250801 - Modelling in Geoengineering

**Coordinating unit:** 250 - ETSECCPB - Barcelona School of Civil Engineering  
**Teaching unit:** 751 - DECA - Department of Civil and Environmental Engineering  
**Academic year:** 2019  
**Degree:** MASTER'S DEGREE IN GEOTECHNICAL ENGINEERING (Syllabus 2015). (Teaching unit Compulsory)  
**ECTS credits:** 5  
**Teaching languages:** Spanish

### Teaching staff

**Coordinator:** JEAN VAUNAT  
**Others:** JEAN VAUNAT

### Opening hours

**Timetable:** Time schedule for personal support is arranged with the teacher during the class or by email.

### 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.
- 13311. 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.

#### General:

- 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.
- 13304. To incorporate new technologies 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.
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Teaching methodology

The course consists of 3 hours per week of classroom activity (large size group).

The 1 hour 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 2 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.

Learning objectives of the subject

To conceive soils and rocks as porous media governed by Solid and Fluid Mechanics.
To characterize the geological environment and its interaction with civil works.
To interpret laboratory tests and field observations so as to identify the mechanisms responsible for soil response. To propose laboratory testing 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 recognize the problems in Civil Engineering.
* To relate the problems in Civil Engineering to the characteristics of the geological environment.
* To conceptualize the problem in Civil Engineering in order to analyze, model and solve them.
* To apply continuum media concepts to analyze and model problems in Civil Engineering.
* To apply numerical techniques to solve Civil Engineering problems.

- Definition of a model. Modelling frameworks.
- Methods to approximate derivatives. Application to Geo-Engineering problems governed by ordinary differential equations.
- Finite differences method. Application to flow problems in soils.
- Methods to approximate integrals. Application to semi-analytical solutions in Geo-engineering.
- Finite elements method. Application to mechanical problems in Geo-Engineering.
- Methods to solve non-linear systems. Application to coupled problems in Geo-Engineering by means of the Finite Element Method.

Study load

<table>
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<tr>
<th>Study load</th>
<th>125h</th>
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<tbody>
<tr>
<td>Theory classes:</td>
<td>19h 30m</td>
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<tr>
<td>Practical classes:</td>
<td>9h 45m</td>
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<tr>
<td>Laboratory classes:</td>
<td>9h 45m</td>
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<tr>
<td>Guided activities:</td>
<td>6h</td>
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<tr>
<td>Self study:</td>
<td>80h</td>
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## Content

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<td><strong>Description:</strong></td>
<td>Theory classes: 1h</td>
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<tr>
<td>Choosing a physical problem</td>
<td>Practical classes: 2h</td>
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<tr>
<td>Formulation of the equations</td>
<td>Self study : 4h 11m</td>
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<tr>
<td>Obtaining the analytical solution</td>
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<tr>
<td><strong>Specific objectives:</strong></td>
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<tr>
<td>To formulate problems in the field of Geotechnical engineering in view of its numerical resolution</td>
<td></td>
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<tr>
<td>To formulate Geotechnical Engineering problems in the form of equations</td>
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<tr>
<th><strong>Solving flow problems using the Finite Difference method</strong></th>
<th><strong>Learning time:</strong> 26h 24m</th>
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<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 3h</td>
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<tr>
<td>Classification of differential equations</td>
<td>Practical classes: 6h</td>
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<td>Approximation of derivatives</td>
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<td>Discretization of the derivative of the ODE</td>
<td>Self study : 15h 24m</td>
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<td>Numerical solution</td>
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<td>Comparison with the analytical solution</td>
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<tr>
<td>Description of the Finite Difference method</td>
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<td>Discretization schemes</td>
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<tr>
<td>Numerical solution of the mass balance equation</td>
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<tr>
<td>Selection of a flow problem</td>
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<tr>
<td>Formulation of the equations</td>
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<tr>
<td>Obtaining an analytical, semi-analytical or empirical solution</td>
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<tr>
<td><strong>Specific objectives:</strong></td>
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<tr>
<td>To workout discretization methods for derivatives and their characteristics</td>
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<tr>
<td>To solve numerically an ODE</td>
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<tr>
<td>To solve mass balance equation using the Finite Difference method</td>
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<tr>
<td>To formulate an EDP in Geotechnical Engineering</td>
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## Solving mechanical problems using the Finite Element method

**Learning time:** 48h  
Theory classes: 16h  
Practical classes: 2h  
Laboratory classes: 2h  
Self study: 28h

**Description:**
- Methods for integral approximation
- Bibliographic search of a semi-analytical solution for problem 3
- Numerical computation of the integral
- Calculation of the semi-analytical solution
- Introduction to the Finite Element method
- Theoretical considerations
- The theorem of virtual work
- Spatial discretization
- Application of the boundary conditions
- Basic programming in Matlab
- Numeric tools available in Matlab
- Data reading tools and print / display results
- Structure of an EF program
- Formulation of two uni-dimensional mechanical problems (settlements for a multi-layer elastic ground, deformation of a diaphragm wall under earth-pressure).
- Programming in Matlab of a program to solve the two problems in a unified way.

**Specific objectives:**
- To compute numerically integrals
- To solve mechanical problems using the Finite Element method
- To code in Matlab a Finite Element program solving a mechanical problem
- Program a Finite Elements code to solve mechanical problems in Geotechnical Engineering

## Solving coupled problems in Geotechnical Engineering

**Learning time:** 12h  
Theory classes: 5h  
Self study: 7h

**Description:**
- Formulation of the consolidation equation
- Analytical solution
- Resolution through Finite Difference and Finite Element methods
- More general coupled problems (2D, 3D, multiphysics)

**Specific objectives:**
- To solve coupled problems in Geotechnical Engineering
The mark of the course is obtained from the ratings of continuous assessment and their corresponding laboratories and/or classroom computers.

Continuous assessment consist in several activities, both individually and in group, of additive and training characteristics, carried out during the year (both in and out of the classroom).

The teachings of the laboratory grade is the average in such activities.

The evaluation tests consist of a part with questions about concepts associated with the learning objectives of the course with regard to knowledge or understanding, and a part with a set of application exercises.

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

Basic:

