Course guides

**2500031 - GECENGGEOT - Geotechnical Engineering**

**Unit in charge:** Barcelona School of Civil Engineering

**Teaching unit:** 751 - DECA - Department of Civil and Environmental Engineering.

**Degree:** BACHELOR’S DEGREE IN CIVIL ENGINEERING (Syllabus 2020). (Compulsory subject).

**Academic year:** 2021  **ECTS Credits:** 4.5  **Languages:** Spanish, English

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**LECTURER**

Coordinating lecturer: SEBASTIAN OLIVELLA PASTALLE

Others: SEBASTIAN OLIVELLA PASTALLE, IVAN PUIG DAMIANS, ALFONSO RODRIGUEZ DONO

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**DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES**

**Specific:**

14402. Knowledge of geotechnics and mechanics of soils and rocks as well as their application in the development of studies, projects, constructions and farms where it is necessary to carry out earthworks, foundations and containment structures. (Common module to the Civil branch)

14416. Capacity for the construction of geotechnical works. (Specific technology module: Civil Construction)

**Generical:**

14380. Scientific-technical training for the exercise of the profession of Technical Engineer of Public Works and knowledge of the functions of advice, analysis, design, calculation, project, construction, maintenance, conservation and exploitation.

14383. Ability to project, inspect and direct works, in their field.


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**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.
LEARNING OBJECTIVES OF THE SUBJECT


1 Ability to carry out the construction project of a shallow foundation structure from a geological-geotechnical report.
2 Ability to carry out the construction project of a deep foundation structure based on a geological-geotechnical report.
3 Ability to project a retaining structure including stability and serviceability analysis.

Application of geotechnical and mechanical knowledge of soils and rocks in the development of studies, projects, constructions and exploitations in which earthmoving, foundations and retaining structures are necessary. Knowledge of terrain recognition. Knowledge of the behavior of shallow foundations including calculation of bearing and settlement capacity, designing and testing. Knowledge of the behavior of deep foundations including calculation of bearing and settlement capacity, designing and testing. Knowledge of the theory of earth thrust for its application to the calculation of thrusts in retaining structures. Knowledge of the behavior of rigid and flexible retaining structures including drainage, instrumentation control, anchoring elements, as well as stability and in-service 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. Rock mechanics and underground excavations, basic concepts.

* 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>Type</th>
<th>Hours</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Self study</td>
<td>63,0</td>
<td>56.00</td>
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<tr>
<td>Guided activities</td>
<td>4,5</td>
<td>4.00</td>
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<tr>
<td>Hours large group</td>
<td>22,5</td>
<td>20.00</td>
</tr>
<tr>
<td>Hours medium group</td>
<td>22,5</td>
<td>20.00</td>
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Total learning time: 112.5 h

CONTENTS

SUBJECT 1. INTRODUCTION TO THE COURSE

Description:
1.1. CONTENT AND FOCUS 1.2. DEVELOPMENT, PROGRAM AND BIBLIOGRAPHY 1.3. EVALUATION

Specific objectives:
Basic knowledge of the main types of problems that are posed and solved in the subject and of the general aspects of their organization (approach, development of the classes, program, bibliography and evaluation).

Full-or-part-time: 2h 24m
Theory classes: 1h
Self study : 1h 24m
SUBJECT 2. SOIL EXPLORATION

Description:
2.1 APPROACH TO THE PROBLEM. OBJECTIVES
2.1.1 Punctual information and information in extension
2.1.2 Obtaining useful parameters in the geotechnical calculation
2.2 PREVIOUS SURVEY
2.2.1 Study of the maps available in the zone
2.2.2 Studies in adjacent zones
2.2.3 Direct observation of the terrain
2.3 METHODS OF RECOGNITION
2.3.1 Manual recognition
2.3.2 Surveys. Sample extraction. Profiles
2.4 IN SITU TESTS
2.4.1 Penetrometric tests
2.4.2 Load tests
2.4.3 Geophysical tests
2.5 GEOTECHNICAL REPORT. CONTENT AND STRUCTURE

Exercises of topic 2, complemented with additional concepts of theory

Specific objectives:
Knowledge, understanding and ability to reason and apply on the techniques used in the recognition of the terrain in order to identify the properties that characterize the behavior of the same (deformability, resistance) and allow to undertake the project of foundations, foundation structures and other actions geotechnical (slope stability analysis, terrain improvement, excavation drainage, etc.), including the general reconnaissance approach and design, existing methods, penetrometric, load or geophysical in situ tests, and the development of geotechnical reports. Knowledge of typical parameters of different terrain recognition procedures.

Practice and deepening of the concepts, knowledge and developments of the subject 2

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study: 5h 36m

SUBJECT 3. FUNCTION AND TYPES OF FOUNDATIONS

Description:
3.1. FUNCTION OF THE FOUNDATIONS. LIMIT CONDITIONS TO BE COMPLIED WITH
3.2. TYPES OF FOUNDATIONS AND GENERAL FIELDS OF APPLICATION
3.3. GENERAL PROCEDURE AND CONDITIONAL FACTORS OF THE FOUNDATION PROJECT

Specific objectives:
Knowledge, understanding and reasoning ability of the function, typology, basic behavior and general fields of application of the superficial, deep and semi-deep foundations, of the limit conditions that must fulfill the same, and of the general procedure and conditioning factors of the project of foundations. Knowledge of typical dimensions of different types of foundations.

Full-or-part-time: 2h 24m
Theory classes: 1h
Self study: 1h 24m
SUBJECT 4. SHALLOW FOUNDATIONS

Description:
4.1. INTRODUCTION. TYPOLOGY AND GENERAL FIELD OF APPLICATION 4.2. ALLOWABLE OR WORKING PRESSURES 4.3.
BEARING CAPACITY. GENERAL ASPECTS 4.3.1. Failure mechanisms 4.3.2. Brinch Hansen. Correction coefficients 4.3.3. Eccentric
load. Approximate procedure 4.3.4. Drained and undrained processes in cohesive soils 4.3.5. Effect of water 4.3.6. Other specific
cases 4.4. FAILURE LOAD. STRATIFIED LAND 4.4.1. Introduction. General aspects 4.4.2. Empirical approaches 4.4.3. Case of two
layers with puncture of the superior 4.4.4. Other cases 4.5. ESTIMATION OF BEARING CAPACITY AND PRESSURE FROM IN SITU
Actions to consider. Verification procedure 4.8.3. Constructive aspects
Exercises and problems of unit 4, complemented with additional concepts of theory

Specific objectives:
Knowledge, comprehension and reasoning ability and resolution of exercises and problems in relation to the permissible pressures
or working of the land, the load of subsidence and the settlements of surface foundations in various conditions of stratigraphy
(homogeneous or stratified lands), actions (vertical or inclined load, centered or eccentric), existence of water (dry or saturated),
term (drained or non-drained conditions), type of surface foundation (run or isolated), support of the same (surface or deep) ,
etc., and its sizing in all these cases. Knowledge, understanding and reasoning ability of the typology, general field of application
and mechanisms of breaking of the surface foundations, of the estimation of the admissible pressure and of the load of sinking
from tests in situ, of the definition of security factors, and the development of specific projects. Knowledge of typical values of
parameters related to the calculation of surface foundations (permissible pressures and subsidence of different types of terrain,
safety factors, etc.).
Practice and deepening of the concepts, knowledge and developments of the subject 4

Full-or-part-time: 12h
Theory classes: 3h
Practical classes: 2h
Self study: 7h
SUBJECT 5. DEEP FOUNDATIONS

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 of topic 5, complemented with additional concepts of 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 the concepts, knowledge and developments of the subject 5

Full-or-part-time: 12h
Theory classes: 3h
Practical classes: 2h
Self study: 7h

SUBJECT 6. FUNCTION AND TYPE OF RETAINING STRUCTURES

Description:
6.1 FUNCTION OF CONTAINMENT STRUCTURES. BASIC NOMENCLATURE 6.2 TYPOLOGY OF CONTAINMENT STRUCTURES 6.3 LATERAL PRESSURE

Specific objectives:
Knowledge and understanding of the function, nomenclature, typology and general behavior of containment structures

Full-or-part-time: 2h 24m
Theory classes: 1h
Self study: 1h 24m
SUBJECT 7. WALLS

Description:
7.1. INTRODUCTION. 7.2. ACTIVE EARTH PRESSURE. COULOMB THEORY 7.2.1. Approach to the basic case. Effect of cohesion
7.2.2. Effect of surface loads on the ground 7.2.3. Water action 7.2.4. Other cases 7.3. ACTIVE EARTH PRESSURE. RANKINE
THEORY 7.4. ACTIVE LOAD ON SPECIFIC TYPES OF WALLS 7.4.1. Walls in L 7.4.2. Other types of specific walls 7.5. OTHER
METHODS FOR ESTIMATING ACTIVE EARTH PRESSURE 7.5.1. Elastic method 7.5.2. Semi-empirical distributions 7.6. PASSIVE
EARTH PRESSURE 7.6.1. Introduction. Coulomb and Rankine theories and methods based on static solutions 7.6.2. Modification of
Drainage systems. 7.7.4. Other types of walls. Reinforced earth 7.7.5. Constructive aspects
Exercises and problems of unit 7, complemented with additional concepts of theory

Specific objectives:
Knowledge, comprehension and ability to reason and solve exercises and problems related to the estimation of active (and
passive in certain cases) earth pressure using Coulomb and / or Rankine theories or other approximate procedures (elastic
method, distributions semi-empirical) in various situations of type of transdoses (flat, vertical or non-vertical, in L), external loads
(evenly distributed or arbitrary), terrain (cohesive or non-cohesive), stratigraphy (homogeneous or stratified terrain), existence
of water (dry or with groundwater level), term (short or long term), and with the design of walls including the pre-dimensioning
process, the estimation of the actions to consider and the specific phases of the verification procedure (safety to overturn, safety
to sliding, and eccentricity of the reaction at the base).
Practice and deepening of the concepts, knowledge and developments of the subject 7

Full-or-part-time: 12h
Theory classes: 3h
Practical classes: 2h
Self study : 7h

SUBJECT 8. SHEET WALLS

Description:
8.1. INTRODUCTION. TYPOLOGY AND MECHANICAL BEHAVIOR 8.2. ESTIMATION OF EARTH PRESSURES 8.3. METHODS OF
CALCULATING SHEET WALLS 8.3.1. Classical methods 8.3.2. Other methods 8.4. METHODS OF CALCULATING ANCHORED SHEET
WALLS 8.4.1. Sheets anchored in a level 8.4.2. Sheets anchored in more than one level 8.4.3. Anchors 8.5. SUPPORTS 8.6.
TECHNOLOGICAL STANDARDS AND CONSTRUCTION ASPECTS 8.7. SHEET WALL PROJECT 8.7.1. Predimensioned. Actions to
consider 8.7.2. Verification procedure 8.7.3. Other types of sheets. 8.7.4. Constructive aspects
Exercises and problems of unit 7, complemented with additional concepts of theory

Specific objectives:
Knowledge, understanding and reasoning ability in relation to the typology, behavior, estimation and distribution of earth
pressure and mechanisms of possible failure in sheets, anchored at one level or anchored to more than one level, and with the
behavior of anchors and props. Knowledge, understanding and reasoning ability and resolution of exercises and problems related
to the calculation of the stability of sheet walls using classical methods, in drained or non-drained conditions, and semi-empirical,
of sheet walls anchored under the assumption of free support or fixed and sheet walls anchored to more than one level using
specific calculation assumptions. Knowledge of typical values of parameters in sheet walls, anchored at one level or anchored at
several levels, of anchors and props.
Practice and deepening of the concepts, knowledge and developments of the subject 7

Full-or-part-time: 12h
Theory classes: 3h
Practical classes: 2h
Self study : 7h
SUBJECT 9. ROCK MECHANICS AND TUNNELS

Description:
9.1. INTRODUCTION TO ROCK MECHANICS 9.1.1. Basic definitions, 9.1.2. General concepts of rock mechanics, 9.1.3. Applications of rock mechanics 9.2. BEHAVIOR AND MECHANICAL PROPERTIES OF ROCKS AND DISCONTINUITIES 9.2.1 Basic characteristics of rocks, 9.2.2 Mechanical behavior of rocks, 9.2.3 Criteria of rupture, 9.2.4 Post-rupture behavior of rocks, 9.2.5 Anisotropy of rocks, 9.2.6 Influence of time on rock rupture, 9.2.7 Mechanical properties of discontinuities 9.3. BEHAVIOR AND GEOMECHANICAL CHARACTERIZATION OF ROCK MASSES 9.3.1 Geomechanical classifications of rock massifs, 9.3.2 Characterization of peak peak properties of rock massifs, 9.3.3 Characterization of rock mass deformability properties, 9.3.4 Post-rupture behavior of rock massifs 9.4. DESIGN OF UNDERGROUND EXCAVATIONS AND SUPPORT 9.4.1 Approach to the design of galleries and tunnels, 9.4.2 Design of underground excavations, 9.4.3 Methodology of convergence-confinement curves, 9.4.4 Mechanical approach to the convergence-confinement curve method

EXERCISES AND PROBLEMS

Specific objectives:
Knowledge of theoretical and applied rock mechanics

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study: 5h 36m

SUBJECT 10. INSTRUMENTATION OF GEOTECHNICAL STRUCTURES

Description:
10.1. MEASUREMENT OF STRESSES AND DISPLACEMENTS 10.2. ON-SITE MEASURING INSTRUMENTS 10.2.1. Generalities 10.2.2. Piezometers. Type 10.2.3. Total load cells. Type 10.2.4. Tape for convergences. 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: dam of loose materials and concrete 10.3.2. Cases in excavations: tunnel and urban open-air excavation 10.3.3. Cases in foundations: support and large pylon

Specific objectives:
Knowledge, understanding and ability to reason and apply on the techniques used in the instrumentation of geotechnical structures in order to analyze the behavior in service of these; possible motivations for its implementation; variables (displacements, stresses, loads) to be measured; and instruments available for this (piezometers, full load cells, convergence tapes, rod extensometers, sliding micrometer, pendulum inclinometer and others) Knowledge and understanding of the procedure to be followed in a project of instrumentation and specific cases of application (dams of loose materials or urban tunnel among others). Knowledge of typical parameters of different procedures for instrumentation of geotechnical structures.

Full-or-part-time: 4h 48m
Practical classes: 2h
Self study: 2h 48m
SUBJECT 11. NUMERICAL METHODS IN GEOTECHNICAL ENGINEERING

Description:
11.1. INTRODUCTION, 11.2. FINITE DIFFERENCES METHOD FOR STATIONARY FLOW EQUATION 11.2.1 Introduction 11.2.2 Flow Equation in Finite Differences 11.2.3 Boundary Conditions 11.2.4 Solving Transient Problems 11.3 BASIC CONCEPTS OF THE FINITE ELEMENT METHOD APPLIED TO THE EQUILIBRIUM EQUATION IN A CONTINUOUS Media 11.3.1 Introduction 11.3.2 Deformations 11.3.3 Shape or Interpolation Functions 11.3.4 Deformations Using Form Functions 11.3.5 Green's Theorem 11.3.6 Equilibrium Equations tensions 11.4 THE MODELING PROCESS 11.5 REFERENCES, APPENDIX. Description of CODE_BRIGHT and GID: definition, geometry, data to be entered for CODE_BRIGHT

Computer practice of numerical calculation with geotechnical engineering problems, complemented with additional concepts of theory

Specific objectives:
Knowledge, understanding and ability to reason and apply in relation to existing numerical methods for the calculation of common geotechnical problems (contour problems related to flow, consolidation, deformation and resistance of foundations, containment structures or excavations in dry or saturated soil), of its characteristics, of the available contour conditions, of typical and special elements for the discretization of the environment, of existing programs and of the procedure of operation that must be followed (approach of the problem, discretization, conditions of contour, processing, etc.). Knowledge of typical values of parameters of commercial programs of application.

Practice and deepening of the concepts, knowledge and developments of the subject 11

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study : 5h 36m

SUBJECT 12. GROUND IMPROVEMENT

Description:
12.1. INTRODUCTION. OBJECTIVES 12.2. LAND IMPROVEMENT METHODS 12.2.1. Densification methods 12.2.2. Methods with field additions 12.2.3. Thermal methods 12.2.4. Reinforcement methods 12.2.5. Other methods

Specific objectives:
Knowledge, understanding and reasoning ability and application of the main techniques for improving the properties of the soil (strength, deformability, permeability, etc.) through procedures of densification, additions to the soil, thermal methods, reinforcement or others, including the objectives of the same, the advantages and limitations of each of them, their basic fields of application and the execution procedure. Knowledge of typical parameters of the land improvement procedures explained.

Full-or-part-time: 4h 48m
Practical classes: 2h
Self study : 2h 48m

EVALUATION

Full-or-part-time: 14h 23m
Laboratory classes: 6h
Self study : 8h 23m
GRADING SYSTEM

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.

EXAMINATION RULES.

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: