250240 - ENGGEOTEC - Geotechnical Engineering

Coordinating unit: 250 - ETSECCPB - Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering
Academic year: 2017
Degree: BACHELOR'S DEGREE IN PUBLIC WORKS ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 4.5
Teaching languages: Catalan, Spanish

Teaching staff

Coordinator: SEBASTIAN OLIVELLA PASTALLE
Others: ALEJANDRO JOSA GARCIA-TORNEL, SEBASTIAN OLIVELLA PASTALLE, IVAN PUIG DAMIANS, ALFONSO RODRIGUEZ DONO, JOSÉ LUIS ZORNOZA GÓMEZ

Opening hours

Timetable: The hours are carried out both during the intervals between classes and through personally or by e-mail agreed hours

Degree competences to which the subject contributes

Specific:
3074. Knowledge of soil and rock geotechnics and mechanics and the ability to apply it in carrying out studies, projects, constructions and exploitations in which earthmoving, foundations and retention structures are necessary.
3080. Knowledge of the design, calculation, construction and maintenance of building works in regard to their structure, finishes, installations and equipment.
3083. Ability to construct and conserve railway lines with knowledge of the application of the specific technical regulations, differentiating the characteristics of the rolling stock.
3085. Ability to construct geotechnical works.
3087. Knowledge of and ability to design and dimension hydraulic works and facilities, energy systems and the harnessing of hydroelectric energy, and plan and manage surface and underground hydraulic resources.
3091. Ability to construct, conserve, dimension and design roads and the items comprising basic road provision.
3092. Ability to construct and conserve railway lines with knowledge of the application of the specific technical regulations, differentiating the characteristics of the rolling stock.

Generical:
3105. Students will learn to identify, formulate and solve a range of engineering problems. They will be expected to show initiative in interpreting and solving specific civil engineering problems and to demonstrate creativity and decision-making skills. Finally, students will develop creative and systematic strategies for analysing and solving problems.
3106. Students will learn to assess the complexity of the problems examined in the different subject areas, identify the key elements of the problem statement, and select the appropriate strategy for solving it. Once they have chosen a strategy, they will apply it and, if the desired solution is not reached, determine whether modifications are required. Students will use a range of methods and tools to determine whether their solution is correct or, at the very least, appropriate to the problem in question. More generally, students will be encouraged to consider the importance of creativity in science and technology.
3107. Students will learn to identify, model and analyse problems from open situations, consider alternative strategies for solving them, select the most appropriate solution on the basis of reasoned criteria, and consider a range of methods for validating their results. More generally, students will learn to work confidently with complex systems and
Students will learn to apply knowledge of geotechnical engineering, soil mechanics and rock mechanics in studies, projects, construction work and operations that require earthworks, foundations or retaining walls.

Learning objectives of the subject

Students will learn to apply knowledge of geotechnical engineering, soil mechanics and rock mechanics in studies, projects, construction work and operations that require earthworks, foundations or retaining walls.
Upon completion of the course, students will have acquired the ability to: 1. Develop the construction specifications for a shallow foundation structure on the basis of a geological-geotechnical study. 2. Develop the construction specifications for a deep foundation structure on the basis of a geological-geotechnical study. 3. Design a retaining wall and carry out a stability and in-service performance analysis.

Site-investigation techniques: Behaviour of shallow foundations, calculation of bearing capacity and settlement, design and checking; Behaviour of deep foundations, calculation of bearing capacity and settlement, design and checking; Lateral earth pressure theory and its application to the calculation of pressure coefficients in retaining walls; Behaviour of rigid and flexible retaining walls including drainage, stability monitoring, anchorage elements, and stability and in-service performance analysis

Expected outcomes for student learning:

* Knowledge, understanding and reasoning ability and solving exercises and problems with manual and computer calculation and design of actual basic cases of shallow and deep foundations and retaining structures (walls and sheet pile walls) with different water and load states and stratigraphy, knowledge, understanding and reasoning abilities of complementary aspects such as soil exploration, instrumentation or improvement, and several examples of foundations in special cases as large span bridges or buildings of great height.

* Knowledge of typical values and orders of magnitude of the variables used and critical capacity of values for them.

* Capability of independent study, use of library resources, teamwork and of following more advanced courses in the field of geotechnical engineering.

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 112h 30m</th>
<th>Hours large group: 30h</th>
<th>26.67%</th>
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<tbody>
<tr>
<td>Hours medium group: 9h</td>
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<tr>
<td>Hours small group: 6h</td>
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<td>Guided activities: 4h 30m</td>
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<tr>
<td>Self study: 63h</td>
<td>56.00%</td>
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## Content

### UNIT 1. INTRODUCTION TO THE SUBJECT

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<th>Description:</th>
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<td>1.1. CONTENTS AND APPROACH</td>
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<td>1.2. DEVELOPMENT, PROGRAM AND REFERENCES</td>
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<td>1.3. EVALUATION</td>
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**Specific objectives:**
Basic knowledge of the main types of problems encountered and solved in the subject and general aspects of its organization (focus, development of classes, program, literature and evaluation).

<table>
<thead>
<tr>
<th>Learning time: 2h 24m</th>
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<tbody>
<tr>
<td>Theory classes: 1h</td>
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<td>Self study: 1h 24m</td>
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### UNIT 2. SOIL EXPLORATION

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<td>2.1 STATEMENT OF THE PROBLEM. OBJECTIVES</td>
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<td>2.1.1 Information and information timely extension</td>
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<td>2.1.2 Obtaining useful parameters for the geotechnical calculation</td>
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<td>2.2 PREVIOUS EXAMINATION</td>
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<tr>
<td>2.2.1 Study of the maps available in the area</td>
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<td>2.2.2 Studies in adjacent areas</td>
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<td>2.2.3 Direct observation of the ground</td>
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<td>2.3 METHODS OF RECOGNITION</td>
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<td>2.3.1 Manual recognition</td>
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<tr>
<td>2.3.2 Soundings. Sampling. Profiles</td>
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<td>2.4 IN SITU TESTS</td>
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<tr>
<td>2.4.1 Penetrometric tests</td>
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<td>2.4.2 Load tests</td>
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<td>2.4.3 Geophysical tests</td>
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<td>2.5 GEOTECHNICAL REPORT. CONTENT AND STRUCTURE</td>
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Exercises of item 2, supplemented with additional concepts from theory

**Specific objectives:**
Knowledge, understanding and reasoning ability and application of the techniques used in soil exploration to identify the properties that characterize the soil behavior (deformability, strength) and allow the undertaking of the project of foundations, foundation structures and other geotechnical problems (analysis of slope stability, soil improvement, drainage, excavation, etc.), including soil exploration design, existing soil exploration methods, penetrometric geophysical and loading in situ tests, or the development of the soil exploration report.

Knowledge of typical parameters of different procedures for soil exploration.
Practice and deepening of concepts, knowledge and developments in item 2

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<th>Learning time: 12h</th>
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<tbody>
<tr>
<td>Theory classes: 4h</td>
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<td>Practical classes: 1h</td>
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<tr>
<td>Self study: 7h</td>
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### UNIT 3. FUNCTION AND TYPES OF FOUNDATIONS

**Description:**
- 3.1. FUNCTION OF FOUNDATIONS. LIMIT CONDITIONS TO MEET
- 3.2. TYPES OF FOUNDATIONS AND GENERAL APPLICATION FIELDS
- 3.3. GENERAL PROCEDURE AND FACTORS CONDITIONING THE PROJECT OF FOUNDATIONS

**Specific objectives:**
Knowledge, understanding and reasoning ability of the function, type, basic behavior and general fields of application of shallow and deep foundations, of the limit conditions to be met by them, and the general procedure and conditioning factors of the foundation project.

