Course guide
250816 - 250816 - Unsaturated Soil Mechanics

Last modified: 25/01/2024

Unit in charge: Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN GEOTECHNICAL ENGINEERING (Syllabus 2015). (Optional subject).

Academic year: 2023 **ECTS Credits:** 5.0 **Languages:** Spanish

LECTURER

Coordinating lecturer: ENRIQUE EDGAR ROMERO MORALES

Others: ENRIQUE EDGAR ROMERO MORALES, JEAN VAUNAT

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
13308. To conceive soils and rocks as porous media governed by Solid and Fluid Mechanics.
13310. To interpret laboratory tests and field observations so as to identify the mechanisms responsible for soil response. To propose laboratory testing programmes.
13312. To analyze, discriminate and integrate geological and geotechnical information in studies and projects.

Generical:
13300. To apply advanced knowledge in sciences and technology to the profesional or research practice.
13301. To lead, coordinate and develop integrated projects in Geo-Engineering.
13302. To identify and design solutions for geo-engineering problems within ethical, social and legislative frameworks.
13303. To evaluate the impact of Geo-engineering on environment, sustainable social development and the significance of working within reliable and consciensous profesional environment.
13304. To incorporate new techncologies and advanced tools in Geo-engineering into profesional and research activities.
13305. To conceive Geo-engineering as a multi-disciplinary field that includes relevant aspects from geology, sismology, hydrogeology, geotechnical and earthquake engineering, geomechanics, physics of porous media, geophysics, geomatics, natural hazard, energy and climate interactions.
13306. To promote innovation for the development of methodology, analyses and solutions in Geo-engineering
13307. To tackle and solve advanced mathematical problems in engineering from the drafting of the problem to the development of formulation and further implementation in computer programs. Particularly, to formulate, code and apply analytical and numerical advanced computational tools to project calculations in order to plan and manage them as well as to interpret results in the context of Geo-engineering and Mining engineering.

TEACHING METHODOLOGY

The course consists of 1,5 hours per week of classroom activity (large size group) and 1,5 hours weekly with half the students (medium size group).

The 1,5 hours in the large size groups are devoted to theoretical lectures, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises.

The 1,5 hours in the medium size groups is devoted to solving practical problems with greater interaction with the students. The objective of these practical exercises is to consolidate the general and specific learning objectives.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENEA: content, program of learning and assessment activities conducted and literature.

Although most of the sessions will be given in the language indicated, sessions supported by other occasional guest experts may be held in other languages.

LEARNING OBJECTIVES OF THE SUBJECT

To conceive soils and rocks as porous media governed by Solid and Fluid Mechanics.
To interpret laboratory tests and field observations so as to identify the mechanisms responsible for soil response. To propose laboratory research programmes.
To formulate and implement Finite Element and Finite Differences numerical models with the objective to analyze the processes that govern ground response, to interpret field information and to predict soil response.
To analyze, discriminate and integrate geological and geotechnical information in studies and projects.

* To recognize and interpret the response of soils to the presence of thermo-hydro-mechanical coupling phenomena.
* To suggest advanced laboratory tests to determine thermo-hydro-mechanical parameters in soils and rocks.
* To apply scientific advanced concepts to suggest new solutions for problems rising in Geotechnical Engineering, in which thermo-hydro-mechanical coupling plays a governing role (waste storage, geothermics, interaction of geo-infrastructures with the weather...).

Introduction: unsaturated soils in geotechnical practice.
- Basic concepts in unsaturated soil mechanics.
- Experimental techniques.
- Mechanical behaviour. Constitutive models.
- Flow and deformation. Coupled problems.

Conceptualize partially saturated soils as a porous media governed by Solid and Fluid Mechanics concepts.
Interpret laboratory tests and field observations to identify the mechanisms responsible for the response of the soil.
Plan programs of experimentation in the laboratory.
Formulate and program numerical models to analyze the processes that govern the response of the soil.
Interpret the field information and predict the response of the soil.
Analyze, discriminate and integrate in studies and projects the available geotechnical and geological information.

* Recognizes and interprets the response of the soil in the presence ofcoupled thermo-hydro-mechanical phenomena.
* Plans advanced laboratory tests to determine the parameters thermo-hydro-mechanical soil and rocks.
* Apply advanced scientific concepts to propose innovative solutions to emerging problems in Geotechnical Engineering where thermo-hydro-mechanical coupling plays a significant role (waste storage, geothermal, geoinfraestructures interaction of climate ...).

- Introduction: unsaturated soils geotechnical practice.
- Basics of unsaturated soil mechanics.
- Experimental techniques.
- Mechanical behavior. constitutive models.
- Flow and deformation. Coupled problems.

STUDY LOAD

Type	Hours	Percentage
Hours small group	9,8	7.83
Self study	80,0	63.95
Hours large group	25,5	20.38
Hours medium group	9,8	7.83

Total learning time: 125.1 h

CONTENTS

I: Introduction and basics concepts

Description:
1. Introduction. Engineering importance of unsaturated soils: Foundations, pavements, terreplenes, earth dams, slope stability, clay barriers, radioactive waste storage.
2. Natural soils. Arid climates. Residual soils. Geotechnical behavior. Foundation problems.
Basic properties of water. Properties of vapor. Properties of air and the dissolved air. Psychrometric law .Total, capillary and osmotic suction. Water potential. Retention curve.

