Course guide
2500020 - GECGEOTECN - Geotechnics

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:** 6.0 **Languages:** Catalan, English

LECTURER

Coordinating lecturer: ALBERTO LEDESMA VILLALBA, NURIA MERCE PINYOL PUIGMARTI

Others: MAURICIO ALVARADO BUENO, ALBERTO LEDESMA VILLALBA, CARLOS MARIA LOPEZ GARELLO, NURIA MERCE PINYOL PUIGMARTI, PERE PRAT CATALAN, ANNA RAMON TARRAGONA, ENRIQUE EDGAR ROMERO MORALES, DANIEL TARRAGÓ MUNTÉ

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)

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.
14389. Knowledge of the history of civil engineering and training to analyze and assess public works in particular and construction in general.

TEACHING METHODOLOGY

The course encourages the participation of students and their work before and after classes. Two thirds of the scheduled hours are typically devoted to more conceptual and theoretical matters while the other third 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, the course includes laboratory sessions (three in total during the year) and, eventually, conferences and technical visits of geotechnical interest, are organized. The invited lecturers or professors helping at laboratory sessions may speak in a different language to the one of the course. In the classes the blackboard and sometimes audiovisual material (Internet, slides or videos) are used. Lab sessions are conducted in the soil mechanics laboratory available in Campus Nord for degree students.

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

Nature of soils and rocks, identification, basic properties and hydraulic and mechanical parameters. Knowledge of the mechanics of the continuous medium applied to saturated porous media and definition of the concept of effective stresses. Concepts and theory of water flow in soils to reach the consolidation theory. Knowledge of the experimental study of the soils and the stress trajectories of the most used tests: identification, edometric, shear, triaxial and permeability. Constitutive equations and stress, strain and strength of saturated soils. Analysis of soil behaviour at service and failure and application to simple contour problems. Basic concepts of unsaturated soils applied to compacting soils.

1 Ability to solve flow problems in saturated porous media. Ability to carry out drainage projects in excavations.
2 Ability to solve problems of consolidation of low permeability strata, as well as basic sizing of drainage systems to accelerate the process.
3 Ability to study the soil failure and serviceability behavior in basic foundations problems and retaining structures.

Geotechnical and mechanical knowledge of soils and rocks. Ability to solve basic soil behavior problems. Understand the nature of soils and rocks, their identification, basic properties, hydraulic and mechanical parameters. Knowledge of the water flow through the soil, including the conservation of the mass and the moment. Principle of effective stresses. Continuous medium mechanics knowledge applied to saturated porous medium. Stress and strain paths using invariants. Fundamental constitutive equations. Knowledge of the experimental study of saturated soil in edometric and triaxial tests. Behavior of unsaturated soils and in particular in relation to compaction. Analysis of ground failure using collapse and limit equilibrium theorems. Knowledge of flow-deformation coupling in soil.

Expected outcomes for student learning:

* Knowledge, understanding and reasoning ability and problem solving exercises and behaviors related to soil characteristics (parameters and basic properties, effective stresses, flow and water flow, siphoning, consolidation, deformation and strength ... primarily of saturated soils, but also with an introduction to unsaturated soils) and some key implementation (slope stability).

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

* Ability to study independently using library resources, teamwork and follow more advanced courses in the field of Soil Mechanics.

STUDY LOAD

Type	Hours	Percentage
Hours medium group	24,0	16.00
Hours small group	6,0	4.00
Guided activities	6,0	4.00
Self study	84,0	56.00
Hours large group	30,0	20.00

Total learning time: 150 h

CONTENTS

UNIT 0. INTRODUCTION TO THE SUBJECT

Description:
PURPOSE OF GEOTECHNICS
Soil Mechanics and Geotechnical Engineering
Examples of geotechnical problems
ORGANIZATION OF THE COURSE AND DOCUMENTATION
Approach
Development of classes
Requirements, objectives, program and literature
Evaluation

Specific objectives:
ITEM 1. Basic knowledge of the main types of problems encountered and solved in the subject and general aspects of its organization (focus, development of classes, programs, literature and evaluation).

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

UNIT 1. SOIL CHARACTERIZATION AND CLASIFICATION

Description:
1.1 PHASES OF THE SOIL AND PARAMETRES.
1.2 THE SIZE OF SOLID PARTICLES. GRANULOMETRY
1.3 CONSISTENCY OF THE SOIL. ATTERBERG'S LIMITS. CHARTS OF PLASTICITY
1.4 SOIL CLASSIFICATION SYSTEM

Exercises, supplemented by additional concepts of theory

Specific objectives:
Knowledge, understanding and reasoning ability and solving exercises related to the quantification of the state of a soil. Determination of the relationship between weight and volume of different phases within it. The student must understand that soil is a porous medium in which the interstices left by the mineral particles that compose it (solid phase) may be liquid water and/or air (liquid or gas phases, respectively).

Must meet the tests aimed at identifying and classifying a real soil with the classification criteria accepted in the geotechnical environment and some aspects of deformation and movement of water within the soil explained intuitively to liaise with the concepts introduced in item 4.
Practice and deepening of concepts, knowledge and developments

Full-or-part-time: 19h 12m
Theory classes: 6h
Practical classes: 2h
Self study : 11h 12m

UNIT 2. FUNDAMENTAL CONCEPTS: STRESSES AND STRAINS

Description:
2.1 BASIC CONCEPTS OF CONTINUUM MECHANICS
2.2 MOHR CIRCLES
2.3 TOTAL AND EFFECTIVE STRESS
2.4 LAMBE AND CAMBRIDGE STRESS REPRESENTATION
2.5 CONCEPTS OF ELASTICITY AND PLASTICITY
2.6 EXAMPLES OF STRESS PATHS. ELASTIC SOLUTIONS
Exercises, supplemented by additional concepts of theory

Specific objectives:
Knowledge, understanding and reasoning ability and problem solving exercises in relation to the following: stress units in the SI and others, total stress and effective stress, Mohr circle, invariant matrix stresses and strains, paths of stresses in invariant planes (confinement and shear stress), and one-dimensional stress conditions.

Justification by matrix algebra equations of tangential normal stress on a plane of arbitrary slope, and the invariants of the matrix stress and strain.

Knowledge of typical values and orders of magnitude of vertical and horizontal stresses in a soil due to weight-saturated conditions.
Practice and deepening of concepts, knowledge and developments

Full-or-part-time: 12h
Theory classes: 4h
Practical classes: 1h
Self study : 7h

LABORATORY

Description:
Basic identification and classification of soils. Visual and tactile identification and classification and determination of basic geotechnical parameters (grain size distribution, Atterberg limits and unified clasification of soils).
Water flow in saturated soil. Concepts of flow, unit flow, hydraulic gradient, permeability, critical gradient and flotation. Determination of the permeability with constant and variable head permeameters and experimental determination of the critical gradient achieving flotation.
Compaction and oedometer and triaxial tests. Consolidation and strength of compacted soils. Compaction methods and curve. Collapse and swelling and shear strength of compacted soils.

Specific objectives:
Direct experimenting with soils of different types and characteristics and knowledge, understanding and capability of visual and tactile identification of soils and of the experimental determination of basic geotechnical parameters (grain size distribution, Atterberg limits and unified clasification).
Experimenting with water flow in saturated soil and knowledge, understanding and reasoning ability with the concepts of flow, unit flow, hydraulic gradient, permeability, critical gradient and flotation and of the determination of permeability with constant and variable head permeameters and of the critical gradient achieving flotation
Direct experimenting with soil compaction and compacted soils in oedometer and triaxial tests and knowledge, understanding and reasoning ability with the compaction of soils, the phenomena of collapse and swelling and the development of standard triaxial and oedometer tests.

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

UNIT 3. FLOW OF WATER IN SATURATED AND NON-DEFORMABLE SOIL

Description:
3.1 HYDRAULIC HEAD AND WATER TABLE
3.2 EQUATION OF WATER CONTINUITY AND DARCY LAW.
3.3 SEEPAGE FORCES, CRITICAL GRADIENT AND LIQUEFACTION
3.4 GRAPHICAL METHOD FOR FLOW PROBLEMS

Exercises and problems, supplemented with additional concepts of theory

Specific objectives:
Knowledge, understanding and reasoning ability and problem solving of exercises in relation to the following: concepts of flow and water flow, hydraulic head, Darcy law, permeability, aquifers, equivalent permeability and flow in layered soil, flotation, hydraulic and critic gradients, interpretation of all types of flow networks in saturated soil (flow, hydraulic gradients, pore pressure) and determination of graphical flow networks and excavation drainage (in the excavation itself, with wells or with well-pints) in simple cases (isotropic saturated and homogeneous soils or simple heterogeneous and anisotropic soils).

Knowledge of typical values and orders of magnitude of permeability of soils, and flotation situations (critical hydraulic gradients, and pore and total pressure, etc.).. Knowledge and understanding of the concepts of water table, 'filtration forces', and drains and filters, earth dams and the equations of motion and water flow.
Practice and deepening of concepts, knowledge and developments

Full-or-part-time: 19h 12m
Theory classes: 6h
Practical classes: 2h
Self study : 11h 12m

UNIT 4. EXPERIMENTAL BEHAVIOUR OF SOILS AND STRESS-STRAIN PATHS

Description:
4.1 TRIAXIAL TEST
4.2 OEDOMETRIC TEST
4.3 SHEAR TEST
4.4 EXPERIMENTAL BEHAVIOUR OF SAND AND CLAYS
Exercises and problems complemented with additional concepts of theory

Specific objectives:
Knowledge, understanding and reasoning ability on the experimental techniques mostly used in soil mechanics. Knowledge and understanding of the determination of the value of the parameters used in soil behavior models under arbitrary stress states and of the relationship between actual soil behavior and the idealized models used to study it.

Knowledge and understanding of different types of tests: identification, permeability and mechanical. As for the latter group, differentiation of tests imposing a certain state of stress and measuring the deformations (oedometer test) from those that, additionally, reach the failure state of the soil (triaxial and direct shear tests).
Practice and deepening of the concepts, knowledge and developments

Full-or-part-time: 19h 12m
Theory classes: 6h
Practical classes: 2h
Self study : 11h 12m

EVALUATION

Full-or-part-time: 9h 36m
Laboratory classes: 4h
Self study : 5h 36m

UNIT 5. SATURATED SOIL CONSOLIDATION

Description:
5.1. COMPONENTS OF SOIL DEFORMATION. CONSOLIDATION
5.2. PRIMARY CONSOLIDATION PROCESS
5.3. EQUATION OF PRIMARY CONSOLIDATION. SOIL DEFORMATION IN OEDOMETRIC CONDITIONS
5.4. ONE-DIMENSIONAL EQUATION OF CONSOLIDATION. NON-DIMENSIONAL APPROACH. DEGREE OF CONSOLIDATION
5.5. SOLUTION OF THE EQUATION OF THE VERTICAL FLOW WITH ONE-DIMENSIONAL CONSOLIDATION
5.5.1. Uniformly distributed load on finite strata
5.5.2. Variation of piezometric levels in finite layer
5.5.3. Approximate expression for the degree of consolidation
5.5.4. Variable external load
5.6. SIMPLIFIED APPROACH CASES WITH NO VERTICAL FLOW
5.6.1. Radial consolidation
5.6.2. Two-dimensional and three-dimensional consolidation
5.7. SECONDARY CONSOLIDATION
Exercises and problems complemented with additional concepts from theory

Specific objectives:
Knowledge, understanding and reasoning ability and problem solving of exercises in relation to pore pressures, recoverable and irrecoverable deformations measured with different parameters and degrees of consolidation and settlements produced in various cases of soil stratigraphy and draining or impervious bottom layers in primary consolidation processes upon the effect of external loads and / or variations in piezometric heights in oedometric conditions, and with the approximate approach of radial, two-dimensional and three dimensional consolidation.

Knowledge of typical values and orders of magnitude of coefficients of compressibility, oedometric modules and coefficients of consolidation of different soil types and for different conditions.

Knowledge and understanding of the components of soil deformation and of the concepts of instantaneous and delayed deformations with time and with effective stress, the processes of primary and secondary consolidation, the equations of primary consolidation (soil deformation in oedometric conditions) and one-dimensional consolidation in dimensional and dimensionless terms, the solution of the equation of one-dimensional consolidation for vertical flow produced by uniformly distributed load on finite layer and changes in piezometric levels, the approach for variable external load, and the secondary consolidation.
Practice and deepening of concepts, knowledge and development

Full-or-part-time: 14h 23m
Theory classes: 4h
Practical classes: 2h
Self study : 8h 23m

UNIT 6. STRESS-STRAIN-STRENGTH BEHAVIOUR

Description:
6.1 INTRODUCTION
6.2 CRITICAL STATE CONSTITUTIVE MODEL: CAM CLAY
6.3 MOHR-COULOMB SHEAR STRENGTH
6.4 UNDRAINED SHEAR STRENGTH
6.5 LIMIT EQUILIBRIUM AND SAFETY FACTOR OF A SLOPE
Exercises and problems, supplemented with additional concepts from theory

Specific objectives:
Knowledge, understanding and reasoning ability and exercise and problem solving concerning triaxial tests both on sands and clays (including the determination of drained and undrained modulus of deformation), representing results of triaxial tests through paths in stress invariant planes (determination of the strength obtained in a test, including the drained and undrained concepts) and in the void ratio versus stress plane, pore pressure generation in undrained tests (determination of Skempton parameter from tests), Mohr-Coulomb failure criterion (cohesion and internal friction angle), undrained shear strength (justification and calculation), constitutive equations (function and necessity), elastic and elasto-plastic models (concept, foundations and basic equations); and Cam-Clay model (approach, development and reproduction of typical behaviors).

Knowledge of typical values and orders of magnitude of the internal friction angle, undrained shear strength and dilatancy parameters and of specific models for different soil types and different states of them.

Knowledge of some relationships between soil moisture and strength and between the earth pressure coefficient at rest and the friction angle of soils.
Practice and deepening of the concepts, knowledge and development

Full-or-part-time: 26h 24m
Theory classes: 7h
Practical classes: 4h
Self study : 15h 24m

UNIT 7. UNSATURATED AND COMPACTED SOILS

Description:
7.1. BASIC CONCEPTS: SURFACE TENSION AND CAPILLARY ASCENSION
7.2 THE EFFECT OF SUCTION ON UNSATURATED SOILS
7.3 COMPACTED SOILS AND PROCTOR TEST

Specific objectives:
Knowledge, understanding and reasoning ability of the most relevant aspects of soil properties in unsaturated state, the concept of suction and its application to soil retention curves, the definition of effective stress, the phenomena of collapse and swelling, the description of specific laboratory tests for these soils, the compaction curve and the process of compaction in practice, including various procedures, how the compaction conditions influence the final characteristics of compacted soil and the control methods.

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

GRADING SYSTEM

The subject can be passed both by continuous assessment taking into account all the activities carried out during the course (exams, laboratory sessions and course work) or by the weighted averaged of the exams marks only.

