Course guide
2500219 - GEA0219 - Geomechanics

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Unit in charge: Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: BACHELOR'S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2020). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: SEBASTIAN OLIVELLA PASTALLE

Others: SEBASTIAN OLIVELLA PASTALLE, ANNA RAMON TARRAGONA

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
14446. Solve mathematical problems that may arise in engineering by applying knowledge about: linear algebra, geometry, differential geometry, differential and integral calculus, optimization, ordinary differential equations.
14447. Obtain basic knowledge about the use and programming of computers, operating systems, databases and basic numerical calculation and applied to engineering.
14448. Manage the basic concepts about the general laws of mechanics and thermodynamics, concept of field and heat transfer, and apply them to solve engineering problems.
14450. Describe the global functioning of the planet: atmosphere, hydrosphere, lithosphere, biosphere, anthroposphere, biogeochemical cycles (C, N, P, S), soil morphology and apply it to problems related to geology, geotechnics, edaphology and climatology.
14453. Describe and apply the techniques of analysis of physical, chemical and biological parameters; Integrate the experimental evidence found in field and / or laboratory data with the theoretical knowledge and interpret its results.
14457. Identify the fundamentals of structure theory, sustainable procedures for construction and dismantling of buildings and civil works; and describe the technology bases of the materials used in construction.
14458. Apply the methodologies of studies and evaluations of environmental impact and, in general, of environmental technologies, sustainability and waste treatment and of the management of international standards of environmental quality. Life cycle analysis, carbon footprint and water footprint and assess natural hazards (river, coastal floods, droughts, fires, soil erosion and landslides).
14459. Describe the components and modes of transport and the impact of their externalities on the environment; identify the principles of environmental management of transport systems and sustainable planning of the territory; and introduce the tools for the management and operation of transport systems.
14461. Analyze, design, simulate and optimize processes and systems with environmental relevance, both natural and artificial, and their resolution techniques, as well as recognize techniques for analysis and evaluation of climate change.
14465. Identify renewable energy generation techniques and energy transition concept.

Generical:
14440. Identify, formulate and solve problems related to environmental engineering.
14441. Apply the functions of consulting, analysis, design, calculation, project, construction, maintenance, conservation and exploitation of any action in the territory in the field of environmental engineering.
14442. To use in any action in the territory proven methods and accredited technologies, in order to achieve the greatest efficiency respect for the environment and the protection of the safety and health of workers and users.

TEACHING METHODOLOGY

The course consists of 2.3 hours per week of classroom activity (large size group) and 1.2 hours weekly with half the students (medium size group).

The 2.3 hours in the large size groups are devoted to theoretical lectures, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises.

The 1.2 hours in the medium size groups is devoted to solving practical problems with greater interaction with the students. The objective of these practical exercises is to consolidate the general and specific learning objectives.

The rest of weekly hours devoted to laboratory practice.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENEA: content, program of learning and assessment activities conducted and literature.

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

Basic properties of soils and rocks. Sandy soils and clay soils. Permeability, deformability and resistance of geo-materials. Movement of water and steam in porous, unsaturated and deformable medium. Drainage in facilities. Soil compacting. Embankments and slopes. Isolation barriers. Introduction to environmental geotechnics: geothermal energy, fluid injection, waste storage, earth dams, geomembranes and geotextiles for insulation, mining waste reservoirs.

1. Know the fundamentals of the geomechanics and mechanical behavior of the soil.
2. Know the relationship between geomechanics and energy in liquids and gases, nuclear energy and energy and salt rocks.
3. Understand practical geoenvironmental problems and applied solutions and actions.

Geomechanical. In this subject the bases of geomechanics are studied to understand the use and storage of energy in the field (energy geothermal). Aspects of energy in liquids and gases, nuclear energy and energy in salt rocks are also discussed from the point of view of geomechanics.

Basic properties of soils and rocks. Permeability, deformability and geo-material strength. Movement of water and vapor in unsaturated and deformable porous medium. Drainage. Soil compaction. Embankments and slopes. Isolations engineered barriers. Introduction to environmental geotechnics: geothermal, fluid injection, waste storage, earthing, geomembranes and geotextiles for insulation, mining waste reservoirs. Geomechanics. In this subject the bases of geomechanics are studied to understand different geoenvironmental problems some of which are linked to the management of the energy cycle.

STUDY LOAD

Type	Hours	Percentage
Self study	90,0	60.00
Hours small group	15,0	10.00
Hours large group	30,0	20.00
Hours medium group	15,0	10.00

Total learning time: 150 h

CONTENTS

Topic 1. Introduction to the subject

Description:
Object of geomechanics, geotechnics and geotechnical engineering, Organization of the subject and documentation

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: 4h 48m
Theory classes: 2h
Self study : 2h 48m

Topic 2. Basic properties of soils. Identification and classification

Description:
Soil formation and nature. Observation scales. Soil phases. Basic types of soils Granulometry. Soil consistency. Limits. Soil classification system Basic soil behavior.
Exercises of topic 2, complemented with additional concepts of theory

Specific objectives:
Knowledge, understanding and ability to reason and solve exercises in relation to the quantification of the state of a soil. It is a question of determining the relation between weights and volumes of the different phases that integrate it. The student must understand that soil is a porous medium in which the gaps left by the mineral particles that make it up (solid phase) may be liquid water and / or air (liquid or gas phases respectively). It will be necessary to know the tests whose objective is to identify and classify a real ground by means of the criteria of classification accepted in the geotechnical environment and some aspects on deformation and movement of the water inside the ground that is they will indicate intuitively.
Practice and deepening of the concepts, knowledge and developments of the subject 2

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study : 5h 36m

Subject 3. Tensions and deformations. Effective tension.

Description:
Definition of stresses and strains. Principle of effective stresses. Invariant stresses and strains. Stress state in horizontal terrain.
Exercises of topic 3, complemented with additional concepts of theory

Specific objectives:
Knowledge, comprehension and ability to reason and solve exercises and problems in relation to the following aspects: units of stress in SI and others, total stresses and effective stresses, Mohr circles, invariants of the stress and strain matrix, stress trajectories in invariant planes (confinement and shear stress), and stress laws in one-dimensional conditions. Justification by algebra of matrices of the equations of normal and tangential stress in an arbitrary plane of inclination, and of the invariants of the matrix of stresses and deformations. Knowledge of typical values and orders of magnitude of vertical and horizontal stresses in a field due to weight according to saturation conditions.
Practice and deepening of the concepts, knowledge and developments of the subject 3

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

Laboratory practices

Description:
Identification and basic classification of soils. Visual and tactile identification and classification and determination of basic geotechnical parameters (granulometry, Atterberg boundaries and unified soil classification).
Water flow in saturated soil. Concepts of flow, unit flow, hydraulic gradient, permeability, critical gradient and siphoning. Determination of permeability with constant and variable load permeability and measurement of the critical gradient when reaching siphoning.
Compaction and edometric and triaxial testing. Consolidation and resistance of compacted soils. Compaction methods and curve. Collapse and swelling and shear strength of compacted soils.

Specific objectives:
Direct experimentation with soils of different types and characteristics and knowledge, understanding and capacity for visual and tactile identification of soils and experimental determination of basic geotechnical parameters (granulometry, Atterberg limits and unified classification).
Experimentation with water flow in saturated soil and knowledge, understanding and ability to reason with the concepts of flow, unit flow, hydraulic gradient, permeability, critical gradient and siphoning and with the determination of permeability with constant and variable load parameters and the measurement of the critical gradient when reaching siphoning.
Experimentation with soil compaction and compacted soils in edometric and triaxial tests and knowledge, understanding and reasoning ability with soil compaction, collapse and swelling phenomena and with the development of standard edometric and triaxial tests.

Full-or-part-time: 21h 36m
Laboratory classes: 9h
Self study : 12h 36m

Item 4. Water flow in porous medium

Description:
Water in the ground. Water density. Porosity. Degree of saturation. Piezometric level. Groundwater level. Darcy's Law. Permeability. Relative permeability. Water flow equation. Free and confined aquifers. Pumps. Drains and filters. Landings. Excavations.
Exercises

Specific objectives:
Knowledge, understanding and ability to reason and solve exercises and problems in relation to the following aspects: concepts of water flow and flow; piezometric height, Darcy's law, permeability, aquifers, equivalent permeability and flow in stratified soils; siphoning; hydraulic and critical gradient, interpretation of all types of flow networks in saturated soils (flows, hydraulic gradients, interstitial pressures), and graphical obtaining of flow networks and excavation drainage project (in the excavation itself, with wells or wells tip) in simple cases (isotropic and homogeneous saturated soils, and simple anisotropes or heterogeneous). Knowledge of typical values and orders of magnitude of terrain permeabilities (hydraulic and critical gradients, interstitial and total pressures, etc.).

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

Item 5. Consolidation

Description:
Deformation of the soils. Primary consolidation. Consolidation equation. One-dimensional consolidation. Edometric test. Degree of consolidation. Solution of the one-dimensional consolidation equation. Secondary consolidation.
Exercises and problems of topic 5 complemented with additional concepts of theory

Specific objectives:
Knowledge, comprehension and reasoning ability and resolution of exercises and problems in relation to interstitial pressures, recoverable and irrecoverable deformations measured with different parameters and settlements and degrees of consolidation produced in various cases. Knowledge of typical values and orders of magnitude of compressibility coefficients, edometric modules and consolidation coefficients of different types of soils and for different states of the same. Knowledge and understanding of the components of soil deformation and the concepts of instantaneous and deferred deformations in time and effective stresses, of the processes of primary and secondary consolidation, of the equations of primary consolidation (soil deformation in edometric conditions) and one-dimensional consolidation.
Practice and deepening of the concepts, knowledge and developments of the subject 5

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

Item 6. Soil compaction

Description:
Unsaturated soils. Retention curve. Swelling and collapse. Compaction, density diagrams - water content in the soil.
Exercises

Specific objectives:
Knowledge, understanding and reasoning ability of the most relevant aspects of the properties of unsaturated soils, the concept of suction and its application to the soil retention curve, the definition of effective stress, collapse phenomena and inflation, of the specific laboratory tests for these soils, of the compaction curve and of the compaction process in practice including various procedures.

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study : 5h 36m

Item 7. Strength of geomaterials

Description:
Friction and cohesion in soils. Mohr-Coulomb break criterion. Breaking tests. Breakage in drained and undrained conditions. Friction and cohesion angle values in different types of soils and rocks.
Exercises and problems of unit 7 complemented with additional concepts of theory

Specific objectives:
Knowledge, comprehension and reasoning ability and resolution of exercises and problems in relation to real triaxial tests in both sands and clays (including determination of drained and non-drained deformation modules), representation of results of triaxial tests in the form of trajectories in terms of stress invariants (determination of the resistance obtained in a test, including the concept of drained and undrained). Knowledge of typical values and orders of magnitude of the internal friction angle, resistance to cutting without drainage. Knowledge of some relationships between the humidity of a soil and the resistance, as well as between the coefficient of thrust at rest and the angle of friction of a soil.
Practice and deepening of the concepts, knowledge and developments of the subject 7

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study : 5h 36m

Item 8. Geo-environmental problems

Description:
Reservoirs. Earth dams. Geomembranes and geotextiles.
Bibliographic review and self-learning

Full-or-part-time: 15h 36m
Theory classes: 5h
Practical classes: 1h 30m
Self study : 9h 06m

Item 9. Geo-environmental problems

Description:
Engineering barriers for waste isolation. Fluid storage in the field. Geomechanics and energy. Geothermal problems.
Bibliographic review and self-learning

Full-or-part-time: 15h 36m
Theory classes: 5h
Practical classes: 1h 30m
Self study : 9h 06m

Evaluation

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

GRADING SYSTEM

The mark of the course is obtained from the ratings of continuous assessment and their corresponding laboratories and/or classroom computers.

Continuous assessment consist in several activities, both individually and in group, of additive and training characteristics, carried out during the year (both in and out of the classroom).

The teachings of the laboratory grade is the average in such activities.

Mark = 0.6 x MAX ((NEP + NEC)/2, NEC)) + 0.4 x NT

NEP = Mark Mid term Exam
NEC = Mark Final Exame
NT = Mark average of assignments

The evaluation tests consist of a part with questions about concepts associated with the learning objectives of the course with regard to knowledge or understanding, and a part with a set of application exercises.

BIBLIOGRAPHY

Basic:
- Verruijt, A. Soil mechanics. Delft: VSSD, 2007. ISBN 9065620583.
- Lambe, T.W.; Whitman, R.V. Mecánica de suelos. 2a ed. México: Limusa : Noriega, 1995. ISBN 9681818946.
- 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.
- Terzaghi, K,; Peck, R.B.; Mesri, G. Soil mechanics in engineering practice. 3a ed. New York: John Wiley & Sons, 1995. ISBN 0471086584.
- Mitchell, J.K.; Soga, K. Fundamentals of soil behavior. 3rd ed. Hoboken: John Wiley & Sons, 2005. ISBN 0471463027.

Complementary:
- Serra Gesta, J.; Oteo Mazo, C.; García Gamallo, A.Mª; Rodríguez Ortiz, J.M. Mecánica del suelo y cimentaciones. 2a ed. Madrid: Fundación Escuela de la Edificación, 1995. ISBN 8486957621.
- Olivella, S. [et al.]. Mecánica de suelos: problemas resueltos [on line]. Barcelona: Edicions UPC, 2001 [Consultation: 10/05/2021]. Available on: http://hdl.handle.net/2099.3/36251. ISBN 8483015234.
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