Course guide
2500020 - GECGEOTECN - Geotechnics

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: 2022  ECTS Credits: 6.0  Languages: Catalan, English

LECTURER

Coordinating lecturer: NURIA MERCE PINYOL PUIGMARTI
Others: ALBERTO LEDESMA VILLALBA, CARLOS MARIA LOPEZ GARELLO, NURIA MERCE PINYOL PUIGMARTI, PERE PRAT CATALAN, IVAN PUIG DAMIANS, ANNA RAMON TARRAGONA, ENRIQUE EDGAR ROMERO MORALES

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, 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 tries 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, lab sessions (three in total during the year) 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. Lab sessions are conducted in the academic geotechnical laboratory available.
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.


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

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>84,0</td>
<td>56.00</td>
</tr>
<tr>
<td>Guided activities</td>
<td>6,0</td>
<td>4.00</td>
</tr>
<tr>
<td>Hours medium group</td>
<td>24,0</td>
<td>16.00</td>
</tr>
<tr>
<td>Hours small group</td>
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<td>4.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>30,0</td>
<td>20.00</td>
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</tbody>
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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 CLASSIFICATION

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 classification of soils).
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 classification).
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 final grade is obtained from the corresponding to each of the activities carried out (continuous evaluation, overall evaluation and lab sessions) 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 instance the continuous evaluation has a total weight of approximately 40%, the overall evaluation has a total weight of approximately 60% and the lab sessions have a total weight of approximately 10%.

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.

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:

Complementary: