F. Nicot, F. Darve: The H-microdirectional model: accounting for a mesoscopic scale. Mechanics of Materials 43: 918-929 (2011).

X. Li, H.-S. Yu, X.-S. Li: Macro-micro relations in granular mechanics. International Journal of Solids and Structures, 46: 4331-4341 (2009).

X. Li, H.-S. Yu: Fabric, force and strength anisotropies in granular materials: A micromechanical insight. Acta Mechanica, 225: 2345-2362 (2014).

J. Duriez, M. Eghbalian, R. Wan, F. Darve: The micromechanical nature of stresses in triphasic granular media with interfaces. Journal of the Mechanics and Physics of Solids 99: 495-511 (2017).

R. Wan, S. Khosravani, M. Pouragha: Micromechanical analysis of force transport in wet granular soils. Vadose Zone Journal, 13: vzj2013.06.0113 (2014).

N. Lu, W. J. Likos: Unsaturated Soil Mechanics, Wiley (2004).

INVITED LECTURERS

Francesco dell'Isola - University of L'Aquila, Italy
6 lectures on: micro-macro identification between discrete and continuum models, multiscale architectured metamaterials, complex discrete Lagrangian systems, higher gradient and microstructured continua.

Niels Kruyt - University of Twente, The Netherlands
6 lectures on: basics of continuum mechanics, Discrete Element Method simulations; micromechanics and homogenization of granular materials; micromechanical expression for stress and strain; fabric; dilatancy.

Xia Li - Southeast University, Nanjing, Jiangsu, China
6 lectures on: experimental observations of the complex soil constitutive behaviour, structure description and state characterization, particle-continuum scaling-up, directional statistic technique, implementation of complex loading path in DEM simulation, force-transmission and deformation pattern, micro-mechanisms contributing to the loading and history dependence of granular materials.

Olivier Millet - University of La Rochelle, France
6 lectures on: partially saturated granular media, solutions of Young-Laplace equation for axisymmetric capillary bridges, minimization of surface energy under constraints, states of equilibrium, stability analysis and rupture of capillary bridges, experimental measurement techniques.

François Nicot - Irstea, Grenoble, France
6 lectures on: stress computation in granular media, multiscale approach for geo-environmental issues, micromechanically-based modeling of failure and instability in granular geomaterials.

Richard Wan —University of Calgary, Canada
6 lectures on: transport in wet granular materials with focus on micromechanical approaches; characteristics of triphasic media, definition of stress tensor in a system of particles interacting with distributed capillary bridges, homogenization, notion of capillary stress tensor, Discrete Element Method simulations for wet granular assemblies.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.