COURSE OUTLINE

1. GENERAL

SCHOOL	SCHOOL OF ENGINEERING		
ACADEMIC UNIT	DEPARTMENT OF MINERAL RESOURCES ENGINEERING		
LEVEL OF STUDIES	*Undergraduate*		
COURSE CODE	MRE811	**SEMESTER**	8th
COURSE TITLE	Retaining and Support of Surface & Underground Excavations		

INDEPENDENT TEACHING ACTIVITIES	**WEEKLY TEACHING HOURS**	**CREDITS**
Lectures	2	5
Laboratory or Tutorials	2	
Overall	4	

COURSE TYPE	Background Course (Special Infrastructure course)
PREREQUISITE COURSES:	Mechanics - Structures (MRE204) Geotechnical and Soil Mechanics (MRE401) Rock Mechanics - Engineering Geology (MRE701)
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek
IS THE COURSE OFFERED TO ERASMUS STUDENTS	NO
COURSE WEBSITE (URL)	

2. LEARNING OUTCOMES

Learning outcomes

The course material aims at understanding the basic principles of Geotechnical Engineering, the consolidation of knowledge regarding the behavior of the soil and rock mass in the Supports, shoring & bracing of excavations and the application of specialized computer software in modeling, analysis and design of surface support-retaining and shoring systems & Underground Works.

On Surface Retaining Structures: Advanced knowledge in the field of analysis and design of support systems as well as advanced skills for solving complex problems with modeling, analysis-simulation and synthesis. For the support of the face of excavations will be used indicatively but not restrictively:

- Support with wood joints (with horizontal or vertical planking).
- Special supports with prefabricated shoring elements.
- "Berlinoise" type support systems.
- Support with steel section piles.
- Support with nailing.
- Support with any other retaining structural method.

On Underground Excavation Support Systems: After an introduction to the relevant concepts and terminology, the course focuses on measures to support and geotechnically improve geo-mass (rock mass and soil mass). Students are taught the technology and load-bearing capacity of active and passive nails (anchors or bolts, sockets), pre-reinforced and pre-supported elements in front of underground excavations, Reliable solutions for tunnel boring machines, solid and mesh steel frames, Fore poling.

Underground excavation support design, Support of wedges or blocks which arc free to fall, Support of wedges or blocks which are free to slide, Rock-support interaction analysis, Summary of rock-support interaction equations, Examples of rock-support interaction analysis, Discussion on rock-support interaction analysis, Use of rock mass classifications for estimating support, Comparison of underground excavation support predictions, Pre-reinforcement of rock masses, Suggestions for estimating support requirements, Rockbolts, shotcrete and mesh, Organization of a rockbolting programme, Review of typical rockbolt systems, Rockbolt installation, Wire mesh, Shotcrete, Mix design, Engineering properties of shotcrete, Placement of shotcrete, Fiber reinforced shotcrete.

An important element of the course is the teaching of the change in stress caused by the excavation of underground openings in the surrounding geomass and its response as an elastic (in the case of solid rocks mass) or elastoplastic (in the case of weak rock mass or soil mass) means. The interaction of the

support system with the geomass and the calculation of the required support measures are examined. The interaction of the support system with the geomass and the calculation of the required support systems and measures are examined. The methods of support on the face of underground mines are developed as special applications, such as the support of chambers and pillars, the filling of the gaps and openings of the exploitation and the calculation of uprights and beams on elongated exploitation fronts. The calculations are consolidated by students through practice exercises, case studies and the use of specialized software.

Upon successful completion of the course the student will be able to:

- Critically examines the principles and methods of supporting underground excavations and their practical application in mining and engineering projects.
- Calculates the stress state of the geomass around underground excavations as well as the excavation response to stress changes.
- Selects measures to support underground excavations in solid, blocky, bedded and fractured rocks, in weak rock masses and in soil formations.
- Calculates the required support method/system of individual rock regions against falling, toppling, plane or wedge failure sliding mechanisms.
- Designs the support system for underground mining and engineering projects.
- Collaborates with his classmates to solve practical engineering support problems.
- Understands the basic background of dealing with Landsliding phenomena and underground failures.
- Calculates support and retaining/shoring systems and measures for above ground projects.
- Calculates support and retaining/shoring systems and measures for underground projects.

General Competences

The course contributes to the acquisition of the following skills:

- Applying knowledge in practice,
- Researching, Analyzing & Synthesizing Data & Information using necessary technologies,
- Adapting to new situations,
- Decision-making,
- Working independently,
- Working in an international environment,
- Working in groups (Teamworking),
- Promoting Free, Creative & Inductive thinking.

3. SYLLABUS

General: Geostatic stress state: Stresses and displacements based on the theory of linear Elasticity, Estimation of "elastic" settlement in foundations. Winkler theory of elastic foundation, compressibility and consolidation of soil materials (preloading). Strength and failure of non-cohesive soils: The strength and the basic mechanism of failure of non-cohesive soils, Friction and expansion, Taylor theory of expansion friction, Applications: Critical depth of unsupported tunnel, Estimation of tensile strength. Critical state theory, Behavior of granular soils under drained conditions – Liquidation/Liquefaction.

Theory: Introduction. Underground project loading. Coulomb - Rankine support and support failure criteria. Methods of calculating active and passive earth pressures and thrusts. Methods of calculating earth pressures and thrusts with field in-situ tests. Design and construction of above ground support / retaining systems. Methods of analysis of slope stability. Slope stability control and calculations. Slope & Landslide Stabilizations. Instrumental landslide monitoring. Design and construction of underground support / retaining systems. Measures for immediate stabilization of the rock mass. Permanent measures for rock mass stabilization.

Tutorial exercises: Solving typical projects of mineral resources exploitation by implementing above-ground and underground support methods and support systems.

More specifically for Surface Support / Retaining Structures:

General knowledge of the subject of Support / Retaining systems and their solution in the context of the limit equilibrium method. Use of numerical methods to design Support / Retaining systems. Provisions of Eurocode EC-7 and 8 regarding the design of Support / Retaining systems. Parametric determination of envelop bearing capacity in combination with actions of vertical forces, horizontal forces and bending moments. Pile bearing capacity under vertical load (DIN 5014, EC-7). Individual pile response under vertical loading. Method t-z. Pile bearing capacity under horizontal loading (Broms method). Individual pile response under horizontal loading. Method p-y.

Results processing, back-engineered analyzes using numerical methods. Response of pile groups under vertical loading. Pile group interaction, use of empirical coefficients of pile bearing capacity and stiffness. Use of numerical methods and determination of response of characteristic piles and pile caps. Response of pile groups under horizontal loading. Pile group interaction, use of empirical coefficients of bearing capacity and stiffness. Use of numerical methods and determination of response of characteristic piles. Example of a pile group under vertical and horizontal loading. Modeling, analysis, design, reinforcement of piles and pile caps. Ground Supports and Retaining Walls. Earth pressures and thrusts (earth pressure at rest, active and passive earth pressures). Stress redistribution as a function of displacements. Change in thrusts during seismic action. Design of retaining walls from reinforced concrete (flexible). Design of retaining walls with sheet piles (construction arrangements). Soil-Structure Interactions.

Design of retaining walls using piles and diaphragm walls. Application in support systems using sheet pile walls and bulkheads.

Advanced knowledge in the field of analysis and design of supports as well as advanced skills for solving complex problems with analysis-simulation and synthesis requirements.

More specifically for Underground Excavation Support Systems:

Introduction, Terminology. Nails and Bolts. Long Elements. Steel frames. Concrete cover and shotcrete. Support of rock wedges. Rockbolting of layered bedrock. Elastic rock response around underground opening. Elastoplastic rock response around tunnels. Response to rock mass support measures. Rock - support interaction. Support of rock chambers with rock pillars. Filling of exploitation gaps. Posts and beams on elongated fronts.

4. TEACHING and LEARNING METHODS - EVALUATION

DELIVERY	In the classroom and in the laboratory (Face-to-face). Webinars. Tutorials. Laboratory demonstrations. Possibility of distance lectures if required via Zoom Cloud Meeting.

USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY	Presentation of lectures using PC (presentations, experimental videos, etc.). Support of learning process through the electronic platform eLearning and electronic communication with students (Online announcements and comments, forum, email etc.). Self-assessment questionnaires in the eLearning environment of the course and asynchronous training platform - eclass. Assistance in completing assignments through result files for each individual student.
TEACHING METHODS	

Activity	***Semester Workload***
Lectures	26
Laboratory exercises and processing of results with computational procedures	26
Individual assignments on laboratory exercises & theory (Coursework) and application exercises	30
Independent Home Study	48
Overall Course Set (26 hours of workload per credit unit)	***130***

STUDENT PERFORMANCE EVALUATION	Written final theory exam that includes: • Theoretical judgment questions in course subjects (short answer questions and multiple choice questions). • Problem solving-exercises. • Solving of laboratory exercises. Delivery of assignments and oral examination that includes: • Laboratory work (processing of results of laboratory exercises). • Solving of application exercises. • Examining the understanding of basic concepts.

5. SUGGESTED BIBLIOGRAPHY

- Sachpazis, C., "Geotechnical Engineering Lecture-Notes for Tunnels - Dams", 2019.
- Sachpazis, C., (2020) "Geotechnical Engineering of Dams". Academic Book, 455 Pages, Code in Eudoxus: 77120847. ISBN Code: 978-618-83547-0-8. Ch. Tsapraili Publications © 2019.
- Sofianos, A., 2015. Support of underground projects. [digital book] Athens: Association of Greek Academic Libraries. Available at: http://hdl.handle.net/11419/3457
- Brady, BHG, Brown, ET (2006). Rock Mechanics for Underground Mining. 3rd Ed, Springer.
- Hoek E and Brown ET (1980). Underground Excavations in Rock, The Institution of Mining and Metallurgy, London.
- Hoek Evert, «Rock Slope engineering», Chapman and Hall, 1997.
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- Hoek E, Kaiser PK, & Bawden WF (1995). Support of underground excavations in hard rock, Balkema.
- Komodromos, Aim. (2012) Foundations - Supports: Limit State Equilibrium - Numerical Methods, ISBN 978-960-478-506-3, Klidarithmos publications, Athens.
- Bowles, EJ (1996). Foundation analysis and design. 5th edition, McGraw Hill, NY Poulos, GH (1980). Pile foundation analysis and design. J. Wiley & Sons, NY Tomlinson, MJ (1994). Pile design and construction practice. E&FN Spon, London.
- Prakash, S. and Sharma, DH (1990). Pile foundations in engineering practice. J. Wiley & Sons, NY
- Barnes, GE (2005). Soil Mechanics: Principles and Applications. Klidarithmos Publications, Athens.
- Aydan O. (2018). Rock Reinforcement and Rock Support. 1st Edition, CRC Press
- Stillborg B (1994). Professional users handbook for rock bolting, Trans Tech Publications
- Thompson AG, E. Villaescusa, CR Windsor (1999). Rock Support and Reinforcement Practice in
- Mining. 1st Edition, Routledge.
- ICE (2004). Tunnel lining design guide. Thomas Telford Publishing
- Ch. Maragos, "Engineering Infrastructure Works: Constructions on the rock surface, underground constructions, Dams", MARAGOS Publications, Thessaloniki, 2007.
- I. Tsoutrelis, "Underground Works", NTUA Publications, 1987.

Related scientific journals:

- Electronic Journal of Geotechnical Engineering
- Rock Mechanics and Geotechnical Engineering
- Journal of Geotechnical and Geoenvironmental Engineering Geotechnique
- Tunneling and Underground Space Technology
- Geotechnical and Geological Engineering Canadian Geotechnical Engineering
- International Journal of Rock Mechanics and Mining Sciences
- Rock Mechanics and Rock Mechanics