DIPARTIMENTO DI INGEGNERIA
STRUTTURALE E GEOTECNICA

SAPIENZA
UNIVERSITÀ DI ROMA

DOTTORATO IN
INGEGNERIA STRUTTURALE E GEOTECNICA

PROGRAMMA ATTIVITA' DIDATTICA A.A. 2016/17

CONSTITUTIVE MODELLING IN SOIL PLASTICITY

Lecture Series by

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ABSTRACT
This short course will address the formulation and application of the constitutive theory of plasticity to soil mechanical response. After the general formulation in terms of internal variables and outline of the Critical State Theory (CST) as a constitutive framework for soils, specific constitutive models for clays and sands will be presented in triaxial and multiaxial stress space. The role of Bounding Surface for cyclic loading and state dependent dilatancy for compliance with the premises of CST will be emphasized. Finally the recently developed Anisotropic Critical State Theory (ACST) that brings into the constitutive framework the role of fabric will be elaborated, and the adjustment of previous models from CST to ACST will be illustrated. Some special topics will be briefly addressed, such as the zero elastic range models and the extension to rate-dependent visco-plasticity.

TARGET AUDIENCE: PhD students (*main*), Post-doctoral fellows (*secondary*), Researchers from both Italy and abroad.

DATES AND VENUE
Dates: 9 – 12 October 2017
Venue: DISG – Aula Caveau, Faculty of Civil and Industrial Engineering, Via Eudossiana 18, 00184 Rome

LAYOUT OF THE COURSE:
- ✓ Monday, 9th October: 11:30 – 13:30, 14:30 – 16:30 (Lecture 1)
- ✓ Tuesday, 10th October: 11:30 – 13:30, 14:30 – 16:30 (Lecture 2)
- ✓ Wednesday, 11th October: 11:30 – 13:30, 14:30 – 16:30 (Lecture 3)
- ✓ Thursday, 12th October: 11:30 – 13:30, 14:30 – 16:30 (Lecture 4)

1. **Elasto-plasticity in mechanics**
   Relevant experimental evidences – Formulation of classical elastoplasticity – Hardening and softening: the role of internal variables

2. **Constituitve modelling in soil plasticity: triaxial formulation**
   Critical State Theory-Isotropic and anisotropic models for soils – Bounding surface plasticity - Zero elastic range model

3. **Constituitve modelling in soil plasticity: multiaxial formulation**
   Generalization of triaxial formulation and concepts to multiaxial stress space

4. **Particular topics**
   Anisotropic critical state theory (ACST) - Role of Discrete Element Method (DEM) – Non-coaxiality - Rate dependence (visco-plasticity).

OUTLINE

These lectures, supplemented by selected publications, will introduce the readers to both basic and advanced features of constitutive modeling in soils plasticity. The underlying framework will be that of macroscopic mathematical theory of plasticity with internal variables. The exposition of the material will be done in phases, as follows.

In the first phase, relevant experimental data under various loading conditions, monotonic and cyclic, will help to identify the main features of elastic-plastic response that must be modeled. Subsequently the basic analytical formulation of classical elastoplasticity will be presented in a particularly simple way, encompassing any material and all classical models within the framework of plastic internal variables, and motivated by a simple friction-block mechanistic model of the underlying microscopic mechanism of plastic deformation. The role of hardening and softening in conjunction with the evolution equations of the internal variables and the ensuing value of the plastic modulus will be emphasized, as well as the important aspect of the material response under stress reversals which upon repetition lead to cyclic loading.

In the second phase the corresponding soil plasticity formulation will be presented within the general framework of the first phase, and will be restricted to triaxial stress and strain spaces. The general constitutive framework of Critical State Theory (CST) will underlie the formulation, but instead of considering CST as the starting point, it will rather be considered as a particularly relevant response framework within the general classical elastoplasticity formulation. This is believed to facilitate the understanding of both soil plasticity and CST in a mutually helpful way.
The role of dilatancy will be emphasized as the main distinguishing feature from metal plasticity. Both isotropic and anisotropic models for soils will be presented, the latter motivated by the inability of isotropic models to capture important features of the soil response, such as the response under cyclic loading conditions. The bounding surface plasticity concept will be presented and specialized to soil plasticity with applications to both clays and sands; as a corollary the zero elastic range model will be outlined. While the general framework is the same for all soils, salient differences between sands and clays will necessitate to present different particular models for each category.

In the third phase, the focus will be directed towards a systematic way to generalize a constitutive model from the triaxial to the multiaxial (or generalized) stress space. The educational benefits of this phase notwithstanding, it will provide the means for the construction of constitutive models at a level that allows their implementation in existing numerical codes for general boundary value problem analysis. The process of generalization will show that it is not enough to obtain a model in the triaxial space, without having first thought of how to extend its features to the general stress space. Examples will illustrate the above including the models developed in the second phase for the triaxial space, as well as the multiaxial generalization of the bounding surface concept.

In the fourth phase the classical critical state theory (CST) will be revisited in view of the important role that fabric anisotropy plays in regards to soil mechanical response. The recently developed Anisotropic Critical State Theory (ACST) will be presented as a necessary extension of CST to include fabric effects, and corresponding constitutive modeling within ACST will be outlined. The role of Discrete Element Method (DEM) in those topics will be presented. Particular topics will be briefly addressed, such as the extension to rate dependent plasticity (visco-plasticity), the non-coaxiality aspects for anisotropic soils and the response of soils when subjected to stress principal axes rotation with fixed stress principal values.

NOTE: Relevant NOTES on some of the course material will be distributed and will be used together with selected publication during the course presentation; the audience is requested to have those notes and publications in the classroom.
Each lesson will be arranged in a 3+1h scheme; the +1h will be devoted to Q&A in the lecture room so that everybody can take advantage of the discussion on attendants' questions and specific research curiosities.

SPEAKER BIO
Yannis F. Dafalias received the diploma in Civil Engineering from the National Technical University of Athens (NTUA), the M.Sc. in Engineering Mechanics from Brown University and the PhD in Engineering Sciences from the University of California, Berkeley. Currently he is Distinguished Professor at the CEE department of the University of California, Davis and Emeritus Professor at the NTUA. His major field is Continuum Mechanics, with application in the areas of solid, structural and soil mechanics. His research focuses on inelastic constitutive modeling of engineering materials, with additional contributions to structural optimization, turbulence modeling in fluid dynamics, biomechanics and cellular mechanics.

He is the recipient of the Walter L. Huber Civil Engineering Research Prize from ASCE, the Foreign Researcher Shield Plate by the Japanese Society of Soil Mechanics and Foundation Engineering, the Nathan M. Newmark Medal awarded by the EMI and SEI of ASCE and the Norman Medal of ASCE. He delivered the Mindlin Lecture at Columbia University and he was awarded a prestigious FP7 IDEAS Advanced Grant for research from the European Research Council. He is Fellow of EMI and ASCE.

Attendees will be awarded a certificate that is valid for accreditation (5 CFU)
Ai partecipanti sarà rilasciato un certificato per l'acquisizione di 5 CFU.

The course is free of registration fees. Applications must be submitted to the Secretariat of the PhD program:

L'iscrizione al corso è gratuita ma è necessario inviare la richiesta di partecipazione alla Segreteria del Dottorato:

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