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250423 - TUNMECROQU - Tunnels and Rock Mechanics

Coordinating unit: 250 - ETSECCPB - Barcelona School of Civil Engineering

Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering

Academic year: 2015

Degree: MASTER'S DEGREE IN CIVIL ENGINEERING (RESEARCH TRACK) (Syllabus 2007). (Teaching unit Optional)
MASTER'S DEGREE IN CIVIL ENGINEERING (PROFESSIONAL TRACK) (Syllabus 2012). (Teaching unit Optional)
MASTER'S DEGREE IN CIVIL ENGINEERING (PROFESSIONAL TRACK) (Syllabus 2012). (Teaching unit Optional)
MASTER'S DEGREE IN CIVIL ENGINEERING (RESEARCH TRACK) (Syllabus 2009). (Teaching unit Optional)

ECTS credits: 5 Teaching languages: Spanish

Teaching staff

Coordinator: EDUARDO ALONSO PEREZ DE AGREDA

Others: EDUARDO ALONSO PEREZ DE AGREDA, IGNACIO CAROL VILARASAU, NURIA MERCE PINYOL PUIGMARTI

Degree competences to which the subject contributes

Specific:

8200. The ability to apply knowledge of soil and rock mechanics to the study, design, construction and operation of foundations, cuts, fills, tunnels and other constructions over or through land, whatever its nature and state, and whatever the purpose of the work.

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

Specialization subject in which knowledge on specific competences is intensified.

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Knowledge and skills at specialization level that permit the development and application of techniques and methodologies at advanced level.

Contents of specialization at master level related to research or innovation in the field of engineering.

Ability to build geotechnical works, in special underground excavations in soils and rocks.

By the end of the course the students will be able: 1. To determine the properties of a rock from laboratory results geomechanically and hydrologically. 2. To characterize a rock massif through field data. 3. To solve problems regarding underground excavations identifying the materials to be crossed, proposing test campaigns and the most adequate machinery and analyzing the ground response.

Contents of the course:
Properties of the matrix. Discontinuities. Mechanics of failure. In situ stresses. Rock foundations. Hydraulics of rock massifs. Knowing the stability of slopes. History of tunnelling. The age of channels and railways. "National" methods of excavation. Outlook of modern techniques. Geomechanical classifications adapted to tunnelling. Terzaghi & Lauffer classifications. Modern classifications: Q rate, RMR. In situ stress state. Influence of tectonics. Effect of the anisotropy of a rock massif. In situ measurements. Tunnels in elastic regime. Analytical solutions. Stress-strain distribution. Structural stability. Determination of unstable faults when there are three discontinuity families. Determination of the security coefficient. Strength of rock matrix. Hoek & Brown criterion. Effect of discontinuities on rupture criterion. Adaptation of Hoek & Brown criterion to rock massifs. Correlation of the criterion parameters with RMR an Q rates. Characteristic curve of the tunnel. Curve derivation in elastoplastic regime. Elastic phase. Determination of plastic crown. Bearing characteristic curves. Shotcrete. Thrusts. Bolts. Continuous lining. Determination of equilibrium conditions. New Austrian Method. Building cycle. Portals. Boring, blasting, debris removal, forward bearing, monitoring. TBMs. Tunnelling in soils. Belgian and German methods. Shields. Tunnels and water. Modifying the elastoplastic solution when leaking occurs. Effects of injection and draining. Watertightness of the lining. Superficial settlements due to tunnelling. Influence of buildings. Tunnel collapse. measures to be adopted. Description of case stories.

Study load

Total learning time: 125h	Theory classes:	19h 30m	15.60%
	Practical classes:	9h 45m	7.80%
	Laboratory classes:	9h 45m	7.80%
	Guided activities:	6h	4.80%
	Self study:	80h	64.00%

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Content

Introduction

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

Description:
- Excavations and tunnels. History of tunnelling
- Dyke foundations. Example: The failure of Malpasse.
- Stability of rock slopes. Example: The failure of Vaiont

Introduction to fracture mechanics

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

Description:
- Introduction. Mechanisms and modes.
- Linear fracture mechanics (Griffith theory, stress intensity factor, toughness)
- Nonlinear fracture mechanics. Scale effect. Onset and propagation of fractures
- Example/Practice: Scale effect on the behaviour of the earth-dam

Rock matrix, joints and rock mass

Learning time: 7h 11m
Practical classes: 3h
Self study : 4h 11m

Description:
- Rock matrix. Tests. Mohr-Coulomb & Hoek-Brown criteria
- Discontinuities. General aspects. Patton & Barton Choubey failure criteria

Insitu stresses

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

Description:
- Significance. Stress states in an excavation site.
- "In situ" stress measurements. "In situ" stress release. Stress restitution. Hydraulic failure. Changes in stress in inclusions.

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Circular tunnel in elastoplastic soil. Characteristic curves	Learning time: 9h 36m Theory classes: 4h Self study : 5h 36m

Description:
- Plain deformation. Mohr-Coulomb elastoplastic model. Hoek-Brown elastoplastic model.
- Spherical cavity. Mohr-Coulomb elastoplastic model. Hoek-Brown elastoplastic model.

Interaction tunnel support	Learning time: 4h 48m Theory classes: 2h Self study : 2h 48m

Description:
Bearing curves. Bolts. Circular linings and ribs. 3D phenomena in the face.

Water and rock mass	Learning time: 7h 11m Theory classes: 3h Self study : 4h 11m

Description:
- Permeability of fracture. Flow in fracture networks. Effective stress law. Hydro coupling.
- Characteristic curves of tunnels in the presence of water flow. Implications.

Construction of tunnels in rock	Learning time: 7h 11m Theory classes: 3h Self study : 4h 11m

Description:
Traditional methods. New Austrian Method. Stability of portals. TBMs and TSMs

Tunnel face stability	Learning time: 3h 35m Practical classes: 1h 30m Self study : 2h 05m

Description:
Application of plastic collapse theorems. 2D and 3D solutions for circular tunnels

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Construction of tunnels in soil	Learning time: 9h 36m Theory classes: 4h Self study : 5h 36m

Description:
- Traditional Belgian and German methods. Example/Practice: Subway construction in Barcelona
- Shields. Example/Practice: HST line

Movements induced by tunneling	Learning time: 9h 36m Theory classes: 4h Self study : 5h 36m

Description:
- Superficial settlements. Empirical methods. Ground loss.
- Sliding near a tunnel. Theoretical and semiempirical methods. Effect of movement on structures. Burland & Boscardin-Cording methods.

Test	Learning time: 10h 48m Laboratory classes: 4h 30m Self study : 6h 18m

Qualification system

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.

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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:

Atkinson, B.K. (editor). Fracture Mechanics of Rock. Academic Press, 1987.

Jaeger, J.C. i N.G.W. Cook. Fundamentals of Rock Mechanics. London: Chapman and Hall, 1979.

López Jimeno, C. (ed.). Manual de túneles y obras subterráneas. Maddrid: E.T.S.I. Minas - Universidad Politécnica de Madrid, 2011. ISBN 9788496140370.

B. Maidl, M. Herrenknecht, U. Maidl, G. Wehrmeyer. Mechanised Shield Tunnelling. Germany: Wiley-Blackwell, 2012. ISBN 978-3-433-02995-4.

Complementary:

Bieniawski, Z.T.. Design Methodology in Rock Engineering. Balkema, 1992.

Broek, D.. The Practical Use of Fracture Mechanics. Kluiwer Academic Publishers, 1989.

Broek, D.. Elementary Engineering Fracture Mechanics. Kluiwer Academic Publishers, 1982.

Chernyshev, S.N. and W.R. Dearman. Rock Fractures. Butterworth-Heinemann, 1991.

González de Vallejo, L.I., M. Ferrer, L. Ortuño i C. Oteo. Ingeniería Geológica. Pearson Educación - Prentice Hall. Madrid, 2002.

Goodman, R.E.. Introduction to Rock Mechanics. John Wiley, 1989.

Goodman, R.E.. Engineering Geology. Rock in Engineering Construction. John Wiley & Sons, 1993.

Jumikis, A.R.. Rock Mechanics. Trans Tech Publications, 1983.

Hoek, E. Practical Rock Engineering. www.rockscience.com, 2000.

* Hoek, E. i E.T. Brown. Underground excavations in rock. Institution of Mining and Metallurgy, 1980.