RUHR-UNIVERSITÄT BOCHUM

RUB

FAKULTÄT FÜR
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INGENIEURWISSENSCHAFTEN

Directory of Modules

M.Sc. Subsurface Engineering

- Module Descriptions PO 2024
- Curriculum

SuSe 2025 Valid: 03.04.2025

Modifications:

Module No.	Module name	Modification
SE-C-4	Groundwater Hydraulics	Change of module coordinator
SE-CO-3	Numerical Simulation in Geotechnics and Tunneling	Changes to courses and lecturers from SuSe 25
SE-CO-4	Design of Tunnel Linings	no offer
SE-CO-6	Design of Geotechnical Structures – Shallow and Deep Foundations	Change of lecturers Additional homework with bonus points for exam
SE-CO-7	Problematic Soils and Soil Dynamics	From WiSe 25/26 New Module name: „Soil Dynamics and Geotechnical Earthquake Engineering" The lesson "Problematic Soils" becomes an independent optional module SE-O-18
SE-CO-9	Drilling Engineering	no offer
SE-CO-10	Constitutive Models for Geomaterials	New Module name: "Advanced Constitutive Models for Geomaterials" Changes to courses and lecturers from SuSe 25
SE-CO-14	Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement	Change of lecturers Additional homework with bonus points for exam
SE-CO-15	Hydrogeological Methods	Change of module coordinator
SE-CO-20	Inelastic Finite Element Methods for Structures	New before „FEM for Nonlinear Analyses of Inelastic Materials and Structures" Course from SE-CO10
SE-CO-21	Optimization Aided Design – Reinforced Concrete	New
SE-CO-22	Geothermal Drilling Engineering and Subsurface Technologies	New Substitute for „Drilling Engineering" (SE-CO-9)
SE-CO-23	Nonlinear Finite Element Methods for Structures	New
SE-CO-24	Rock Mass Mechanics and Rock Engineering	New
SE-O-10	Scientific Programming	Editorial changes
SE-O-17	Uncertainty Quantification in FE Analyses with Surrogate Modeling	New
SE-O-18	Problematic Soils	New from WiSe 25/26

Modules

Index by areas of study

1) M.Sc. SSE Compulsory Courses, ECTS: 33

Weight of the mark for the final score

FAK = 1

DIV = 120

2) M.Sc. SSE Compulsory Optional Courses, ECTS: 42

Weight of the mark for the final score

FAK = 1

DIV = 120

3) M.SC. SSE Optional Courses, ECTS: 15

Weight of the mark for the final score

FAK = 1

DIV = 120

Advanced Constitutive Models for Geomaterials

Advanced Constitutive Models for Geomaterials

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP44 /SE-CO-10/CE-W06	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Advanced Constitutive Models for Geomaterials	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Christoph Schmüdderich, Dr.-Ing. Merita Tafili

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students are able to

- model the material behavior of soil using suitable, advanced constitutive models,
- select suitable numerical methods and constitutive models for practical questions and assess limitations according to the selected approaches,
- calibrate the parameters of the advanced constitutive models and evaluate the model performance based on single integration point simulations

Contents

a)

The course deals with the introduction of advanced soil mechanical behavior and appropriate constitutive models allowing to capture advanced effects. Model formulations and parameter calibration for different soil model families are taught. In addition, an introduction to single integration point finite element simulations with Incremental Driver (ID) is provided and simulations of different laboratory tests are conducted with ID using different elasto-plastic and hypoplastic constitutive models.

Advanced soil mechanics:

- Critical state soil mechanics
- Crushable soil mechanics
- Unsaturated soil mechanics
- Soil memory effects and their modelling
- Clay structure and small-strain stiffness anisotropy
- Influence of temperature on soil behavior and its modelling

Sophisticated constitutive models for soils:

- Modified Cam-Clay model
- Sanisand
- Hypoplasticity with Intergranular Strain
- Clay Hypoplasticity
- Hypoplasticity for crushable soils
- Visco-hypoplasticity

- Barcelona Basic Model

Educational form / Language

a) Lecture (4 WLH) / English

Examination methods

• Written exam 'Advanced Constitutive Models for Geomaterials' (180 min., Part of modul grade 100 %)

• Optional homework to achieve bonus points for the written exam

Requirements for the award of credit points

- Passed final written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Applied Geophysics

Applied Geophysics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-12	10 CP	300 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Reservoir Geophysics b) Rock Physics	a) 3 WLH (45 h) b) 3 WLH (45 h)	a) 120 h b) 90 h	a) each summer b) each summer

Module coordinator and lecturer(s)

Prof. Dr. Jörg Renner

a) Prof. Dr. Jörg Renner

b) Prof. Dr. Jörg Renner

Admission requirements

Recommended previous knowledge:

Sound mathematical skills (vector calculus, differential- and integral calculus)

Learning outcome, core skills

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

Contents

a)

- 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)

- 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)

Educational form / Language
a) Lecture (3 WLH) / English
b) Lecture (3 WLH) / English / German

Examination methods
• Written exam 'Applied Geophysics' (180 min., Part of modul grade 100 %, + report on lab experiments)

Requirements for the award of credit points
Passed module exam

Module applicability
- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 10 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information
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”

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

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

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-2	2 CP	60 h	3. Sem.	1 Semester[s]	20

Courses	Contact hours	Self-study	Frequency
a) Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	a) 2 WLH (30 h)	a) 30 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes

Admission requirements

Learning outcome, core skills

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.

Contents

a)

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

Educational form / Language

a) Internship / English

Examination methods

• Internship 'Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice' (60 h., ungraded, Full time participation)

Requirements for the award of credit points

- Full time participation

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 0, ungraded

Further Information

Conventional and Mechanised Tunneling: Design – Engineering – Technologies

Conventional and Mechanised Tunneling: Design – Engineering – Technologies

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP11/SE-CO-2	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Design, engineering and techno-logies in Tunneling and Pipeline Construction	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. Britta Schößer

Admission requirements

Recommended previous knowledge:

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

Learning outcome, core skills

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.

Contents

a)

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

a) 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

b) 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

Educational form / Language

a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods

• Written exam 'Design, engineering and technologies in Tunneling and Pipeline Construction' (120 min., Part of modul grade 100 %, optionally English or German)
• Term paper 'Design, engineering and technologies in Tunneling and Pipeline Construction - Homework' (30 h., Part of modul grade 0 %, optionally English or German)

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. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

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

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

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-14	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Merita Tafili, Dr.-Ing. Nazanin Irani, Prof. Dr.-Ing. Torsten Wichtmann

Admission requirements

Learning outcome, core skills

After successfully completing the module, 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

Contents

a)

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

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement' (180 min., Part of modul grade 100 %)

• Homework with GGU application to geotechnical problems, giving bonus points for the exam.

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

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Further Information

Tutorials include computer exercises with program GGU

Design of Geotechnical Structures – Shallow and Deep Foundations

Design of Geotechnical Structures – Shallow and Deep Foundations

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-6	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Design of Geotechnical Structures – Shallow and Deep Foundations	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Nazanin Irani, Prof. Dr.-Ing. Torsten Wichtmann

Admission requirements

Learning outcome, core skills

After successfully completing the module, 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

Contents

a)

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

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Design of Geotechnical Structures – Shallow and Deep Foundations' (180 min., Part of modul grade 100 %)

• Homework with GGU application to geotechnical problems, giving bonus points for the exam.

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

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DIV: The values can be taken from the table of contents.

Further Information

Digital Rock Physics
Digital Rock Physics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-7	5 CP	150 h	2. Sem.	1 Semester[s]	20

Courses	Contact hours	Self-study	Frequency
a) Digital Rock Physics	a) 3 WLH (45 h)	a) 105 h	a) each summer

Module coordinator and lecturer(s)
Prof. Dr. Erik Saenger
a) Prof. Dr. Erik Saenger

Admission requirements

Learning outcome, core skills
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

Contents
a)
- 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

Educational form / Language
a) Tutorial (2 WLH) / Lecture (1 WLH) / English / German

Examination methods
• Term paper 'Digital Rock Physics' (30 h., Part of modul grade 100 %)

Requirements for the award of credit points
final report on computer exercises

Module applicability
- M.Sc. Subsurface Engineering

• M.Sc. Geosciences
Weight of the mark for the final score Percentage of total grade [%] = 5 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Environmental Geotechnics

Environmental Geotechnics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-5	3 CP	90 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Environmental Geotechnics	a) 2 WLH (30 h)	a) 60 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Wiebke Baille, Dr.-Ing. D. König

Admission requirements

Recommended previous knowledge:
completed module Soil and rock behaviour (including lecture: Soil behaviour and simple constitutive models for soils).

Learning outcome, core skills

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 soils,
- identify the design principles of technical barrier systems used for landfills and low contaminated soils.

Contents

a)
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

Educational form / Language

a) Project / Lecture (2 WLH) / English

Examination methods

• Term paper 'Environmental Geotechnics - Project work' (0 h., ungraded)
• Written exam 'Environmental Geotechnics' (90 min., Part of modul grade 100 %)

Requirements for the award of credit points

Passed final module examination: written examination
Presentation of the project

Module applicability
• M.Sc. Subsurface Engineering
Weight of the mark for the final score
Percentage of total grade [%] = 3 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Finite Element Methods in Linear Structural Mechanics

Finite Element Methods in Linear Structural Mechanics

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-P05/SE-C-2/FEM-I	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Finite Element Methods in Linear Structural Mechanics	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)
Prof. Dr. Roger A. Sauer
a) Prof. Dr. Roger A. Sauer

Admission requirements
Recommended previous knowledge:
Basics in Mathematics, Mechanics and Structural Analysis (Bachelor level)

Learning outcome, core skills
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 discretized 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.

Contents
a)
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, two-dimensional elements, beams, three-dimensional volume elements for application in statics and dynamics,
- 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.

Educational form / Language
a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'Finite Element Methods in Linear Structural Mechanics' (120 min., Part of modul grade 100 %)

• Optional tasks to be solved at home and announced during the course, to get the bonus points for the exam.

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

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

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

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP10/SE-CO-1	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Design, engineering and technologies in Foundation Engineering and Utility Pipe Construction	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. Britta Schößer

Admission requirements

Recommended previous knowledge:

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

Learning outcome, core skills

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.

Contents

a)

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

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Design, engineering and technologies in Foundation Engineering and Utility Pipe Construction' (120 min., Part of modul grade 100 %, optionally English or German)
• Term paper 'Process Technology and Construction Management - Homework' (30 h., Part of modul grade 0 %, optionally English or German)

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. Civil Engineering
- M.Sc. Environmental Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Geology of the Earth´s Crust Geology of the Earth´s Crust					
Module number SE-C-3	**Credits** 6 CP	**Workload** 180 h	**Semester[s]** 1. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Special methods in structural geology b) Structural geology field camp			**Contact hours** b) 2 WLH (30 h)	**Self-study** a) 50 h b) 60 h	**Frequency** a) each winter b) each winter
Module coordinator and lecturer(s) Prof. Dr. Wolfgang Friederich a) Prof. Dr. Christophe Pascal b) Prof. Dr. Wolfgang Friederich					
Admission requirements					
Learning outcome, core skills After successful completion of the course the students are • familiar with the main characteristics of the different types of sedimentary basins, • know the mechanisms driving basin subsidence, • able to elaborate a coherent geological model from field data.					
Contents a) 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) 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					
Educational form / Language a) Block seminar / English b) Internship / English					
Examination methods • Written exam 'Geology of the Earth´s Crust' (120 min., Part of modul grade 100 %) • Term paper 'Geology of the Earth´s Crust - Essay' (20 h., Part of modul grade 0 %)					
Requirements for the award of credit points Pass the examinations and compulsory attendance in the field camp					
Module applicability • M.Sc. Subsurface Engineering					
Weight of the mark for the final score					

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Literature: Davis and Reynolds, 1996. Structural Geology of Rocks and Regions, John Wiley & Sons. Twiss and Moores, 1992 (2007). Structural Geology, Freeman

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<tr><td colspan="6">Geothermal Drilling Engineering and Subsurface Technologies
Geothermal Drilling Engineering and Subsurface Technologies</td></tr>
<tr><td>Module number
139080</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Semester[s]
3. Sem.</td><td>Duration
1 Semester[s]</td><td>Group size
no limitation</td></tr>
<tr><td colspan="3">Courses
a) Geothermal Drilling Engineering and Subsurface Technologies</td><td>Contact hours
a) 4 WLH (60 h)</td><td>Self-study
a) 90 h</td><td>Frequency
a) each winter</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
Prof. Dr. rer. nat. Rolf Bracke
a) Prof. Dr. rer. nat. Rolf Bracke</td></tr>
<tr><td colspan="6">Admission requirements
Recommended previous knowledge:
English language skills: "Test of English as a Foreign Language" (TOEFL): the test result in the internet version (iBT) should be at least 80 points, or "International English Language Testing System" (IELTS): minimum overall score "6" ("academic").</td></tr>
<tr><td colspan="6">Learning outcome, core skills
The course provides an introduction to the principles of resource geology, deep drilling technologies, reservoir production and subsurface technologies. Students will learn how to evaluate a resource and propose suitable utilization concepts, plan a drilling project including well design, and select tools and equipment for reservoir production and monitoring. The lecture is accompanied by an exercise with practical examples and two excursions

Students will be able to:
• explain resource geology methods and parameters,
• define conceptual reservoir models
• tell principles of resource management
• compute thermal power outputs,
• explain the main methods and parameters of drilling technology
• develop drilling and production concepts,
• calculate casing designs,
• describe potential drilling problems,
• define the composition of the cost structure of a drilling project
• describe reservoir test principles,
• calculate production parameters</td></tr>
<tr><td colspan="6">Contents
a)
• Introduction to subsurface technologies and applications
• Geothermal resource characterization: temperature, pressure, and, fluid flow in the geological subsurface + 1 excursion
• Geological and mininig law act</td></tr>
</table>

- Deep drilling basics (drilling rig, strings, and, bits) + 1 excursion
- Drilling techniques and processes (conventional and advanced drilling technologies);
- Casing design and calculation;
- Drilling fluid/mud system;
- Cementation and well control;
- Health safety and environment;
- Economics and Reporting;
- Well integrity and Logging technologies
- Monitoring techniques
- Reservoir production technologies
- Deep geothermal heat exchangers

Educational form / Language

a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods

• Written exam 'Geothermal Drilling Engineering and Subsurface Technologies' (90 min., Part of modul grade 100 %)

• Semester-accompanying exercises

Requirements for the award of credit points

- Passed final module examination: written exam
- Passed semester-accompanying exercises

Module applicability

MSc. Mechanical Engineering

MSc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 5 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Geothermal Energy Systems Geothermal Energy Systems					
Module number SE-CO-13	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 1. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Geothermal Energy Systems			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 90 h	**Frequency** a) each summer

Module coordinator and lecturer(s)
Prof. Dr. rer. nat. Rolf Bracke
a) Prof. Dr. rer. nat. Rolf Bracke

Admission requirements

Learning outcome, core skills

- After the course the students know how geothermal heat pumps can be used for heating and cooling. Students are able to dimension borehole heat exchangers (BHE) for small shallow geothermal systems (≤30 kW). They are also able to plan large systems which require a design by simulations. They can decide which design techniques and software is required for a specific site and project. The students know how a Thermal Response Test enhances the quality of the planning process and are able to interpret the measured data of the test.
- The students know the fundamentals of 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.

Contents

a)

- 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

Educational form / Language
a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods

• Written exam 'Geothermal Energy Systems' (60 min., Part of modul grade 100 %, 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 examination

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geoscience

Weight of the mark for the final score

Percentage of total grade [%] = 5 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Ground Exploration Methods

Ground Exploration Methods

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-11	10 CP	300 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Geophysical Inverse Problems b) Seismic and electromagnetic field methods	a) 3 WLH (45 h) b) 3 WLH (45 h)	a) 105 h b) 105 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr. Wolfgang Friederich
a) Prof. Dr. Wolfgang Friederich
b) Prof. Dr. Wolfgang Friederich

Admission requirements

Learning outcome, core skills

- 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.

Contents

a)
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)
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

Educational form / Language

a) Lecture (3 WLH) / English
b) Lecture (3 WLH) / English / German

Examination methods

• Written exam 'Ground Exploration Methods' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

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

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 10 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further 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

<table>
<tr><td colspan="6">Groundwater Hydraulics
Groundwater Hydraulics</td></tr>
<tr><td>Module number
SE-C-4</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Semester[s]
1. Sem.</td><td>Duration
1 Semester[s]</td><td>Group size
no limitation</td></tr>
<tr><td colspan="3">Courses
a) Groundwater Hydraulics</td><td>Contact hours
a) 4 WLH (60 h)</td><td>Self-study
a) 90 h</td><td>Frequency
a) each winter</td></tr>
</table>

Module coordinator and lecturer(s)
PD Dr. Thomas Heinze
a) PD Dr. Thomas Heinze

Admission requirements

Learning outcome, core skills
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.

Contents
a)

- 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

Educational form / Language
a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'Groundwater Hydraulics' (60 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passing the written examination

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score
Percentage of total grade [%] = 5 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

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

High-Performance Computing on Clusters

High-Performance Computing on Clusters

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP55/SE-O-9	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) High-Performance Computing on Clusters	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)
Prof. Dr. Andreas Vogel
a) Prof. Dr. Andreas Vogel

Admission requirements

Learning outcome, core skills
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

Contents
a)
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.

Educational form / Language
a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'High-Performance Computing on Clusters' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points
Passed written examination

Module applicability

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

Weight of the mark for the final score Percentage of total grade [%] = 6 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information Computerlab Exercises

High-Performance Computing on Multicore Processors

High-Performance Computing on Multicore Processors

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP56/CE-WP25/SE-O-8	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) High-Performance Computing on Multicore Processors	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr. Andreas Vogel

a) Prof. Dr. Andreas Vogel

Admission requirements

Learning outcome, core skills

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.

Contents

a)

The lecture addresses parallelization on multicore processors. Thread-based programming concepts and techniques, including pthreads, C++11 threads, OpenMP and SYCL, 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.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'High-Performance Computing on Multicore Processors' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Civil Engineering
- M.Sc. Applied Computer Science
- M.Sc. Subsurface Engineering

Weight of the mark for the final score Percentage of total grade [%] = 6 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Hydrogeological Methods

Hydrogeological Methods

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-15	8 CP	240 h	2. Sem.	1 week Semester[s]	40

Courses	Contact hours	Self-study	Frequency
a) Tracers in Hydrogeology b) Hydrogeological Field Camp	a) 3 WLH (45 h) b) 3 WLH (45 h)	a) 75 h b) 75 h	a) each summer b) each summer

Module coordinator and lecturer(s)

PD Dr. Thomas Heinze

a) PD Dr. Thomas Heinze

b) Prof. Dr. Stefan Wohnlich

Admission requirements

Recommended previous knowledge:

Passing of the examination for "Groundwater Hydraulics"

Learning outcome, core skills

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.

Contents

a)

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)

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.

Educational form / Language

a) Block seminar / English / German

b) Tutorial (2 WLH) / Lecture (1 WLH) / German

Examination methods

• Term paper 'Hydrogeological Methods' (10 h., Part of modul grade 100 %)

Requirements for the award of credit points

- Pass Written report (part of final mark 100 %) and active participation on the field exercises

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 8 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

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

<table>
<tr><td colspan="6">Inelastic Finite Element Methods for Structures
Inelastic Finite Element Methods for Structures</td></tr>
<tr><td>Module number
BI-WP59/CE-WP06/SE-CO-20</td><td>Credits
6 CP</td><td>Workload
180 h</td><td>Semester[s]
3. Sem.</td><td>Duration
1 Semester[s]</td><td>Group size
no limitation</td></tr>
<tr><td colspan="3">Courses
a) Inelastic Finite Element Methods for Structures</td><td>Contact hours
a) 4 WLH (60 h)</td><td>Self-study
a) 120 h</td><td>Frequency
a) each winter</td></tr>
</table>

Module coordinator and lecturer(s)

Prof. Dr. Roger A. Sauer
a) Dr.-Ing. Vladislav Gudzulic, Prof. Dr. Roger A. Sauer

Admission requirements

Recommended previous knowledge:
Basic knowledge of tensor analysis, continuum mechanics and linear Finite Element Methods.

Previous participation in the course Nonlinear Finite Element Method for Structures is recommended and participation Object-Oriented Modeling and Implementation of Structural Analysis Software is advantageous.

Learning outcome, core skills

After successfully completing the module the students will

- understand the fundamentals of dissipative processes in the context of modeling inelasticity in quasi-brittle materials, using concrete as the main example.
- learn the computational approaches for modeling elastoplastic, damage and friction behavior.
- be familiar with the concept of strain localization and localized failure, including their mathematical and numerical implications, as well as strategies to address them.
- gain practical experience with implementation and algorithmic treatment of inelasticity in the context of incremental-iterative nonlinear structural analysis.
- develop skills to select appropriate numerical methods and material models, including multi-scale approaches, for practical problems and critically assess their limitations.
- be able to perform incremental analyses of progressive structural failure, critically evaluate the results, and assess the key design parameters such as load and deformation at the onset of inelasticity and structural redundancy (plastic reserve/residual strength).

Contents

a)
The course is concerned with inelastic material models including their algorithmic formulation and implementation in the framework of nonlinear finite element method. Strain localization and localized failure will be explored in detail, focusing on their mathematical and numerical implications, as well as the strategies to address them. Further, the course covers the fundamental theory and implementation aspects of frictional contact. Special attention will be given to efficient algorithms for physically nonlinear structural analyses, including elastoplastic and damage models for quasi-brittle materials, as well as friction algorithms. While concrete serves as a primary example, these modeling approaches are equally applicable to other materials such as rocks, fiber composites, sea ice, bone, stiff soils, and wood. The course includes

coding exercises and a final assignment, where students implement a selected inelastic model into a finite element program and apply it to nonlinear structural analysis.
Educational form / Language a) Lecture with tutorial / English
Examination methods • Term paper 'Inelastic Finite Element Methods for Structures' (90 h., Part of modul grade 100 %, Project work (implementation of an inelastic model into FE code) with final student presentation / bonus points for homework assignments)
Requirements for the award of credit points • Passed final module examination
Module applicability • M.Sc. Civil Engineering • M.Sc. Computational Engieering • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 6 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Introduction to advanced numerical methods for particulate media

Introduction to advanced numerical methods for particulate media

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-16	3 CP	90 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Introduction to advanced numerical methods for particulate media	a) 2 WLH (30 h)	a) 60 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Mohammad Salimi

Admission requirements

Recommended previous knowledge:
completed module in Numerical Simulation in Geotechnics

Learning outcome, core skills

After successfully completing the module, students will be able to:

- Understand DEM fundamentals and applications
- Implement particle and boundary modeling techniques
- Apply force models and contact detection schemes
- Utilize time integration methods
- Comprehend DEM's strengths and limitations
- Develop basic DEM code for triaxial test simulations
- Apply DEM to real-world geotechnical engineering problems

Contents

a)

This course introduces the Discrete Element Method (DEM), a powerful computational technique for analyzing particulate materials in subsurface engineering. The lecture contents cover the following topics:

1. Foundations of Computational Methods
2. Theoretical Fundamentals
3. Computational Aspects
4. Soft Sphere Approach in Detail
5. Damping Mechanisms
6. Stress Analysis in DEM
7. Strain and Measurable Quantities
8. Forces and Torques
9. Advanced Contact Models
10. Non-Spherical Particle Shapes
11. Boundary Conditions
12. Model Validation and Calibration
13. Servo Mechanisms and Scaling
14. Advanced Forces and Torques
15. DEM in Practice

The course emphasizes physical understanding over programming details, using easy-to-follow slides and practical examples. This course provides a foundation for those interested in pursuing advanced topics in computational methods for particulate media.

Educational form / Language

a) Lecture (2 WLH) / English

Examination methods

• Term paper 'Introduction to advanced numerical methods for particulate media' (60 h., Part of modul grade 100 %, deadline will be announced at the beginning of the semester)

Requirements for the award of credit points

- Successful completion and presentation of the final project

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering
- M.Sc. Computational Engineering

The skills and knowledge gained in this course are transferable to various fields dealing with particulate media and computational modeling.

Weight of the mark for the final score

Percentage of total grade [%] = 3 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Master Thesis Master Thesis					
Module number SE-MT	**Credits** 30 CP	**Workload** 900 h	**Semester[s]** Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Master Thesis			**Contact hours**	**Self-study** a) 900 h	**Frequency** a) keine Angabe

Module coordinator and lecturer(s)
All professors of the study program
a) Professors, Lecturers and Assistants

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

Learning outcome, core skills
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.

Contents
a)
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.

Educational form / Language
a) Final thesis / English / German

Examination methods
• Final thesis 'Master Thesis' (900 h., Part of modul grade 100 %, Review of the Master Thesis Report and Oral Presentation (30 min))

Requirements for the award of credit points

- Successful evaluation (grade greater than 50%) of Master Thesis and Oral Presentation

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 30 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information 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).

Mathematical Aspects of Differential Equations and Numerical Mathematics

Mathematical Aspects of Differential Equations and Numerical Mathematics

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-P01/SE-C-1/MADENM	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Mathematical Aspects of Differential Equations and Numerical Mathematics	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Barney Bramham

a) Prof. Dr. Barney Bramham

Admission requirements

Recommended previous knowledge:

No prior knowledge or preliminary modules. Basic calculus and experience with matrices.

Learning outcome, core skills

The course will focus on the mathematical formulation of differential equations with applications to elastic theory and fluid mechanics. It gives an introduction to geometric linear algebra with emphasis on function spaces, coupled with the elementary aspects of partial differential equations. The students should learn to understand the mathematics side of the Finite Element Method (FEM) for elliptic PDE
in low dimensions, appropriate Sobolev geometries, the FEM for Dirichlet and Neumann problems. For that reason, the basic principles in methods of error estimation are described to realize the understanding of fast and efficient solvers for the resulting matrix equations. As overall learning goal, the students should attain familiarity with modern methods and concepts for the numerical solution
of complicated mathematical problems.

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.

Contents

a)

Linear algebra: 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.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Mathematical Aspects of Differential Equations and Numerical Mathematics' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Remark: Due to the mixed background of the students, the exercise sessions often amount to additional lectures.

Mechanical Modeling of Materials

Mechanical Modeling of Materials

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-P02/SE-CO-19/MMoM	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Mechanical Modelling of Materials	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Daniel Balzani

a) Prof. Dr.-Ing. Daniel Balzani

Admission requirements

Recommended previous knowledge:

Basic knowledge in Mathematics and Mechanics (Statics, Dynamics and Strength of Materials)

Learning outcome, core skills

The objective of this course is to present advanced issues of mechanics and the continuum-based modelling of materials starting with basic rheological models. The concepts introduced will be applied to numerous classes of materials. Basic constitutive formulations will be discussed numerically.

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.

Contents

a)

Several advanced issues of the mechanical behaviour 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 modelling
- 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

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'Mechanical Modeling of Materials' (90 min., Part of modul grade 100 %)
Requirements for the award of credit points • Passed final module examination
Module applicability • M.Sc. Computational Engineering • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 6 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Nonlinear Finite Element Methods for Structures

Nonlinear Finite Element Methods for Structures

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-WP05/CE-WP04/SE-CO-23	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Nonlinear Finite Element Methods for Structures	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)
Prof. Dr. Roger A. Sauer
a) Assistants, Prof. Dr. Roger A. Sauer

Admission requirements
Recommended previous knowledge:
Finite Element Methods in Linear Structural Mechanics (CE-P05/SE-C-2/FEM-I), Basic knowledge in Structural Mechanics

Learning outcome, core skills
After successfully completing the module, the students

- understand the origins and implications of nonlinearities in structural mechanics
- are able to formulate and solve nonlinear engineering problems with the finite element method accounting for geometrical and material nonlinearities
- can perform structural analyses, where the linear (1st order) theory is not valid (e.g. cables, membrane structures, load bearing and stability analyses beyond limit loads), and they can assess the results.

Contents
a)
The main topics of the course are:

- formulation and finite element discretization of the basic equations for nonlinear materials and geometrically nonlinear analysis in structural mechanics
- development of algorithms for the solution of the underlying nonlinear material and structural equations
- application to analyze the structural behavior considering material nonlinearity and large deformations
- nonlinear stability analysis of structures

Educational form / Language
a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'Nonlinear Finite Element Methods for Structures' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points
- Passed final module examination

Module applicability
- M.Sc. Civil Engineering

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Numerical Methods and Stochastics

Numerical Methods and Stochastics

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-WP08/SE-CO-8/NMS	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Numerical Methods and Stochastics	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr. Martin Kronbichler

a) Assistants, Prof. Dr. Martin Kronbichler

Admission requirements

Recommended previous knowledge:

Basic knowledge of: partial differential equations, numerical methods and stochastics

Learning outcome, core skills

Students should become familiar with modern numerical and stochastic methods

After successfully completing the module, the students

- should be able to formulate and analyze data from a probabilistic perspective,
- should understand the theoretical aspects of FEM and FVM methods,
- should be familiar with modern iterative solvers for large systems of linear equations and their necessity for numerical PDE solving,
- should be familiar with standard methods for solving optimization problems.

Contents

a)

Numerical Methods:

- Boundary value problems for ordinary differential equations (shooting, difference and finite element methods)
- Finite element methods (brief retrospection as a basis for further material)
- Efficient solvers (preconditioned conjugate gradient and multigrid algorithms)
- Finite volume methods (systems in divergence form, discretization, relation to finite element methods)
- Nonlinear optimization (gradient-type methods, derivative-free methods, simulated annealing)

Stochastics:

- Fundamental concepts of probability and statistics, such as random variables, univariate distributions & densities, descriptive statistics, parameter estimation, & law of large no
- Regression, such as univariate and multivariate linear regression, least-squares estimation, data transformations, qualitative predictors, and regularization
- Exploratory data analysis, such as qq-plots and summary statistics

Educational form / Language

a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods • Written exam 'Numerical Methods and Stochastics' (180 min., Part of modul grade 100 %)
Requirements for the award of credit points • Passed final module examination
Module applicability • M.Sc. Computational Engineering • M.Sc. Civil Engineering • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 6 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Numerical Simulation in Geotechnics and Tunneling Numerical Simulation in Geotechnics and Tunneling					
Module number BI-WP24/CE-WP09/SE-CO-3	**Credits** 6 CP	**Workload** 180 h	**Semester[s]** 2. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Numerical Simulation in Geotechnics and Tunneling			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 60 h	**Frequency** a) each summer

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Christoph Schmüdderich

Admission requirements

Learning outcome, core skills
After successfully completing the module, the students are able to

- implement numerical models of complex boundary value problems in geotechnical engineering and tunneling, 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 or tunneling problems with focus on the interactions between the soil and structures.

Contents
a)
The course deals with the numerical modeling of various geotechnical structures and tunnels:

- Overall insight to the numerical simulation of geotechnical problems by using the finite element method and concise review of simple constitutive models
- Introduction to Hardening Soil (HS) and Hardening Soil Small Strain (HSS) model and calibration of constitutive parameters of the HS and HSS model
- Simulation of lab tests and optimization of constitutive parameters
- Details for proper simulation in geotechnics by addressing constructional details, optimum discretization, boundary and initial conditions
- Fundamentals of contact elements and their applications in geotechnical modeling
- Considering water pressures in numerical simulations: soil-water interactions in drained, undrained, consolidation, and fully coupled hydromechanical analyses
- Creation of models, execution of calculations and analysis of results for various geotechnical boundary value problems: shallow foundations, retaining walls, excavation, embankments, consolidation, slope failure, tunneling
- 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
- Introduction to FE simulations with Plaxis 2D and numgeo
- Introduction to Finite Element Limit Analysis (FELA) and the FE software OptumG2
- Comparison of Plaxis2D, numgeo and OptumG2 for different boundary value problems
- Brief overview of other numerical methods (e.g. DEM, MPM, boundary element method)

Educational form / Language a) Lecture (4 WLH) / English
Examination methods • Written exam 'Numerical Simulation in Geotechnics and Tunneling' (180 min., Part of modul grade 100 %)
Requirements for the award of credit points • Passed final module examination
Module applicability • M.Sc. Civil Engineering • M.Sc. Subsurface Engineering • M.Sc. Computational Engineering
Weight of the mark for the final score Percentage of total grade [%] = 6 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Operation and Maintenance of Tunnels and Utility Pipes

Operation and Maintenance of Tunnels and Utility Pipes

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-WP26/SE-CO-5	6 CP	180 h	3. Sem.	1 Semester[s]	20

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Facility management of under-ground transportation infrastructure b) Pipeline maintenance and network management	a) 2 WLH (30 h) b) 2 WLH (30 h)	a) 60 h b) 60 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes
a) Dr.-Ing. Roland Leuker, Prof. Dr.-Ing. Markus Thewes
b) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. habil. Bert Bosseler

Admission requirements

Recommended previous knowledge:
Knowledge in "construction operation and construction process engineering" as well as constructional knowledge

Learning outcome, core skills

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.

Contents

a)

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)
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

Educational form / Language
a) Lecture (2 WLH) / English
b) Lecture (2 WLH) / English

Examination methods
• Written exam 'Operation and Maintenance of Tunnels and Utility pipes' (120 min., Part of modul grade 100 %, optinally Englisch or German)

Requirements for the award of credit points

- Passed module examination: Written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score
Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
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Further Information
b) Digital teaching within the meaning of the HDVO

Optimization Aided Design - Reinforced Concrete

Optimization Aided Design - Reinforced Concrete

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
CE-WP02/SE-CO-21/OAD-RC	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Optimization Aided Design - Reinforced Concrete	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Peter Mark

a) Prof. Dr.-Ing. Peter Mark, Assistants

Admission requirements

Recommended previous knowledge:

Basic knowledge in structural engineering, mechanics of beam and truss structures, reinforced concrete design and material properties matrices.

Learning outcome, core skills

The students should be able to understand and apply the fundamental principles in calculating and designing reinforced concrete (RC) members and structures. They should gain special knowledge in the application of optimization aided design for concrete engineering.

After successfully completing the module the students

- should understand the design of reinforced concrete structures and members as well as crosssections using optimization methods
- should be able to derive and optimize RC structures and members for given constraints, e.g. design space, loads and boundaries

Contents

a)

The module includes the following topics:

- principles and safety concept
- bending design
- strut-and-tie-modelling
- fundamentals of structural optimization
- outer form finding for the identification of structures
  o using one or bi-material topology optimization
  o steering of stresses and material, respectively
- internal form finding for effective reinforcements
  o using continuum, truss or hybrid topology optimisation
- design of cross-sections using optimisation methods

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Optimization Aided Design - Reinforced Concrete' (90 min., Part of modul grade 100 %)

• Optional seminar papers, partially with presentations, to getbonus points for the exam (60 hours, deadlines will be announced at the beginning of the semester)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Practical Soil Mechanics

Practical Soil Mechanics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-4	3 CP	90 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Practical Soil Mechanics	a) 2 WLH (30 h)	a) 60 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Wiebke Baille

Admission requirements

Recommended previous knowledge:

Completed module in Soil and Rock behaviour (Soil behaviour and simple constitutive models for soils)

Learning outcome, core skills

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.

Contents

a)

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)

Educational form / Language

a) Seminar / English / German

Examination methods

• Exercises 'Practical Soil Mechanics - Exercises' (<Ohne>, Part of modul grade 0 %)

• Written exam 'Practical Soil Mechanics' (90 min., Part of modul grade 100 %)

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

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 3 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

<table>
<tr><td colspan="6">Practical Training on Tunneling and Pipeline Construction Techniques
Practical Training on Tunneling and Pipeline Construction Techniques</td></tr>
<tr><td>Module number
BI-W03/SE-O-1</td><td>Credits
2 CP</td><td>Workload
60 h</td><td>Semester[s]
2. Sem.</td><td>Duration
1 Week Semester[s]</td><td>Group size
20</td></tr>
<tr><td colspan="3">Courses
a) Practical Training on Tunneling and Pipeline Construction Methods</td><td>Contact hours
a) 3 WLH (45 h)</td><td>Self-study
a) 15 h</td><td>Frequency
a) each summer</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
Prof. Dr.-Ing. Markus Thewes
a) Prof. Dr.-Ing. Markus Thewes</td></tr>
<tr><td colspan="6">Admission requirements</td></tr>
<tr><td colspan="6">Learning outcome, core skills
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.</td></tr>
<tr><td colspan="6">Contents
a)
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</td></tr>
<tr><td colspan="6">Educational form / Language
a) Internship / Block seminar / English</td></tr>
<tr><td colspan="6">Examination methods
• Internship 'Practical Training on Tunneling and Pipeline Construction Methods' (60 h., ungraded, Regular participation)</td></tr>
<tr><td colspan="6">Requirements for the award of credit points
• Full time participation</td></tr>
<tr><td colspan="6">Module applicability
• MSc. Civil Engineering
• MSc. Subsurface Engineering</td></tr>
<tr><td colspan="6">Weight of the mark for the final score</td></tr>
</table>

Percentage of total grade [%] = 0, ungraded
Further Information Usually takes place in the first week of the lecture-free period in the summer semester.

Problematic Soils
Problematic Soils

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-18	3 CP	90 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Problematic Soils	a) 2 WLH (30 h)	a) 60 h	a) each winter

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Wiebke Baille

Admission requirements

Learning outcome, core skills
After successfully completing the modules, the students are able to

- assess unsaturated soil behaviour, special soil mechanical properties, phenomena, and the behavior of problematic soils,
- can design an appropriate experimental program (laboratory / field tests) for an investigation of problematic soils,
- assess difficult ground conditions and develop solutions for these situations.

Contents
a)
The course deals firstly with the basics of unsaturated soil behaviour, and further with different phenomena, that can cause difficulties in civil works for some types of soils:

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

Educational form / Language
a) Lecture with tutorial / English

Examination methods
• Written exam 'Problematic Soils' (180 min., Part of modul grade 100 %)

Requirements for the award of credit points
- Passed final written examination

Module applicability
- M.Sc. Subsurface Engieering

Weight of the mark for the final score
Percentage of total grade [%] = 3 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

<table>
<tr><td colspan="6">Project Work
Project Work</td></tr>
<tr><td>Module number
SE-C-6</td><td>Credits
4 CP</td><td>Workload
120 h</td><td>Semester[s]
3. Sem.</td><td>Duration
1 Semester[s]</td><td>Group size
no limitation</td></tr>
<tr><td colspan="3">Courses
a) Project Work</td><td>Contact hours</td><td>Self-study
a) 120 h</td><td>Frequency
a) each winter</td></tr>
</table>

Module coordinator and lecturer(s)

All professors of the study program

a) Professors, Lecturers and Assistants

Admission requirements

Learning outcome, core skills

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.

Contents

a)

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

Educational form / Language

a) / English / German

Examination methods

• Term paper 'Project Work' (120 h., Part of modul grade 100 %, 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 • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 4 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Reservoir Engineering Reservoir Engineering					
Module number SE-CO-18	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** 20
Courses a) Reservoir Engineering			**Contact hours** a) 3 WLH (45 h)	**Self-study** a) 105 h	**Frequency** a) each winter

Module coordinator and lecturer(s)
Prof. Dr. Erik Saenger
a) Prof. Dr. Erik Saenger

Admission requirements

Learning outcome, core skills
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

Contents
a)
- 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

Educational form / Language
a) Tutorial (1 WLH) / Lecture (2 WLH) / English

Examination methods
• Oral exam 'Reservoir Engineering' (60 min., Part of modul grade 100 %, Presentation with lecture (45 min) + Discussion (15 min))

Requirements for the award of credit points
- Pass module exam

Module applicability
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 5 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Rock Mass Mechanics and Rock Engineering

Rock Mass Mechanics and Rock Engineering

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-24	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Rock Mass Mechanics	a) 2 WLH (30 h)	a) 40 h	a) each summer
b) Rock Engineering	b) 2 WLH (30 h)	b) 40 h	b) each summer
c) Rock Mechanical Lab Training		c) 10 h	c) each summer

Module coordinator and lecturer(s)

Prof. Dr. Tobias Backers
a) Dr. Mandy Duda
b) Dr. Mandy Duda
c) Dr. Mandy Duda

Admission requirements

Learning outcome, core skills

As a field of geomechanics, rock mass mechanics deals with the description of the rheological properties and associated material models of rock and discontinuities; through integration, the deformation behaviour of rock mass (= rock + discontinuities) can be evaluated in response to changes in thermal, hydraulic or mechanical boundary conditions. Understanding the thermos-hydro-mechanical behaviour of rock mass forms the basis for its use as a structural or material resource.

Rock engineering deals with structural measures in rock mass. The structural engineering measures include excavation, stabilization, extraction, foundations, and the creation of cavities. Based on the fundamentals of rock mass mechanics, the principles of rock engineering are discussed.

Laboratory experiments to describe and classify rock and rock mass will be conducted

Participants are familiar with the fundamentals of rheology, the mechanical behaviour of rocks and discontinuities, rock mass classification and mechanical properties of rock mass. They know and understand the typical characteristic properties in terms of their significance and magnitude and how there are derived from laboratory experiments. Furthermore, they deepen their knowledge of geomechanical principles and interrelations. Participants are also familiar with the basics of constructing and securing rock structures considering the properties of rock and discontinuities as a mechanical system.

Contents

a)
Deformation and failure of rock; introduction to laboratory experiments; deformation and failure of discontinuities; rock mass classifications; deformation and failure of rock mass; excavation, stabilization, characteristics of slopes, foundations, tunnels, and mines; approaches for geotechnical/geomechanical monitoring.

b)
see above

c)
see above

Educational form / Language

a) Lecture with tutorial / English
b) Lecture with tutorial / English
c) Laboratory / English

Examination methods

• Written exam 'Rock Mass Mechanics and Rock Engineering' (90 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Susbsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Relevant specialized literature will be presented at the beginning of each course. Brady B, Brown E. 2006. Rock Mechanics for underground mining. Springer Science

Scientific Programming
Scientific Programming

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-P04/SE-O-10/SP	6 CP	180 h	3 Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Scientific Programming	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)
Prof. Dr. Andreas Vogel
a) Prof. Dr. Andreas Vogel, Assistants

Admission requirements

Learning outcome, core skills
After successfully completing the module, the students

- have acquired the fundamental skills for the development of software solutions, including programming concepts and constructs, data structures and algorithms,
- are able to analyze problems with respect to their structure and requirements and are capable of designing and implementing suitable software code,
- can implement typical problems in scientific computing using the Python programming language and are able to quickly adapt the learned concepts to other programming languages.

Contents
a)
The lecture covers programming concepts such as

- procedural programming, including data types, statements and functions,
- object-oriented programming, including encapsulation, polymorphism and inheritance,
- generic programming.

Furthermore, fundamental data structures as well as efficient algorithms are presented, relevant software libraries are surveyed, and the organization of software projects is discussed.
In hands-on sessions, programming exercises are used to discuss and illustrate the presente

Educational form / Language
a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'Scientific Programming' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points
- Passed final module examination

Module applicability
- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.
Further Information

Seismotectonics and Seismic Hazard

Seismotectonics and Seismic Hazard

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-16	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Seismotectonics and Seismic Hazard	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Rebecca Harrington
a) Prof. Dr. Rebecca Harrington

Admission requirements

Learning outcome, core skills

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.

Contents

a)
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.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English / German

Examination methods

• Written exam 'Seismotectonics and Seismic Hazard' (2 h., Part of modul grade 100 %, includes evaluated written reports of the exercises)

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.

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

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

Selected Topics in Reservoir Characterization

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-17	9 CP	270 h	2.-4. Sem.	2 Semester[s]	15

Courses	Contact hours	Self-study	Frequency
a) Deep geothermal energy	a) 3 WLH (45 h)	a) 85 h	a) each summer
b) Well logging rudiments	b) 2 WLH (30 h)	b) 55 h	b) each winter
c) Well logging II, analysis, interpretation	c) 2 WLH (30 h)	c) 55 h	c) each summer

Module coordinator and lecturer(s)

Prof. Dr. Jörg Renner
a) Prof. Dr. Jörg Renner
b) Prof. Dr. Jörg Renner
c) Prof. Dr. Jörg Renner

Admission requirements

Recommended previous knowledge:
Basic knowledge in mathematics and physics, basic command of sheet-calculation software

Learning outcome, core skills

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

Contents

a)

- classification of geothermal systems
- dimensioning geothermal plants
- flow through porous and fractured rocks
- monitoring fluid injection and stimulation measures
- heat transfer mechanisms

b)

- Borehole completion
- Logging tools
- Basics of measurements

c)

- Introduction to wellcad
- Case studies

Educational form / Language

a) Tutorial (1 WLH) / Lecture (2 WLH) / English / German

b) Tutorial (1 WLH) / Lecture (1 WLH) / English / German
c) Tutorial (1 WLH) / Lecture (1 WLH) / English / German

Examination methods

• Written exam 'Selected Topics in Reservoir Characterization' (3 h., Part of modul grade 100 %, + pass handed in assignments)
• Term paper 'Selected Topics in Reservoir Characterization - Homework I' (0 h., ungraded)
• Term paper 'Selected Topics in Reservoir Characterization - Homework II' (0 h., ungraded)

Requirements for the award of credit points

- Passed exams

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 9 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Soil Dynamics and Geotechnical Earthquake Engineering

Soil Dynamics and Geotechnical Earthquake Engineering

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-7	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Soil Dynamics	a) 2 WLH (30 h)	a) 60 h	a) each winter
b) Geotechnical Earthquake Engineering	b) 2 WLH (30 h)	b) 60 h	b) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Meisam Goudarzy

b) Dr.-Ing. Felipe Prada, Dr.-Ing. Nazanin Irani

Admission requirements

Learning outcome, core skills

After successfully completing the modules, the students are able to

- understand soil dynamic problems and describe them mathematically,
- design and evaluate laboratory or field testing programs to determine dynamic soil properties,
- estimate dynamic soil properties by means of empirical approaches,
- design foundations subjected to dynamic loading (e.g. machine foundations),
- determine the loading resulting from earthquakes considering the ground conditions,
- estimate the risk of soil liquefaction and choose suitable countermeasures,
- design geotechnical structures (e.g. foundations, slopes) against earthquake loads.

Contents

a)

The lecture deals with the fundamentals of Soil Dynamics:

- Fundamentals of vibration theory
- Homogeneous systems
- 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, wave velocity measurements).

b)

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

- Principles of Engineering Seismicity: earthquake description, source characterization, intensity, magnitude and duration parameters, maximum magnitude, concept of response spectra, ground motion prediction (attenuation equations)
- Deterministic and probabilistic estimation of seismic hazard. Microzoning studies.

- 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

Educational form / Language

a) Lecture with tutorial / English

b) Lecture with tutorial / English

Examination methods

• Written exam 'Soil Dynamics and Geotechnical Earthquake Engineering' (180 min., Part of modul grade 100 %)

• Homework with bonus points for the exam for both parts of the module.

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Soil and Rock Behaviour

Soil and Rock Behaviour

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-C-5	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Soil Behaviour and Simple Constitutive Models for Soils b) Stress Field and Rock Mass Behavior	a) 2 WLH (30 h) b) 4 WLH (60 h)	a) 60 h b) 30 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Christoph Schmüdderich, Prof. Dr.-Ing. Torsten Wichtmann

b) Prof. Dr. Tobias Backers

Admission requirements

Learning outcome, core skills

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.

Contents

a)

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)

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.

Educational form / Language

a) Lecture (2 WLH) / English

b) Block seminar / English

Examination methods

• Seminar 'Stress Field and Rock Mass Behavior' (60 h., ungraded)

• Written exam 'Soil and rock behaviour' (180 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passing the examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Technologies in Mechanised Tunneling

Technologies in Mechanised Tunneling

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-W51/SE-O-3	2 CP	60 h	2. Sem.	1 Semester[s]	20

Courses	Contact hours	Self-study	Frequency
a) Technologies in Mechanised Tunneling	a) 2 WLH (30 h)	a) 30 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes
a) Dr.-Ing. Gerhard Wehrmeyer

Admission requirements

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

Learning outcome, core skills

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 a special attention must be paid, which special solutions exist and in which direction research and development is in this area currently moving.

Contents

a)
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)

Educational form / Language

a) Lecture (2 WLH) / English

Examination methods • Written exam 'Technologies in Mechanised Tunneling' (60 min., Part of modul grade 100 %, optionally English or German)
Requirements for the award of credit points • Passed Module examination
Module applicability • MSc Civil Engineering • MSc Subsurface Engineering • MSc Geosciences • MSc Mechanical Engineering
Weight of the mark for the final score Percentage of total grade [%] = 2 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Training of Competences (Part 1)

Training of Competences (Part 1)

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-W01/SE-O-14/ToC I	4 CP	120 h	1./3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Training of Competences and German Language course	a) 4 WLH (60 h)	a) 60 h	a) each winter

Module coordinator and lecturer(s)

N.N.

a) University Language Center (ZFA) of Ruhr-University Bochum

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students

- are able to employ at a minimum 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.

Contents

a)

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. On a basic level, the main focus of the course lies on action-oriented speaking, listening, reading and writing comprehension so that the students learn to cope with everyday situations of their life in Germany. The classes consist of small groups, ensuring that students have ample opportunities 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.

Educational form / Language

a) Lecture with tutorial / English / German

Examination methods

• Written exam 'Training of Competences and German Language course' (120 min., Part of modul grade 100 %, and Homework (20 h) / German)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface engineering
- Special offer for foreign students of the course

Weight of the mark for the final score

Percentage of total grade [%] = 4 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information University Language Center (ZFA) of Ruhr-University Bochum

Training of Competences (Part 2) Training of Competences (Part 2)					
Module number CE-W02/SE-O-15/ToC II	**Credits** 4 CP	**Workload** 120 h	**Semester[s]** 2./4. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Training of Competences II			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 60 h	**Frequency** a) each summer

Module coordinator and lecturer(s)
N.N.
a) University Language Center (ZFA) of Ruhr-University Bochum

Admission requirements
Participation on CE-W01/SE-O14/ToC I is obligatory

Learning outcome, core skills
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.

Contents
a)
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 learn to cope with everyday situations of their life in Germany. This course continues the learning goals of the module Training of Competences 1.

Educational form / Language
a) Lecture (4 WLH) / English / German

Examination methods
• Written exam 'Training of Competences (Part 2)' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points
- Passed final module examination

Module applicability
- M.Sc. Computational Engineering
- M.Sc. Subsurface engineering
- Special offer for foreign students of the course

Weight of the mark for the final score
Percentage of total grade [%] = 4 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
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Further Information
University Language Center (ZFA) of Ruhr-University Bochum

Uncertainty Quantification in FE Analyses with Surrogate Modeling Uncertainty Quantification in FE Analyses with Surrogate Modeling					
Module number BI-WP58/CE-WP29/SE-O-17	**Credits** 6 CP	**Workload** 180 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Uncertainty Quantification b) Surrogate Modeling			**Contact hours** a) 2 WLH (30 h) b) 2 WLH (30 h)	**Self-study** a) 60 h b) 60 h	**Frequency** a) each winter b) each winter

Module coordinator and lecturer(s)
Prof. Dr. Roger A. Sauer
a) Dr.-Ing. Gerrit E. Neu
b) Dr.-Ing. Ba Trung Cao

Admission requirements
Recommended previous knowledge:
Fundamental knowledge in structural analysis, Finite Element Method, probability theory, and basic programming (MATLAB, Python)

Learning outcome, core skills
The course equips students with theoretical foundations and practical skills to model, propagate, and mitigate uncertainties in structural analysis. Students will be able to define an uncertainty quantification problem, evaluate the effect of aleatory, epistemic as well as polymorphic uncertainty onto computational models and to interpret the results. It delves into surrogate modeling methods that approximate high-fidelity simulations, enabling efficient uncertainty assessment in complex systems. Applications to structural reliability, optimization, and risk-informed decision-making are emphasized, with hands-on experience using state-of-the-art computational tools.

After successfully completing the modules, the students are able to

- Understand the role and significance of uncertainty in structural engineering and computational models.
- Apply probabilistic and non-probabilistic methods for modeling uncertain parameters.
- Develop and implement surrogate models for efficient uncertainty propagation and sensitivity analysis.
- Use state-of-the-art tools and frameworks to solve real-world problems involving uncertain data.

Contents
a)
The course deals with the uncertain data involving in structural analysis:

- Fundamentals of uncertainty quantification: types and sources of uncertainty (aleatory vs. epistemic)
- Sources of uncertainty in structural engineering: material properties, geometry, boundary conditions, and external loads
- Computing with uncertainty models: stochastic model, interval analysis, fuzzy logic, and polymorphic model
- Evaluation of model responses due to uncertain inputs: Quantification by statistical measures, sensitivity analysis and structural reliability

b)

The course deals with the development of numerical surrogate models to accelerate the computation with uncertain data:

- Surrogate models based on black-box machine learning techniques (Artificial Neural Network)
- Surrogate models based on reduced order methods (Proper Orthogonal Decomposition)
- Surrogate models based on hybrid combination (Physics-informed machine learning)
- Comparison of surrogate modelling techniques: accuracy vs. computational efficiency

Educational form / Language

a) Lecture (2 WLH) / English
b) Lecture (2 WLH) / English

Examination methods

• Term paper 'Uncertainty Quantification in FE Analyses with Surrogate Modeling' (90 h., Part of modul grade 100 %, Final project assignment + presentation of the results is used to determine the final grade Deadline will be announced at the beginning of the semester.)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engieering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Variational Calculus and Tensor Analysis

Variational Calculus and Tensor Analysis

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-WP01/SE-O-6/VCTA	5 CP	150 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Variational Calculus and Tensor Analysis	a) 3 WLH (45 h)	a) 105 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Johanna Waimann

a) Dr.-Ing. Ulrich Hoppe

Admission requirements

Recommended previous knowledge:

Mathematics

Learning outcome, core skills

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.

Contents

a)

- Tensor Analysis: Vector and tensor notation, vector and tensor algebra, dual bases, coordinates in Euclidean space, 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

Educational form / Language

a) Tutorial (1 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Variational Calculus and Tensor Analysis' (90 min., Part of modul grade 100 %, or Oral Examination (30 Min). Examination Methods will be defined at the beginning of the Semester due to the number of participants)

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc Computational Engineering
- M.Sc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 5 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Curriculum Subsurface Engineering

Category	Specializ.	Module No.	Module name	Coordinator / Lecturers	CP	Sem.	
Compulsary: 33 CP	Both Specializations (GT + SCU)	SE-C-1	Mathematical Aspects of Differential Equations and Numerical Mathematics	Prof. B. Bramham (coordinator)	6	1	WiSe
		SE-C-2	Finite Element Methods in Linear Structural Mechanics	Prof. R. Sauer (coordinator)	6	1	WiSe
		SE-C-3	Geology of the Earth's Crust a) Special Methods in Structural Geology (block course) b) Structural Geology Field Camp (block course)	 Prof. C. Pascal Prof. W. Friederich	6 3 3	1	WiSe
		SE-C-4	Groundwater Hydraulics	Dr. T. Heinze (coordinator)	5	1	WiSe
		SE-C-5	Soil and Rock Behaviour a) Soil Behaviour and Simple Constitutive Models for Soils b) Stress Field and Rock Mass Behavior (block course)	 Prof. T. Wichtmann (coordinator) Prof. T. Backers	6 3 3	1	WiSe
		SE-C-6	Project Work	Professors, lecturers and assistants	4	3	WiSe
Compulsary Optional: GT + SCU: 42 CP	Geotechnics and Tunneling (GT)	SE-CO-1	Foundation Engineering and Utility Pipe Construction: Design-Engin.-Techn. a) Design, engineering and technologies in Foundation Engineering b) Design, engineering and technologies in Utility Pipe Construction	Prof. M. Thewes (coordinator) Dr. B. Schößer	6 3 3	3	WiSe
		SE-CO-2	Conventional and Mechanised Tunneling: Design-Engineering-Technologies a) Design, engineering and technologies in Tunneling b) Design, engineering and technologies in Pipeline Construction	Prof. M. Thewes (coordinator) Dr. B. Schößer	6 3 3	2	SuSe
		SE-CO-3	Numerical Simulation in Geotechnics and Tunneling	Prof. T. Wichtmann (coordinator) Dr. C. Schmüdderich	6	2	SuSe
		SE-CO-5	Operation and Maintenance of Tunnels and Utility Pipes a) Facility management of underground transportation infrastructure b) Pipeline maintenance and network management	Prof. M. Thewes (coordinator) Prof. R. Leuker Prof. B. Bosseler	6 3 3	3	WiSe
		SE-CO-6	Design of Geotechnical Structures - Shallow and Deep Foundations	Prof. T. Wichtmann (coordinator) Dr. N. Irani	6	2	SuSe
		SE-CO-7	Soil Dynamics and Geotechnical Earthquake Engineering a) Soil Dynamics b) Geotechnical Earthquake Engineering	Prof. T. Wichtmann (coordinator) Dr. M. Goudarzy Dr. F. Prada, Dr. N. Irani	6 3 3	3	WiSe
		SE-CO-14	Design of Geotechnical Structures - Excavation Pits, Retaining Structures and Soil Improvement	Prof. T. Wichtmann (coordinator) Dr. M. Tafili, Dr. N. Irani	6	3	WiSe
		SE-CO-21	Optimization Aided Design - Reinforced Concrete	Prof. P. Mark (coordinator)	6	2	SuSe
	Both Specializations (GT + SCU)	SE-CO-8	Numerical Methods and Stochastics	Prof. M. Kronbichler (coordinator)	6	2	SuSe
		SE-CO-10	Advanced Constitutive Models for Geomaterials	Prof. T. Wichtmann (coordinator) Dr. C. Schmüdderich, Dr. M. Tafili	6	2	SuSe
		SE-CO-11	Ground Exploration Methods a) Geophysical Inverse Problems b) Seismic and electromagnetic field methods	Prof. W. Friederich (coordinator)	10 5 5	3	Wise
		SE-CO-19	Mechanical Modeling of Materials	Prof. D. Balzani (coordinator)	6	3	Wise
		SE-CO-20	Inelastic Finite Element Method for Structures	Prof. R. Sauer (coordinator) Dr. V. Gudzulic	6	3	WiSe
		SE-CO-22	Geothermal Drilling Engineering and Subsurface Technologies	Prof. R. Bracke (coordinator)	5	3	WiSe
		SE-CO-23	Nonlinear Finite Element Method for Structures	Prof. R. Sauer (coordinator)	6	2	SuSe
		SE-CO-24	Rock Mass Mechanics and Rock Engineering	Prof. T. Backers (coordinator) Dr. M. Duda	6	2	SuSe
	Subsurface Characterization and Utilization (SCU)	SE-CO-12	Applied Geophysics a) Reservoir Geophysics b) Rock Physics	Prof. J. Renner (coordinator)	10 5 5	2	SuSe
		SE-CO-13	Geothermal Energy Systems	Prof. R. Bracke (coordinator)	5	2	SuSe
		SE-CO-15	Hydrogeological Methods a) Tracers in Hydrogeology b) Hydrogeological Field Camp	Dr. T. Heinze (coordinator)	8	2	SuSe
		SE-CO-16	Seismotectonics and Seismic Hazard	Prof. R. Harrington (coordinator) Dr. D. Essing	6	3	WiSe
		SE-CO-17	Selected Topics in Reservoir Characterization a) Deep geothermal energy b) Well logging rudimens c) Well logging II, analysis, interpretation	Prof. J. Renner (coordinator)	9 5 2 2	 2,4 3 2,4	both SuSe WiSe SuSe
		SE-CO-18	Reservoir Engineering	Prof. E.H. Saenger (coordinator)	5	3	WiSe
Optional: 15 CP	Both Specializations (GT + SCU)	SE-O-1	Practical Training on Tunneling and Pipeline Construction Techniques	Prof. M. Thewes (coordinator)	2	2	SuSe
		SE-O-2	Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	Prof. M. Thewes (coordinator)	2	3	WiSe
		SE-O-3	Technologies in Mechanised Tunneling	Prof. M. Thewes (coordinator) Dr. G. Wehrmeyer	2	2	SuSe
		SE-O-4	Practical Soil Mechanics	Prof. T. Wichtmann (coordinator) Dr. W. Baille	3	3	WiSe
		SE-O-5	Environmental Geotechnics	Prof. T. Wichtmann (coordinator) Dr. W. Baille, Dr. D. König	3	2	SuSe
		SE-O-6	Variational Calculus and Tensor Analysis	Prof. J. Waimann (coordinator) Dr. U. Hoppe	5	3	WiSe
		SE-O-7	Digital Rock Physics	Prof. E.H. Saenger (coordinator)	5	2	SuSe
		SE-O-8	High-Performance Computing on Multicore Processors	Prof. A. Vogel (coordinator)	6	2	SuSe
		SE-O-9	High-Performance Computing on Clusters	Prof. A. Vogel (coordinator)	6	3	WiSe
		SE-O-10	Scientific Programming	Prof. A. Vogel (coordinator)	6	3	WiSe
		SE-O-16	Introduction to advanced numerical methods for particulate media	Prof. T. Wichtmann (coordinator) Dr. M. Salimi	3	3	WiSe
		SE-O-17	Uncertainty Quantification in FE Analyses with Surrogate Modeling	Prof. R. Sauer (coordinator) Dr. B.T. Cao, Dr. G. Neu	6	3	WiSe
		SE-O-18	Problematic Soils	Prof. T. Wichtmann (coordinator) Dr. W. Baille	3	3	WiSe
		SE-O-14	Training of Competences (Part 1)		4	1,2,3,4	both
		SE-O-15	Training of Competences (Part 2)		4	1,2,3,4	both
Master Thesis: 30 CP		SE-MT	Master Thesis	Professors, lecturers and assistants	30	4	SuSe