

## Course guides

# 250407 - GEOMENGTER - Geomechanical and Geotechnical Engineering

**Last modified:** 06/10/2020

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

**Degree:** MASTER'S DEGREE IN CIVIL ENGINEERING (PROFESSIONAL TRACK) (Syllabus 2012). (Compulsory subject).  
MASTER'S DEGREE IN GEOTECHNICAL AND EARTHQUAKE ENGINEERING (Syllabus 2009). (Optional subject).  
MASTER'S DEGREE IN CIVIL ENGINEERING (PROFESSIONAL TRACK) (Syllabus 2012). (Compulsory subject).

**Academic year:** 2020    **ECTS Credits:** 6.0    **Languages:** English

### LECTURER

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**Coordinating lecturer:** SEBASTIAN OLIVELLA PASTALLE

**Others:** ANTONIO GENS SOLE, ALBERTO LEDESMA VILLALBA, SEBASTIAN OLIVELLA PASTALLE

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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**Specific:**

8200. The ability to apply knowledge of soil and rock mechanics to the study, design, construction and operation of foundations, cuts, fills, tunnels and other constructions over or through land, whatever its nature and state, and whatever the purpose of the work.

**Transversal:**

8559. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding the mechanisms on which scientific research is based, as well as the mechanisms and instruments for transferring results among socio-economic agents involved in research, development and innovation processes.

8562. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

8563. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

### TEACHING METHODOLOGY

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The course consists of 4 hours per week of classroom activity.

The 4 hours are devoted to theoretical lectures/ practical lectures and laboratory practical sessions, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises. Some sessions are "hands on" using geotechnical software.

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.

## LEARNING OBJECTIVES OF THE SUBJECT

Students will learn to use analytical and numerical models to conduct geomechanical analyses of geotechnical structures. They will also learn to diagnose geomechanical factors in situations encountered in geotechnical engineering.

Upon completion of the course, students will be able to:

Use analytical and numerical models to conduct geomechanical analyses of geotechnical structures, and diagnose geomechanical factors in situations encountered in geotechnical engineering;

Use nonlinear critical-state models to analyse geotechnical processes involving soil-rock interactions, including hydromechanical coupling;

Plan, design, construct and maintain foundations, embankments, tunnels and other geotechnical structures.

Advanced study of critical-state theories (state parameters in sand models) and description of real behaviour; Aspects of the real behaviour of soils and rocks, including nonlinearity (focusing on small deformations), structure (bonding), mechanical and hydraulic anisotropy, softening (progressive localization and fracture), yield strength, behaviour of unsaturated soils and liquefaction; Case studies examining the influence of these aspects on engineering applications; Planning, design, construction and maintenance of foundations, cut-slopes, embankments, tunnels and other geotechnical structures

## STUDY LOAD

Type	Hours	Percentage
Theory classes	26,0	17.33
Guided activities	2,0	1.33
Practical classes	13,0	8.67
Self study	96,0	64.00
Laboratory classes	13,0	8.67

**Total learning time:** 150 h

## CONTENTS

### Theme 1. Geomaterials

#### Description:

General description of natural materials. Soils. Formation, structure, sedimentary basins, residual soils, cemented soils. Hard soils and soft rocks. Discontinuities in massive rocks. Creep. Geomechanical analysis: continuum media, discrete elements, joints.

#### Specific objectives:

An introduction to geomaterials is carried out.

**Full-or-part-time:** 4h 48m

Theory classes: 2h

Self study : 2h 48m



## Theme 2. Hidro-mechanical coupling in geomaterials

### Description:

Flow and deformation coupling. Formulation based on displacements and pressures. Undrained conditions, undrained shear strength. Consolidation. Drained conditions.

Extension of the coupled formulation to the thermo-hydro-mechanical behaviour of porous media (including vapour migration). Generalized constitutive laws for mechanical, hydraulic and thermal.

Introduction to numerical methods in geotechnical analysis. Excavation and construction of elements. Initial stresses. Mesh extension. Structural elements.

Application to cases that use simple models in order to become familiar with boundary value problems, initial conditions and boundary conditions, intervals, structural elements, properties of programs.

### Specific objectives:

Development of the formulation

Development of the formulation. To be able to incorporate or eliminate terms associated to processes depending on the type of problems to be solved.

To learn the basic aspects of numerical methods applied for the solution of geotechnical problems.

Practical session to introduce geotechnical modelling.

**Full-or-part-time:** 19h 12m

Theory classes: 4h

Practical classes: 2h

Laboratory classes: 2h

Self study : 11h 12m

## Theme 3. Geomechanical behaviour of clays and sands

### Description:

Stress strain response of clays. Critical state theory and Cam-clay model

Typical behaviour of sands. State parameters. Liquefaction. Cyclic mobility.

Analytical and numerical simulation of oedometric and triaxial tests in saturated soils using coupled models.

### Specific objectives:

To understand the experimental response of argillaceous soils subjected to a general stress-strain path. To be able to anticipate, in a qualitative way, the response in a laboratory experiment.

Understanding the experimental response of granular soils subjected to general stress-strain solicitations. To be able to anticipate, in a qualitative way, the response in a laboratory experiment.

To learn using modelling tools and its application to simulate laboratory tests including parameter determination and establishing the capabilities and limitations of the equations considered.

**Full-or-part-time:** 14h 23m

Theory classes: 4h

Laboratory classes: 2h

Self study : 8h 23m



#### Theme 4. Unsaturated soils

**Description:**

Suction. Behaviour of unsaturated soils: expansion and collapse deformations. Elastic models. State variables. Models for unsaturated geomaterials. Barcelona Basic Model and other models. Swelling and collapse. Shear strength.

Expansive and collapsible soils. Soil structure. Compaction criteria and representation of compaction in the models. Swelling pressure.

Simulation of oedometric and triaxial tests in unsaturated soils using coupled models. Embankment construction, effect of rain. Earth dam construction, reservoir filling and rapid drawdown.

**Specific objectives:**

To introduce the basic concepts of unsaturated soils, and the deformations proces taking place. To show the different state variables that can be used in constitutive models according to different model capabilities.

To describe the derivation of models for unsaturated geomaterials and to understand the physical processes that help to derive the macroscopic models.

To understand the processes of expansión/swelling in soils, the applications that can be considered or the problems that may appear due to expansion/swelling in soils, how the structure is modified during swelling and collapse, and how these processes are represented in constitutive models.

To reach, by means of practice, the knowledge of the response of unsaturated and saturated soils and the models that can be used to reproduce the response against loading and inundation proceses.

**Full-or-part-time:** 21h 36m

Theory classes: 6h

Laboratory classes: 3h

Self study : 12h 36m

#### Theme 5. Hard soils and soft rocks.

**Description:**

Behaviour of bonded soils. Results of oedometric and triaxial tests. Description of processes causing the bonding and their influence on the response of geomaterials.

Extension of models to incorporate bonding. Introduction of the concept of residual strength. Softening by bonding degradation. Drained and undrained conditions.

Progressive failure. Application to slope failure.

**Specific objectives:**

Understanding the mechanisms that explain the features observed in cemented/bonded soils. To understand how the mehanisms are related with the stress-strain response.

To stablish the way that constitutive models can be modified to incorporate the effect of soil bonding, starting from basic models usually applied in geotechnique.

Failure of some geotechnical structures can only be explained by means of progressive failure. For this, models that incorporate a stress-strain curve with a residual strength after the peak-strength can be used.

**Full-or-part-time:** 14h 23m

Theory classes: 4h

Practical classes: 2h

Self study : 8h 23m



## Theme 6. Small strain nonlinear behaviour

### Description:

Behaviour of soils at small strains. Nonlinear elasticity. Characterization by means of geofisical testing and laboratory resonant column.

Application of small strain elasticity theory for the analysis of history cases such as tunnels in urban areas. Instrumentation systems.

### Specific objectives:

To introduce the deviations that occur on the elastic response of the geomaterials at zones that undergo small strain, for instance, because these are far from the zone of larger influence.

To understand, based on applications, the effects that may induce the variable stiffness of the ground depending the sollicitation level, on the movements of geotechnical constructions, mainly on the underground constructions.

**Full-or-part-time:** 9h 36m

Theory classes: 2h

Practical classes: 2h

Self study : 5h 36m

## Evaluation

### Description:

Global Evaluation

**Full-or-part-time:** 9h 36m

Laboratory classes: 4h

Self study : 5h 36m

## Theme 7. Other aspects on the real behaviour of geomaterials

### Description:

Structural anisotropy in soils and soft rocks. Induced anisotropy. Mechanical and hydraulic anisotropy.

Static liquefaction and liquefaction under cyclic loading. Models for geomaterials including dynamic effects.

Thermal behaviour of soils. Frozen soils. Vapour in soils. Thermo-hidro-mecanical problems.

Creep in soils and rocks. Physical processes that explain creep of geomaterials. Secondary consolidation.

### Specific objectives:

To understand the causes for mechanical and hydraulic anisotropy that occur in geomaterials.

To understand the liquefaction phenomenon, and to learn the engineering aspects that are involved.

To understand and apply non-isothermal conditions to geomaterials.

To understand and apply processes associated to delayed response of geomaterials.

**Full-or-part-time:** 19h 12m

Theory classes: 8h

Self study : 11h 12m



## Theme 8. Geotechnical analysis using numerical methods.

### Description:

Particular aspects of geotechnical analysis using finite element method. Coupled and uncoupled analysis. History cases, modelling methodology, assumptions to develop a geotechnical model from a real case.

### Specific objectives:

To be able to determine the added value that a numerical analysis may bring to the study of a geotechnical problem and to be able to determine the level of complexity required in the model (processes, dimensionality, constitutive models).  
To be able to transform a real problem into a model. Process of model verification and validation.

### Full-or-part-time: 12h

Practical classes: 5h

Self study : 7h

## GRADING SYSTEM

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Two exams will be done, one of them as global. The mark will be calculated as the maximum between the arithmetic average of the two exams and the mark of the global exam. In addition, a practical part will contribute with 20% to the final mark.

## EXAMINATION RULES.

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Failure to perform a practical exercise or continuous assessment activity in the scheduled period will result in a mark of zero in that activity.

## BIBLIOGRAPHY

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### Basic:

- Wood, D.M. Soil behaviour and critical state soil mechanics. Cambridge: University Press, 1990. ISBN 0521337828.
- Potts, D.M.; Zdravkovic, L. Finite element analysis in geotechnical engineering. London: Thomas Thelford, 1999-2001. ISBN 0727727532.
- Atkinson, J. The mechanics of soils and foundations. 2nd ed. London: Taylor & Francis, 2007. ISBN 9780415362566.