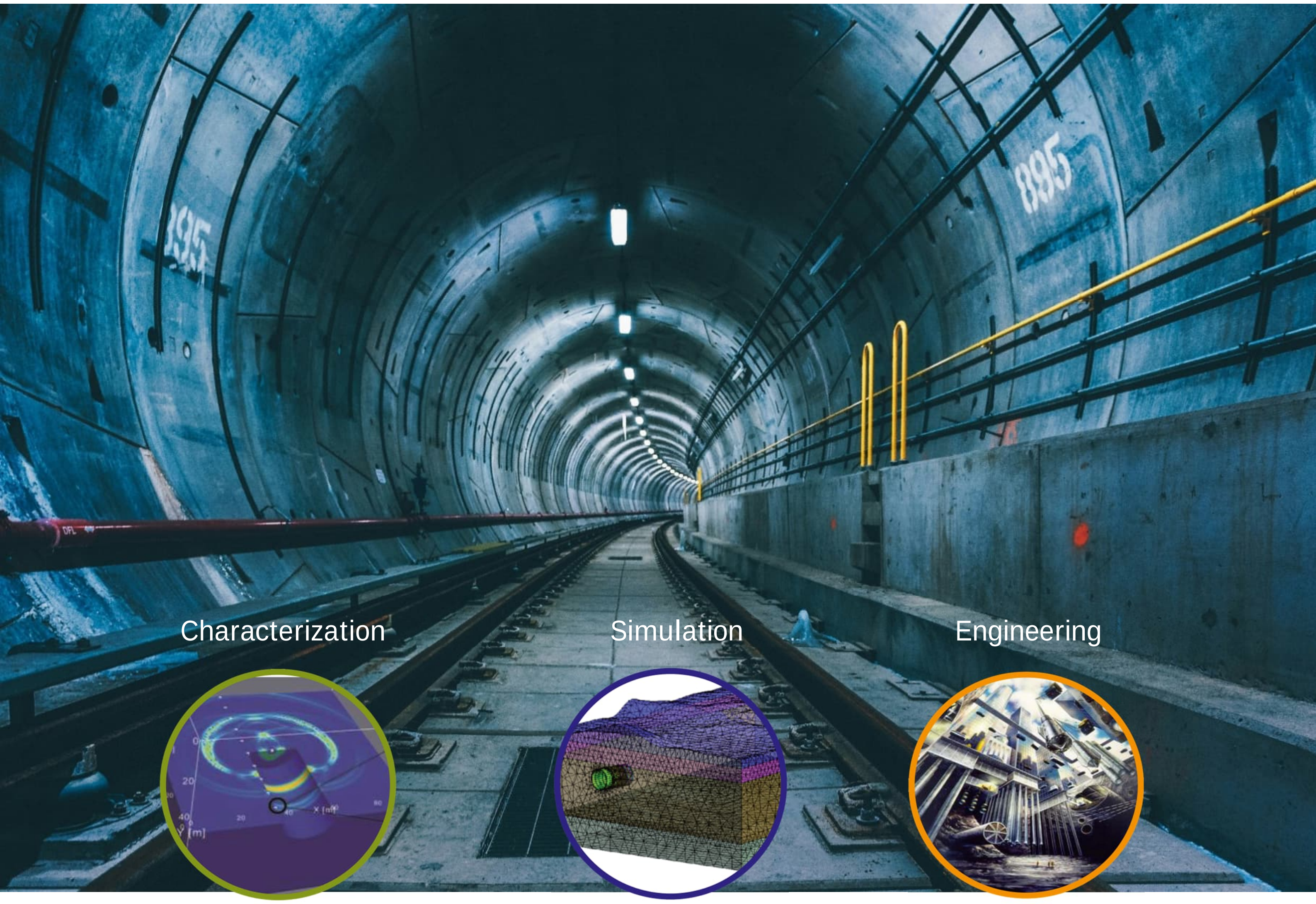
MASTER OF SCIENCE
SUBSURFACE ENGINEERING

RUB

MODULE HANDBOOK



FAKULTÄT FÜR
BAU- UND UMWELT-
INGENIEURWISSENSCHAFTEN

FAKULTÄT FÜR
GEOWISSENSCHAFTEN

Introduction

The Module handbook provides detailed information regarding the course content and curriculum of the Master Program 'Subsurface Engineering'.

1. Modularisation (Modularisierungskonzept)
   - The course curriculum has a modular structure. It consists of compulsory modules, elective modules and optional modules.
   - Credit points (CP) according to the European Credit Transfer System (ECTS) are awarded for the successful completion of each module. One CP according to the ECTS corresponds to an average student workload of 30 hours. The number of credit points awarded for a certain module depends on the workload (see module description of the lecture for further details).
2. Curriculum (Studienplan)
   - The master program consists of 4 semesters. The compulsory courses in the first semester build a core set of skills in Mathematics, Soil and Rock Mechanics, Hydraulics and Computational Methods. The specialization phase in the second and third semesters is flexible and allows students to specialize either in Geotechnics and Tunnelling (GT) or Subsurface Characterization and Utilization by choosing courses of their choice from the course catalog. In the fourth semester, the students work on a master thesis on basic or applied research in subsurface engineering. In total, 120 CP according to the ECTS is required for the successful award of the master degree. The complete course catalog is provided in the next page.
3. Examination form (Prüfungsform) and Examination regulations (Prüfungsordnung)
   - With the exception of the Master's thesis, examinations are module examinations, graded or ungraded (see module descriptions for further details). Assessment can be in the form of a written examination, an oral examination, by working on tasks set during the course, a project, a seminar paper, a report or a colloquium lecture. Please refer to the Examination regulations (Prüfungsordnung) for further details
4. Consultation (Beratung)
   - A student consultation service for students of the Master Program 'Subsurface Engineering' is provided by the Faculty of Civil and Environmental Engineering and the Faculty of Geosciences. In addition, the professors involved in the master program are available for consultation, during which students can clarify questions concerning the respective course.

Changes:

Module number	Name	Change
SE-C-2old	Computational Methods I	Dropped Module
SE-C-2/CE-P05	Finite Element Methods in Linear Structural Mechanics	New Module
SE-C-3	Geology of the Earth's Crust	Volume is reduced to 6CP
SE-C-5	Soil and Rock Behaviour	New Module
SE-CO-6 old	Design of Geotechnical Structures	Dropped Module
SE-CO-6	Design of Geotechnical Structures – Shallow and Deep Foundations	New Module
SE-CO-14	Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement	New Module
SE-CO-10 old	Computational Methods II	Dropped Module
SE-CO-09	Drilling Engineering	Volume is reduced to 6CP
SE-CO-10/BI-WP44	Constitutive Models for Geomaterials	New Module
SE-O-6 old	Introduction to the Design of Geotechnical Structures according to EC7	Dropped Module
SE-O-6/CE-WP-01	Variational Calculus and Tensor Analysis	New Module
SE-O-8/BI-WP-56	High-Performance Computing on Multicore Processors	Change of Module Name, old Name: High-Performance Computing on Multi and Manycore Processors

Winter Semester 2023/2024 30.10.2023

Curriculum ‚Subsurface Engineering‘				
with specialization in Geotechnics and Tunneling (GT) or Subsurface Characterization and Utilization (SCU)				
		CP	GT	SCU
Compulsory 33 CP	Mathematical Aspects of Differential Equations and Numerical Mathematics	6	x	x
	Finite Element Methods in Linear Structural Mechanics	6	x	x
	Geology of the Earth's Crust	6	x	x
	Groundwater Hydraulics	5	x	x
	Soil and Rock Behaviour	6	x	x
	Project Work	4	x	x
Compulsory Optional Required: 48 CP	Foundation Engineering and Utility Pipe Construction: Design-Engineering-Technologies	6	x	
	Conventional and Mechanized Tunneling: Design-Engineering-Technologies	6	x	
	Numerical Simulation in Geotechnics and Tunneling	6	x	
	Design of Tunnel Linings	6	x	
	Operation and Maintenance of Tunnels and Utility Pipes	6	x	
	Design of Geotechnical Structures – Shallow and deep foundations	6	x	
	Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement	6	x	
	Problematic Soils and Soil Dynamics	6	x	
	Numerical Methods and Stochastics	6	x	x
	Mechanical Modeling of Materials	6	x	x
	Drilling Engineering	6	x	x
	Constitutive models for geomaterials	6	x	x
	Ground Exploration Methods	10	x	x
	Applied Geophysics	10		x
	Geothermal Energy Systems	5		x
	Hydrogeological Methods	8		x
	Seismotectonics and Seismic Hazard	6		x
	Selected Topics in Reservoir Characterization	7		x
	Reservoir Engineering	5		x
Optional Required: 9 CP	Practical Training on Tunneling and Pipeline Construction Technique	2	x	x
	Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	2	x	x
	Technologies in Mechanized Tunneling	2	x	x
	Practical Soil Mechanics	3	x	x
	Environmental Geotechnics	3	x	x
	Variational Calculus and Tensor Analysis	5	x	x
	Digital Rock Physics	5	x	x
	High-Performance Computing on Multicore Processors	6	x	x
	High-Performance Computing on Clusters	6	x	x
	Modern Programming Concepts in Engineering	6	x	x
	Deutschkurs - A1	4	x	x
	Deutschkurs - A2	4	x	x
	Compulsory Optional Modules (see above)		x	x
30 CP	Master Thesis	30	x	x

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Mathematical Aspects of Differential Equations and Numerical Mathematics

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-C-1/ CE-P01	6 CP	180 h	1	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group size
Mathematical Aspects of Differential Equations and Numerical Mathematics	4 h/week (60 h)	120 h	-

Learning outcomes

After successfully completing the module the students

- should understand the mathematics side of the Finite Element Method for elliptic PDE in low dimensions, appropriate SOBOLEV geometries, the FEM for DIRICHLET and NEUMANN problems.
- should attain familiarity with modern methods and concepts for the numerical solution of complicated mathematical problems

Content

Basic concepts and techniques for finite- and infinite-dimensional function spaces stressing the role of linear differential operators. Numerical algorithms for solving linear systems. The mathematics of the finite element method in the context of elliptic partial differential equations (model problems) in dimension two.

Teaching Methods

Lecture (2h / week), Exercises (2h / week) / English

Modes of assessment

Written examination (180 min)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

M.Sc. Computational Engineering

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr. B. Bramham

Other information

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Finite Element Methods in Linear Structural Mechanics

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-C-2/ CE-P05	6 CP	180 h	1	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group Size
FEM in Linear Structural Mechanics	4 h/week (60 h)	120 h	-

Learning outcomes

After successfully completing the module, the students

- have basic knowledge of the Finite Element Method (FEM),
- are able to transfer initial boundary value problems of structural mechanics into discretised calculation models based on FEM and thus to solve simple tasks of structural mechanics independently (e.g. calculation of truss structures, disc-like or volume structures),
- have advanced knowledge to understand the functionality of calculation programs based on FEM and to critically evaluate their results,
- are able to independently implement corresponding user-defined elements in FE programs and perform numerical analyses of beam and shell structures,
- have knowledge to solve simple coupled problems (temperature, structural mechanics).

Content

The course covers the basic knowledge of linear FEM, which is based on the principle of virtual work. In particular, the following topics are taught in the course:

- Isoparametric finite elements for trusses, slices, beams, shells, three-dimensional volume elements for application in statics and dynamics,
- Finite element formulations for coupled (e.g. thermo-mechanical) problems,
- Consistent explanation of the fundamentals (basic equations, principle of variation),
- Numerical integration, assembly of the elements to a discretized structure and the solution of the static and dynamic structure equation,
- Discussion of stiffening effects ("locking") and their avoidance.

Teaching methods / Language

Lecture (2h / week), Exercises (2h / week)/ English

Modes of assessment

Written examination (180 min.)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

M.Sc. Computational Engineering
M.Sc. Bauingenieurwesen

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr. techn. G. Meschke

Other information
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Geology of the Earth's Crust

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-C-3	6 CP	180 h	1	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group size
a) Special methods in structural geology	Block course (40 h)	50 h	-
b) Structural geology field camp	4 days (30 h)	60 h	

Learning outcomes

After successful completion of the course the students are

- familiar with the main characteristics of the different types of natural fractures,
- know the mechanisms of tectonic fracture and fluid transfer,
- able to identify and interpret fractures in the field.

Content

a) Special methods in structural geology

This lecture addresses various aspects of tectonic fractures. Firstly, the different types of fractures are introduced in detail with emphasis to their identification and correct interpretation in nature. In the following, fundamentals of fracture mechanics are presented in relation to specific characteristics of natural fractures. The discussion is then expanded to include the impact of fractures on fluid and heat transfer, in particular, and their relevance for operation of geo-energy systems.

b) Structural geology field camp

The exercise involves the structural/geological mapping in fine detail of selected areas using traditional techniques and tools (i.e. compass, hammer, lens...). As such the field camp aims to strengthen field work experience and sharpen geologist skills. In the course of the writing of the report, the student will learn how to analyse field data and how to extract from them a coherent geological synthesis

Teaching Methods / Language

a) Block course (40 h) /English

b) 4 day training in the field (30 h) /English

Modes of assessment

Written Exam (2 h)

Written essay (20 h).

Requirements for the award of credit points

Pass the examinations and compulsory attendance in the field camp

Module applicability (in other study programs)

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Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) a) Prof. Dr. C. Pascal b) Prof. Dr. W. Friederich (coordinator), Prof. Dr. J. Renner
Other information Literature: Davis and Reynolds, 1996. Structural Geology of Rocks and Regions, John Wiley & Sons. Twiss and Moores, 1992 (2007). Structural Geology, Freeman

Groundwater Hydraulics

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-C-4	5 CP	150 h	1	Yearly (WiSe)	1 Semester
Courses			Contact time	Self-study	Group size
Groundwater Hydraulics			4 h/week (60 h)	90 h	-

Learning outcomes

After completion of this module, the students will

- be able to describe and evaluate groundwater flow and conservative mass transport in the subsurface.
- know methods of experimental investigation and determination of hydraulic parameters under different boundary conditions, and can derive and evaluate these mathematically.
- be familiar with the evaluation and interpretation of groundwater hydraulic parameters and use them to deal with classical hydrogeological problems.

Content

- Methods for the collection and evaluation of hydraulic parameters (Darcy-tests, pump tests, Slug&Bail tests)
- Conveyance of knowledge about groundwater flow and the construction of groundwater level plans
- Execution and evaluation of pumping tests by means of graphical and analytical solutions
- Practical tasks for lowering the groundwater level through well systems in excavation pits or calculation of well yield

Teaching Methods / Language

Lectures with accompanying calculation exercises / English

Modes of assessment

Written examination (60 minutes)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

M.Sc. Geosciences

Weight of the mark for the final score

4.17 %

Module coordinator and lecturer(s)

Dr. T. Heinze

Other information

Relevant literature and specific study material will be supplied at the beginning of the lectures.

Soil and Rock Behaviour

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-C-5	6 CP	180 h	1	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group Size
a) Soil Behaviour and Simple Constitutive Models for Soils	2 h/week (30 h)	60 h	-
b) Stress Field and Rock Mass Behavior	Block course (60 h)	30 h	

Learning outcomes

After successfully completing the module, the students

- can assess the constitutive behaviour of the soil under different hydromechanical loading conditions,
- are able to develop strategies to apply simple constitutive laws to model the fundamental soil behaviour in numerical simulations and understand the limitations of these models,
- are able to determine the parameters of simple constitutive models from laboratory test results,
- are familiar with rock and rock mass behaviour and the sources of stress in the earth's crust. They know how to estimate and measure rock mass stress.

Content

a) Soil Behaviour and Simple Constitutive Models for Soils

The course introduces the conventional and advanced laboratory testing methods and addresses expected soil behaviour under monotonic and cyclic loading conditions from numerical modeling perspectives. Fundamentals of standard elastoplasticity applied to geotechnical materials in accordance to failure criteria will be introduced. Additionally, it discusses the fundamentals, advantages and limitations of widely used simple constitutive models for soils such as:

- Linear Elastic (LE) model
- Mohr-Coulomb (MC) model
- Hardening Soil (HS) model

Finally, the calibration of simple constitutive models from laboratory tests will be discussed and these models will be applied to different geotechnical problems.

b) Stress field and rock mass behavior

Definition of stress, rock deformation, rock failure, rock mass definition, sources of stress in the earth crust, methods of stress measurement and stress modelling, determination of stress alterations and stress redistribution.

Teaching methods / Language

a) Lecture (2h / week) / English

b) Block course (60 h) / English

Modes of assessment

Written examination (180 min.)

Requirements for the award of credit points Passing the written examination
Module applicability (in other study programs) -
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) a) Prof. Dr.-Ing. habil. T. Wichtmann (coordinator); M.Sc. C. Schmüdderich b) Prof. Dr. T. Backers
Other information -

Project Work

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-C-6	4 CP	120 h	3	Each WiSe	1 semester
Courses			Contact time	Self-study	Group size
Project Work			-	120 h	---

Learning outcomes

After completion of the project work, the students

- will have gained experience in working on a problem individually or in small groups.
- are able to organize and Coordinate the assignment of tasks independently under the supervision of an advisor.
- should have gathered new information and insights into the activities of practicing engineers while acquiring skills in innovative research fields.
- will be able to present technical projects, and to develop problem solution strategies and will hence also obtain worthwhile communication skills.

Content

The project topic is usually determined by the respective lecturer or one of his/her assistants. In addition to this, students may also conduct project work on topics defined by companies from industry or other equivalent institutions. However, the project work must be completed under the supervision of one of the lecturers from the study program Subsurface engineering. The student - or a small group of students - conducts a project independently and presents the results in the form of a written report and optionally, an oral presentation (upon agreement with the respective lecturer). The projects are usually devised so as to integrate interdisciplinary aspects such as

- Noticing problems and describing them
- Formulating envisaged goals
- Team-oriented problem solutions
- Organizing and optimizing one's time and work plan
- Interdisciplinary problem solutions
- Literature research and evaluation as well as the consultation of experts
- Documentation, illustration and presentation of results

Teaching Methods / Language

Independent work in seminar rooms and computer labs; testing plants, where applicable / English

Modes of assessment

Home assignment: project work (120 h) with optional oral presentation (20 min)

Requirements for the award of credit points

The project paper and presentation will be graded. For this purpose, the individual achievements of the students within the project groups are separately evaluated. The evaluation includes: Written report / 75% (100% without a final presentation) and Final presentation / 25% (optional)

Module applicability (in other study programs) -

Weight of the mark for the final score

3.33 %

Module coordinator and lecturer(s)

Professors, lecturers and assistants

Other information

Foundation Engineering and Utility Pipe Construction: Design – Engineering – Technologies

Modul-No. SE-CO-1/ BI-WP10	Credits 6 CP	Workload 180 h	Semester 3	Frequency Yearly (WiSe)	Duration 1 Semester
Courses Design, engineering and technologies in Foundation Engineering and Utility Pipe Construction			Contact time 4 h/week (60 h)	Self-study 120 h	Group size 25 Students

Learning outcomes

The module intends to provide students with a comprehensive understanding of the field of design, engineering and technology regarding Foundation Engineering and Utility Pipe construction. They will acquire in-depth knowledge for special areas of foundation engineering for the accomplishment of engineering tasks on areas planning, construction and operation. Foundation engineering is the field of civil engineering, which deals with the design and construction of subsurface structures which typically are built in open excavation pits. The students will learn to work on tasks from these areas and to develop an understanding of the methods. They will be enabled to independently solve the common problems of foundation engineering and utility pipe construction. Connections of this field with other areas of the building industry as interdisciplinary task are recognized and integrated into the solutions of project processing. The students acquire knowledge that is necessary for the preparation and processing of construction projects in construction management. The methods commonly used in practice shall be applied.

Recommended prior knowledge:

Bachelor-level knowledge of construction operations and construction process engineering, Bachelor-level knowledge of foundation engineering and soil mechanics

Content

The lecture deals with the extended basic knowledge of construction process engineering.

Design, engineering and technologies in Foundation Engineering

- Dewatering / Water management
- Construction pit system (Girder System, Diaphragm Wall, Bored Pile Wall, etc.)
- Caisson systems
- Grout injection techniques (low and high pressure methods, etc.)
- Injected piles
- Underpinning
- Cut and Cover method
- Conventional sealing methods (waterproofing)
- Construction of jointing
- Open trench methods in Pipeline Construction

Pipeline Construction (Trenchless Construction Techniques - unmanned)

- Technical principals of unmanned techniques – steerable
- Technical principals of unmanned techniques – non-steerable
- HDD Horizontal Directional Drilling, Direct Pipe

Teaching Methods / Language

Lectures (2 h/week) and Exercises (2 h/week) in English language
Modes of assessment ● Homework assignment on Foundation Engineering and Utility Pipe Construction including basic design problems (30 h, weight for the final grade of this module: 0%) ● Written module examination on Foundation Engineering and Utility Pipe Construction including basic design problems (120 min, weight for the final grade of this module: 100%) ● Language of the homework assignment or the written examination in English or German by choice of the student (Klausur nach individueller Wahl in englischer oder deutscher Sprache)
Requirements for the award of credit points ● Presentation of the results of the homework assignment ● Passed written examination of the module
Module applicability ● M.Sc. Bauingenieurwesen ● M.Sc. Geosciences
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) Prof. Dr.-Ing. M. Thewes, Dr.-Ing. Britta Schoesser
Other information -

Conventional and Mechanised Tunneling: Design – Engineering – Technologies

Modul-No. SE-CO-2/ BI-WP11	Credits 6 CP	Workload 180 h	Semester 2	Frequency Yearly (SoSe)	Duration 1 Semester
Courses Design, engineering and technologies in Tunneling and Pipeline Construction			Contact time 4 h/week (60 h)	Self-study 120 h	Group size 25 Students

Learning outcomes

The module is intended to familiarize students comprehensively with the whole field of tunneling. The participants will acquire in-depth knowledge for engineering tasks in the areas of planning, construction and operation of tunnels. The students will learn to independently work on tasks from these areas and to develop a specific understanding of the methods. They will be enabled to solve the common problems of tunnel design and construction and to work independently and purposefully. Relations of this area with other areas of civil engineering as an interdisciplinary task are recognized and integrated into the solutions. The students will acquire knowledge that is necessary for the preparation and execution of construction projects of tunnel construction. The methods commonly used in practice shall be applied.

Recommended prior knowledge:

Bachelor-level knowledge of construction operations and construction process engineering, Bachelor-level knowledge of foundation engineering and soil mechanics

Content:

The lecture deals with the extended basic knowledge of Tunnel Engineering.

Design, engineering and technologies in Tunneling

- Planning methods for tunnel constructions
- Methods and components of for temporary and final tunnel lining
- Conventional Tunneling
- Excavation techniques for soil and rock
- Conventional tunneling with mechanized excavation of the rock mass
- Sprayed concrete method
- Compressed air method
- Mechanized tunneling, different Tunnel Boring Machines adapted to the boundary conditions on rock and soil formations
- Single-shell and double-shell tunnel linings
- Special construction methods
- Monitoring and process management
- Special features of tunneling logistics and ventilation
- Safety aspects during construction and operation
- Settlement prediction for green-field and buildings

Design, engineering and technologies for Trenchless Construction Techniques (manned)

- Technical principals of manned techniques – steerable
- Microtunnelling,
- Pipe Jacking
- Construction and structural analysis of Jacking Pipes
- Jacking Forces, Jacking Force Prediction

Teaching Methods / Language Lectures (2 h/week) and Exercises (2 h/week) in English language
Modes of assessment ● Homework assignment on Design, engineering and technologies in Tunneling and Pipeline Construction including basic design problems (30 h, weight for the final grade of this module: 0%) ● Written module examination on Design, engineering and technologies in Tunneling and Pipeline Construction including basic design problems (120 min, weight for the final grade of this module: 100%) ● Language of the homework assignment or the written examination in English or German by choice of the student (Klausur nach individueller Wahl in englischer oder deutscher Sprache)
Requirements for the award of credit points ● Presentation of the results of the homework assignment ● Passed written examination of the module
Module applicability ● M.Sc. Bauingenieurwesen ● M.Sc. Geosciences
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) Prof. Dr.-Ing. M. Thewes, Dr.-Ing. Britta Schoesser
Other information

Numerical Simulation in Geotechnics and Tunneling

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-3/ CE-WP09	6 CP	180 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group Size
a) Numerical Simulation in Tunneling	2 h/week (30 h)	60 h	-
b) Numerical Simulation in Geotechnics	2 h/week (30 h)	60 h	

Learning outcomes

After successfully completing the modules, the students are able to

- implement numerical models of complex boundary value problems of tunnels and geotechnics, creating the adequate geometrical models,
- evaluate numerical models and their results in a critical way,
- acquire adequate knowledge in fundamentals of the finite element method to be able to adopt numerical simulation in design and control of geotechnical problems with focus on the interactions between the soil and structures.

Content

a) Numerical Simulation in Tunneling

The course deals with the numerical modeling of tunnel structures and tunnel driving:

- basic aspects of numerical modeling of tunnel construction problems,
- practical application of FE software environments to model a conventional tunnel advance in 3D
- automatic and parameter-controlled generation of complex models

b) Numerical Simulation in Geotechnics

The course deals with the numerical modeling of geotechnical structures and construction methods:

- Overall insight to the numerical simulation of geotechnical problems by using the finite element method
- Details for proper simulation in geomechanics by addressing constructional details, optimum discretization, boundary and initial conditions
- Quick review of simple constitutive models, including calibration and discussion of important criteria to choose relevant constitutive models for distinct applications
- Methods to validate and verify the reliability of numerical models by exploring the numerical outputs in space and time and the evaluation of numerical results
- The soil-water interactions in drained, undrained and consolidation analyses, fully coupled hydromechanical finite element solutions.
- Creation of models, execution of calculations and analysis of results for various geotechnical structures: shallow foundations, retaining walls, excavation, embankments, consolidation, slope failure
- Fundamentals of contact elements and their applications in geotechnical modeling
- Introduction to FE simulations with Plaxis 2D and other FE programs (Abaqus, Numgeo, etc.)
- Brief overview of other numerical methods (e.g. DEM, MPM, boundary element method).

Teaching methods / Language

a) Lectures (2 h/week) / English   b) Lectures (2 h/week) / English
Modes of assessment Final written examination (120 min)
Requirements for the award of credit points Passed final written examination
Module applicability (in other study programs) M.Sc. Computational Engineering, M.Sc. Bauingenieurwesen
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) a) Prof. Dr. techn. G. Meschke (coordinator) b) C. Schmüdderich, M.Sc.
Other information -

Design of Tunnel Linings

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-4	6 CP	180 h	3	Yearly (WiSe)	1 semester

Courses	Contact time	Self-study	Group size
a) Systems & concrete technology	2 h/week (30 h)	60 h	no restriction
b) Design	2 h/week (30 h)	60 h	

Learning outcomes

The Students

- possess a deepened understanding of concrete technological conception as well as the concrete works in tunnel- and subsurface engineering
- are able to apply and validate important material laws and normative rules for concrete executions in relation to tunnel construction processes
- are able to derive fundamental concrete aspects for tunnel constructions on the basis of material science and to independently work on concrete technological and planning issues
- are able to derive sectional forces of reinforced concrete (RC) tunnels in lateral (ring) or longitudinal direction incl. the setup of suitable static systems
- learn how to design the tunnel in Ultimate Limit States (ULS) as well as Serviceability Limit States (SLS)
- learn the detailing of reinforcements for tunnels with segmental linings, frame or shell structures

Content

a) Systems & concrete technology

The design and conception of concretes for tunnels with different properties and environmental conditions is the subject of this course. The utilization of special concrete constituents and the resulting material properties as well as current production processes and construction methods are presented. The main topics of the event are as follow:

- Basics of concrete technology
- Sprayed Concrete for Tunnel Linings
- Open Construction
- Base Concrete
- Inner-Shell Concrete Tunnel Lining
- Precast Lining Elements
- Annular Gap Mortar

b) Design

For usual tunnels in soft rock having trough or frame structures, segmental linings or curved shells, methods for calculating sectional forces, deformations and stresses within the tunnel will be presented. Moreover, basic design methods we be developed. They include the conceptual design of the tunnel itself, ULS and SLS design methods as well as the detailing of reinforcements.

- Static systems for tunnels with frame structure, segmental linings or shell lining
- Sectional forces in ring and longitudinal direction incl. stability checks
- Design methods using M/N-interactions, strut-and-tie modelling and crack control
- Detailing methods for hybrid reinforcements

Teaching Methods/ Language Lectures (4 h/week) / English
Modes of assessment written examination (120 min)
Requirements for the award of credit points Passed module final examination: Written examination (120 min)
Module applicability (in other study programs) -
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) a) Univ.-Prof. Dr.-Ing. habil. Peter Mark (coordinator) b) Univ.-Prof. Dr.-Ing. Rolf Breitenbücher
Other information Knowledge of building materials technology and construction physics presupposed Further literature will be announced during the lecture

Operation and Maintenance of Tunnels and Utility Pipes

Modul-Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-5/ BI-WP26	6 CP	180 h	3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group size
a) Facility management of underground transportation infrastructure b) Pipeline maintenance and network management	a) 2 h/week (30 h) b) 2 h/week (30 h)	a) 60 h b) 60 h	20 Students

Learning outcomes

This module teaches a wide range of aspects of operation and maintenance of tunnels and underground utility pipelines. Aspects of structural protection and the necessary methods and techniques of building maintenance are presented, the equipment and techniques of operating concepts (normal and emergency operation) of underground infrastructure are shown and management concepts and evaluation mechanisms for economic and financial efficiency studies are discussed. The students should thus be put in a position to select appropriate measures for the maintenance of tunnels and utility pipes, or to carry out profitability analyses of such structures - for example based on principles for the operation and maintenance of tunnels and lines. For a professional activity as operators of pipeline networks or tunnel constructions such basic knowledge is indispensable. Basic skills for operation and maintenance of underground infrastructure are presented. These are – in reference to a declining new construction activity and increasing maintenance requirements of the enormously large existing infrastructure stock – of high importance for the future occupational profile of civil and environmental engineers.

Content

a) Facility management of underground Transportation infrastructure

The courses of this part-module deal with the extended basic knowledge of operation and maintenance of tunnels. This includes:

- Regulations and boundary conditions in reference to transport modes
- Operating equipment in tunnels
- Operation of tunnels (concepts, features and structure of control center operation, surveillance and inspection)
- Safety and security
- Rehabilitation and maintenance (points of maintenance, upgrade under operation, rehabilitation techniques, rehabilitation under operation)
- Building management / Tunnel Facility Management (collecting and processing of operation data, operating concept e.g. PPP, Lifecycle-Management)

b) Pipeline Maintenance and Network management

The courses of this part-module deal with the extended basic knowledge of operation and Maintenance of lines. This includes:

- Introduction: underground sewer and pipeline engineering
- Open cut method – practical use
- Structural safety of pipes in open-cut construction

• New sewers and pipelines using trenchless methods including pipe jacking • Rehabilitation – objectives and tasks • Rehabilitation – Replacement • Rehabilitation – Repair • Rehabilitation - Renovation • Service-life of sewers and pipelines including tightness, root resistance, heavy rainfall events
Teaching Methods Lectures in English language
Modes of assessment Module examination: 120 min (60 min per part) Language of the written examination in English or German by choice of the student (Klausur nach individueller Wahl in englischer oder deutscher Sprache)
Requirements for the award of credit points Passed module examination 100% (6CP)
Module applicability ● M.Sc. Bauingenieurwesen ● M.Sc. Geosciences
Weight of the mark for the final score 5%
Module coordinator and lecturer(s) Coordinator: Prof. Dr.-Ing. M. Thewes Lecturer a): Prof. Dr.-Ing. R. Leuker Lecturer b): Prof. Dr.-Ing. B. Bosseler
Other information -

Design of Geotechnical Structures – Shallow and Deep Foundations

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-6	6 CP	180 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group Size
Design of Geotechnical Structures - Shallow and Deep Foundations	4 h/week (60 h)	120 h	-

Learning outcomes

After successfully completing the modules, the students are able to

- perform the proofs of ultimate limit state and serviceability limit state for different types of foundations in accordance with Eurocode 7, supported by in-situ testing and laboratory experiments,
- recommend the appropriate foundation type according to soil conditions, expected loads and design requirements

Content

The course deals with the design of the following foundation types:

- Shallow single and strip foundations
- Plate foundations
- Single pile foundations under vertical loading
- Single pile foundations under horizontal loading
- Pile groups under vertical or horizontal loading
- Drilled-shaft (caisson) foundations

Teaching methods / Language

Lectures with accompanying exercises (4 h/week), among them computer exercises with program GGU / English

Modes of assessment

Final written exam (180 min.)

Requirements for the award of credit points

Passed final written examination

Module applicability (in other study programs)

-

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr.-Ing. habil. T. Wichtmann (coordinator)

Dr.-Ing. M. Tafili, Dr.-Ing. N. Irani, Dr.-Ing. M. Salimi

Other information

-

Problematic Soils and Soil Dynamics

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-7/ BI-WP42	6 CP	180 h	3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group Size
a) Problematic soils	2 h/week (30 h)	60 h	---
b) Soil dynamics	1 h/week (15 h)	45 h	
c) Geotechnical earthquake engineering	1 h/week (15 h)	15 h	

Learning outcomes

After successfully completing the modules, the students are able to

- assess special soil mechanical properties, phenomena, and the behavior of problematic soils and can design an appropriate experimental program (laboratory / field tests) for an investigation of problematic soils,
- understand soil dynamic problems and describe them mathematically,
- determine the loading resulting from earthquakes and design geotechnical structures for these loads,
- assess difficult ground and loading conditions and develop solutions for these situations.

Content

a) Problematic soils

The course deals with different phenomena, that can cause difficulties in civil works for some types of soils:

- Soft plastic and organic soils
- Swelling and shrinkage behaviour
- Collapsible soils
- Physico-chemical effects
- Structure and fabric, compacted soils
- Unsaturated soils
- Experimental methods for investigations on these soils and phenomena

b) Soil dynamics

The lecture deals with the fundamentals of Soil Dynamics:

- Fundamentals of vibration theory
- Wave propagation in elastic isotropic half space
- Laboratory tests on dynamic characteristics of soils
- Methods to estimate dynamic characteristics of soils
- Dynamic field measurement methods
- Design of dynamically loaded foundations
- Soil-structure interaction under dynamic loading
- High cyclic loading of soils (practical problem: offshore wind turbines)
- Laboratory exercise (Resonant column experiment, Bender elements).

c) Geotechnical earthquake engineering

The lecture covers the effects of a seismic event on geotechnical structures and the design of such structures against earthquakes:

• Causes of soil liquefaction under seismic loading; methods to estimate the liquefaction risk; countermeasures • Design of slopes against seismic loading • Design of retaining structures against seismic loading • Ground response analysis
Teaching methods / Language a) Lectures with accompanying exercises (2 h/week) / English b) Lectures with accompanying exercises (1 h/week) / English c) Lectures with accompanying exercises (1 h/week) / English
Modes of assessment Final written exam (180 min.)
Requirements for the award of credit points Passed final written examination
Module applicability (in other study programs) -
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) Prof. Dr.-Ing. habil. T. Wichtmann (coordinator) a) Dr.-Ing. W. Baille b) Dr.-Ing. M. Goudarzy c) Dr.-Ing. F. Prada
Other information -

Numerical Methods in Stochastics

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-8/ CE-WP08	6 CP	180 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group size
Numerical Methods and Stochastics	4 h/week (60 h)	120 h	-

Learning outcomes

After successfully completing the module the students, the students should become familiar with modern numerical and stochastic methods.

Content

Numerical Methods:

- Numerical methods for ordinary differential equations
- Numerical methods for partial differential equations (finite element method)
- Efficient solution of large linear systems
- Numerical optimization algorithms

Stochastics:

- Fundamentals of probability and statistics
- Exploratory data analysis and unsupervised learning
- Inferential data analysis
- Machine learning

Teaching Methods / Language

Lectures (3h / week), Exercises (1h / week) / English

Modes of assessment

Written examination (180 min)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

M.Sc. Computational Engineering

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr. K. Kormann (coordinator), Prof. Dr. J. Lederer, Assistants

Drilling Engineering

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-9	6 CP	180 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group size
a) Geotechnical and Near-Surface Drilling	2 h/week (30 h)	60 h	-
b) Deep Drilling Engineering and Technologies	2 h/week (30 h)	60 h	

Learning outcomes

The students after completion of the module will have the following competencies:

- Basics of shallow drilling
- Coring and cuttings
- Geotechnical exploration, probing and analysis (DIN 4021 / EN ISO 22475)
- Foundation work and drilling
- Water well drilling and completion
- Shallow geothermal drilling, completion and applications including standard W120
- Quality assurance and control of shallow geothermal BHE systems
- Fundamentals of deep drilling systems
- Drilling tooling
- Well and casing stability
- Site management skills
- Mud circulation
- LWD / MWD techniques
- Explain the main methods and parameters of drilling technology – Describe potential drilling problems
- Define the composition of the cost structure of a drilling project – Calculate casing designs
- Development of deep drilling concepts

Content

a) Geotechnical and Near-Surface Drilling

The course presents an introduction to drilling technologies, focusing on shallow, near-surface applications like geothermal borehole heat exchangers, water and monitoring wells, geotechnical as well as environmental investigation. Dry, augering and mud drilling techniques will be compared and discussed, as well as sampling and coring for different applications.

- Introduction to geotechnical investigations and selected standards
- Rotary drilling with direct circulation including tooling
- Rotary drilling with indirect circulation including tooling, applications, airlifting
- Mud losses, artisean conditions while drilling, cementing
- Water and monitoring wells, well testing, sampling
- Shallow geothermal, borehole heat exchanger systems
- Environmental Direct Push sampling, coring, onsite analysis
- Differentiate shallow and deep drilling
- Learn all the various shallow drilling methods from rotary, augering to Direct Push
- Know drilling, sampling, coring and their applications
- Monitoring and water well planning and drilling
- Geotechnical and foundation work

- Environmental investigation schemes
- Basic mud rotary drilling
- Dry, augering type drilling methods
- Coring
- Sampling
- DirectPush
- Water well systems
- Shallow geothermal wells

b) Deep Drilling Engineering and Technologies

The course gives an introduction to the principles of conventional and advanced deep drilling technologies. Students learn how to plan a drilling project including wellbore planning and selection of toolings and devices.

- Deep drilling basics; mechanical rock destruction process
- Drilling techniques and process
- Rotary drilling
- Percussion drilling
- Directional drilling
- Innovative and unconventional drilling techniques (thermal, hydraulic, coiled tubing)
- Drilling specific laboratory analysis
- Mudlogging
- Health, safety issues and environmental impacts of drilling projects

Teaching Methods / Language

Lectures, exercises, field work and site visit / English

Modes of assessment

Written module examination (180 min)

Requirements for the award of credit points

Passed module examination

Module applicability (in other study programs)

M.Sc. Geosciences

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr.-Ing. habil. T. Wichtmann (coordinator), external lecturers

Other information

Constitutive Models for Geomaterials

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-10/ BI-WP44	6 CP	180 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group size
a) FEM for Nonlinear Analyses of Inelastic Materials and Structures	2 h/week (30 h)	60 h	-
b) Advanced Constitutive Models for Soils	2 h/week (30 h)	60 h	

Learning outcomes

After successfully completing the modules, the students are able to

- formulate and to implement inelastic material models for ductile and brittle materials within the context of the finite element method and to perform nonlinear ultimate load structural analyses
- model the material behavior of soil using suitable, complex constitutive models,
- select suitable numerical methods and constitutive models for practical questions and assess limitations according to the selected approaches.

Content

a) FEM for Nonlinear Analyses of Inelastic Materials and Structures

The course is concerned with inelastic material models including their algorithmic formulation and implementation in the framework of nonlinear finite element analyses. Special attention will be paid to efficient algorithms for physically nonlinear structural analyses considering elastoplastic models for metals, soils and concrete as well as damaged based models for brittle materials. As a final assignment, the formulation and implementation of inelastic material models into an existing finite element program and its application to nonlinear structural analyses will be performed in autonomous teamwork by the participants.

b) Advanced Constitutive Models for Soils

The course extends the existing knowledge on soil behaviour and its mathematical description by introducing following constitutive models:

- Hardening Soil, Hardening Soil Small Strain
- Modified Cam-Clay
- Softsoil Creep (SSC) model
- Hypoplasticity with intergranular strain
- Viscohypoplasticity
- Bounding surface plasticity models SaniSand / SaniClay
- Calibration process of advanced constitutive models
- Effects of the constitutive model on the FE-prediction (selected examples)

Teaching methods / Language

a) Lectures (1 h/week) and Exercises (1 h/week) / English

b) Lectures (2 h/week) / English

Modes of assessment

Final written examination; project work (60 h) with oral presentation

Requirements for the award of credit points Project works with oral presentation for a) and b) (Date for presentation will be announced at the start of the semester)
Module applicability (in other study programs) M.Sc. Computational Engineering M.Sc. Bauingenieurwesen
Weight of the mark for the final score 5 %
Module coordinator and lecturer(s) a) Prof. Dr. Günther Meschke (coordinator) b) Dr.-Ing. M. Tafili, MSc. C. Schmüdderich
Other information

Ground Exploration Methods

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-11	10 CP	300 h	3	Yearly (WiSe)	1 semester

Courses	Contact time	Self-study	Group size
a) Geophysical Inverse Problems	3 h/week (45 h)	105 h	-
b) Seismic and electromagnetic field methods	3 h/week (45 h)	105 h	

Learning outcomes

- Students understand the theoretical foundations of seismic and electromagnetic field methods and know up-to-date measuring and data-acquisition procedures. They know and understand state-of-the-art methods of data analysis and interpretation.
- Students understand the general philosophy of how to properly set up and solve geophysical inverse problems to create subsurface models from geophysical field surveys. They know different approaches to mathematically formulate an inverse problem and various techniques to obtain solutions in practice. They are able to solve small-scale problems themselves by writing a computer program.

Content

a) Geophysical Inverse Problems

Mathematical precursor on linear vector and Hilbert spaces, the continuous linear inverse problem with exact and uncertain data, discrete linear inverse problems with uncertain data, singular value decomposition, resolution analysis, conjugate gradient minimization, linearized iterative inverse problems

b) Seismic and electromagnetic field methods:

Data acquisition in reflection seismics, seismic data processing, ray and wave-equation migration, basic electromagnetic theory, electromagnetic fields in matter, geoelectric sounding and induced polarization, electromagnetic diffusion and waves in matter and ground penetrating radar

Teaching Methods / Language

Lectures accompanied by assignments to be worked out and solved at home encompassing mathematical problems and programming tasks / English

Modes of assessment

written module examination, 120 minutes

Requirements for the award of credit points

passed module examination, bonus points for voluntary presentation of solutions to exercises

Module applicability (in other study programs)

M.Sc. Geosciences

Weight of the mark for the final score

8.33 %

Module coordinator and lecturer(s)

Prof. Dr. W. Friederich

Other information Literature: Parker, R.: Geophysical Inverse Problems; Menke, W.: Geophysical Data Analysis, Discrete Inverse Theory; Feynman: Lectures on Electrodynamics; Telford, Geldart, Sheriff: Applied Geophysics, Everett, M., Near surface applied geophysics, 403 pp. Cambridge University Press, 2013

Applied Geophysics

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-12	10 CP	300 h	2	Yearly (SoSe)	1 semester

Courses	Contact time	Self-study	Group size
a) Reservoir Geophysics	3 h/week (45 h)	120 h	According to demand; lab experiments in groups of max. 3 persons
b) Rock Physics	3 h/week (45 h)	90 h	

Learning outcomes

After successful completion of the module students

- appreciate the scale-dependent approach to the physical characterization of rocks (micro- to decimeter-scale) and reservoirs (deci- to kilometer-scale)
- understand the relation between physical properties of rocks and their chemical composition and microstructure
- learned the use and limits of empirical and theoretical concepts for the description of heterogeneous media
- know the practical aspects of a suite of methods in exploration geophysics
- are familiar with the mathematical description of physical processes on rock and reservoir scale
- understand the origin of the governing partial differential equations and master some approaches to their solution

Content

a) Reservoir geophysics (reservoir-scale perspective):

- Introduction to reservoirs (hydrocarbon, geothermal)
- Physical properties of reservoir fluids
- Hydraulic transport (Kozeny-Carman relation) and storage (linear poro-elasticity I: isostatic stress states)
- Theory and practice of pumping tests (diffusion equation, scaling)
- Geothermics (add advection to diffusion)
- Aspects of waves in real media (wave equation, linear poro-elasticity II: add deviatoric stresses)

b) Rock physics (grain-scale perspective)

- Introduction to rocks and minerals
- Porosity and interface phenomena
- Hydraulic transport in rocks (Darcy's law, permeability models)
- Elasticity (stress, strain, Hooke's law, averaging schemes)
- Failure of rocks (fracture and friction)
- Laboratory practical: students independently conduct simple experiments to determine basic physical properties of rocks (density, porosity, permeability, elastic wave velocities, electrical conductivity) and fluids (density, viscosity)

Teaching methods / Language

Lectures, assignments (deepening of contents through own research, solving of analytic and numerical problems), laboratory experiments / English
Mode of assessment Written final exam (3 hours) + report on lab experiments
Requirements for the award of credit points Passed module exam
Module applicability (in other study programs) -
Weight of the mark for the final score 8.33 %
Module coordinator and lecturer(s): Prof. J. Renner (coordinator)
Further information: Prerequisites: Sound mathematical skills (vector calculus, differential- and integral calculus) Literature: Jaeger, Cook, Zimmerman “Fundamentals of Rock Mechanics”; Gueguen, Palciauskas “Introduction to the physics of rocks“; Schön “Physical properties of rocks“; Mavko, Mukerji, Dvorkin “The rock physics handbook“; AGU reference shelf “Rock physics and phase relations“; Sully “Elements of petroleum geology”; Wang “Theory of linear poro-elasticity”; Fetter “Applied hydrogeology”; Zoback “Reservoir geomechanics”; Carcione “Wave-fields in real media”

Geothermal Energy Systems

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-13	5 CP	150 h	1	Yearly (SoSe)	1 Semester
Courses			Contact time	Self-study	Group size
Geothermal Energy Systems			4 h/week (60 h)	90 h	-

Learning outcomes

The students know the fundamentals of energy conversion systems such as electricity generation from geothermal resources at low and at high enthalpy. They describe the function of the components of a power plant and understand the thermodynamics of fluid and steam cycles. They are able to design simple district heating networks and develop concepts for industrial applications for infrastructural and agricultural uses.

Knowledges:

- Components of a hydrothermal system
- Methods of enhancing geothermal reservoirs
- Reservoir principles for thermal water generation
- Schematic flow and temperature / entropy processes for geothermal plants
- Equipment for plants for electricity generation from steam and binary cycles and for direct uses
- Estimate the environmental and social impacts of geothermal projects

Skills:

- Define the elements of thermodynamics
- Formulate the laws of thermodynamics
- Recite principles of the conversion of heat to work
- Distinguish entropy from exergy

Competences:

- Explain the structure and dimensions of the earth and the related heat potential
- Give an outlook to the expected major future applications of geothermal energy
- Name the main sources and amounts of heat deriving from the subsurface
- Explain the temperature distribution inside the earth over space and time
- Distinguish between the nuclear, thermal and solar heat sources within the earth's structure and their sustainability
- Define the hydraulic characteristics of geothermal systems
- Differentiate the temperature versus depth parameters of low temperature fields and sedimentary basins
- Describe the main technical solutions for direct, indirect and combined electricity and heat production uses
- Propose possible applications for available resource temperatures
- Describe the interactions of geothermal energy conversion systems: reservoir -well – piping – plant – reinjection
- Match the different power plant types and technical applications to corresponding reservoir conditions
- Identify the components of heat conversion technologies
- Develop technical solutions for given reservoir conditions, and regional or local energy demands

• Compare the different cooling energy sources and choose the right cooling system for a site • Name the main elements for transmission and urban underground pipeline systems • Define the impacts of plants on the environment • Illustrate the phases and cumulative costs at various stages of development
Content • Global geothermal resources • Elements of thermodynamics, fluid mechanics, and heat transfer applied to geothermal energy conversion systems • Power plant technologies based on flash steam, direct steam, binary conversion systems, and hybrid systems • Cooling technologies • District heating networks and direct uses • Pumping the reservoir • Hybrid uses (water desalination) • Mine water applications • Corrosion and scaling processes • Social and environmental impacts • Case studies • Economics, finance, and risk analysis of a geothermal project
Teaching Methods / Language Lectures (3h) / Exercises (1h) / English
Modes of assessment Written final exam (60 min), Optional homework (40 h), max. 10 pages, 4 weeks time for completion, submission deadline is announced at the beginning of the semester, bonus points in the examination in case of successful completion), exercise tasks
Requirements for the award of credit points Pass the final examination, pass the homework (no grade), presence in class, regular work on exercise tasks (no grade)
Module applicability (in other study programs) MSc. Geoscience
Weight of the mark for the final score 4.16 %
Module coordinator and lecturer(s) Prof. Dr. R. Bracke
Other information

Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-14	6 CP	180 h	3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group Size
Design of Geotechnical Structures - Excavation Pits, Retaining Structures and Soil Improvement	4 h/week (60 h)	120 h	-

Learning outcomes

After successfully completing the modules, the students are able to

- perform the proofs of ultimate limit state and serviceability limit state for different types of retaining structures as well as other components of construction pits in accordance with Eurocode 7, supported by in-situ testing and laboratory experiments,
- recommend the appropriate retaining structure according to soil conditions, expected loads and design requirements,
- recommend the appropriate method of soil improvement according to soil conditions, expected loads and design requirements

Content

The course:

- Introduces possible failure mechanisms of retaining systems, soil slopes as well as excavation pits and soil dikes
- Gives a general overview to different type of retaining structures (e.g. flexible and rigid) with active and passive facings
- Discusses different calculation methods to determine the safety factor of the slopes, excavation pits and retaining structures against failure
- Explains multitude of supporting techniques (e.g. back anchoring, nailing, etc.) with their corresponding design methods
- Gives an overview to geosynthetic soil reinforced geostructures
- Introduces different methods of soil improvement

Teaching methods / Language

Lectures with accompanying exercises (4 h/week) / English

Modes of assessment

Final written exam (180 min.)

Requirements for the award of credit points

Passed final written examination

Module applicability (in other study programs)

-

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr.-Ing. habil. T. Wichtmann (coordinator) Dr.-Ing. M. Tafili, Dr.-Ing. N. Irani, Dr.-Ing. M. Salimi
Other information -

Hydrogeological Methods

Modul Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-15	8 CP	240 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group size
a) Tracers in Hydrogeology	3 h/week (45 h)	75 h	40 Students
b) Hydrogeological Field Camp	3 h/week (45 h)	75 h	

Learning outcomes

At the end of the module, participants will

- be able to perform various hydrogeological field experiments and analyze the results,
- understand the concept of applying organic substances as Tracers for groundwater flow,
- plan and execute tracer tests, use field and laboratory equipment for tracer detection, process and analyze the tracer test results,
- write a scientific report,
- communicate with water- and environmental authorities and
- transfer theoretical knowledge to practical applications.

Content

a) Tracers in Hydrogeology

Basics concepts, terms and methods in tracer hydrology: different kind of tracers, their chemical and hydrodynamical properties, planning and performance of the tracer tests under real world conditions: tracer injection, sampling, analytical detection. Moreover, the hydrogeological interpretation of the results, calculation of hydrodynamic parameters as well as the use of computer programs will be trained and documented by writing a report.

b) Hydrogeological Field Camp

The most important hydrogeological Field methods will be used to evaluate and plan the water supply well: pumping tests, infiltration tests, run of measurements extraction of groundwater and petrochemical sampling determination of petrochemical and physical groundwater parameters, use of hydrochemical analyses in the field, shallow drilling, hydrogeological and engineering geology goal characterization of the soil profile in boreholes, measuring of the groundwater level and plotting of groundwater contour maps. All the data of the performed experiments are documented and interpreted in a written report.

Teaching methods / Language

a) field excercise (5 days, 45h) / English
b) Lecture (1h) / Exercise (2h) / English

Mode of assessment

written report (10h)

Requirement for the award of credit points

active participation in the field exercises and evaluated written report

Module applicability (in other study programs)

M.Sc. Geosciences

Weight of the mark for the final score 6.7 %
Module coordinator and lecturer(s) Prof. Dr. S. Wohnlich (coordinator), Dr. T. Heinze
Further information relevant literature and specific study material will be supplied at the beginning of the lectures.

Seismotectonics and Seismic Hazard

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-16	6 CP	180 h	2	Yearly (SoSe)	1 Semester
Courses			Contact time	Self-study	Group size
Seismotectonics and Seismic Hazard			4 h/week (60 h)	120 h	-

Learning outcomes

A multidisciplinary approach is strongly needed in order to better understand the seismic potential of any region in the world. Geological data give us a long-term (thousands of years) view of earthquake phenomena, but they are limited to the first meters of the crust. Seismological and geophysical data can generally better describe deformation processes occurring at depth, but usually with a smaller temporal (tens of years) and spatial resolution. This course will provide an introduction to the earthquake problem from both geological and geophysical points of view, with emphasis on the methodologies commonly used to produce the data necessary to understand and quantify the seismic hazard in any active region.

After successful completion of the module, students will be able to

- Understand the relationship between lithosphere rheology and earthquake distribution;
- Understand the relationship between frictional properties and faulting;
- Understand the basics of earthquake detection and location;
- Understand the relationship among subsequent earthquakes (earthquake and fault interactions);
- Understand the primary (faulting) and secondary (liquefaction, landslides, etc.) effects produced by seismic events;
- Understand the basics of Tectonic Geodesy;
- Understand the basics of Tectonic Geomorphology;
- Understand the basics of Paleoseismology;
- Understand the basics of probabilistic and deterministic seismic hazard calculations.

Content

Topics included in the course are: Rheology of the lithosphere, frictional properties of faults, the seismic cycle, earthquake location, geological effects of earthquakes, tectonic geodesy, tectonic geomorphology, paleoseismology, earthquake and fault interactions, probabilistic and deterministic seismic hazard.

In addition to theoretical information presented via lecture material, the practical exercises teach fundamental data analysis via MATLAB, and other software distributed during the course.

Teaching Methods / Language

Lecture period of 2 h/week with practical exercises of 2 h/week. Exercises are completed primarily in digital format (basic programming in Matlab). / English

Mode of assessment

Final written exam (2h)

Requirements for the award of credit points

Exercises must be completed (evaluated written reports) with a passing grade of 60% in order to access the final exam. Pass the final exam.

The module grade is based on the final exam grade.

Module applicability (in other study programs) M.Sc. Geosciences
Weight of the mark for the final score 5 %
Module coordinator and lecturer Prof. Dr. R. Harrington (coordinator), Dr. A. Verdecchia
Further information Students must have successfully completed a BSc in the earth sciences. The course consists of exercises as well as lecture, and exercises must be completed with a passing grade (60%) to access to the final exam on which the module grade will be based. The course will take place in English, therefore effective oral and written communication skills in English are required. *Literature:* Structural Geology, Haakon Fossen, Cambridge University Press, 2013. The Geology of Earthquakes, R. S. Yeats, K. Sieh and C. R. Allen, Oxford University Press, 1997. The Mechanics of Earthquakes and Faulting, C. H. Scholz, Cambridge University Press, 2012. Paleoseismology, J. P. McCalpin, Academic Press, 2nd Ed.

Selected Topics in Reservoir Characterization

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-17	7 CP	210 h	2 and 3	Yearly in SoSe and WiSe	2 semesters

Courses	Contact time	Self-study	Group size
a) Deep geothermal energy (SoSe)	3 h/week (45 h)	45 h	According to demand, practical exercise in c) are limited to ~15 students due to license availability
b) Well logging rudiments (WiSe)	2 h/week (30 h)	30 h	
c) Well logging II, analysis, interpretation (SoSe)	2 h/week (30 h)	30 h	

Learning outcomes

After successful completion of the module students

- appreciate the differences of hydrothermal and petrothermal energy provision
- learned to make basic calculations regarding the feasibility of geothermal energy provision (in general and site specific)
- understand the approach to geophysical surveys in boreholes
- are familiar with the basic data processing methods and correlation approaches applied to outcomes of different logging methods
- can operate the “industry standard”, wellcad

Content

a) Deep geothermal energy:

- Introduction to reservoirs (hydrocarbon, geothermal)
- Physical properties of reservoir fluids
- Hydraulic transport (Kozeny-Carman relation) and storage (linear poroelasticity I: isostatic stress states)
- Theory and practice of pumping tests (diffusion equation, scaling)
- Geothermics (add advection to diffusion)
- Aspects of waves in real media (wave equation, linear poroelasticity II: add deviatoric stresses)

b) Well logging rudiments

- Borehole completion
- Logging tools
- Basics of measurements

c) Well logging II, analysis, interpretation

- Introduction to wellcad
- Case studies

Teaching methods / Language

a) Lecture (2h) / Exercise (1h) / English
b) Lecture (1h) / Exercise (1h) / English
c) Lecture (1h) / Exercise (1h) / English

Mode of assessment Written exams (3h) + handed in assignments
Requirements for the award of credit points Passed final exam
Module applicability (in other study programs) -
Weight of the mark for the final score 5.83 %
Module coordinator and lecturer(s): Prof. J. Renner (coordinator)
Further information: Prerequisites: Basic knowledge in mathematics and physics, basic command of sheet-calculation software

Reservoir Engineering

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-CO-18	5 CP	150 h	3	Yearly (WiSe)	1 semester

Courses	Contact time	Self-study	Group size
Reservoir Engineering	3 h/week (45 h)	105 h	20

Learning outcomes

The students will learn the fundamentals of reservoir engineering. This broad range of knowledge will be taught with a special emphasis to geothermal and hydrocarbon exploration. After successful completion of the course, the students will be able:

- to understand microseismic monitoring
- to understand geophysical data from boreholes
- apply the fundamentals of reservoir engineering to estimate the risks of reservoir stimulations and to estimate reservoir permeability
- to transfer the fundamentals of reservoir engineering to scientific projects, e.g. to transfer the knowledge of several case histories to new sites and to plan a reservoir monitoring system

Content

- Fundamentals of reservoir engineering with the focus on geothermal applications
- Interpretation of downhole measurements
- Interpretation of spinner results
- Measuring reservoir permeability
- Conceptual models of geothermal fields
- Reservoir modelling
- Reservoir monitoring
- Reservoir stimulation
- Case Histories

Teaching Methods / Language

Lectures 2 h/week, Exercises 1 h/week. / English

Modes of assessment

final examination or oral talk

Requirements for the award of credit points

oral talk (60 min): Presentation with lecture (45 min) + Discussion (15 min)

Module applicability (in other study programs)

-

Weight of the mark for the final score

4.17 %

Module coordinator and lecturer(s)

Prof. Dr. Erik H. Saenger

Mechanical Modeling of Materials

Module No.	Credits	Workload	Semester	Frequency	Duration
SE-CO-19/ CE-P02	6 CP	180 h	1 or 3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group Size
Mechanical Modeling of Materials	4 h/week (60 h)	120 h	-

Learning outcomes

After successfully completing the module, the students

- should have a deep understanding of the theoretical basis of classical material models,
- should know how to derive constitutive equations from rheological models,
- should be able to implement a material model with a suitable algorithmic treatment in finite element software.

Content

Several advanced aspects regarding the modeling of the mechanical behavior of materials are addressed in this course. More precisely, the following topics will be covered:

- Basic concepts of continuum mechanics (introduction)
- Introduction to the rheology of materials
- Theoretical concepts of constitutive modeling
- Derivation of 1- and 3-dimensional models in the geometrically linearized setting for
  - Linear- and nonlinear elasticity
  - Damage
  - Visco-elasticity
  - Elasto-plasticity
- Aspects of parameter identification/adjustment
- Algorithmic implementation in the context of the finite element method and analysis of simple boundary and initial value problems

Teaching methods / Language

Lecture (2h / week), Exercises (2h / week) / English

Modes of assessment

Final written exam (90 min.)

Requirements for the award of credit points

Passed final written examination

Module applicability (in other study programs)

MSc. Computational Engineering

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr.-Ing. D. Balzani, assistants

Other information

-

Practical Training on Tunneling and Pipeline Construction Techniques

Modul-Nr. SE-O-1/ BI-W03	Credits 2 CP	Workload 60 h	Semester 2	Frequency Yearly (SoSe)	Duration 1 week
Courses Practical Training on Tunneling and Pipeline Construction Methods			Contact time 3 h/week (45 h)	Self-study 15 h	Group size 20

Learning outcomes

The module is designed to give students a basic understanding of the processes and techniques used in tunnel and pipeline construction that are common processing and building material testing methods. The students should learn to independently apply standards from these areas in a practice-oriented way and to develop a corresponding basic understanding. They should be acquired to critically examine the usual construction site conditions and the conditions of the techniques of tunnel and pipeline construction and foundation engineering.

Content

The Practical Training results in basic knowledge to selected and to monitor techniques of Tunneling, Pipeline Construction and Foundation Engineering:

- Sprayed Concrete (Shotcrete) in conventional tunneling
- Early strength testing of sprayed concrete
- Foam conditioning of soil in mechanized tunneling
- Sealing techniques: welding and testing of plastic geomembranes
- Chemical sealing and rehabilitation processes of leaks and concrete damage
- In-situ inspection of utility pipes
- Application of bentonite suspensions: standardised test methods

Teaching Methods / Language

Practical training in the laboratories, introductory lectures in English language

Modes of assessment

Practical Training / Seminar

Requirements for the award of credit points

Full time participation

Module applicability

M.Sc. Bauingenieurwesen

Weight of the mark for the final score

Module coordinator and lecturer(s)

Prof. Dr.-Ing. M. Thewes and assistants

Other information

Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-2	2 CP	60 h	3	Yearly (WiSe)	2 Days

Courses	Contact time	Self-study	Group size
Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	2 h/week (30 h)	30 h	20

Learning outcomes

In this module, practical knowledge about planning, construction and management of current projects in tunneling and subsurface construction practice is offered through selected lectures of guest experts of by participation in on the worldwide largest conferences for tunneling, the STUVA conference. This module is offered every two years (in the uneven years) in cooperation with STUVA e.V.

Content

- The module deals with the extended practical knowledge of tunnel design, construction, operation and safety. Typical topics include:
- Tunnel construction and tunnel operation
- International projects
- BIM, monitoring, digitalization
- Technical alteration to national and international standards
- Combined construction techniques
- Mechanized tunneling
- Developments in segmental lining (tubbing)
- Artificial freezing of ground
- Tunneling in swelling soil
- Safety in road tunnels
- Tunnel planning, tunnel refurbishment
- Start of operation and energy saving
- Traffic tunnel and geothermic applications in tunneling

Teaching Methods / Language

Lectures and accompanying Trade Fair, Excursion / English or German

Modes of assessment

Seminar

Requirements for the award of credit points

Full time participation

Module applicability (in other study programs)

-

Weight of the mark for the final score

1.7 %

Module coordinator and lecturer(s) Prof. Dr. M. Thewes
Other information

Technologies in Mechanised Tunneling

Modul-Nr. SE-O-3/ BI-W51	Credits 2 CP	Workload 60 h	Semester 2	Frequency Yearly (SoSe)	Duration 1 Semester
Courses Technologies in Mechanised Tunneling			Contact time 2 h/week (30 h)	Self-study 30 h	Group size 20

Learning outcomes

The performance-related design and the process engineering layout of a Tunnel Boring Machine (TBM) is an important interface on tunnel construction sites between the disciplines of civil engineering, geotechnics and mechanical engineering. The associated know-how enables the engineer to make a correct selection and dimensioning of individual components of the TBM and thus potentially determines the safety as well as the structural and economic success of a mechanised tunnel advance. It is therefore an indispensable tool for future Tunnel Engineers and Tunnel Project Managers in the field of mechanized tunneling.

The students are introduced to the different machine types and details, which vary depending on the specific geotechnical boundary conditions. They will learn how to dimension them, to which details special attention must be paid, which special solutions exist and in which direction research and development is currently moving in this area.

Recommended prior knowledge:

Bachelor-level knowledge of construction operations and construction process engineering, Bachelor-level knowledge of foundation engineering and soil mechanics

Content

The lecture deals with the extended basic knowledge of construction process engineering.

- Definition of different types of Tunnel Boring Machines and application ranges
- Detailed consideration of assembly units
- Shield (geometrical correlations, hydraulic forces of thrust jacks, load assumptions and evidence)
- Cutting wheel / cutterhead (excavation process, soil excavation, application ranges, wear and change of cutting tools)
- Cutterhead Drive (torque, sealing systems, lubrication and monitoring)
- Handling of segmental linings and of alternative tunnel lining systems
- Conveyor systems (hydraulic transport, screw conveyor, belt conveyor, monitoring of excavation volume)
- Backup installations and TBM Logistics
- Customized solutions (accessible Cutting Wheel, Variable Density Machines)
- Emerging Technologies (Robotics, large Diameter, Diagnosis and Maintenance)

Teaching Methods / Language

Lectures in English language

Language of the written examination in English or German by choice of the student (Klausur nach individueller Wahl in englischer oder deutscher Sprache)

Modes of assessment

Written module examination: 60 min

Requirements for the award of credit points

Passed module examination: (2 CP)
Module applicability ● M.Sc. Bauingenieurwesen ● M.Sc. Geosciences ● M.Sc. Mechanical Engineering (Maschinenbau)
Weight of the mark for the final score
Module coordinator and lecturer(s) Coordinator: Prof. Dr.-Ing. M. Thewes Lecturer: Dr.-Ing. Gerhard Wehrmeyer
Other information

Practical Soil Mechanics

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-4	3 CP	90 h	3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group size
Practical Soil Mechanics	2 h/week (30 h)	60 h	-

Learning outcomes

After successfully completing the modules, the students can

- develop strategies for the experimental investigation of practical geotechnical problems,
- analyze the results of the experimental investigation.

Content

Different measuring methods used in geotechnical laboratory and field tests are presented. The structure of a measuring chain is explained. Selected laboratory and field tests will be performed and analyzed by the students (including discussion / interpretation of the test results):

- Soil classification tests (water content, grain size distribution, Atterberg limits (plasticity properties), maximum and minimum density, particle density),
- Determination of shear strength parameters (direct shear test, triaxial test),
- Determination of compressibility of soils (oedometer test)

Teaching methods / Language

Laboratory practical work (block courses, dates will be announced at beginning of the course), Beamer presentations, one-to-one and small groups discussions / English.

Modes of assessment

Final written exam (90 minutes)

Exercises (protocols and analysis of performed tests; deadlines will be announced at the beginning of the course)

Requirements for the award of credit points

Passed final module examination: written examination

Exercises (protocols and analysis of performed tests)

Attendance during classes.

Module applicability (in other study programs)

-

Weight of the mark for the final score

2.5 %

Module coordinator and lecturer(s)

Prof. Dr.-Ing. habil. T. Wichtmann (coordinator)

Dr.-Ing. W. Baille

Other information

-

Environmental Geotechnics

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-5	3 CP	90 h	2	Yearly (SoSe)	1 Semester

Courses	Contact time	Self-study	Group size
Environmental Geotechnics	2 h/week (30 h)	60 h	---

Prerequisite for participation

Recommended previous knowledge: completed module in Computational Methods-1 (including lecture: Soil behaviour and simple constitutive models for soils).

Learning outcomes

After successfully completing the modules, the students are able to

- assess environmental pollutants with regard to their hazard potential and migration behaviour in soil and groundwater,
- develop strategies for the demobilization of pollutants and remediation of contaminated sites based on a comprehensive understanding of physical-chemical properties of pollutants and soils,
- identify the design principles of technical barrier systems used for landfills and low contaminated soils.

Content

Interdisciplinary knowledge necessary for the safe disposal of environmentally hazardous substances and the remediation of contaminated soil is presented from the perspective of soil, groundwater and soil-air interactions. Furthermore, technical barriers for the encapsulation of landfills will be addressed.

The lecture contents cover the following topics:

- Relevant environmental pollutants and their respective industrial sectors
- Advective and diffusive transport of pollutants in porous media
- Methods for soil remediation and containment of pollutants
- Barrier systems for landfills and low contaminated soils
- Individual project work dealing with specific questions of environmental geotechnics
- Future challenges of environmental geotechnics

Teaching methods / Language

Lectures (2 h/week) / English

Project work with oral presentations / English

Modes of assessment

Final written exam (90 minutes)

Presentation of project work (Deadline will be announced at the beginning of the semester)

Requirements for the award of credit points

Passed final module examination: written examination

Presentation of the project

Module applicability (in other study programs)

-
Weight of the mark for the final score 2.5 %
Module coordinator and lecturer(s) Prof. Dr.-Ing. habil. T. Wichtmann (coordinator) Dr.-Ing. W. Baille, Dr.-Ing. D. König
Other information

Variational Calculus and Tensor Analysis

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-6/ CE-WP01	5 CP	150 h	1 or 3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group size
Variational Calculus and Tensor Analysis	3 h/week (45 h)	105 h	-

Learning outcomes

After successfully completing the module, the students will be able

- to read, write and interpret tensor expression in index and abstract notation,
- to know and apply tools for formulating and manipulating the equations of continuum mechanics,
- to understand and solve variational problems in mechanics.

Content

Tensor Analysis:

- Vector and tensor notation and algebra
- Coordinates in Euclidean space, change of coordinates
- Differential calculus
- Scalar invariants and spectral analysis
- Isotropic functions

Variational Calculus:

- First variation
- Boundary conditions
- PDEs: Weak and strong form
- Constrained minimization problems, Lagrange multipliers
- Applications to continuum mechanics

Teaching methods / Language

Lecture (2h / week), Exercises (1h / week) / English

Modes of assessment

Final written examination (90 min)

Requirements for the award of credit points

Passed final written examination

Module applicability (in other programs)

M.Sc. Computational Engineering

Weight of the mark for the final score

4.17 %

Module coordinator and lecturer(s)

Prof. Dr. rer. nat. K. Hackl, Dr.-Ing. U. Hoppe

Other information

-

Digital Rock Physics

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-7	5 CP	150 h	2	Yearly (SoSe)	1 semester

Courses	Contact time	Self-study	Group size
Digital Rock Physics	3 SWS (45 h)	105 h	20

Learning outcomes

The students will learn the fundamentals of digital rock physics. This broad range of knowledge will be taught with a special emphasis on geothermal and hydrocarbon exploration.

After successful completion of this module, the students will:

- know the fundamentals of digital rock physics:
  - e.g. use of high-performance computer systems
  - e.g. understand the resolution limits of CT devices
- be able apply the fundamentals of digital rock physics:
  - to predict effective material properties
  - to improve digital images with respect to the real rock
- be able to apply the fundamentals of digital rock physics to scientific projects:
  - to upscale elastic properties to understand field scale observations
  - to interpret uncertainties in the digital rock physics workflow

Content

- The basics of the digital rock physics workflow will be introduced: CT-imaging, reconstruction, segmentation, calculation of physical properties.
- The basics of parallel computing on high-performance computer systems will be introduced.
- The basics of finite-different-schemes to solve the elastodynamic wave equation will be introduced.
- The parallel computer program "Heidimod" to model elastic waves in highly heterogeneous and anisotropic media will be introduced in detail and will be applied to problems in the field of digital rock physics

Teaching Methods

lectures (1h) and (computer) exercises (2h) / English

Modes of assessment

final report: Home Assignment (30h)

Requirements for the award of credit points

Pass the final report

Module applicability (in other programs)

M.Sc. Geosciences

Weight of the mark for the final score

4.17 %

Module coordinator and lecturer(s)

Prof. Dr. Erik H. Saenger

Other information

High-Performance Computing on Multicore Processors

Module-No. SE-O-8/ CE-WP25/ BI-WP56	Credits 6 CP	Workload 180 h	Semester 2	Frequency Yearly (SoSe)	Duration 1 Semester
Courses High-Performance Computing on Multicore Processors			Contact hours 4 SWS (60 h)	Self-Study 120 h	Group Size: No Restrictions

Learning outcomes

After successfully completing the module, the students

- are enabled to design and create programs for multicore processors,
- can critically evaluate multi-threaded programs and shared-memory access patterns,
- can assess the benefits and challenges of multicore programming techniques.

Content

The lecture addresses parallelization on multicore processors. Thread-based programming concepts and techniques (pthreads, C++11 threads, OpenMP, OpenCL) are introduced and best practices are highlighted using applications from scientific computing.

An overview of the relevant hardware aspects including multicore architectures and memory hierarchies is provided. An in-depth introduction to multi-threaded programming on multicore systems with special emphasis on shared-memory parallelization is given and parallelization patterns, thread management and memory access strategies are discussed.

In hands-on sessions, programming exercises are used to discuss and illustrate the presented content.

Teaching methods / Language

Lecture (2h / week), Exercises (2h / week) / English

Mode of assessment

Written examination (120 min., 100%)

Requirement for the award of credit points

Passed final module examination

Module applicability

M.Sc. Bauingenieurwesen
M.Sc. Angewandte Informatik
M.Sc. Computational Engineering

Weight of the mark for the final score

6%

Module coordinator and lecturer(s)

Prof. Dr. A. Vogel, Assistants

Other information

High-Performance Computing on Clusters					
Module Nr. SE-O-9/ BI-WP55	Credits 6 CP	Workload 180 h	Semester 3	Frequency Yearly (WiSe)	Duration 1 Semester
Courses High-Performance Computing on Clusters			Contact time 4 h/week (60 h)	Self-study 120 h	Group size -

Learning outcomes

After successfully completing the module the students

- are enabled to design and create programs for parallel computing clusters
- can critically evaluate distributed-memory systems and programming patterns
- can assess the mathematical properties of iterative solvers and their scalability

Content

The lecture deals with the parallelization on cluster computers. Distributed-memory programming concepts (MPI) are introduced and best-practice implementation is presented based on applications from scientific computing including the finite element method and machine learning.

Special attention is paid to scalable solvers for systems of equations on distributed-memory systems, focusing on iterative schemes such as simple splitting methods (Richardson, Jacobi, Gauß-Seidel, SOR), Krylov-methods (Gradient descent, CG, BiCGStab) and, in particular, the multigrid method. The mathematical foundations for iterative solvers are reviewed, suitable object-oriented interface structures are developed and an implementation of these solvers for modern parallel computer architectures is developed.

Numerical experiments and self-developed software implementations are used to discuss and illustrate the theoretical results.

Teaching Methods / Language

Lecture (2h / week), Computer lab (2h / week) / English

Modes of assessment

Written examination (120 min)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

M.Sc. Computational Engineering
M.Sc. Bauingenieurwesen
M.Sc. Angewandte Informatik

Weight of the mark for the final score

5 %

Module coordinator and lecturer(s)

Prof. Dr. A. Vogel, Assistants

Other information

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Modern Programming Concepts in Engineering

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-10/ CE-P04	6 CP	180 h	3	Yearly (WiSe)	1 Semester

Courses	Contact time	Self-study	Group size
Modern Programming concepts in Engineering	4 h/week (60 h)	80 h	-

Learning outcomes

After completion of the course the students:

- acquire fundamental skills for the development of software solutions for engineering problems.
- are capable of analysing a problem with respect to its structure such that adequate object-oriented software concepts, data structures and algorithms can be applied and implemented.

Content

Lectures and exercises cover the following topics:

- Principles of object-oriented modelling (Encapsulation, Polymorphism, Inheritance)
- Unified Modelling Language (UML)
- Basic programming constructs
- Fundamental data structures
- Implementation of efficient algorithms
- Vector and matrix operations
- Solving systems of linear equations
- Grid generation techniques
- Using software libraries
  View3d a visualization toolkit
  Packages for graphical user interfaces
- During the exercises, students practice object-oriented programming techniques in the computer lab on the basis of fundamental engineering problems.

Teaching Methods / Language

Data projector, blackboard, demo programs, computer lab / English

Modes of assessment

Module examination and Homework

Requirements for the award of credit points

Passed module examination 70%
Completed exercises 30%

Module applicability (in other study programs)

M.Sc. Computational Engineering

Weight of the mark for the final score

5 %
Module coordinator and lecturer(s) Prof. Dr. M. König
Other information -

Deutschkurs – A1

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-11	4 CP	120 h	1, 2, 3 and 4	each semester	1 Semester
Courses			Contact time	Self-study	Group size
Deutschkurs – A1			4 h/week (60 h)	60 h	-

Learning outcomes

After successfully completing the module the students,

- are able to employ at a basic level all four skills (speaking, listening, reading and writing) in familiar universal contexts or shared knowledge situations such as greeting, small talk, shopping, making appointments, eating out, orientation, biography, healthcare etc.

Content

The learning goals of this German language course fulfill the special requirements of foreign students majoring in a subject that uses English as a teaching language. The main focus of the course lies on basic level action oriented speaking, listening, reading and writing comprehension so that the students manage more easily to cope with everyday situations of their life in Germany. The classes consist of small groups, ensuring that students have ample opportunity to speak as well as having their individual needs attended to.All of our instructors are university graduates experienced in teaching DaF (Deutsch als Fremdsprache -German as a foreign language) and have been selected for their experience in working with students and their ability to make language learning an active and rewarding process. An optional intensive block course after the winter semester helps to activate and to intensify the newly acquired language skills

Teaching Methods / Language

Lecture (4h / week) / German

Modes of assessment

Written examination (120 min)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

-

Weight of the mark for the final score

3.33 %

Module coordinator and lecturer(s)

University Language Center (ZFA) of Ruhr-University Bochum

Other information

-

Deutschkurs – A2

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-O-12	4 CP	120 h	1, 2, 3 and 4	each semester	1 Semester
Courses			Contact time	Self-study	Group size
Deutschkurs – A2			4 h/week (60 h)	60 h	-

Learning outcomes

After successfully completing the module the students,

- are able to employ at an intermediate level all four skills (speaking, listening, reading and writing) in familiar universal contexts or shared knowledge situations such as greeting, small talk, shopping, making appointments, eating out, orientation, biography, healthcare etc.

Content

The learning goals of this German language course fulfill the special requirements of foreign students majoring in a subject that uses English as a teaching language. The main focus of the course lies on intermediate level action oriented speaking, listening, reading and writing comprehension so that the students manage more easily to cope with everyday situations of their life in Germany.

This course continues the learning goals of module Training of Competences 1.

Teaching Methods / Language

Lecture (4h / week) / German

Modes of assessment

Written examination (120 min)

Requirements for the award of credit points

Passing the written examination

Module applicability (in other study programs)

-

Weight of the mark for the final score

3.33 %

Module coordinator and lecturer(s)

University Language Center (ZFA) of Ruhr-University Bochum

Other information

Master Thesis

Module Nr.	Credits	Workload	Semester	Frequency	Duration
SE-MT	30 CP	900 h	4	-	1 semester

Courses	Contact time	Self-study	Group size
Master Thesis	-	900 h	-

Learning outcomes

With the completion of the master thesis

- the students acquire the ability to plan, organize, develop, operate and present complex problems in Subsurface Engineering.
- qualifies students to work independently in the field of Subsurface Engineering under the supervision of an advisor.
- the associated presentation serves to promote the students' ability to deal with subject-specific problems and to present them in an appropriate and comprehensible manner.

Further, it serves to prove whether the students have acquired the profound specialised knowledge, which is required to take the step from their studies to professional life, whether they have developed the ability to deal with problems from their in-depth subject by applying scientific methods, and to apply their scientific knowledge.

Content

The master thesis can either be a theoretical or a practical work. The topic is determined by the respective supervisor. The results should both be visualized and illustrated in writing in a detailed manner. This particularly includes a summary, an outline and a list of the references used within a specific thesis.

Teaching Methods / Language

Independent work in seminar rooms and computer labs; testing plants, where applicable.

The topic of a Master Thesis is formulated by a lecturer of the course. The student conducts research independently and presents the results in the form of a final written report and an oral presentation (upon agreement with the respective lecturer). / English

Modes of assessment

Review of the Master Thesis Report (900 h) and Oral Presentation (30 min)

Requirements for the award of credit points

Successful evaluation (grade not greater than 4) of Master Thesis and Oral Presentation

Module applicability (in other study programs)

-

Weight of the mark for the final score

25 %

Module coordinator and lecturer(s)

Professors, lecturers and assistants

Other information

In order to be admitted to the master's thesis, modules amounting to 70 credit points must be successfully completed.