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250131 - MECSOLS - Soil Mechanics

Coordinating unit: 250 - ETSECCPB - Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering
Academic year: 2018
Degree: BACHELOR'S DEGREE IN CIVIL ENGINEERING (Syllabus 2017). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN CIVIL ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 9 Teaching languages: English

Teaching staff

Coordinator: PERE PRAT CATALAN

Others: ALBERTO LEDESMA VILLALBA, ANTONIO LLORET MORANCHO, CARLOS MARIA LOPEZ GARELLO, PERE PRAT CATALAN, ANNA RAMON TARRAGONA, ENRIQUE EDGAR ROMERO MORALES

Opening hours

Timetable: At the end of each class period and at times fixed by mutual agreement between teacher and student

Degree competences to which the subject contributes

Specific:

3029. Knowledge of soil and rock geotechnics and mechanics and the ability to apply this knowledge in carrying out studies, projects, constructions and exploitations in which earthmoving, foundations and retention structures are necessary.
3030. Understanding of, and the ability to apply, predictive models of water filtration in soils and the mechanical behaviour of, and structural faults in, soils and rocks.

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 INFORMATI0N 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.

Teaching methodology

The course consists of 6 hours per week of classes in the classroom or the laboratory for 15 weeks (90 hours total). Not all the material included in the program is taught in class: the classes focus on those aspects of greatest importance and difficulty, leaving the rest for the students to work with the help of personal notes and additional documentation provided.

Support materials are provided at the Digital Campus ATENEA: class-notes, programming and evaluation activities, directed learning and literature.

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Learning objectives of the subject

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

History of soil mechanics; 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; Elastic-plastic constitutive equations and solutions to simple cases; Critical state models (such as Cam-Clay) for soil plasticity and constitutive models for unsaturated soils; Experimental study of saturated soil by means of oedometric compression tests and triaxial shear tests; Mechanical behaviour and the basic laws of soil mechanics; 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

Study load

Total learning time: 225h	Hours large group:	48h	21.33%
	Hours medium group:	18h	8.00%
	Hours small group:	24h	10.67%
	Guided activities:	9h	4.00%
	Self study:	126h	56.00%

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Content

1. Soil characterization	Learning time: 21h 36m Theory classes: 4h Practical classes: 2h Laboratory classes: 3h Self study : 12h 36m

Description:

Soil structure. Representation of the phases of the soil. Definition of basic parameters that characterize the soil.
Obtaining experimental parameters in the laboratory and in the field.
Characterization of the solid phase of the soil with grain-size curves.
Definition of consistency and Atterberg limits. Casagrande plasticity chart. Universal soil classification system from grain-size curves and Atterberg limits.
Exercises to develop practically the concepts introduced in this topic.
Experimental practice related to the concepts introduced in this topic.

Specific objectives:

Learning the meaning of the various parameters used to characterize the soils, how they are obtained and their relationships, using the phase diagram.
Introduce the concept of grain-size curve, learning how to obtain it and its use, and acquire the ability to interpret the type of soil from the shape of the curve.
Introduce the concept of Atterberg limits, learning its meaning and how they are obtained in the laboratory.
Learn how to classify soils from its basic parameters and its plastic properties.
Developing practical skills from theory learned in this topic.
Provide minimal contact with a Soil Mechanics Laboratory, with a practical application of some of the theoretical concepts formulated in this topic.

2. Flow	Learning time: 43h 12m Theory classes: 11h Practical classes: 4h Laboratory classes: 3h Self study : 25h 12m

Description:

Concepts of total and effective stress. Principle of effective stresses. Piezometric level as a measure of energy. Water table. Stress distribution in a horizontal soil: vertical and horizontal stresses.
Concept of unit flow rate. Deduce the differential equation of flow from the equation of conservation of water mass and the equation of motion (Darcy's law). Permeability. Application to the case of flow in isotropic homogeneous medium assuming incompressible fluid and constant porosity. Laplace equation. Boundary conditions in one and two dimensions.
Seepage forces from the equilibrium equations. Concepts of critical hydraulic gradient, liquefaction and quick condition.
Discussion of different methods for solving the flow equation (Laplace equation). The hypothesis of Dupuit in the one-dimensional case and the graphical method in the two-dimensional case. The case of homogeneous soils with transverse anisotropy and the case of heterogeneous soils.
Basics of flow in unsaturated soil: capillarity, retention curves and suction. Effect of suction on soil strength.
Exercises to develop practically the concepts introduced in this topic.
Experimental practice related to the concepts introduced in this topic.

Specific objectives:

Introduce the concepts of total stress and effective stress and the effective stress principle. Apply hydraulics concepts to flow of water in the soil. Learn how to get vertical and horizontal stresses on a horizontal soil, introducing the concept of coefficient of lateral pressure at rest.
Learn how to obtain the differential equation of flow in a saturated soil and how to use it in simple conditions. Introduce the concepts of unit flow rate and permeability.
Acquiring the concept of critical hydraulic gradient and learning the conditions that can result in liquefaction of the ground.
Learning to solve basic flow problems in one and two dimensions.
Acquire a minimum knowledge of flow in unsaturated soils and the concepts of capillarity and suction.
Developing practical skills from theory learned in this topic.
Provide minimal contact with a Soil Mechanics Laboratory, with a practical application of some of the theoretical concepts formulated in this topic.

3. Experimental behavior	Learning time: 40h 48m Theory classes: 12h Practical classes: 2h Laboratory classes: 3h Self study : 23h 48m

Description:

Review the basic concepts of the mechanics of a continuous medium that are necessary for the understanding of the following topics of this course. Introduction and reminder of the basic concepts of the theories of elasticity and plasticity.
Introduction of the concept of stress path in soil mechanics. Lambe and Cambridge representations.
Description of the triaxial apparatus and the procedures for conducting drained and undrained test. Calculation of the porewater pressure in undrained tests: Skempton's formula. Stress paths.
Description of the oedometer and the procedure for performing the oedometer test. Results of the oedometer test. Parameters. Stress history. Normally consolidated and overconsolidated soils. Secondary consolidation.
Basic description of the various shear tests.
Description of the experimental results of triaxial tests (drained and undrained) with clay and sand.
Exercises to develop practically the concepts introduced in this topic.
Experimental practice related to the concepts introduced in this topic.

Specific objectives:

Strengthen the knowledge of the mechanics of a continuous medium to facilitate the understanding of future course contents. Give the basics and the formal framework allowing the development of the following topics of the course.
Learning to represent stress variations in soil using the common stress representation used in soil mechanics.
Learn the operation of a triaxial apparatus and the procedure for conducting drained and undrained tests and obtaining results.
Learn how to operate the oedometer and the procedure to perform the test and obtain results.
Learn the basic ideas of the shear tests in soils.
Analyze the results of the triaxial tests to learn about the material behavior in order to formulate a constitutive model.
Developing practical skills from theory learned in this topic.
Provide minimal contact with a Soil Mechanics Laboratory, with a practical application of some of the theoretical concepts formulated in this topic.

TEST-1	Learning time: 4h 48m Laboratory classes: 2h Self study : 2h 48m

4. Mechanical behaviour	Learning time: 43h 12m Theory classes: 14h Practical classes: 4h Self study : 25h 12m

Description:

Mathematical formulation of the Cam-clay model for clay. Predictions of the model for normally consolidated and overconsolidated soils with drained and undrained conditions.
Define critical state and formalize the model, describing the observed behavior trends and predictions for normally consolidated and overconsolidated soils with drained and undrained conditions.
The classical Mohr-Coulomb strength criterion for soils. Relation between the Mohr-Coulomb criterion and the critical state theory. Strength parameters.
The concept of undrained shear strength and its use as a soil characteristic parameter: applications and limitations. Drained and undrained analysis in soil mechanics.
Basic concepts of strength for unsaturated soils.
Exercises to develop practically the concepts introduced in this topic.

Specific objectives:

Develop a mathematical model to predict the behavior of clays, analyze and compare the model predictions with the experimental results described in the previous topic.
Learn to identify trends in the behavior of soils when the state of stress approaches the critical state for normally consolidated and overconsolidated soils with drained and undrained conditions.
Learn to use the Mohr-Coulomb strength criterion to determine the failure conditions of the soil, comparing them to the predictions of the critical state theory.
Learn to use properly the undrained shear strength parameter. Mastering the concepts of drained and undrained analysis in soil mechanics.
Acquire a minimum knowledge of the mechanical behavior of unsaturated soils.
Developing practical skills from theory learned in this topic.

5. Failure analysis	Learning time: 33h 36m Theory classes: 10h Practical classes: 4h Self study : 19h 36m

Description:
Introduction to show real cases of soil failure and description of the different methods available to solve such problems.
Definition of Rankine state and solution of the active and passive states under drained and undrained conditions.
Enunciate the plastic collapse theorems in the context of soil mechanics. Applications of the upper bound theorem to geotechnical problems. Mechanisms. Energy dissipated in a slip line. Fans of slippage lines.
Applications of the lower bound theorem to geotechnical problems. Stress discontinuity. Fans of stress discontinuity lines.
Slope stability analysis in simple cases. The limit equilibrium method: global equilibrium and the method of slices.
The method of Bishop. Line of influence and neutral point.
Exercises to develop practically the concepts in this topic.

Specific objectives:
To show real cases of soil failure and to discuss the available methods of analysis.
To acquire the concepts of active and passive Rankine states and the ability to apply them to simple real cases.
Learn to use the theorems of plastic collapse to evaluate the failure load in the failure analysis of soils.
Learn to use the limit equilibrium method to solve slope stability problems.
Developing practical skills from theory learned in this topic.

6. Consolidation	Learning time: 14h 23m Theory classes: 4h Practical classes: 2h Self study : 8h 23m

Description:
Hydro-mechanical coupling. Terzaghi-Fröhlich equation of one-dimensional consolidation. Solution of the consolidation equation. Isochrones. Degree of consolidation. Consolidation due to changes of the hydraulic conditions.
Introduction to the case of consolidation with combined vertical and radial flow.
Exercises to develop practically the concepts this topic.

Specific objectives:
Introduce the concept of hydro-mechanical coupling in order to obtain the time-evolution of water pressures in the ground and of settlements.
Study the case of radial flow when vertical drains exist in the ground as a mean to accelerate the consolidation.
Developing practical skills from theory learned in this topic.

TEST-2	Learning time: 4h 48m Laboratory classes: 2h Self study : 2h 48m

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

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Qualification system

The evaluation method explained below is also valid for the group in English.

The grade of the subject (NF) is obtained from:
- the marks of two exams made during the course in the periods set by the School (E1, E2)
- the mark of the group work (TG)
- the assessment of the evaluable activities carried out in teaching hours, which will be specified at the beginning of each academic year (AA)
- the evaluation of the report of laboratory practices (PL)

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

NF = 0.25*E1 + 0.4*E2 + 0.2*TG + 0.1*AA + 0.05*PL

In order for the assessment of evaluable activities carried out in teaching hours (AA) to be included in the previous formula, it is necessary that the student's participation in these activities is equal to or greater than 80%. Otherwise, AA = 0.

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

Examinations will be held in regular teaching hours (or in the “grey band” if necessary), will last 2 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:
- to submit exam E2, 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
- to make and present the course work (TG)
- to carry all laboratory practices and deliver the final report (PL)
If these conditions are not satisfied, the final grade will be "NOT PRESENTED" (NF = NP)

According to the 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 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. It will be done on the day and time that the School determines, outside of the teaching hours of the subject.

The re-evaluation test will be graded as PASS/FAIL - if it is PASS, the final grade NF = 5.0 ("aprovat") will be awarded; if it is FAIL, the previous NF mark from the evaluation process will be retained, with the description of "suspens".

Special exams will be made for those students who have not been able to carry out some of the tests 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 professor responsible for the subject, and will be carried out within the corresponding academic term.

Regulations for carrying out activities

Failure to perform a scheduled test during the period (without justified cause with documentary evidence) will result in a zero-score for that test.
Failure to perform one or more laboratory practices or failure to deliver the group work will result in an "incomplete" (NP) final grade even in the case of a grade average NF greater than or equal to 5.0

Bibliography

Basic:

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Iglesias, C. Mecánica del suelo. Madrid: Síntesis, 1997. ISBN 847738438X.

Atkinson, J. The mechanics of soils and foundations. 2nd ed. Oxford, UK: Taylor & Francis, 2007. ISBN 9780415362566.

Complementary:

Smith, I. Smith's elements of soil mechanics. 9th. Oxford, UK: Blackwell Publishing, 2014. ISBN 9780470673393.

Verruijt, A. Soil mechanics. Delft: VSSD, 2012. ISBN 9789065620583.

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