The grade on the continuous assessment (N) is obtained from:
- the weighted average of the marks of two exams (Partial EP, Final EF) made during the year in the periods set by the School.
- the mark of the coursework (W) that includes solving and submitting an exercise related to each of the subjects of the course (6 in total as maximum) that will be assigned by the course coordinator (individually)
- the mark from the report of laboratory practices (L) (3 in total)

Each of these activities is graded with a score between 0 and 10. The final grade of the continuous assessment is calculated as follows:

N = 0.3*EP + 0.5*EF + 0.1*L + 0.1*W

If the student does not follow the continuous assessment process, the mark will be obtained from the exams:

E = 0.4*EP + 0.6*EF

In any case, it is mandatory to attend the laboratory sessions. If repeating the subject, it is not required to repeat the laboratory sessions again.

The final grade (NF) of the course is calculated as follows:

NF=max[N,E]

The subject is passed whenever NF is equal to or greater than 5.0

Examinations will be held at the dates and times set by the School, will last 3 hours and will consist of a QUESTIONNAIRE of short questions or mini-exercises, and a PRACTICAL EXERCISE. Each of these two parts has the same weight in the mark of the exam. The subject matter for each exam corresponds to the contents from the beginning of the
course to the date of the exam.

It is mandatory for the continuous assessment:
a) to submit exams, including both parts (questionnaire + practical exercise) with a sufficient minimum of elaboration of each part at the discretion of the professor responsible for the subject
b) to write and present the coursework (W)
c) to perform all 3 laboratory practices and deliver the 3 final reports (L)

If these conditions are not satisfied, the final grade will be "NOT PRESENTED" (N = NP)

According to Academic Regulations, a re-evaluation test is established for those students who have not obtained an NF-mark equal to or greater than 5.0 as a result of the evaluation process. The maximum grade of the course obtained in the re-evaluation test is 5.

The students who have already passed the subject with an NF-mark equal to or greater than 5.0 or those qualified as "NOT PRESENTED" cannot attend the re-evaluation exam. The non-attendance of a student summoned to the re-evaluation test, held in the period set, may not lead to the carrying out of another test at a later date.

The re-evaluation test will last 3 hours and will consist of a QUESTIONNAIRE and a set of PRACTICAL EXERCISES. This examination will be held at the date and time set by the School.

If the final grade of the re-evaluation test is lower than 5, the final grade of the course will be the maximum grade between the grade obtained previously and the grade obtained in the re-evaluation test, with the description of "suspens" (fail).

Special exams will be made for those students who have not been able to carry out some of the exams described because of accredited extraordinary reasons. These special exams must be authorized by the head of studies of the Degree, at the request of the course coordinator, and will be carried out within the corresponding academic term.

EXAMINATION RULES.

Examinations will be held at the dates and times set by the School, will last 3 hours and will consist of a QUESTIONNAIRE of short questions or mini-exercises, and PRACTICAL EXERCISES. The subject matter for each exam corresponds to the contents from the beginning of the course to the date of the exam.

BIBLIOGRAPHY

Basic:

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- Lambe, T.W.; Whitman, R.V. Mecánica de suelos. México: Limusa : Noriega, 1995. ISBN 968-18-1894-6.
- Jiménez Salas, J.A.; Justo Alpañés, J.L. Geotecnia y cimientos I. Propiedades de los suelos y de las rocas. Madrid: Rueda, 1975. ISBN 8472070085 (V.1).
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- Wood, D.M. Soil behaviour and critical state soil mechanics. Cambridge: University Press, Cambridge. ISBN 0-521-33782-8.

Complementary:

- Serra Gesta, J.; Oteo Mazo, C.; García Gamallo, A.Mª; Rodríguez Ortiz, J.M. Mecánica del suelo y cimentaciones. Madrid: Ed. UNED, 1995. ISBN 8486957621.
- Rico, A.; del Castillo, H. La ingeniería de suelos en las vías terrestres: carreteras, ferrocarriles y aeropistas. México: Limusa, 1999. ISBN 9681800540.
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