Course guide
2500031 - GECENGGEOT - Geotechnical Engineering

Last modified: 01/10/2023

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: 2023 **ECTS Credits:** 4.5 **Languages:** English

LECTURER

Coordinating lecturer: MARCOS ARROYO ALVAREZ DE TOLEDO

Others: MAURICIO ALVARADO BUENO, MARCOS ARROYO ALVAREZ DE TOLEDO, SEBASTIAN OLIVELLA PASTALLE, ALFONSO RODRIGUEZ DONO, JEAN VAUNAT

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.
14390. Identify, formulate and solve engineering problems. Pose and solve construction engineering problems with initiative, decision-making skills and creativity. Develop a systematic and creative method of analysis and problem solving. (Additional school competition).

TEACHING METHODOLOGY

The course is taught trying to encourage the participation of students and their work before and after classes. Two of the three scheduled weekly hours are typically devoted to more conceptual and theoretical matters while the other is focused to more practical aspects and to solve exercises and problems. During the classes not the whole subject is taught and they actually focus on the issues of greater importance and difficulty, leaving the rest for the personal work of students using the additional documentation provided in the context of the subject. Additionally, voluntary sessions for discussing questions that the students may have and, eventually, conferences and technical visits of geotechnical interest, are organized. In the classes the blackboard and sometimes audiovisual material (Internet, slides or videos) are used. Besides, the students have to develop two assignments related to the manual and computer calculation of geotechnical practical cases developed in small groups.

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

Soil recognition. Function and type of foundations. Shallow foundations. Deep foundations. Function and type of retaining structures. Walls. Sheet pile walls. Numerical methods in Geotechnics. Instrumentation of geotechnical structures. Soil improvements. Examples of foundations in special cases.

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 explotations 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, desgining 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

Type	Hours	Percentage
Hours medium group	22,5	20.00
Guided activities	4,5	4.00
Hours large group	22,5	20.00
Self study	63,0	56.00

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: 19h 12m
Theory classes: 6h
Practical classes: 2h
Self study : 11h 12m

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 TESTS 4.6. SETTLEMENTS SHALLOW FOUNDATIONS 4.6.1. Introduction. Nomenclature 4.6.2. Elastic method 4.6.3. Edometric method 4.6.4. Other methods 4.7. SAFETY FACTORS 4.8. PROJECT OF SHALLOW FOUNDATIONS 4.8.1. Predimensioned 4.8.2. 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 Kp. Parabolic reduction 7.7. WALL PROJECT 7.7.1. Predimensioned. Actions to consider 7.7.2. Verification procedure 7.7.3. 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 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 11.2.3 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

EVALUATION

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

GRADING SYSTEM

The subject is evaluated through two partial tests that contribute 50% to the final grade. Those students whose mark in the first partial is less than 2.5 will be evaluated in the second exam of the whole subject. During the development of the subject, exercises will be proposed whose resolution can contribute to the final grade, raising the one obtained from the exams. Qualification and admission criteria for reassessment: Students who have failed the ordinary assessment and have regularly taken the assessment tests for the failed subject will have the option of taking a reassessment test within the period set in the academic calendar. Students who have already passed it or students qualified as not presented may not take the reassessment test of a subject. The maximum grade in the case of taking the reassessment exam will be five (5.0). The non-attendance of a student summoned to the re-evaluation test, held within the set period, may not lead to another test being held at a later date. Extraordinary evaluations will be carried out for those students who, due to accredited force majeure, have not been able to take any of continuous assessment tests. These tests must be authorized by the corresponding head of studies, at the request of the professor responsible for the subject, and will be carried out within the corresponding school period.

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:
- Salgado, Rodrigo. The Engineering of Foundations, Slopes and Retaining Structures. 2. Boca Raton, FL: CRC Press, 2022. ISBN 9781138197640.
- Rodríguez Ortiz, J.M.; Serra Gesta, J.; Oteo Mazo, C. Curso aplicado de cimentaciones. 7a ed. corr. Madrid: Colegio Oficial de Arquitectos de Madrid, 1996. ISBN 84-8557-237-8.
- Jiménez Salas, J.A.; Justo Alpañés, J.L. Geotecnia y cimientos. vol II, Mecánica del suelo y de las rocas. 2a ed. Madrid: Rueda, 1981. ISBN 84-7207-021-2 (V.2).
- Jiménez Salas, J.A.; Justo Alpañes, J.L. Geotecnia y cimientos: v. III: cimentaciones, excavaciones y aplicaciones de la geotecnia. Partes 1 y 2. Madrid: Rueda, 1980. ISBN 84-7207-017-4.
- Peck, R.B.; Hanson, W.E.; Thornburn, T.H. Ingeniería de cimentaciones. 2a ed. México: Limusa. Noriega, 1990. ISBN 968-18-1414-2.
- Das, B.M. Principios de ingeniería de cimentaciones. 5a ed. México: Thomson, 2004. ISBN 970-68-6481-4.

Complementary:
- Suriol, J., Lloret, A. y Josa, A. Reconocimiento geotécnico del terreno [on line]. Barcelona: Edicions UPC, 2007 [Consultation: 29/04/2020]. Available on: http://hdl.handle.net/2099.3/36268. ISBN 9788483019429.
- Alonso, E. y Gens, A. Instrumentación de obras. Barcelona: Universitat Politecnica de Catalunya, 1989. ISBN 8476530250.
- Olivella, S., Josa, A., y Valencia, F.J. Cimentaciones y estructuras de contención : problemas resueltos [on line]. Barcelona: Edicions UPC, 1999 [Consultation: 02/02/2021]. Available on: http://hdl.handle.net/2099.3/36411. ISBN 8483013576.