Knowledge of typical dimensions of different types of foundations.

**Learning time:** 2h 24m
- Theory classes: 1h
- Self study: 1h 24m
UNIT 4. SHALLOW FOUNDATIONS

Description:
4.1. INTRODUCTION. TYPES AND GENERAL APPLICATION FIELD
4.2. SOIL WORKING STRESSES
4.3. BEARING CAPACITY. GENERAL ASPECTS
   4.3.1. Failure mechanisms
   4.3.2. Expression of Brinch Hansen. Correction factors
   4.3.3. Eccentric load. Approximate procedure
   4.3.4. Drained and undrained processes in cohesive soils
   4.3.5. Water Effect
   4.3.6. Other specific cases
4.4. BEARING CAPACITY. LAYERED SOIL
   4.4.1. Introduction. Overview
   4.4.2. Empirical approaches
   4.4.3. Case of two layers with punching in the upper one
   4.4.4. Other cases
4.5. ESTIMATE OF THE BEARING CAPACITY AND WORKING STRESSES FROM SITE TESTS
4.6. SETTLEMENT OF SHALLOW FOUNDATIONS
   4.6.1. Introduction. Terminology
   4.6.2. Elastic method
   4.6.3. Oedometric method
   4.6.4. Other methods
4.7. SAFETY FACTORS
4.8. PROJECT OF SHALLOW FOUNDATIONS
   4.8.1. Preliminary dimensioning
   4.8.2. Actions to consider. Verification procedure
   4.8.4. Constructive aspects
Exercises and problems of item 4, supplemented by additional concepts of theory

Specific objectives:
Knowledge, understanding and reasoning ability and solving exercises and problems in relation to the soil working stresses, the bearing capacity and settlements of shallow foundations under varying conditions of stratigraphy (homogeneous or stratified soil), loads (vertical or inclined, centered or eccentric), water (dry or saturated), conditions (drained or undrained), type (strip or isolated), support (shallow or deep), and its design in all these cases.

Knowledge, understanding and reasoning ability of the typology, the general field of application and failure mechanisms of shallow foundations, the estimation of the working stresses and bearing capacity from on-site testing, the definition of the safety factors, and the development of specific projects.

Knowledge of typical values of parameters relating to the calculation of shallow foundations (working pressures and bearing capacity of different soil types, safety factors, etc.).
Practice and deepening of concepts, knowledge and developments of item 4
## UNIT 5. DEEP FOUNDATIONS

### Learning time:
- **Theory classes:** 4h
- **Practical classes:** 1h 30m
- **Self study:** 7h 42m

### Description:
- **5.1. INTRODUCTION**
- **5.2. TYPES OF PILES**
- **5.3. INDIVIDUAL PILE. BEARING CAPACITY**
  - **5.3.1. Introduction**
  - **5.3.2. Tip resistance. Static and semi-empirical expressions**
  - **5.3.3. Shaft resistance**
  - **5.3.4. Piling formulas and load tests**
- **5.4. PILE GROUPS. BEARING CAPACITY**
- **5.5. DISTRIBUTION OF LOADS ON PILE GROUPS**
- **5.6. FAILURE AND SERVICE DESIGN**
- **5.7. NEGATIVE SKIN FRICTION AND OTHER SPECIAL ACTIONS**
- **5.8. CALCULATION PROCEDURE AND TECHNOLOGICAL CODES**
- **5.9. PROJECT OF DEEP FOUNDATIONS**
  - **5.9.1. Preliminary dimensioning**
  - **5.9.2. Actions to consider. Verification procedure**
  - **5.9.4. Constructive aspects**
- **Exercises item 5, supplemented with additional concepts from theory**

### Specific objectives:
- **Knowledge and understanding of the different types of piles in relation to the load transmission to the soil, construction procedure, pile manufacture and material, and general fields of application.**
- **Knowledge, understanding and reasoning ability and solving exercises and problems of individual piles in relation to both the tip and the shaft bearing components (theoretical formulas based on static failure mechanisms and actual calculation based on in situ penetrometric results or piling formulas), pile groups (bearing capacity and load distribution as a result of vertical and horizontal loads), structural strength and settlements.**
- **Knowledge, understanding and reasoning ability in relation to special loads (negative skin friction, bearing capacity with lateral horizontal forces, pulling, bending and lateral pressures from other structures) and in some cases calculation methods for solving exercises and problems, and development of specific projects.**
- **Knowledge of typical values and orders of magnitude of resistance to penetration (static and dynamic), bearing capacity of individual piles, structural strength, pile diameters, separation, length and number of piles in a group. Practice and deepening of concepts, knowledge and developments of item 5**

## EVALUATION

### Learning time:
- **Laboratory classes:** 4h
- **Self study:** 5h 36m
## Unit 6. Function and Types of Soil Retaining Walls

### Description:
- 6.1 Role of Retaining Structures. Basic Nomenclature
- 6.2 Types of Retaining Structures
- 6.3 Earth Pressure

### Specific Objectives:
Knowledge and understanding of the function, basic terminology, typology and general behavior of soil retaining structures.

### Learning Time:
- Theory classes: 1h
- Self study: 1h 24m
UNIT 7. WALLS

Description:
7.1. INTRODUCTION
7.2. ACTIVE EARTH PRESSURE. COULOMB THEORY
7.2.1. Base-case approach. Effect of cohesion
7.2.2. Effect of surface loads
7.2.3. Water effect
7.2.4. Other cases
7.3. ACTIVE EARTH PRESSURE. RANKINE THEORY
7.4. ACTIVE EARTH PRESSURE ON SPECIFIC TYPES OF WALLS
7.4.1. L walls
7.4.2. Other specific types of wall
7.5. OTHER METHODS TO ESTIMATE ACTIVE EARTH PRESSURES
7.5.1. Elastic method
7.5.2. Semi-empirical distributions
7.6. PASSIVE EARTH PRESSURE
7.6.1. Introduction. Theories of Coulomb and Rankine and methods based on static solutions
7.6.2. Modification of Kp. Parabolic reduction
7.7. PROJECT OF WALLS
7.7.1. Preliminary dimensioning. Actions to consider
7.7.2. Basic design procedure
7.7.3. Drainage
7.7.4. Other types of walls. Reinforced earth
7.7.5. Constructive aspects
Exercises and problems of item 7, supplemented with additional concepts from theory

Specific objectives:
Knowledge, understanding and reasoning ability and solving exercises and problems in relation to the estimation of the active earth pressures (and passive in certain cases) using the theories of Coulomb and/or Rankine and other approximate procedures (elastic method, semiempirical distributions) in different wall shapes (flat, broken, vertical or not vertical, L), external loads (uniformly distributed or arbitrary), soil (granular or cohesive), stratigraphy (homogeneous or stratified soil), presence of water (dry or with water table), conditions (short or long term) and the preliminary wall design including the estimation of the actions to be considered and specific phases of the design process (safety to turning and sliding, and eccentricity of base base reaction).

Knowledge of typical values and orders of magnitude of soil parameters, earth pressures and wall shapes and dimensions.