Specific objectives:
Framing the engineering significance of the behavior of unsaturated soils.
Studying the origin of the soil and the interaction between environmental conditions and the distribution of soil moisture.
Study basic soil components and their physical properties. Know the fundamental aspects of the behavior of unsaturated soils as psicrométrica law, capillary, suction components, water potential, water retention curve and relative permeability.

Full-or-part-time: 28h 47m
Theory classes: 6h
Laboratory classes: 6h
Self study : 16h 47m

II: Experimental Techniques

Description:
Techniques for measuring suction. Tensiometers, filter paper, psychrometers, resistive methods, TDR.
Techniques suction control. Suction plate. Translation axis techniques. Osmotic techniques. techniques for relative humidity control.

Controlled suction equipment. Oedometer, isotropic and triaxial cells. Direct shear.
Suction and water content measurement "in situ"

Specific objectives:
Review and analyze of the different techniques of control and measurement of suction.
Application of techniques suction control to perform mechanical laboratory tests.
Know the techniques for measurement of suction and volumetric water content "in situ".

Full-or-part-time: 14h 23m
Practical classes: 3h
Laboratory classes: 3h
Self study : 8h 23m

First test

Description:
First test

Specific objectives:
Doing exercises to determine the level of knowledge attained

Full-or-part-time: 7h 11m
Practical classes: 3h
Self study : 4h 11m

III: Mechanical behavior

Description:
Volumetric behavior of unsaturated soils.
Influence of suction, loading under constant suction or water content .
Suction changes under load. Collapse. Increase in suction. Other stress paths. Humidity cycles. Synthesis.
Effect of deviatoric stress. Suction cycles.
Unsaturated soil stiffness (small deformation). Influence of suction. Triaxial and resonant column tests. Nonlinear elastic models.
Unsaturated soil strength. Failure envelope. Proposed models.
Effective stresses in saturated and unsaturated soils.
Bishop's proposal.
Work due to deformation and changes in water content.
Set of significant stresses. Alternatives
A basic elastoplastic model for unsaturated soils (BBM Model Basic Model of Barcelona).
Elastic-plastic model for isotropic states of stress. Triaxial extension states.
Generalized stress formulation (3D).
Model parameters. Critical models and BBM.
Comparing model predictions with experimental results.

Specific objectives:
Knowing unsaturated response against changes paths with suction and isotropic load floor. Analysis of reversible and irreversible changes due to suction or tension strains.
Knowing the effect of suction on the soil response under shear stresses.
To characterize the strength of unsaturated soil.
Knowing the dificulatdes to generalize the concept of effective stress in unsaturated soils.
Knowing the alternatives to define the generalized stress state in the soil.
Knowing the formulation of Barcelona basic model (BBM).
Compare model predictions with the actual behavior of the soil. Know the limitations of BBM.

Full-or-part-time: 28h 47m
Theory classes: 12h
Self study : 16h 47m

IV: Behavior of compacted soil

Description:
Compaction principles.
Properties of compacted soils.
Microstructure of compacted soils.
Constitutive modeling.
Practical criteria.
Foundations on compacted soils.

Specific objectives:
Knowing the properties of compacted soils.
Highlight the role of the microstructure.
Knowing a constitutive model.
Learn practical applications.

Full-or-part-time: 7h 11m
Theory classes: 3h
Self study : 4h 11m

V: Behavior of expansive soils

Description:
Behavior of expansive soils.
Basic mechanisms of expansion: microstructure of expansive soils.
Qualitative behavior of soil following common test paths. Foundations on swelling soils.
Modeling of expansive soils.
Thermo-hydro-mechanical coupling.
Modeling clay barriers in radioactive waste repositories.

Specific objectives:
Knowing the mineralogy and expansion mechanisms of expansive soils.
Knowing the hydro-mechanical behavior of expansive soils.
Knowing techniques of foundations on expansive soils.
Present real cases of modeling of the behavior of clay barriers in radioactive waste disposals.

Full-or-part-time: 14h 23m
Theory classes: 3h
Practical classes: 3h
Self study : 8h 23m

Second Test

Description:
Second tets

Full-or-part-time: 7h 11m
Practical classes: 3h
Self study : 4h 11m

GRADING SYSTEM

The final grade is based on an assessment of:

1.Two tests to perform within one hour of class time .
2. A written work that is done individually on a topic related to the subject. The work is delivered through Athena following the instructions of the revue "Géotechnique" described in the document "Guidelines for the drafting of the work." The evaluation will consider both the scientific quality of the work, as the quality of the written presentation.
3.An oral presentation of the written work in class during a time of 20 minutes (+ 5 minutes of questions on the subject presented). the presentation will be evaluated on the basis of qualification guidelines established in the document "Criteria for evaluating the oral exposure."

The weighting in the final grade for each of these three aspects will be:

Final grade = 0.3 * Average ratings of tests + 0.5 * Rate of written work + 0.2 * Rate of oral presentation.

EXAMINATION RULES.

5 short questions about what is explained in class.

BIBLIOGRAPHY

Basic:
- Ng, C.W.W; Menzies, B. Advanced Unsaturated Soil Mechanics and Engineering [on line]. London: Taylor and Francis, 2007 [Consultation: 22/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781118280492. ISBN 9780415436793.
- D. G. Fredlund, H. Rahardjo and M. D. Fredlund. Unsaturated Soil Mechanics in Engineering Practice [on line]. 2012. John Wiley & Sons, Inc., 2012 [Consultation: 18/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781118280492. ISBN 9781118280515.