



# NATM-Engineer

## Course Content

# Overview

Course	Course Type	Lecturer	ECTS-Credits
<b>Investigation and Ground Characterization</b>	LECT <sup>1</sup>	Schubert, Kieffer, Klima, Blümel, Pittino	11.5
<b>Geotechnical Design and Tunnel Layout</b>	LECT	Schubert, Tschuchnigg, Goricki, Galler	21.0
<b>Risk Analysis and Management</b>	LECT	Schubert, Galler	4.0
<b>Site Organization, Construction Contract and Construction Management</b>	LECT	Haberland, Galler	6.0
<b>Instrumentation, Monitoring, Data Evaluation and Interpretation</b>	LECT / EX <sup>2</sup>	Rabensteiner, Golser, Schubert	6.75
<b>Ground Improvement</b>	LECT	Kieffer, Holter, Hognestad	3.0
<b>Conventional and Mechanical Excavation Techniques including basics in TBM-Tunnelling</b>	LECT / EX	Galler, Restner, Pichler, Ganster	6.0

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<sup>1</sup> Lecture

<sup>2</sup> Exercise

# Course Content

## Investigation and Ground Characterization

### Introduction:

- Historical review of the development of tunnelling, fundamentals of NATM, its advantages and disadvantages in comparison to other methods
- Procedure of design and construction under consideration of the basics of the observational method

### Investigation:

- Overview of requirements, methods and analysis of engineering-geological investigation methods
- Planning of exploration programs depending on the project stage, the requirements and the geological conditions
- Overview of appropriate investigation methods
- Engineering-geological field mapping: tasks, methods, models, thematic maps, field methods to identify parameters
- Reporting: Structure, requirements, contents, international standards, selected examples

### Classification and Characterization:

- Classification and Characterization of Rock and Rock Mass
- Determination of Ground Types
- Determination of mechanical and hydraulic rock parameters, objectives and methods
- International standards and guidelines

### Laboratory Testing:

- Rock mechanical laboratory techniques and test methods, analysis, determination of parameters, compilation of a lab report

*Aim:* Ability to develop and conduct project-related investigation and laboratory testing programmes, to define the objects of the exploration, ability to identify benefits and limits of each investigation method ability to characterize rock masses and soils.

## Geotechnical Design and Tunnel Layout

### Geotechnical Design:

- Introduction to structured design approach
- Identification of influencing factors
- Analysis of ground behaviour, using closed form solutions and numerical simulations
- Support methods, effects and characteristics of supports
- Assignment of excavation and support methods to characteristic geotechnical situations
- Analysis of system behaviour; estimation of stresses and deformation, structural design of shotcrete linings
- Special measures in soft soils, for tunnels with high overburden, and tunnels below the groundwater table

### Numerical Analysis:

- Fundamentals of simulations
- Available material models in the field of geonumerics
- Fundamentals in FE-Programs: FLAC, UDEC, Plaxis, ABAQUS
- Pre-processing, Post-processing
- Compilation of inputs
- Interpretation of results

### Tunnel Layout:

- Basic approach in the development of tunnel profiles
- Clearance profile
- Ducts, cables, and drainage
- Ventilation systems
- Safety installations, fire protection
- Waterproofing and drainage systems
- Inner lining design; requirements, regulations
- Sequential excavation: typical excavation and support sequences, criteria for application, structural details
- Construction sequences for large underground openings, bifurcations, underground stations, etc.
- Excavation methods in soil and rock; typical fields of application, criteria and limitations
- Design of tunnel profiles: use of ACAD

*Aim:* Ability to perform geotechnical design from the evaluation of exploration results to structural design. Ability to use numerical simulation programs and to interpret the results. Ability to design tunnel profiles and construction sequences.

## Risk Analysis and Management

- Risk analysis methods
- Definition of requirements and boundary conditions
- Identification and quantification of hazards
- Evaluation of probability of events
- Evaluation of risks
- Selection of mitigation measures
- Corridor assessment, route selection

*Aim:* Ability to identify and quantify hazards in NATM tunnelling; ability to execute a risk analysis; ability to conduct corridor assessment and route selection.

## Site Organization, Construction Contract and Construction Management

### Site Organization and Construction Management:

- work preparation in tunnelling
- equipment and staff disposition
- estimation of performance
- cost estimation
- Basics of tunnel layout for operation:
  - Aerodynamics
  - Tunnel safety
  - Drainage
  - Optimal data flow
  - Mechanical equipment
  - 50 Hertz devices
  - Electrical power supply
  - Design of access to the operation facilities

### Construction Contract:

- Introduction of NATM-relevant standards and guidelines
- Presentation and discussion of different construction contract models and their application
- Structure of construction contracts

### Practical execution of contracts

*Aim:* Knowledge of the most important aspects of construction contracts, construction management and operation including tunnel safety (from aerodynamics to drainage). Good knowledge of the rights and duties of contractors and clients.

## Instrumentation, Monitoring, Data Evaluation and Interpretation

- Fundamentals of geotechnical measurement methods in tunnel construction
- Design of measurement programmes
- Selection of data
- Data flow
- Precondition for geotechnical measurements
- Measuring instruments and their functions
- Installation of measuring targets and instruments
- Execution of geotechnical measurements
- Processing of measurement data
- Large scale tests and their instrumentation
- Analysis of geotechnical measurement data
- Comparison of geotechnical measurement results with calculation results during the design
- Interpretation of geotechnical measurement results
- Use of measurement results for the prediction of ground quality
- Use of measurement results for the estimate of lining loads

*Aim:* Ability to work with monitoring instruments, ability to evaluate monitoring results, ability to merge geological, geotechnical data and measurement data to a geotechnical model; ability to judge whether behaviour is normal; interpretation of deviations from normal behaviour, prediction of rock mass quality based on displacement trends.

## Ground Improvement

### Grout Injection:

- Grout types and rheology
- Limited mobility grouting
- Cement grouting in rock
- Permeation grouting of soils
- Limited mobility grouting
- Jet grouting
- Pre-excavation grouting in rock tunnelling
- Anchors and micropiles
- Deep mixing and diaphragm walls
- Crisis management - massive inflows
- Instrumentation
- Case histories

### Artificial Ground Freezing:

- Objectives and applications
- Design considerations
- Case histories

*Aim:* Basic knowledge of all methods of ground improvement.

## Conventional and Mechanical Excavation Techniques including basics in TBM- Tunnelling

- Explosives chemistry
- Explosives production (plant mixing / site mixing)
- The properties of explosives
- Firing methods
- Tunnelling blast design
- Blasting emissions prognosis and measurements
- Geotechnical definitions, laboratory tests and site investigations for road headers
- Rock testing in detail and operating data assessment for road headers
- Cutting tests done on test rigs and cutting simulations done on computer
- Machine prototype testing and machine optimization
- Laboratory visit in Zeltweg
- Rock mass cuttability rating in detail
- Today's cutting limits referring to roadheader application
- Detailed tunnelling project study
- Tunnelling roadheaders - product overview and details
- Infrastructure and job site layout for roadheader application
- Exemplary excavation cost calculation for roadheader operation
- Operational reports of roadheader applications
- Tunnel boring machines - an overview
- Penetration models for TBMs
- Cutter wear prognosis
- Basics in segmental lining design

*Aim:* Basic knowledge of all methods of excavation used in tunnelling.