Knowledge, understanding and reasoning ability of the entire process of a wall design, drainage strategies and systems, behavior and design procedure of other types of walls (reinforced earth) and basic construction aspects. Practice and deepening of concepts, knowledge and developments in item 7.
# UNIT 8. SHEET PILE WALLS

**Learning time:** 13h 12m  
Theory classes: 4h  
Practical classes: 1h 30m  
Self study : 7h 42m

## Description:

8.1. INTRODUCTION. TYPES AND MECHANICAL BEHAVIOR  
8.2. ESTIMATION OF EARTH PRESSURES  
8.3. DESIGN OF CANTILEVER SHEET PILE WALLS  
8.3.1. Classical methods  
8.3.2. Other methods  
8.4. DESIGN OF ANCHORED SHEET PILE WALLS  
8.4.1. Sheet pile walls anchored at one level  
8.4.2. Sheet pile walls anchored at more than one level  
8.4.3. Anchors  
8.5. SHORING  
8.6. PROJECT OF SHEET PILE WALLS  
8.6.1. Preliminary dimensioning. Actions to consider  
8.6.3. Basic design procedure  
8.6.4. Other types of sheet pile walls  
8.6.5. Constructive aspects  
Exercises and problems of item 7, supplemented with additional concepts from theory

## Specific objectives:

Knowledge, understanding and reasoning ability in relation to the type, behavior, estimation and distribution of earth pressures and possible failure mechanisms of cantilever, anchored at one level or anchored at more than one level sheet pile walls, and the behavior of anchors and shoring.

Knowledge, understanding and reasoning ability and solving exercises and problems in relation to the calculation of the stability of cantilever sheet pile walls by classical methods in drained or undrained conditions, and by semiempirical procedures, of anchored at one level sheet pile walls under the hypothesis of free or fixed support, and of anchored at more than one level sheet pile walls by specific calculation assumptions.

Knowledge of typical values of parameters in cantilever, anchored at one level or anchored at more than one level sheet pile walls, anchoring and shoring.

Practice and deepening of concepts, knowledge and developments of item 7
## UNIT 9. NUMERICAL METHODS IN GEOTECHNICAL ENGINEERING

**Description:**
9.1. INTRODUCTION
9.2. METHOD OF FINITE DIFFERENCES FOR THE STEADY FLOW EQUATION
9.2.1 Introduction
9.2.2 Flow equation in finite differences
9.2.3 Boundary conditions
9.2.4 Resolution of transient problems
9.3 BASIC CONCEPTS OF FINITE ELEMENT METHOD APPLIED TO THE EQUILIBRIUM EQUATION FOR A CONTINUUM MEDIA
9.3.1 Introduction
9.3.2 Strains
9.3.3 Shape functions or interpolation functions
9.3.4 Strains using the shape functions
9.3.5 Green’s theorem
9.3.6 Equilibrium equations of tensions
9.4 PROCESS OF MODELATION
9.5 REFERENCES
APPENDIX 1. Overview of the PLAXIS software: general settings, generation of geometry, eg. Shallow circular foundation on sands.
APPENDIX 2. Description of CODE_BRIGHT and GID: definition, geometry, data input for CODE_BRIGHT

**Specific objectives:**
Knowledge, understanding and reasoning skills and application in relation to existing computer methods for calculating common geotechnical problems (boundary problems related to flow, consolidation, deformation and strength of foundations, retaining structures or excavations in dry or saturated soil), to its features, common boundary conditions, typical and special elements for the problem discretization, existing programs and procedures (problem definition, discretization, boundary conditions, processing, etc.).

Knowledge of typical characteristics and parameters of commercial software applications.

## LAB

**Description:**
Computer practice with geotechnical engineering problems supplemented with additional concepts from theory

**Specific objectives:**
Practice and deepening of concepts, knowledge and developments in item 9
UNIT 10. INSTRUMENTATION OF GEOTECHNICAL STRUCTURES

Description:
10.1. MEASUREMENT OF STRESS AND DISPLACEMENT
10.2. MEASURING INSTRUMENTS USED IN SITU
   10.2.1. Overview
   10.2.2. Piezometers. Types
   10.2.3. Total-load cells. Types
   10.2.4. Convergence tape
   10.2.5. Rod Extensometer
   10.2.6. Extensometer with magnetic detector
   10.2.7. Sliding micrometer
   10.2.8. Pendulum inclinometer
10.3. APPLICATION TO REAL CASES
   10.3.1. Cases in dams: earth and concrete dams
   10.3.2. Cases in excavations: urban excavation and tunnel
   10.3.3. Case in foundations: reinforcement and big piles
Exercises and problems of item 10, supplemented with additional concepts from theory

Specific objectives:
Knowledge, understanding and reasoning ability and application of the techniques used in the instrumentation of geotechnical structures in order to analyze their actual behavior, possible reasons for their implementation, variables (displacements, stresses, loads) to measure, and tools available to it (pressure gauges, total-load cells, convergence tapes, rod extensometers, sliding micrometer, pendulum inclinometer and others).

Knowledge and understanding of the procedure to follow in the instrumentation project and application specific cases (earth dams, urban tunnel).

Knowledge of typical parameters of different procedures for geotechnical structures instrumentation.
Practice and deepening of concepts, knowledge and developments of item 10
### UNIT 11. SOIL IMPROVEMENT

**Description:**
- 11.1. INTRODUCTION. OBJECTIVES
- 11.2. METHODS FOR SOIL IMPROVEMENT
  - 11.2.1. Densification methods
  - 11.2.2. Soil additions methods
  - 11.2.3. Thermal methods
  - 11.2.4. Reinforcement methods
  - 11.2.5. Other methods

**Specific objectives:**
Knowledge, understanding and reasoning ability and application of basic techniques for improving soil properties (strength, deformability, permeability, etc.) by densification procedures, soil additions, thermal methods, reinforcement or other, including the objectives of each method, their advantages and limitations, the basic fields of application and the implementation procedure.

Knowledge of typical parameters of the soil improvement procedures explained.

### UNIT 12. EXAMPLES OF FOUNDATIONS IN SPECIAL CASES

**Description:**
- 12.1. BRIDGE FOUNDATIONS
- 12.2. BASEMENTS BETWEEN BUILDINGS
- 12.3. REINFORCEMENT OF FOUNDATIONS
- 12.4. OTHER CASES

**Specific objectives:**
Knowledge, understanding and reasoning ability on a few significant examples of foundations in special cases (bridges, foundations close to buildings, reinforcements, high buildings), including discussion and justification and advantages and limitations.

Knowledge of basic data on the cases of special foundations explained.
Qualification system

The final grade is obtained from the corresponding to each of the activities carried out (continuous evaluation (includes several concepts), overall evaluation and computer assignments on geotechnical practical cases) as detailed in a separate document available on the subject Internet website with the complete assessment procedure.

The subject can be passed both by continuous assessment taking into account all the activities carried out during the course or by the overall assessment only. In the first case the partial evaluation has a total weight of approximately 25%, the overall evaluation has a total weight of approximately 45% and the rest has the remaining percentage.

Criteria for re-evaluation qualification and eligibility: Students that failed the ordinary evaluation and have regularly attended all evaluation tests will have the opportunity of carrying out a re-evaluation test during the period specified in the academic calendar. Students who have already passed the test or were qualified as non-attending will not be admitted to the re-evaluation test. The maximum mark for the re-evaluation exam will be five over ten (5.0). The non-attendance of a student to the re-evaluation test, in the date specified will not grant access to further re-evaluation tests. Students unable to attend any of the continuous assessment tests due to certifiable force majeure will be ensured extraordinary evaluation periods.

These tests must be authorized by the corresponding Head of Studies, at the request of the professor responsible for the course, and will be carried out within the corresponding academic period.

Regulations for carrying out activities

The tests rules are available at a specific document on the subject Internet website with a complete explanation of the evaluation procedure.

The continuous and overall evaluation tests are of multi-choice type and the computer assignments must be developed in group using computer programs applied to specific geotechnical practical cases that must be submitted in time and with a specific format.

For any of the possible procedures to pass the subject a minimum grade of 5 out of 10 must be reached.
Bibliography

Basic:


Complementary:


