250343 - MECROQEXSU - Rock Mechanics and Underground Excavation

Coordinating unit: 250 - ETSECCPB - Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering
Academic year: 2019
Degree: BACHELOR'S DEGREE IN GEOLOGICAL ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 6
Teaching languages: Spanish

Teaching staff
Coordinator: IGNACIO CAROL VILARASAU
Others: IGNACIO CAROL VILARASAU, ALESSANDRA DI MARIANO SIMONCINI, NURIA MERCE PINYOL PUIGMARTI, ANNA RAMON TARRAGONA

Degree competences to which the subject contributes

Specific:
4034. Drilling and support techniques for underground and surface works
4047. Students will acquire knowledge of geotechnical engineering, including modelling of public infrastructures, underground structures and geotechnical structures.
4065. Design and execution of surface and underground works

General:
3103. Students will learn to identify, formulate and solve a range of engineering problems. They will be expected to show initiative in interpreting and solving specific civil engineering problems and to demonstrate creativity and decision-making skills. Finally, students will develop creative and systematic strategies for analysing and solving problems.
3106. Students will learn to assess the complexity of the problems examined in the different subject areas, identify the key elements of the problem statement, and select the appropriate strategy for solving it. Once they have chosen a strategy, they will apply it and, if the desired solution is not reached, determine whether modifications are required. Students will use a range of methods and tools to determine whether their solution is correct or, at the very least, appropriate to the problem in question. More generally, students will be encouraged to consider the importance of creativity in science and technology.
3107. Students will learn to identify, model and analyse problems from open situations, consider alternative strategies for solving them, select the most appropriate solution on the basis of reasoned criteria, and consider a range of methods for validating their results. More generally, students will learn to work confidently with complex systems and to identify the interactions between their components.
3109. Students will learn to plan, design, manage and maintain systems suitable for use in civil engineering. They will develop a systematic approach to the complete life-cycle of a civil engineering infrastructure, system or service, which includes drafting and finalising project plans, identifying the basic materials and technologies required, making decisions, managing the different project activities, performing measurements, calculations and assessments, ensuring compliance with specifications, regulations and compulsory standards, evaluating the social and environmental impact of the processes and techniques used, and conducting economic analyses of human and material resources.
3112. Students will develop an understanding of the different functions of engineering, the processes involved in the life-cycle of a construction project, process or service, and the importance of systematising the design process. They will learn to identify and interpret the stages in preparing a product design specification (PDS), draft and optimise specifications and planning documents, and apply a systematic design process to the implementation and operation phases. Students will learn to write progress reports for a design process, use a range of project management tools and prepare final reports, and will be expected to show an awareness of the basic economic concepts associated with the product, process or service in question.
Students will learn to identify user requirements, to draft definitions and specifications of the product, process or service in question, including a product design specification (PDS) document, and to follow industry-standard design management models. Students will be expected to show advanced knowledge of the steps involved in the design, execution and operation phases and to use the knowledge and tools covered in each subject area to the design and execution of their own projects. Finally, students will assess the impact of national, European and international legislation applicable to engineering projects.

**Transversal:**

585. ENTREPRENEURSHIP AND INNOVATION - Level 1. Showing enterprise, acquiring basic knowledge about organizations and becoming familiar with the tools and techniques for generating ideas and managing organizations that make it possible to solve known problems and create opportunities.  
586. ENTREPRENEURSHIP AND INNOVATION - Level 2. Taking initiatives that give rise to opportunities and to new products and solutions, doing so with a vision of process implementation and market understanding, and involving others in projects that have to be carried out.  
589. SUSTAINABILITY AND SOCIAL COMMITMENT - Level 2. Applying sustainability criteria and professional codes of conduct in the design and assessment of technological solutions.  
594. TEAMWORK - Level 3. Managing and making work groups effective. Resolving possible conflicts, valuing working with others, assessing the effectiveness of a team and presenting the final results.  
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 3 in-class hours in which theory and problem solving will be taught and case stories will be presented. Students will apply the knowledge acquired by means of a report, which will consist in elaborating a preliminary draft of a tunnel in a real life environment. Typically the report should include the following aspects:

- Topographic and geological description of the site  
- Structural description of the rock massif. Section of the tunnel and geomechanical classification. Estimate of the global strength parameters  
- Analysis of the rock-bearing interaction. Determination of the characteristic curves. Linear and non-linear failure envelopes. Bearing curves  
- Definition of bearing from the interaction analysis and the geomechanical classifications  
- Analysis of the structural stability of the excavation  
- Definition of the building procedure

Support materials, such as a detailed teaching plan, can be found in the virtual campus ATENEA: table of contents, activities scheduled and references.

**Learning objectives of the subject**

Students will acquire the knowledge and skills to construct geotechnical infrastructure, in particular underground excavations in soil and rock.

Upon completion of the course, students will be able to:  
1. Determine the geomechanical and hydrological properties of a rock from laboratory data;  
2. Characterise a rock massif on the basis of field data;  
3. Solve a problem involving underground excavation, identifying the materials to be cleared, designing surveys, identifying the most suitable machinery for each task and analysing the ground response.
Matrix properties; Discontinuities; Fracture mechanics; In situ stress; Rock foundations; Hydraulics of rock massifs; Talus slope stability; History of tunnel construction; The canal and railway construction boom; "National" excavation methods; Modern techniques; Geomechanical classifications for tunnel construction; Terzaghi and Lauffer classifications; Modern classifications: Q Index, RMR; In situ stress state; Influence of tectonics; Effect of anisotropy of rock massifs; In situ measurements; Tunnels in elastic regime; Analytical solutions; Stress and deformation distributions; Effect of excavation method; Numerical calculation of stress distribution; Structural stability; Identification of unstable wedges in the presence of three-family discontinuity; Determination of safety coefficients; Rock matrix resistance; Hoek-Brown failure criterion; Impact of discontinuities on the failure criterion; Adaptation of the Hoek-Brown criterion for rock massifs; Correlation of the failure criterion parameters with the Q Index and RMR; Characteristic curve of tunnels; Derivation of the characteristic curve in elasto-plastic regime; Elastic phase; Determination of the plastic crown; Support characteristic curves; Shotcrete; Trusses; Bolts; Continuous coating; Determination of equilibrium conditions; New Austrian Tunnelling method; Construction cycle; Tunnel mouth; Perforation, blasting, clearing rubble, roof support, sounding; Tunnel boring machines; Tunnels in soil; Belgian method and German method; Shields; Tunnels and water; Modification of the elasto-plastic solution in the presence of filtration; Injection effects and drainage; Watertightness of coating; Surface settlement caused by tunnelling; Influence of buildings; Tunnel collapse; Measures to adopt; Case studies

<table>
<thead>
<tr>
<th>Study load</th>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>Hours medium group:</th>
<th>Hours small group:</th>
<th>Guided activities:</th>
<th>Self study:</th>
</tr>
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<tbody>
<tr>
<td>Total learning time:</td>
<td>150h</td>
<td>35h</td>
<td>13h</td>
<td>12h</td>
<td>6h</td>
<td>84h</td>
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<tr>
<td>Hours large group:</td>
<td></td>
<td>23.33%</td>
<td>8.67%</td>
<td>8.00%</td>
<td>4.00%</td>
<td>56.00%</td>
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</table>
# Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time:</th>
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</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>7h 11m</td>
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<tr>
<td>Theory classes: 3h&lt;br&gt;Self study : 4h 11m</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Excavations and tunnels. History of tunnel construction</td>
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<tr>
<td><strong>Introduction to fracture mechanics</strong></td>
<td>16h 48m</td>
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<tr>
<td>Theory classes: 5h&lt;br&gt;Practical classes: 2h&lt;br&gt;Self study : 9h 48m</td>
<td></td>
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<tr>
<td><strong>Description:</strong></td>
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<tr>
<td>Mechanics of nonlinear fractures. Scale effect. Initiation and propagation of fractures in rock</td>
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<tr>
<td>Scale effects on the behavior of rockfill</td>
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<tr>
<td><strong>Rock matrix, joints and rock mass</strong></td>
<td>12h</td>
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<tr>
<td>Theory classes: 5h&lt;br&gt;Self study : 7h</td>
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<tr>
<td><strong>Description:</strong></td>
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<tr>
<td>Discontinuities. Overview. Patton and Barton-Choubey failure criteria</td>
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<tr>
<td><strong>Tensions &quot;in situ&quot;</strong></td>
<td>9h 36m</td>
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<tr>
<td>Theory classes: 4h&lt;br&gt;Self study : 5h 36m</td>
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<tr>
<td><strong>Description:</strong></td>
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<tr>
<td>Importance. Stress states in the vicinity of tunnels and excavations</td>
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<td>Topic</td>
<td>Description</td>
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<td></td>
<td>Correction and stabilization. Complete design of a rock slope</td>
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<tr>
<td>Circular tunnel in elastoplastic ground.</td>
<td>Planar strain. Mohr-Coulomb's elastoplastic model. Hoek-Brown's elastoplastic model</td>
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<tr>
<td>Characteristic curves</td>
<td>Spherical cavity. Mohr-Coulomb's elastoplastic model. Hoek-Brown's elastoplastic model</td>
</tr>
<tr>
<td>Tunnel-support interaction</td>
<td>Support curves. Bolts. Circular lining and trusses. 3D phenomena on the face</td>
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<tr>
<td></td>
<td>Characteristic curves of tunnels in the presence of flow. Implications</td>
</tr>
</tbody>
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# Construction of tunnels in rock

**Learning time:** 4h 48m  
Theory classes: 2h  
Self study: 2h 48m  

**Description:**  

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# Tunnel face stability

**Learning time:** 12h  
Theory classes: 2h  
Practical classes: 3h  
Self study: 7h  

**Description:**  
Application of plastic collapse theorems. 2D and 3D solutions for circular tunnels. Undrained case  
Stability under drained conditions. La Floresta tunnels in slate

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# Tunnelling in soils

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

**Description:**  
Traditional methods. Belgian. German. Construction of the metro in Barcelona  
Shields. Barcelona’s HST line

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# Movements induced by tunneling

**Learning time:** 14h 23m  
Theory classes: 6h  
Self study: 8h 23m  

**Description:**  
Shallow settlements. Empirical methods. Loss of land  
Displacements in the vicinity of tunnels. Theoretical and semiempirical methods. Effect of movements on structures. Burland and Boscardin/Cording methods

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# Evaluation

**Learning time:** 14h 23m  
Laboratory classes: 6h  
Self study: 8h 23m
The course will be evaluated taking the mean of the two tests taken during the course and the final report.

There will be two tests: one at mid-term (E1) and another one by the end of the term (E2). Both tests will evaluate the knowledge of the students with regards to what has been taught by the time of the test is scheduled.

The result of the tests will be the maximum score of the second test plus the weighted mean of both tests (the first test will weight 40% and the second test will weight 60%).

Final test result = max. (0.4 * Result of E1 + 0.6 * Result of E2 ; ResultE2)

The report will be evaluated independently and will be 20% of the final score.

The final score of the course will be calculated as follows:

Final score = 0.8 * Final test result + 0.2 * Report score

The final score will be calculated from partial scores above 4 over 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

Failure to perform the second test or to deliver the report will result in a mark of zero.
Bibliography

Basic:


Complementary:


