Montanuniversität Leoben

LIFE LONG LEARNING

TU Graz

Curriculum for the jointly established University Certificate Master's Programme

NATM and TBM Tunnel Engineering

at Graz University of Technology and the University of Leoben

This curriculum was approved by the Senate of the University of Leoben at the meeting of 22 April 2026, and by the Senate of Graz University of Technology at the meeting of 27 April 2026. This university certificate programme is a master's programme (pursuant to § 56 (3) in conjunction with § 54e of the Universities Act 2002) jointly established by Graz University of Technology and the University of Leoben, in accordance with § 56 (2) of the Universities Act 2002 (UG), Austrian Federal Law Gazette (BGBl.) No. 177/2021, as amended.
The legal basis for this university certificate programme is the Universities Act (UG 2002) as well as the Excerpt of Statutes: Legal Regulations for Academic Affairs of Graz University of Technology and the legal regulations of academic affairs as established in the Statutes of the University of Leoben (*Satzungsteil Studienrechtliche Bestimmungen der Montanuniversität Leoben*) in their currently applicable versions, as amended.

Please note: the English version of this document is a courtesy translation.

Change history

Version	In effect as of	Brief description of the change
01	01/10/2026	First submission

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Curriculum for the jointly established University Certificate Master's Programme

NATM and TBM Tunnel Engineering

Curriculum 2026

I General Provisions

§ 1 Subject, qualification profile, need and relevance

The jointly established University Certificate Master's Programme NATM and TBM Tunnel Engineering is offered as a part-time continuing education programme lasting four semesters. The total scope of the programme is 120 European Credit Transfer and Accumulation System (ECTS) credit points. Graduates of this programme are awarded the university degree of "Master of Science (Continuing Education)", abbreviated as "MSc (CE)".

(1) Subject of the university certificate programme

This university certificate programme was developed to meet the steadily growing global demand for qualified tunnel engineers. Its objective is to provide students with the best possible, state-of-the-art education in geotechnics and tunnelling. This programme enables them to independently implement tunnelling projects according to the latest technological standards, taking into account geotechnical, structural, organisational, contractual and economic requirements. This university certificate programme is aimed at civil engineers, mining engineers, geotechnical engineers and engineering geologists who already have well-founded knowledge in subject-relevant engineering fields and wish to further specialise in tunnelling.

(2) Qualification profile and competences

The University Certificate Master's Programme NATM and TBM Tunnel Engineering provides students with in-depth specialist knowledge in the field of tunnel construction, focusing in particular on the New Austrian Tunnelling Method (NATM) and the use of tunnel boring machines (TBMs). Furthermore, it covers topics such as the maintenance and repair of existing tunnel structures, as well as safety-related issues and risk analyses. Since traditional degree programmes in civil engineering or engineering geology typically only address these topics in part, Graz University of Technology and the University of Leoben have established a dedicated university certificate programme to offer structured and comprehensive continuing education in this specialised field.
Graduates of the University Certificate Master's Programme NATM and TBM Tunnel Engineering are qualified to professionally plan, manage and supervise all essential aspects of tunnel construction projects – including geotechnical, structural, organisational, contractual and economic considerations related to a project. The university certificate programme is designed to build on a relevant university degree along with practical experience, allowing students to acquire the skills needed to independently design tunnel structures, lead their execution, or work as specialist consultants on a project basis.
As part of their studies in tunnel engineering, students acquire the ability to make well-founded decisions even in complex situations. They can formulate scientifically sound assessments,

even when only incomplete or limited information is available – for example, in cases of geological uncertainties, unexpected rock conditions or changing safety requirements. In doing so, they can not only take technical and economic aspects into consideration but also reflect on the societal, social and ethical implications of their actions. This includes taking responsibility for occupational safety, environmental protection, sustainability and the minimisation of risks for both local communities and infrastructure users.
Upon completion of the University Certificate Master's Programme NATM and TBM Tunnel Engineering, graduates are able to clearly present technical facts and project results related to underground and tunnel construction to both specialist audiences and clients, authorities or the public. They are proficient in creating scientific and technical documentation and can employ communication and presentation techniques effectively. An emphasis on flexibility, adaptability and teamworking skills empowers them to work well in interdisciplinary project teams.
Furthermore, they are trained to independently seek and acquire knowledge, work in a goal-oriented manner, motivate themselves and others, and are willing to take the initiative and responsibility in all phases of a tunnel construction project.

(3) Need and relevance of the degree programme for science and the labour market

The University Certificate Master's Programme NATM and TBM Tunnel Engineering is designed for engineers with previously obtained degrees in civil engineering or mining engineering, geotechnical engineering, engineering geology or a related subject area and wishing to specialise further in NATM and TBM tunnelling.
The increasing demand for highly qualified specialists in tunnelling – particularly in light of complex geotechnical challenges, the growing scope and complexity of infrastructure projects and stricter safety and sustainability requirements – necessitates a specialised, academically grounded continuing educational programme such as this. Traditional degree programmes often only cover these topics in part, whereas the University Certificate Master's Programme NATM and TBM Tunnel Engineering offers a practice- and research-oriented, comprehensive qualification that is highly relevant for both scientific progress and competitiveness in the job market.
Future career opportunities for graduates include planning, consulting and construction supervision roles for engineering firms, construction management positions in related companies and positions of responsibility at client organisations and government agencies.

§ 2 University certificate programme organisers

(1) The University Certificate Master's Programme NATM and TBM Tunnel Engineering is a university certificate programme organised and managed jointly by Graz University of Technology (TU Graz) and the University of Leoben (MUL).

(3) The rights and obligations of both universities are regulated in a cooperation agreement.

(4) TU Graz's organisational duties regarding the university certificate programme are managed in cooperation with TU Graz *Life Long Learning*.

§ 3 Duration and scope of the certificate programme

(1) Commensurate with the European Credit Transfer and Accumulation System, the various units are assigned ECTS credit points that reflect the students' workload. One ECTS credit point corresponds to 25 full hours of workload, including both the share of self-study and the semester course hours.

(2) The university certificate programme lasts four semesters with a total scope of 120 ECTS credit points.

§ 4 Course language

(1) As a general rule, all courses and modules are held in English.

(2) The academic director of the university certificate programme is responsible for determining whether the participants have the necessary knowledge of the language of instruction (see § 7 (4)).

§ 5 Forms of teaching and learning

The University Certificate Master's Programme NATM and TBM Tunnel Engineering is offered as a part-time continuing education programme. By offering block-based courses and additional distance teaching units, it is possible to cater specifically to the needs of working students. In addition, a virtual teaching and learning environment (TeachCenter) provides opportunities for networking with lecturers and other students outside of in-person units and accompanies the autonomous part of the relevant modules.

II Admission

§ 6 Admission requirements

(1) The requirement for admission to the University Certificate Master's Programme NATM and TBM Tunnel Engineering is proof of the following qualifications:

a) Completed degree in an engineering, scientific or economic discipline amounting to at least 180 ECTS credit points from a recognised domestic or foreign post-secondary educational institution.

b) At least 2 years of professional work experience in a relevant field.

(2) In addition to the previously mentioned qualifications, proof of sufficient English language skills is a prerequisite for admission to the programme. The type of proof required is specified in § 7 (4).

§ 7 Application and admission procedure

(1) The maximum number of places available for one iteration of the programme is set at twenty-five by the academic director of the university certificate programme based on didactic and organisational considerations. If the number of applicants meeting the admission requirements is greater than the number of available places, places will be assigned in chronological order upon receipt of the stipulated programme fee.

(2) Application for a place is to be made in writing to the academic director of the university certificate programme and consists of an application form, fully completed and signed, proof of identity and proof of fulfilment of the required admission requirements (degree certificate for a degree programme, employment testimonials). An application for a place in the programme does not in itself constitute any right to actual participation. The academic director of the university certificate programme and the Vice Rector for Academic Affairs of Graz University of Technology are entitled to reject applicants.

(3) The procedure for awarding a place consists of preliminary screening of application documents by the *Life Long Learning* organisational unit, review by the academic director of the university certificate programme and, where necessary, an application interview.

(4) Applicants have adequate knowledge of the language (cf. § 6 (2)), either thanks to internationally recognised language certificates or school-leaving certificates (e.g. matriculation certificate, completion of a course of studies in the pertinent language of instruction) or in the course of verification by the academic director of the university

certificate programme. No proof must be furnished if the language of instruction is the applicant's first language.

(5) The academic director of the university certificate programme and the Vice Rector for Academic Affairs of Graz University of Technology make the decision regarding fulfilment of the admission requirements.

(6) Places are awarded in writing by the academic director of the university certificate programme. Admission of non-degree programme students to the university certificate programme is managed by the Rectorate of Graz University of Technology.

III Programme Contents and Examination Regulations

§ 8 Types of courses and modules

The types of courses offered at Graz University of Technology are governed by § 4 of the Excerpt of Statutes: Legal Regulations for Academic Affairs of Graz University of Technology, as amended.

The types of modules offered at the University of Leoben are regulated in § 17 of the legal regulations of academic affairs as established in the Statutes of the University of Leoben (*Satzungsteil Studienrechtliche Bestimmungen der Montanuniversität Leoben*).

§ 9 Modules, courses and semester allocation

Modules of the university certificate programme offered by Graz University of Technology are subdivided into individual courses. They are structured as Compulsory Modules and Elective Modules according to the tables below.

Modules of the university certificate programme offered by the University of Leoben are not subdivided into individual courses. Instead, they are structured as compulsory Core Modules and elective Profile Modules according to the tables below.

The knowledge, methods or skills to be taught in each module are described in detail in Appendix I. The allocation of courses and modules to semesters constitutes the standardised curriculum. The assignment of courses and modules to the participating universities is outlined in Appendix II.

§ 10 Compulsory / core modules

The following twelve Compulsory Modules and Core Modules (A1 to F2) must be completed in their entirety.

Module name	Module/ course type	ECTS	Sem.
A1 Investigation / Exploration Concepts and Parameter Evaluation	VO/VU/PT	1.5/1.5/2	1
A2 Geological, Geotechnical and Numerical Models	VO/VU/PT	1.5/1.5/2	1
B1 NATM- and TBM-Technologies	VO/VU/PT	1.5/1.5/2	1
B2 Tunnel Design Methods	VO/VU/PT	1.5/1.5/2	1
C1 Ground Modelling at ZaB	M	5	1
C2 Excavation and Support Techniques incl. Practical Work at ZaB	M	5	1
D1 Data Science and Machine Learning in Geotechnical Applications	VO/VU/PT	1.5/1.5/2	2
D2 BIM in Tunnelling	VO/VU/PT	1.5/1.5/2	2
E1 Special Construction Methods Related to Underground Infrastr.	M	5	2
E2 Health and Safety in Constr. and Operation incl. Risk Assessment	M	5	2
F1 Cost Determination, Contracts and Site Management	M	5	2
F2 Maintenance and Refurbishment of Undergr. Infrastr. incl. M&E	M	5	2
Total Compulsory & Core Modules A1–F2		60	
Total Elective & Profile Modules acc. to § 11		15	3
Internship(s) acc. to § 12		15	3
Master's thesis and final examination before a committee		30	4
		120	

§ 11 Elective / profile modules

From the eight Elective and Profile Modules (W1–W8) offered, students must complete three modules totalling 15 ECTS credit points.

Module name	Module/ course type	ECTS	Sem.
W1 Exploration	M	5	3
W2 Design and Construction of Underground Structures	M	5	3
W3 Numerical Methods in Geotechnics	M	5	3
W4 Sustainability in Subsurface Engineering	M	5	3
W5 Tunnel Design Aspects including Numerical Methods	VU/VU	3/2	3
W6 Advanced Rock Mechanics and Tunnelling 1	VO/VU	0.5/4.5	3
W7 Advanced Rock Mechanics and Tunnelling 2	VO/VU	0.5/4.5	3
W8 Rock Mechanics Laboratory Testing	LU/PT	3/2	3

§ 12 Internships

As part of the university certificate programme, students must complete a professionally oriented internship worth 15 ECTS credit points. Each working week corresponds to 1.5 ECTS credits in the case of full employment. Subject-relevant work experience in industry or research that is completed at external non-university institutions during the regular duration of study can be credited. This work experience must be relevant to the degree programme and must be approved by both the officer responsible for study matters of the University of Leoben and the officer responsible for study matters of Graz University of Technology. As proof of completion of their professionally oriented internship, students must submit a practical report at the end of the third semester.

§ 10 Examination regulations

(1) A course certificate is issued in accordance with § 74 (1) Universities Act (UG 2002) for completion of each course within a module at Graz University of Technology. The lecturer must determine whether a student has successfully completed a course.
A module certificate is issued in accordance with § 74 (1) Universities Act (UG 2002) for completion of each module at the University of Leoben. The officer responsible for module management must determine whether a student has successfully completed a module.

(2) An examination pass or fail is assessed in accordance with § 72 (2) UG 2002.

(3) Students may resit examinations taken at Graz University of Technology in accordance with § 28 of the Excerpt of Statutes: Legal Regulations for Academic Affairs of Graz University of Technology, as amended. Students may resit examinations taken at the University of Leoben in accordance with § 43 of the legal regulations of academic affairs as established in the Statutes of the University of Leoben (*Satzungsteil Studienrechtliche Bestimmungen der Montanuniversität Leoben*).

(4) At Graz University of Technology, module grades are to be determined by
   a. multiplying the grade of each examination result in connection with the module with the ECTS credit points of the corresponding course,
   b. adding the values calculated according to (a),
   c. dividing the result of the addition by the sum of the ECTS credit points of the courses, and
   d. rounding the result of the division to a whole-numbered grade if required. The grade is rounded up if the decimal place exceeds 5. Otherwise, the grade is rounded down.
   e. A positive grade for the module can only be awarded if every individual examination result is positively assessed.

(5) Furthermore, an overall assessment for the university certificate programme is given. It is "Passed" if each module, the master's thesis and the master's examination have been assessed positively, otherwise it is "Failed". The overall assessment is "Passed with distinction" if none of the modules are awarded a grade worse than "good" (2) and the number of modules awarded the grade "excellent" (1) is at least as high as the number of modules that are awarded the grade "good" (2), and if the master's examination before a committee and the master's thesis are also awarded the grade "excellent" (1).

§ 14 Recognition of courses and achievements

Upon application by the student, courses and academic achievements earned at Graz University of Technology can be recognised by the officer responsible for study matters of Graz University of Technology, in accordance with § 78 of the Universities Act (UG). Upon application by the student, courses and academic achievements earned at the University of Leoben can be recognised by the officer responsible for study matters of the University of Leoben, in accordance with § 78 UG. Any recognition of study credits shall not decrease the programme fee to be paid.

§ 15 Master's thesis

(1) The master's thesis serves as proof of a student's ability to perform independent academic research on scientific topics and master relevant content and methodology. The scope of the master's thesis must be chosen so that it is possible and reasonable for the student to complete the work within six months.

(2) The content of the master's thesis is based on current studies, analyses and developments in the specialist field of the university certificate programme and may be handled on a theoretical and/or practical basis. The topic of the master's thesis must belong to a module. The master's thesis may be performed in cooperation with a partner from the business world and/or make reference to the student's professional activity.

(3) The master's thesis must be registered in writing with the academic director of the university certificate programme before the start of processing. The subject, the associated module and the name of the person supervising the master's thesis must be stated along with the name of the institute or chair. The choice of subject and the supervisor must in any case be agreed in advance with the academic director of the university certificate programme.

(4) After completing the master's thesis, it must be submitted for assessment in electronic form at each of the participating universities to which the supervisor belongs.

§ 16 Final examination before a committee

(1) Prerequisites for registering for the master's examination before a committee are proof of the positive assessment of all modules and proof of the positively assessed master's thesis.

(2) The master's examination before a committee is worth 2 ECTS credit points. The master's examination before a committee consists of

- the presentation of the master's thesis (maximum duration: 30 minutes) and
- the defence of the master's thesis (oral examination by the members of the examination committee on the topic(s) of the master's thesis).

(3) The total duration of the master's examination before a committee is usually 60 minutes and must not exceed 75 minutes.

(4) The examination committee for the master's examination includes the supervisor of the thesis and two other members who are nominated by the officer responsible for study matters, after hearing from the candidate. The committee shall be chaired by one of the members who is not the supervisor of the thesis.

(5) The grade for the master's examination before a committee is determined by the examination committee on the basis of performance during the final examination in accordance with § 24 (6) of the Excerpt of Statutes: Legal Regulations for Academic Affairs of Graz University of Technology and in accordance with § 40 (6) of the legal regulations of academic affairs as established in the Statutes of the University of Leoben (*Satzungsteil Studienrechtliche Bestimmungen der Montanuniversität Leoben*).

§ 17 Completion of studies and degree certificate

(1) Upon positive assessment of all modules, the master's thesis and the master's examination before a committee, the University Certificate Master's Programme NATM and TBM Tunnel Engineering is completed.

(2) Successful completion of the university certificate programme is documented by issuing a certificate. The degree certificate contains

1. a list of all completed modules (along with their ECTS credit points) and their assessments,
2. the title and the assessment of the master's thesis,
3. the assessment of the final master's examination before a committee, and
4. the overall assessment in accordance with § 13 (5).

(3) In accordance with § 87 (2) Universities Act (UG 2002), graduates of this university certificate programme are awarded the academic degree “Master of Science (Continuing Education)”, abbreviated as “MSc (CE)”, by written administrative decision.

IV Organisation

§ 18 Academic course management

(1) The member of the Rectorate responsible for academic affairs must appoint a qualified member of the Institute of Rock Mechanics and Tunnelling of Graz University of Technology or of the Chair of Subsurface Engineering at the University of Leoben with a teaching qualification in a pertinent subject as academic director of the university certificate programme.

(2) The academic director appoints further staff members to executive academic and administrative functions based on organisational requirements.

§ 19 Maximum duration of study

(1) The maximum duration of study is the regular study duration of four semesters plus four additional semesters, i.e. eight semesters. Admission to the university certificate programme expires after the end of the maximum study duration.

(2) If the regular study duration is exceeded, an additional programme fee may be levied for each further semester required in order to cover the costs of continued supervision and tuition of the student. The fee is specified in the current terms and conditions regarding payment and cancellation of TU Graz *Life Long Learning*.

V Final Provisions

§ 20 Legal validity

This curriculum shall come into effect on 1 October 2026.

Versions of the curriculum:

Curriculum	Version	published in the Graz University of Technology University Gazette	published in the University of Leoben Graz University Gazette
2026	01	06/05/2026, 15th issue	28/04/2026, 190th issue

Appendix I Module descriptions
Appendix II Assignment of modules to the participating universities

Appendix I: Module descriptions

Module A1	Investigation / Exploration Concepts and Parameter Evaluation
ECTS credit points:	5
Content:	Exploration planning, evaluation of in-situ and laboratory results, determination of parameters, characterisation and classification methods.
Learning outcomes:	After completing this module, students are able to • independently plan explorations for tunnel structures. • independently evaluate the results of in-situ investigations. • order suitable laboratory tests and evaluate their results. • determine appropriate parameters. • know and apply common characterisation and classification methods. • reliably determine soil, rock and geological parameters and use this knowledge to propose computational parameters depending on the computational model in Module A2.

Module A2	Geological, Geotechnical and Numerical Models
ECTS credit points:	5
Content:	Model creation based on geology, geotechnical models and numerical modelling.
Learning outcomes:	After completing this module, students are able to • create geological models. • create geotechnical models. • perform simple numerical modelling in tunnel construction. • differentiate between geological, geotechnical and numerical models and create them according to project requirements. • apply the content from Module A1 depending on the modelling requirements.

Module B1	NATM- and TBM-Technologies
ECTS credit points:	5
Content:	Fundamentals of tunnel construction methods NATM and TBM.
Learning outcomes:	After completing this module, students are able to • explain the operating principles of the New Austrian Tunnelling Method (NATM). • name the essential TBM tunnelling principles and their corresponding support measures. • apply the acquired know-how to the selection of suitable tunnelling methods.

	• recount the history of NATM and TBM tunnelling and distinguish the two methods from other methods. • communicate the latest developments in NATM and TBM tunnelling.

Module B2	**Tunnel Design Methods**
ECTS credit points:	5
Content:	Basic knowledge of essential planning tools in tunnel construction.
Learning outcomes:	After completing this module, students are able to • perform geomechanical planning according to OEGG guidelines. • describe analytical planning tools. • explain the planning steps depending on the planning phase. • recommend modern planning tools. • interpret the results professionally.

Module C1	**Ground Modelling at ZaB**
ECTS credit points:	5
Content:	Creating geological surveys to enable subsequent analyses of the stability of rock slopes and underground structures.
Learning outcomes:	After completing this module, students are able to • assess the strength of geomaterials. • describe and present existing geological and geotechnical conditions. • collect rock mechanics data in the field. • compare field rock mechanics data with laboratory data. • describe rock slope failure scenarios. • describe underground structure failure scenarios. • apply concepts of stress, strain, elasticity and plasticity to intact rock. • apply concepts of stress, strain, elasticity and plasticity to fractured rock masses. • select appropriate design methods for surface and underground rock engineering projects. • perform basic analyses of the stability of rock slopes and underground structures.

Module C2	Excavation and Support Techniques incl. Practical Work at ZaB
ECTS credit points:	5
Content:	Introduction to conventional and mechanised tunnelling. Practical training in tunnelling work steps.
Learning outcomes:	After completing this module, students are able to • correctly use tunnelling terminology. • plan the work steps for drill and blast tunnelling. • plan the work steps for excavation. • select the appropriate tunnelling methods for shallow and deep tunnels. • select the appropriate support materials for the given conditions. • select the optimal cross section for the given conditions. • select the appropriate machine type for the prevailing geological, hydrogeological and geotechnical conditions. • estimate tunnelling progress. • perform wear predictions. • independently conduct geotechnical measurements. • compare geotechnical measurement results with calculation results. • interpret geotechnical measurement results. • determine the next work steps based on the geotechnical measurement results. • identify hazards and implement preventive measures to plan for damage resulting from the underground mining operations.

Module D1	Data Science and Machine Learning in Geotechnical Applications
ECTS credit points:	5
Content:	AI application in tunnel construction: Data analysis and machine learning.
Learning outcomes:	After completing this module, students are able to • demonstrate knowledge of geotechnical and tunnel construction data (type, structure). • explain the theory of processing and visualising geotechnical/engineering geological data. • apply the basic principles of the Python programming language. • demonstrate aspects of modern data analysis in geotechnics. • apply simple algorithms in the field. • draw on theoretical foundations in applied statistics and machine learning, as well as data preprocessing and visualisation.

Module D2	BIM in Tunnelling
ECTS credit points:	5
Content:	Fundamentals and application of BIM in tunnel construction.
Learning outcomes:	After completing this module, students are able to • apply the fundamentals of BIM in tunnel construction and understand the related processes. • carry out model-based planning and coordination. • apply data and information management. • apply BIM for planning, construction and operation. • collaborate across projects and possess digitalisation skills.

Module E1	Special Construction Methods Related to Underground Infrastructure
ECTS credit points:	5
Content:	Advanced rock and foundation engineering methods.
Learning outcomes:	After completing this module, students are able to • exhaustively describe the methods of rock and foundation engineering. • name and describe the machinery used for special procedures in rock and foundation engineering. • correctly assign the various special procedures of rock and foundation engineering according to the given boundary conditions. • determine special procedures for excavating loose material in shallow overburden. • determine special procedures for excavations in deep tunnelling.

Module E2	Health and Safety in Construction and Operation incl. Risk Assessment
ECTS credit points:	5
Content:	Occupational safety during the construction and operation of underground structures.
Learning outcomes:	After completing this module, students are able to • assess safety aspects in conventional tunnelling. • cite the relevant laws and regulations. • provide an overview of the associated guidelines. • apply existing information sheets. • implement safety aspects as early as the planning phase. • determine the equipment for road tunnel tubes to ensure safe operation. • determine the equipment for railway tunnel tubes to ensure safe operation.

	• determine the necessary internal and external training for their own personnel and emergency services. • outline a safety organisation for construction. • outline a safety organisation for operation. • determine the necessary equipment for safety organisations.

Module F1	**Cost Determination, Contracts and Site Management**
ECTS credit points:	5
Content:	Cost estimation of infrastructure projects. Construction contract models with a focus on tunnel / underground construction. Operations of a tunnel construction site.
Learning outcomes:	After completing this module, students are able to • conduct cost estimates for infrastructure projects depending on the planning phase. • prepare risk analyses related to cost estimation. • develop optimal site organisation. • identify typical risks of construction sites. • establish risk management. • draft a construction contract for tunnel construction in accordance with Austrian laws and regulations. • understand international construction contracts. • understand a FIDIC construction contract according to the Emerald Book. • understand the tunnelling classification for tunnel construction contracts in Germany. • explain the difference between tendering and construction contracts. • conduct a bid evaluation. • determine the planning fee for tunnel structures. • design a site layout area. • plan the site setup. • design ventilation for underground construction sites. • design construction-related facilities such as water protection systems, conveying systems and machinery for operation.

Module F2	Maintenance and Refurbishment of Underground Infrastructures incl. M&E
ECTS credit points:	5
Content:	Tunnel maintenance and repair.
Learning outcomes:	After completing this module, students are able to • explain traditional tunnelling construction methods. • explain modern underground construction methods. • describe the historical development of tunnel cross sections. • understand the equipment in road tunnels. • understand the equipment in railway tunnels. • explain the necessity of maintenance and repair of tunnel structures. • explain the work involved in maintenance and repair. • explain the specific construction methods used in maintenance and repair work. • explain the specific features of tunnel maintenance contracts.

Module W1	Exploration
ECTS credit points:	5
Content:	Geotechnical exploration.
Learning outcomes:	After completing this module, students are able to • design a geotechnical exploration programme. • determine exploration strategies. • define exploration objectives. • identify geotechnical exploration methods. • evaluate exploration data. • process exploration results. • correctly apply exploration results in further planning. • determine geotechnical parameters from in-situ tests. • determine geotechnical parameters from the materials testing laboratory. • write a report in the field of geotechnical exploration.

Module W2	Design and Construction of Underground Structures
ECTS credit points:	5
Content:	Planning and construction of underground structures.
Learning outcomes:	After completing this module, students are able to • explain the planning process for underground structures from conception to realisation. • explain the planning principles. • explain the geological and geotechnical investigations required for planning underground structures. • explain the procedure for environmental impact assessments. • explain the content of an environmental impact report. • identify and explain the substantive legal procedures required to obtain a building permit. • describe and outline the procedure for the transparent determination of support requirements. • explain the failure modes that can occur underground. • explain the organisation of tunnelling or drilling. • justify the choice of tunnel cross section. • explain safety concepts for the construction and operation of underground structures. • explain geotechnical measurements. • interpret geotechnical measurement results. • explain the use of tunnel excavation material and related legal matters. • develop a standard cross section using AutoCAD. • develop a longitudinal section through the underground structure. • understand the basics of Civil3D. • understand digital terrain models. • perform quantity surveys. • explain the basics of editing commands and layer control.

Module W3	Numerical Methods in Geotechnics
ECTS credit points:	5
Content:	Application of numerical modelling tools for solving geotechnical problems.
Learning outcomes:	After completing this module, students are able to • explain the philosophy behind numerical modelling. • understand the workflow for using numerical modelling tools to solve geotechnical problems. • critically evaluate the results of numerical modelling. • understand the different numerical modelling approaches.

	• select and defend appropriate numerical modelling approaches to solve the diverse types of geotechnical problems. • perform a numerical modelling simulation of a geotechnical problem in a selected numerical code, present and justify the chosen numerical modelling approach. • determine stresses around voids using RS2. • conduct slope stability investigations using Slide2 and FLAC 2D. • perform stability analyses using SWedge and UnWedge. • perform a preliminary design of support systems using RocSupport. • assess rockfall risks using RocFall.

Module W4	**Sustainability in Subsurface Engineering**
ECTS credit points:	5
Content:	Sustainability aspects in civil engineering and tunnelling.
Learning outcomes:	After completing this module, students are able to • understand and explain the latest developments in sustainable construction. • explain the procedures for using tunnel excavation material. • understand the relevant legal issues. • aim for “zero waste” in tunnelling. • understand the properties of new materials. • understand the fundamentals of hydrogeology. • explain the basic principles of working with isotopes. • understand the use of natural and artificial tracers for characterising groundwater and geothermal systems. • determine the effects of groundwater extraction on the groundwater system. • incorporate the topic of “groundwater” into the planning and construction of underground structures. • assess groundwater contamination on various scales. • incorporate considerations regarding “geothermal systems” into the planning and construction of underground structures. • collaborate in a multidisciplinary manner with the fields of geology, hydrogeology, hydrogeochemistry, geothermal energy and others.

Module W5	Tunnel Design Aspects including Numerical Methods
ECTS credit points:	5
Content:	Fundamental knowledge for numerical calculations. A practical project on the design of support measures in tunnel construction using discrete element methods to model rock behaviour. Preparatory online self-study phase with joint reflection sessions.
Learning outcomes:	After completing this module, students are able to • confidently apply numerical calculations (continuum and discontinuity). • combine all necessary design verifications for a practical tunnel construction project. • confidently apply the discrete element method.

Module W6	Advanced Rock Mechanics in Tunnelling 1
ECTS credit points:	5
Content:	Classification and engineering assessment of rock and rock masses. Relevant failure mechanisms, taking into account the key influencing factors.
Learning outcomes:	After completing this module, students are able to • interpret geological, geotechnical and geophysical data as well as analytically solve the normal types of linear second-order PDEs. • confidently apply different classification methods in rock mechanics. • name the methods for identifying hazard patterns / failure modes in underground mining.

Module W7	Advanced Rock Mechanics and Tunnelling 2
ECTS credit points:	5
Content:	All aspects of tunnel design, including the selection of appropriate design methods for support measures.
Learning outcomes:	After completing this module, students are able to • determine the key actions on the tunnel lining. • combine all necessary design analyses. • prepare geotechnical and structural design reports.

Module W8	Rock Mechanics Laboratory Testing
ECTS credit points:	5
Content:	Fundamentals of rock mechanics testing methods. Interpretation of results in accordance with standards and guidelines. Sample selection. Various laboratory tests (single-axis and triaxial compression tests, direct shear tests, Brazilian test). Preparation of a laboratory report.
Learning outcomes:	After completing this module, students are able to • design geotechnical investigation programmes taking technical and economic criteria into consideration. • evaluate problem-specific results.

	Master's thesis
ECTS credit points:	30
Content:	In this module, students independently write a scientific thesis in the form of a master's thesis.
Learning outcomes:	After completing this module, students are able to • formulate an overall concept for the master's thesis. • create a table of contents for the master's thesis. • create a project plan in preparation of the master's thesis. • carry out targeted literature research on the topic of the master's thesis. • develop and document the theoretical foundations of the master's thesis. • prepare, carry out and document the practical research for the master's thesis. • document the results of the master's thesis in a suitable form. • work out alternative solutions scientifically. • critically question and discuss results. • complete a master's thesis in accordance with all requirements for a scientific thesis.

Appendix II: Assignment of modules to the participating universities

A1 Investigation / Exploration Concepts and Parameter Evaluation	TU Graz
A2 Geological, Geotechnical and Numerical Models	TU Graz
B1 NATM- and TBM-Technologies	TU Graz
B2 Tunnel Design Methods	TU Graz
C1 Ground Modelling at ZaB	MU Leoben
C2 Excavation and Support Techniques incl. Practical Work at ZaB	MU Leoben
D1 Data Science and Machine Learning in Geotechnical Applications	TU Graz
D2 BIM in Tunnelling	TU Graz
E1 Special Construction Methods Related to Underground Infrastr.	MU Leoben
E2 Health and Safety in Constr. and Operation incl. Risk Assessment	MU Leoben
F1 Cost Determination, Contracts and Site Management	MU Leoben
F2 Maintenance and Refurbishment of Undergr. Infrastr. incl. M&E	MU Leoben
W1 Exploration	MU Leoben
W2 Design and Construction of Underground Structures	MU Leoben
W3 Numerical Methods in Geotechnics	MU Leoben
W4 Sustainability in Subsurface Engineering	MU Leoben
W5 Tunnel Design Aspects including Numerical Methods	TU Graz
W6 Advanced Rock Mechanics and Tunnelling 1	TU Graz
W7 Advanced Rock Mechanics and Tunnelling 2	TU Graz
W8 Rock Mechanics Laboratory Testing	TU Graz
Master's thesis	TU Graz & MU Leoben