250230 - GEOTECN - Geotechnics

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: 9 Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: ALEJANDRO JOSA GARCIA-TORNEL
Others: ALEJANDRO JOSA GARCIA-TORNEL, CARLOS MARIA LOPEZ GARELLO, SEBASTIAN OLIVELLA PASTALLE, ADRIÀ PÉREZ CARRERAS, IVAN PUIG DAMIANS, JOSÉ LUIS ZORNOZA GÓMEZ

Opening hours
Timetable: Hours of assistance to students are carried out both during the intervals between classes and through personally agreed hours or agreed hours by e-mail

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.
3077. Knowledge of the basic concepts of surface and underground hydrology.

Transversal:
592. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 2. Using strategies for preparing and giving oral presentations. Writing texts and documents whose content is coherent, well structured and free of spelling and grammatical errors.
596. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
599. EFFECTIVE USE OF INFORMATION RESOURCES - Level 3. Planning and using the information necessary for an academic assignment (a final thesis, for example) based on a critical appraisal of the information resources used.
602. SELF-DIRECTED LEARNING - Level 3. Applying the knowledge gained in completing a task according to its relevance and importance. Deciding how to carry out a task, the amount of time to be devoted to it and the most suitable information sources.
584. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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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

Students will acquire an understanding of geotechnics, soil mechanics and rock mechanics. They will also learn to solve basic problems related to soil behaviour.

Upon completion of the course, students will have acquired the ability to:
1. Solve problems related to flow in saturated porous media and carry out drainage projects at earthworks sites.
2. Solve problems related to the consolidation of low-permeability strata and carry out the basic design of drainage systems in order to speed up the process.
3. Study the failure and in-service performance of soil in basic problems related to foundations and retaining walls.

The nature of soils and rocks: identification, basic properties, and hydraulic and mechanical parameters; Flow of water through soil, including the conservation of mass and momentum; Effective stress principle; Application of continuum mechanics to saturated porous media; Calculation of stress trajectories and deformations using invariants; Fundamental constitutive equations; Experimental study of saturated soil by means of oedometric compression tests and triaxial shear tests; Behaviour of unsaturated soils, in particular as relates to compaction; Analysis of soil failure using the theorem of plastic collapse and limit equilibrium; 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 (land thrust, bearing capacity, 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>Total learning time: 225h</th>
<th>Theory classes: 53h</th>
<th>23.56%</th>
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<tr>
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<td>Practical classes: 21h</td>
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<tr>
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<td>Laboratory classes: 16h</td>
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<td>Guided activities: 9h</td>
<td>4.00%</td>
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<td>Self study: 126h</td>
<td>56.00%</td>
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# Content

## UNIT 1. INTRODUCTION TO THE SUBJECT

**Description:**
1.1. PURPOSE OF GEOTECHNICS
1.1.1. Soil Mechanics and Geotechnical Engineering
1.1.2. Examples of geotechnical problems
1.2. ORGANIZATION OF THE COURSE AND DOCUMENTATION
1.2.1. Approach
1.2.2. Development of classes
1.2.3. Requirements, objectives, program and literature
1.2.4. 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).

**Learning time:** 2h 24m
- Theory classes: 1h
- Self study: 1h 24m

## UNIT 2. STRUCTURE AND BASIC PROPERTIES OF THE SOIL. IDENTIFICATION AND CLASSIFICATION

**Description:**
2.1 FORMATION AND NATURE OF THE SOIL. OBSERVATION SCALES
2.2 PHASES OF THE SOIL. RELATIONS BETWEEN WEIGHTS AND VOLUMES AND EXPERIMENTAL COLLECTION
2.3 BASIC TYPES OF SOILS. STUDY OF SOLID PARTICLES: MINERALOGY AND PROPERTIES
2.4 THE SIZE OF SOLID PARTICLES. GRANULOMETRY
2.5 CONSISTENCY OF THE SOIL. ATTERBERG’S LIMITS. CHARTS OF PLASTICITY
2.6 SOIL CLASSIFICATION SYSTEM
2.7 INTRODUCTION TO BASIC BEHAVIOR OF SOILS

**APPENDIX**
Exercises of item 2, 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 in item 2

**Learning time:** 16h 48m
- Theory classes: 5h
- Practical classes: 2h
- Self study: 9h 48m
# UNIT 3. STRESSES AND STRAINS. EFFECTIVE STRESSES

<table>
<thead>
<tr>
<th>Description</th>
<th>Learning time: 16h 48m</th>
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<tbody>
<tr>
<td><strong>3.1 DEFINITION OF STRESS AND STRAIN</strong></td>
<td><strong>Theory classes: 5h</strong></td>
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<tr>
<td>3.1.1 Classical definition of stress</td>
<td><strong>Practical classes: 2h</strong></td>
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<tr>
<td>3.1.2 Adaptation of the classical definition to Soil Mechanics</td>
<td><strong>Self study: 9h 48m</strong></td>
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<tr>
<td>3.1.3 Definition of strain</td>
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<tr>
<td><strong>3.2 PRINCIPLE OF EFFECTIVE STRESS</strong></td>
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<tr>
<td><strong>3.3 STRESS AND STRAIN STATES. MOHR CIRCLES</strong></td>
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<tr>
<td>3.3.1 Tensor stress</td>
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<td>3.3.2 Dimensional stress states</td>
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<td>3.3.3 Mohr’s circle</td>
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<td>3.3.4 Total and effective tension states</td>
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<td>3.3.5 Strain states</td>
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<td><strong>3.4 TENSIONAL AND STRAIN VARIABLES. PATHS</strong></td>
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<td><strong>3.5 STRESS STATE IN ONE-DIMENSIONAL CONDITIONS</strong></td>
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<td>Exercises of item 3, supplemented by additional concepts of theory</td>
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**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 development of item 3
### LABORATORY

<table>
<thead>
<tr>
<th>Learning time: 14h 23m</th>
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<tr>
<td>Laboratory classes: 6h</td>
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<td>Self study: 8h 23m</td>
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**Description:**

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.

### EVALUATION

<table>
<thead>
<tr>
<th>Learning time: 24h</th>
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<tbody>
<tr>
<td>Laboratory classes: 10h</td>
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<tr>
<td>Self study: 14h</td>
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UNIT 4. FLOW OF WATER IN SATURATED AND NON-DEFORMABLE SOIL

Description:
4.1. WATER IN SOIL: FLOW OF WATER, HYDRAULIC HEAD, WATER TABLE AND CAPILLARY RISE
4.2. EQUATION OF WATER CONTINUITY
4.3. DARCY LAW. PERMEABILITY
4.4. FREE AND CONFINED AQUIFERS. FLOW WITH PUMPING FROM WELLS AND DITCHES
4.5. EQUIVALENT PERMEABILITY AND FLOW IN LAYERED SOILS
4.6. WATER FLOW EQUATION
4.7. FLOTATION
4.8. SOLUTION OF THE FLOW EQUATION. GRAPHICAL METHOD
4.8.1. Solution methods
4.8.2. Integration of the differential equation in one-dimensional flow cases
4.8.3. Graphical method in two-dimensional flow with isotropic and anisotropic soil
4.9. DRAINS AND FILTERS. EARTH DAMS
4.10. DRAINAGE OF EXCAVATIONS
4.10.1. Introduction. Function and objectives
4.10.2. Types of drainage and drainage project
Exercises and problems of item 4, 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 development of item 4
UNIT 5. SATURATED SOIL CONSOLIDATION

<table>
<thead>
<tr>
<th>Description</th>
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<tbody>
<tr>
<td>5.1. COMPONENTS OF SOIL DEFORMATION. CONSOLIDATION</td>
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<tr>
<td>5.2. PRIMARY CONSOLIDATION PROCESS</td>
</tr>
<tr>
<td>5.3. EQUATION OF PRIMARY CONSOLIDATION. SOIL DEFORMATION IN OEDOMETRIC CONDITIONS</td>
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<tr>
<td>5.4. ONE-DIMENSIONAL EQUATION OF CONSOLIDATION. NON-DIMENSIONAL APPROACH. DEGREE OF CONSOLIDATION</td>
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<tr>
<td>5.5. SOLUTION OF THE EQUATION OF THE VERTICAL FLOW WITH ONE-DIMENSIONAL CONSOLIDATION</td>
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<tr>
<td>5.5.1. Uniformly distributed load on finite strata</td>
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<td>5.5.2. Variation of piezometric levels in finite layer</td>
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<td>5.5.3. Approximate expression for the degree of consolidation</td>
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<td>5.5.4. Variable external load</td>
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<td>5.6. SIMPLIFIED APPROACH CASES WITH NO VERTICAL FLOW</td>
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<td>5.6.1. Radial consolidation</td>
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<td>5.6.2. Two-dimensional and three-dimensional consolidation</td>
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<td>5.7. SECONDARY CONSOLIDATION</td>
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<td>Exercises and problems of item 5 complemented with additional concepts from theory</td>
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<tr>
<th>Specific objectives:</th>
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<tr>
<td>Knowledge, understanding and reasoning ability and problem solving of exercises in relation to pore pressures, recoverable and irreversible 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.</td>
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<td>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.</td>
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<td>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.</td>
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<tr>
<td>Practice and deepening of concepts, knowledge and development of item 5</td>
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Learning time: 24h
- Theory classes: 7h
- Practical classes: 3h
- Self study: 14h
UNIT 6. EXPERIMENTAL TECHNIQUES

Learning time: 16h 48m
- Theory classes: 5h
- Practical classes: 2h
- Self study: 9h 48m

Description:
6.1. STRESS-STRAIN BEHAVIOR OF SOILS. EXPERIMENTAL STUDY IN THE LABORATORY
6.2. LABORATORY TECHNIQUES. OBJECTIVES
6.3. IDENTIFICATION TESTS
6.4. DETERMINATION OF PERMEABILITY
6.5. OEDOMETRIC TESTS
   6.5.1. Test equipment and process
   6.5.2. Measurement of parameter and typical values
6.6. FAILURE TESTS
   6.6.1 Triaxial test: equipment, measurement of parameters and types of tests
   6.6.2. Direct shear test
   6.6.3. Other failure tests
6.7. COMPACTION TESTS
   6.7.1. Proctor test
   6.7.2. Other compaction tests. Standardization
Exercises of item 6, supplemented with additional concepts from 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 concepts, knowledge and developments in item 6
UNIT 7. STRENGTH AND DEFORMATION OF SATURATED SOIL

Description:
7.1 INTRODUCTION
7.2 SHEAR STRENGTH
  7.2.1 Drained processes in sands and clays
  7.2.2 Microstructural mechanism under failure
  7.2.3 Mohr-Coulomb failure criterion
  7.2.4 Parameters and correlations of interest
7.3 FAILURE IN UNDRAINED CONDITIONS
  7.3.1 Undrained processes in clays
  7.3.2 Pore pressures generation
  7.3.3 Undrained shear strength
7.4 CONSTITUTIVE EQUATIONS
  7.4.1 Role and necessity of the constitutive equations. Types
  7.4.2 Linear elastic case
  7.4.3 Basic concepts of plasticity
  7.4.4 Cam-Clay model

Exercises and problems of item 7, supplemented with additional concepts from theory

Specific objectives:
Knowledge, understanding and reasoning ability and exercise and problem solving concerning real 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 of item 7
UNIT 8. SERVICE AND FAILURE ANALYSIS

Description:
8.1. SERVICE ANALYSIS. ELASTICITY
8.1.1. Boundary problems. Approach
8.1.2. Linear elastic case
8.1.3. Elastic solutions of geotechnical interest and applications
8.2. FAILURE ANALYSIS. LIMIT EQUILIBRIUM, RANKINE STATES AND PLASTIC COLLAPSE THEOREMS
8.2.1. Introduction. States of failure. Characteristic lines
8.2.2. Active and passive Rankine states. Applications
8.2.3. Limit theorems. Upper and lower bound. Applications
Exercises and problems of item 8, supplemented with additional concepts from theory

Specific objectives:
Knowledge, understanding and reasoning ability and exercise and problem solving in relation to the two following basic cases of service analysis and failure:

* Application of elasticity to study the field behavior in service and subsequent estimation of seats.

* Rankine states and limit theorems of plastic collapse for modeling soil failure states and the subsequent estimation of bearing capacity and earth pressures.

Practice and deepening of concepts, knowledge and developments in item 8

Learning time: 21h 36m
Theory classes: 6h
Practical classes: 3h
Self study: 12h 36m
UNIT 9. FAILURE APPLICATION TO BASIC BOUNDARY PROBLEMS

Description:

9.1 EARTH PRESSURE OVER RETAINING STRUCTURES
9.1.1 General approach. Active and passive earth pressures
9.1.3 Water effect
9.1.4 Over-earth pressure by external loads. Other cases
9.2 BEARING CAPACITY OF SOIL
9.2.1 General approach. Overall failure mechanism
9.2.2 Prandtl's model for weightless ground
9.2.3 Soil with weight. Other cases
9.3 SLOPE STABILITY IN SOIL
9.3.1 Introduction. Problem
9.3.2 Undefined slope case
9.3.3 Vertical section case
9.3.3.1 Overall balance methods
9.3.3.2 Partial equilibrium methods or method of the slices
9.3.4 General methods of limit balance. Global and partial equilibrium (slices)

Exercises and problems of item 9 supplemented with additional concepts from theory

Specific objectives:

Knowledge, understanding and reasoning ability and exercise and problem solving in relation to the three following types of basic boundary problems:

* Estimation of earth pressures on retaining structures with simple configurations (granular, homogeneous, dry and without external load soils) and in the case of other configurations (cohesive soils and the effect of water and or external loads).

* Analysis of bearing capacity of foundations in the case of global failure mechanisms (Prandtl or Terzaghi models).

* Slope stability approach in soils including the phenomenological description and general solution procedure, the resolution of simple cases (indefinite and vertical slopes) and the general methods of calculation (overall and partial - slices - limit equilibrium methods).

Practice and deepening of concepts, knowledge and developments in item 9
UNIT 10. INTRODUCTION TO UNSATURATED SOIL

Learning time: 9h 36m
Theory classes: 4h
Self study: 5h 36m

Description:
10.1 UNSATURATED SOILS. SUCTION AND EFFECTIVE STRESS DEFINITIONS
10.2 RELATIONSHIP BETWEEN THE SUCTION AND THE DEGREE OF SATURATION
10.3 STRAIN BEHAVIOR. COLLAPSE AND SWELLING
10.4 THE COMPACTION PROCESS. REFERENCE DATA. MOISTURE-DENSITY CURVES
10.5 ANALYSIS OF THE PROPERTIES OF COMPACTED SOILS. APPLICATION TO A REAL CASE
10.6 LABORATORY TESTS ON COMPACTED SOILS
10.7 ENGINEERING APPLICATIONS OF COMPACTION
10.7.1 Method of vibration-compression
10.7.2 Kneading method
10.7.3 Geotechnical aspects related to compaction
10.7.4 Methods of controlling the compaction

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.

Qualification 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.
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 lab sessions must be conducted in group at the academic geotechnical laboratory available and the corresponding individual report 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:


