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M.Sc. Civil Engineering

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Importance of the grade for the final grade

FAK = 1,0

DIV = 171

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2) MSc BI Compulsory Optional Courses, ECTS: 36

Importance of the grade for the final grade

FAK = 1,5

DIV = 171

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3) MSc BI Projects, ECTS: 6

Importance of the grade for the final grade

FAK = 1,5

DIV = 171

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4) MSc BI Optional Courses, ECTS: 20

Importance of the grade for the final grade

FAK = 1,0

DIV = 171

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Practical Training on Tunneling and Pipeline Construction Techniques (BI-W03/SE-O-1, 2 ECTS, each summer semester).....	158
Building process and management in practice (BI-W04, 2 ECTS, each winter semester).....	44
Welding technology for constructional engineers (BI-W06, 2 ECTS, each summer semester).....	181
Glass structures (BI-W07, 2 ECTS, each summer semester).....	36
Experimental based analysis of structural members (BI-W08, 2 ECTS, each winter semester).....	79
Applied Structural Dynamics (BI-W12, 2 ECTS, each winter semester).....	162
Industrialised construction (BI-W13, 2 ECTS, each summer semester).....	110
Structural Engineering for power plants (BI-W15, 2 ECTS, each winter semester).....	42
Occupational Health & Safety 1 (BI-W21, 2 ECTS, each summer semester).....	20
Occupational Health & Safety 2 (BI-W22, 2 ECTS, each summer semester).....	22
Concrete Applications in Practice (BI-W27, 2 ECTS, each summer semester).....	46
Planning, Speaking, Writing : project management and scientific work in engineering (BI-W28, 3 ECTS, each semester).....	154
Maintenance and lifetime management for bridges (BI-W29, 2 ECTS, each winter semester).....	77
Selected Topics of Geotechnical and Geoenvironmental Engineering (BI-W30/SE-O-21, 2 ECTS, each semester).....	26
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BIM in Infrastructure Construction (BI-W66, 5 ECTS, each summer semester).....	30
Non-motorized traffic (BI-W67, 2 ECTS, each summer semester).....	143
Structures under climatic loads (BI-W68, 3 ECTS, each winter semester).....	197
Environmental law (excursion) (W10, 1 ECTS, each summer semester).....	207
Communication for civil engineers (W14, 2 ECTS, each summer semester).....	52
Computational Structural Optimization (CE-WP35/BI-W74/SE-O-19, 6 ECTS, each winter semester).....	56
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5) MSc BI Master's Thesis, ECTS: 30

Importance of the grade for the final grade

FAK = 2,0

DIV = 171

Master Thesis (BI-MA, 30 ECTS, each semester).....	127
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Advanced Building Information Modeling Advanced Building Information Modeling					
Module number BI-WP50	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Advanced Building Information Modeling (128034)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus König a) Prof. Dr.-Ing. Markus König					
Admission requirements					
Learning outcome, core skills The students • acquire advanced competencies in the planning of structures using modern information and communication technologies, • learn methods for the parametric creation of complex domain models, • use software tools for rule-based quality checking of domain models, • acquire advanced competencies in open data exchange, • work on selected BIM use cases, • become familiar with current research approaches through working with contributions in professional journals.					
Contents a) The lecture content covers the following topics: • Parametric modeling • Visual programming • IFC modeling concepts • Model checking • Special topics					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Oral exam 'Advanced Building Information Modeling' (30 min., Part of modul grade 100 %, keine Hilfsmittel zulässig)					
Requirements for the award of credit points • Passed final module examination: successful submission of the term paper					
Module applicability • 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

Literature:

Borrmann, A., König, M., Koch, C., Beetz, J. (Ed.): Building Information Modeling – Technology Foundations and Industry Practice Springer International ISBN 978-3-319-92861-6

Advanced Constitutive Models for Geomaterials					
Advanced Constitutive Models for Geomaterials					
Module number BI-WP44 /SE-CO-10/CE-W06	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Advanced Constitutive Models for Geomaterials (128055)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Merita Tafili a) Prof. 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 [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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

Physical Geology and Soil Mechanics Allgemeine Geologie und Bodenmechanik					
Module number BI-P09	Credits 6 CP	Workload 180 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Physical Geology for non-geologists b) Soil behavior and simple material models			Contact hours a) 1.34 WLH (20.1 h) b) 2 WLH (30 h)	Self-study a) 70 h b) 60 h	Frequency a) each winter b) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Prof. Dr. Tobias Backers b) Prof. Dr.-Ing. Merita Tafili, Prof. Dr.-Ing. Torsten Wichtmann					
Admission requirements Recommended previous knowledge: Completed module in soil mechanics and foundation engineering					
Learning outcome, core skills Students • have a fundamental understanding of the Earth system and its complexity, as well as the social and engineering significance of geological processes and materials • are able to evaluate and solve practical and scientific engineering challenges against this background • have an in-depth understanding of the behavior of soils under mechanical stress, • know how to describe soil behavior using simple material models and are aware of the limitations of such material models, • can derive the parameters of simple material models from the results of laboratory tests					
Contents a) This course consists of two components (i) basics: self study of course material and (ii) application and discussion: two days field camp. It covers topics in geology that are relevant to civil engineering: • Formation of rocks, geological features (e.g., stratification, faults, joints, folds), plate tectonics, and geological formations • Weathering, erosion and mass wasting and the influence of climate • Basic concepts of hydrogeology and engineering geology. • The human impact on Earth's environment b) The course expands on existing knowledge of soil behavior and the mathematical description of this behavior: • Material behavior of sand and clay under oedometer and triaxial monotonic loading, under drained and undrained boundary conditions • Critical states • Notes on material behavior under cyclic/dynamic loading • Shear strength criteria					

• Simple material models: elasticity, Mohr-Coulomb elastoplasticity • Calibration of simple material models based on laboratory tests
Educational form / Language a) Excursion / Inverted Classroom / German / English b) Lecture (2 WLH) / German
Examination methods • Test 'Physical Geology for non-geologists' (15 h., Part of modul grade 50 %, weekly online interrogation and two days field camp) • Written exam 'Soil behavior and simple material models' (90 min., Part of modul grade 50 %)
Requirements for the award of credit points • Passing online interrogation for a) • Participation on two field camps for a) • Passing examination for b)
Module applicability • M.Sc. Civil Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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 Finite Element Methods Applied Finite Element Methods					
Module number BI-WP06/CE-WP11	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Applied Finite Element Methods (126519)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr. Roger A. Sauer a) Dr.-Ing. Gerrit E. Neu, Prof. Dr.Ing. habil. Izabela Lubowiecka					
Admission requirements Recommended previous knowledge: Finite Element Methods in Linear Structural Mechanics (CE-P05 respectively BI-P08) Basics knowledge in Mathematics, Programming, FEM and Structural Analysis					
Learning outcome, core skills After successfully completing the module, the students • have the ability to model structures using finite element software and to verify and assess the simulation results. • can generate simulation models for structures composed of different element types with static and dynamic loading and write reports. • can perform thermal, buckling and contact analyses of materials and structures. • are able to create simulations models of engineering problems under consideration of suitable abstractions, boundary conditions and definition of interactions between elements. • can handle digital interfaces between BIM and structural analysis software to convert building models into structural simulation models.					
Contents a) The course deals with the application of finite element simulations in structural engineering. This includes: • handling of commercial finite element software • modeling methods and sources of modeling errors • pre- and post-processing • BIM-FE interfaces					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / English					
Examination methods • Project report 'Applied Finite Element Methods' (60 h., Part of modul grade 100 %, Project work with a written report (90%) and a presentation, with oral examination (10%))					
Requirements for the award of credit points • Passed oral examination and project work					
Module applicability					

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

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

optional Tutorial (2 WLH)

Occupational Health & Safety 1 Arbeitssicherheit I – Baustellenorganisation					
Module number BI-W21	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Occupational Health & Safety 1			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus Thewes a) Prof. Dr.-Ing. Markus Thewes, Dipl.-Ing. Ralf Germann					
Admission requirements					
Learning outcome, core skills Students • Will develop a fundamental understanding of the importance of occupational health and safety on construction sites, • are introduced to the basic knowledge of appropriate preventive measures in construction planning and execution, • will recognise the special significance of construction management for health and safety aspects from a legal perspective, • will learn to deal with issues in these areas in a practical manner, • will be able to critically examine occupational health and safety issues and implement it in construction organisation					
Contents a) The lecture comprehensively covers the basics of occupational safety. This includes: • Fundamentals of occupational safety • Legal and insurance aspects • Basic knowledge of accident prevention regulations for building construction and civil engineering • Special features of compressed air and blasting work					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Written exam 'Occupational Health & Safety 1' (60 min., Part of modul grade 100 %, Die Klausur findet im Sommersemester vorlesungsnah nach Beendigung der Veranstaltung noch während der Vorlesungszeit statt.)					
Requirements for the award of credit points • Passed module final exam: Written exam					
Module applicability • B.Sc. Civil Engineering • B.Sc. Environmental Engineering • M.Sc. Civil Engineering					

- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

Note: With the Occupational Health & Safety 1 module, students can acquire the first part of the theoretical training to become a health and safety coordinator (SiGe coordinator) with regard to occupational safety knowledge (SiGe occupational safety – occupational safety knowledge in accordance with RAB 30, Appendix B). Continuing from this first module Occupational Health & Safety 1, the second part of the theoretical knowledge of a SiGe coordinator is taught in a further master module W22.

After consultation with the lecturer, students of the Bachelor's programme may also voluntarily participate in the Master's module W22 in order to complete this component of the theoretical training for health and safety coordinators (SiGe coordinators).

In addition to the two modules W21 and W22 on occupational health and safety, training in specific coordinator skills (in accordance with RAB 30, Annex C) is required for the complete theoretical training as a health and safety coordinator. This is not part of the W21 or W22 modules offered here.

Occupational Health & Safety 2 Arbeitssicherheit II - Arbeitsschutzfachlicher Theoriekurs					
Module number BI-W22	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Environmental Engineering			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus Thewes a) Prof. Dr.-Ing. Markus Thewes, Dipl.-Ing. Ralf Germann					
Admission requirements Recommended previous knowledge: Participation in the Occupational Safety I module is recommended.					
Learning outcome, core skills Students • develop an advanced understanding of the importance of occupational health and safety protection on construction sites, • acquire further knowledge of appropriate preventive measures in construction planning and execution, • recognise the special importance of construction management from a legal perspective, • learn how to deal with issues in these areas in a practical manner • are able to critically examine occupational safety issues and implement this task in construction management					
Contents a) The lecture comprehensively covers the basics of occupational safety. This includes: • In-depth study of legal and insurance-related aspects • In-depth knowledge of accident prevention regulations for building construction and foundation engineering • Fire protection during the construction phase • Fundamentals of health and safety planning and coordination • Tasks of the health and safety coordinator in planning and construction					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Written exam 'Occupational Health & Safety 2' (60 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final exam: Written exam					
Module applicability • B.Sc. Civil Engineering • B.Sc. Environmental Engineering • M.Sc. Civil Engineering					

- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

Note: With the Occupational Health & Safety 2 module, students can acquire the second part of the theoretical training to become a health and safety coordinator (SiGe coordinator) with regard to occupational safety knowledge (SiGe occupational safety – occupational safety knowledge in accordance with RAB 30, Appendix B). Continuing from the previous module, Occupational Health & Safety 1, the second part of the theoretical knowledge of a SiGe coordinator is taught in this master module.

In addition to the two modules W21 and W22 on occupational health and safety, training in specific coordinator skills (in accordance with RAB 30, Annex C) is required for the complete theoretical training as a health and safety coordinator. This is not part of the W21 or W22 modules offered here.

Executed railroad bridges Ausgeführte Bahnbrücken					
Module number BI-W60	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Executed railroad bridges			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Prof. Dr.-Ing. Peter Mark, Dr.-Ing. Mathias Strack					
Admission requirements Recommended previous knowledge: Completed modules in fundamentals of Reinforced and Prestressed Concrete Structures, Structural Analysis A and B, Bridges- Conceptual Design and Structural Detailing					
Learning outcome, core skills The Students: • gain an insight into the design and construction of railway bridges • know theoretical, constructive and practical aspects of realised railway bridges from the perspective of planners, authorised designers and construction supervision					
Contents a) The course teaches the basics of railway bridge construction. This includes: • Overview of the history, age and condition of Deutsche Bahn bridges • Overview of typical structures, materials, construction and equipment elements of railway bridges, structure and types of superstructure • Requirements for railway bridges: load-bearing capacity, permissible deformations, end tangent angles, vibrations, resonance risk, bridge-rail interaction • Loads, load models, load class coefficient and load cases of DB • Building and construction height, cross-section parameters, etc. • Railway clearance profiles, danger zones and safety spaces for service, escape and rescue routes • Construction methods, auxiliary bridges, standardised bridges • Basics of the recalculation of existing railway bridges • Overview of applicable documents: EC, RIL, TM, DBS, EITB, DB standard drawings					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Oral exam 'Executed railroad bridges' (30 min., Part of modul grade 100 %, at least 75% attendance)					
Requirements for the award of credit points • At least 75% attendance • Passed final module examination: oral examination					

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

Selected Topics of Geotechnical and Geoenvironmental Engineering					
Ausgewählte Kapitel aus Grundbau und Umweltgeotechnik					
Module number BI-W30/SE-O-21	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Selected Topics of Geotechnical and Geoenvironmental Engineering (128223)			Contact hours a) 1 WLH (15 h)	Self-study a) 45 h	Frequency a) each sem.
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. D. König					
Admission requirements Recommended previous knowledge: Completed modules in soil mechanics and foundation engineering					
Learning outcome, core skills The students • gain an impression of the complexity of practical construction tasks and learn about solutions to specific problems, • are able to engage with innovative ideas and solution strategies, • can transfer the solutions learned to other situations.					
Contents a) In this course, current construction projects and methods are presented by experts e.g. from construction industry. The tasks, technical constraints, planning and design principles, construction works, difficulties encountered, and solutions are explained.					
Educational form / Language a) Lecture (1 WLH) / German					
Examination methods • Oral exam 'Selected Topics of Geotechnical and Geoenvironmental Engineering' (0 min., ungraded, Colloquium)					
Requirements for the award of credit points • Participation • Passed module examination: oral exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Subsurface Engineering • M.Sc. Environmental Engineering					
Weight of the mark for the final score Percentage of total grade [%] = 0, ungraded					
Further Information					

Perhaps excursion/conference participation

Automation in Design and Construction Automation in Design and Construction					
Module number BI-WP48/CE-WP36	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Automation in Design and Construction (129027)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus König a) Dr.-Ing. Philipp Hagedorn, Prof. Dr.-Ing. Markus König					
Admission requirements					
Learning outcome, core skills The students • acquire skills for automating processes in the planning and execution of construction projects, • learn methods for generating as-built models, • apply additive manufacturing for prototyping, • acquire competencies in the application of sensors, data acquisition technologies, and robotics on construction sites, • work in small groups on selected problems related to the automation of processes in the planning and execution of construction projects, • learn about current research approaches to the use of artificial intelligence in the planning and execution of construction projects.					
Contents a) • Sensors and laser scanning on the construction site • Digital twins • Augmented and virtual reality • Additive manufacturing • Use of drones and robotics • Artificial intelligence in construction					
Educational form / Language a) Block seminar / Lecture (2 WLH) / Tutorial (2 WLH) / English					
Examination methods • Term paper 'Automation in Design and Construction' (90 h., Part of modul grade 100 %, with interim and final presentation)					
Requirements for the award of credit points • Passed final module examination: successful submission of the term paper with interim and final presentation					
Module applicability					

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

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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:

Borrmann, A., König, M., Koch, C., Beetz, J. (Ed.): Building Information Modeling – Technology Foundations and Industry Practice Springer International ISBN 978-3-319-92861-6

BIM in Infrastructure Construction BIM im Infrastrukturbau					
Module number BI-W66	Credits 5 CP	Workload 150 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) BIM in Infrastructure Construction			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus König a) Prof. Dr.-Ing. Markus König					
Admission requirements					
Learning outcome, core skills The BIM in Infrastructure Construction module provides in-depth knowledge of the BIM method about infrastructure facilities. Knowledge of the special features of EIR and BEP is explicitly applied to the infrastructure sector and taught practically. Students learn about and evaluate different specialised models, such as subsoil, structural engineering, railway and road infrastructure, and energy and overhead lines, and their trade-specific features. Insights into current construction projects and concrete BIM-based project management deepen the theoretical knowledge. Practical exercises use software solutions particularly suitable for infrastructure planning. Real project data is used on a large scale to simulate sound and noise protection or calculate visibility. Finally, acquired knowledge and skills are applied to the project.					
Contents a) The lecture covers the following topics: • Building Information Modelling in infrastructure construction • Modelling of infrastructure routes • 4D and 5D modelling of linear structures • GIS analysis • Sound and noise protection analyses • Selected specialist models of the existing structure • Tools for BIM-based infrastructure planning					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Project report 'BIM in Infrastructure Construction' (60 h., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed final module examination: Project work					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score					

Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$

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:

Borrmann, A., König, M., Koch, C., Beetz, J. (Ed.): Building Information Modeling – Technology Foundations and Industry Practice Springer International ISBN 978-3-319-92861-6

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. John Wiley & Sons.

Construction and Engineering Contract law Bau- und Ingenieurvertragsrecht					
Module number BI-W02	Credits 3 CP	Workload 90 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Construction and Engineering Contract law			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus Thewes a) Prof. Dr.-Ing. Markus Thewes, Prof. Dr. jur. M.M. Lederer					
Admission requirements Recommended previous knowledge: Knowledge in the field of construction operations and construction process engineering, as well as construction contract law and construction management					
Learning outcome, core skills Students • will be introduced to the basics of construction and engineering contract law, • acquire in-depth basic knowledge of the regulatory structures governing contracts for construction services and for engineering contract fees and, building on this, will be able to allocate risk during contract negotiations and construction in order to minimise potential conflicts and maximise cooperation-based project implementation • deal with the different interests of clients and contractors as well as the authorities and organisations involved that must be included in contract management, • acquire the ability to independently handle standard tasks in the areas of construction and engineering contract law, • acquire a basic understanding of the correct handling of regulations and laws governing contract law and statutory price law.					
Contents a) The lecture comprehensively covers the basic knowledge of construction and engineering contract law based on the German Civil Code (BGB), the German Construction Contract Procedures (VOB/B) and the German Fee Structure for Architects and Engineers (HOAI). This includes: • the basics of the general part of the BGB on the formation of contracts (offer and acceptance, powers of representation, conditions, etc.), • the BGB law on contracts for work and services (§§ 631 ff. BGB) and the VOB/B • supplementary agreement management and dealing with obstacles in the construction process • the acceptance of construction work • the law on defects • Securities in construction contract law in accordance with Section 648a BGB and Section 17 VOB/B Moot Court In addition, a moot court (simulated court hearing) will be held as part of this course, in which students will apply the knowledge they have acquired by working on a case study.					

Educational form / Language a) Seminar / Lecture (2 WLH) / German
Examination methods • Written exam 'Construction and Engineering Contract law' (30 min., Part of modul grade 100 %, Exam covering the entire module) • Seminar 'Moot Court' (5 h., Part of modul grade 0 %)
Requirements for the award of credit points • Passed module final exam: Written exam • Participation in moot court
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering
Weight of the mark for the final score Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$ 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

Construction Operation and Management Baubetrieb und Management					
Module number BI-P06	Credits 6 CP	Workload 180 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Construction industry and construction contracts b) Project and risk management			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.-Ing. Markus Thewes a) Dipl.-Ökonom Hans Adden, Prof. Dr.-Ing. Markus Thewes b) Dr.-Ing. Götz Vollmann, Prof. Dr.-Ing. Markus Thewes					
Admission requirements Recommended previous knowledge: Knowledge in the field of construction operations and construction process engineering as well as construction contract law is recommended.					
Learning outcome, core skills Students • will learn detailed knowledge in the field of tender processing and the variety of construction contract forms; they will gain in-depth knowledge of engineering and legal tasks in these areas, • learn the basics of investment assessment for construction projects, • learn to work independently on tasks and develop a special understanding of construction business methods and associated business aspects, • learn how to independently and purposefully deal with common problems in bid processing, taking into account the usual forms of construction contracts, • gain an understanding construction industry and construction contract management in combination with selected areas of project management • acquire knowledge that will help them prepare and execute construction projects in construction management and project management, and will be able to apply methods commonly used in practice • learn methods for identifying and dealing with technical and economic risks in the construction sector • learn methods of quantitative risk management					
Contents a) The lecture covers advanced basic knowledge of construction industry issues. This includes: • Characteristics of the construction market • Cost estimation methods • Economic planning tools • Public and private construction law • Contract award and contract regulations for construction work (VOB) • In-depth methods for tendering, awarding contracts and invoicing • Awarding of contracts and contract forms • Basics of Public-Private-Partnership (PPP) projects					

- Insurance, security deposits, guarantees
- Acceptance, warranty, dealing with construction defects

b)

The lecture covers advanced basic knowledge of project management in construction. This includes:

- Fundamentals, regulations and laws
- Parties involved and processes
- Organisational management
- Scheduling and monitoring
- Capacity and quality
- Legal aspects
- Risk identification and mitigation
- Methods of quantitative risk management

Educational form / Language

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

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

Examination methods

- Written exam 'Construction Operation and Management' (100 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: Written exam

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Glass structures Bauen mit Glas					
Module number BI-W07	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Glass structures			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing Helen Bartsch a) Dr.-Ing. Hans-Werner Nordhues					
Admission requirements Recommended previous knowledge: Steel and Timber Structures, Structural Analysis A and B					
Learning outcome, core skills The students: • possess advanced knowledge of the theoretical foundations and structural aspects of glass construction and develop solutions for specific problems and tasks. • have the ability to reflect on and assess completed constructions and components, and can critically evaluate them in the context of material and structural choices. • assess the impact of material selection and structural design in glass construction. • can weigh advantages and disadvantages and derive general construction guidelines and execution recommendations from them.					
Contents a) • Properties of the material glass • Composition and manufacturing of glass • Safety requirements for load-bearing components and legal aspects in construction • Structural analysis of glass components • Physical building properties and requirements					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Written exam 'Glass structures' (30 min., Part of modul grade 100 %) • Attendance at at least 75% of the lectures					
Requirements for the award of credit points • Passed module final exam: Written exam • Attendance at at least 75% of the lectures					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $2 \cdot 100 \cdot \text{FAK} / \text{DIV}$					

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

Digital examinations within the meaning of the HDVO

Synthetic material building Bauen mit Kunststoffen					
Module number BI-W45	Credits 1 CP	Workload 30 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Synthetic material building			Contact hours a) 1 WLH (15 h)	Self-study a) 30 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing Helen Bartsch a) Dr.-Ing. Hans-Werner Nordhues					
Admission requirements Recommended previous knowledge: Steel and Timber Structures, Structural Analysis A and B					
Learning outcome, core skills The students: • possess advanced knowledge of the theoretical foundations and structural aspects of building with synthetic materials and develop solutions for specific problems and tasks. • assess the impact of material selection and structural design when building with synthetic materials. • can evaluate advantages and disadvantages and derive general construction guidelines and execution recommendations from them.					
Contents a) • Material properties of synthetic materials • Composition and manufacturing of synthetic materials • Standards and regulations • Application of synthetic materials in construction • Structural analysis of load-bearing components made of synthetic materials • Designing with synthetic materials • Joints and connecting elements					
Educational form / Language a) Lecture (1 WLH) / German					
Examination methods • Written exam 'Synthetic material building' (30 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final exam: Written exam					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $1 * 100 * \text{FAK} / \text{DIV}$ 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

Digital examinations within the meaning of the HDVO

Soil Dynamics and Geotechnical Earthquake Engineering					
Baugrunddynamik und Geotechnisches Erdbebeningenieurwesen					
Module number BI-WP42	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Soil Dynamics b) Geotechnical Earthquake Engineering			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.-Ing. Torsten Wichtmann a) Dr.-Ing. Meisam Goudarzy b) Dr.-Ing. Felipe Prada					
Admission requirements Recommended previous knowledge: Completed module in advanced soil mechanics					
Learning outcome, core skills The students • are able to understand soil dynamic problems and describe them mathematically, • can design and evaluate laboratory or field testing programs to determine dynamic soil properties, • have knowledge to estimate dynamic soil properties by means of empirical approaches, • are able to design foundations subjected to dynamic loading (e.g. machine foundations), • are capable of determining the loading resulting from earthquakes considering the ground conditions, • have knowledge to estimate the risk of soil liquefaction and choose suitable countermeasures, • can design geotechnical structures (e.g. foundations, slopes) subjected to 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 subjected to seismic loading • Design of retaining structures subjected to seismic loading • Analysis of soil motion during earthquakes (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 %) • Optional Homework 'Soil Dynamics and Geotechnical Earthquake Engineering' (40 h, percentage of module grade 0 %) to get bonus points for the examination
Requirements for the award of credit points • asessed final module examination: written examination
Module applicability • M.Sc. Civil Engineering • M. Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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

Structural Engineering for power plants Bautechnik für Kraftwerke und Energieanlagen					
Module number BI-W15	Credits 2 CP	Workload 60 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Structural Engineering for power plants			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Prof. Dr.-Ing. Peter Mark					
Admission requirements Recommended previous knowledge: Completed modules in fundamentals of Reinforced and Prestressed Concrete Structures, Structural Analysis					
Learning outcome, core skills The Students: • are familiar with current issues in the field of power plant and energy plant construction, • are familiar with the special features of power plant-specific construction types, action effects and anchorages					
Contents a) The course addresses the 'Structural Engineering for Power Plants and Energy Systems' in the form of a series of lectures. Renowned speakers from the field report on current topics in the field of energy plant construction and cover the extensive spectrum of nuclear, fossil and renewable energy utilisation. The lectures will cover the following topics: • Fundamentals of power plant technology • Industrial construction for large-scale projects • Conception and planning of new nuclear construction projects • Structural engineering features in the construction of nuclear power plants • Aspects of construction and plant engineering for cooling towers • Dynamic effects in power plant construction • Anchoring technology in power plant construction • Solar thermal power plants • Offshore wind power plants • Hydroelectric power plants					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Oral exam 'Structural Engineering for power plants' (30 min., Part of modul grade 100 %) • At least 75% attendance					
Requirements for the award of credit points • At least 75% attendance					

- Passed final module examination: oral examination

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

Building process and management in practice Bauverfahrenstechnik und Baumanagement in der Praxis					
Module number BI-W04	Credits 2 CP	Workload 60 h	Semester[s] ab dem 1. Sem.	Duration 2 Tage Semester[s]	Group size no limitation
Courses a) Building process and management in practice			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency 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 Students • will learn specific techniques for planning, executing, and managing current projects in construction practice, • will deepen the knowledge acquired in the modules "Construction Engineering for Tunnel Construction," "Construction Engineering for Civil Engineering and Pipeline Construction," and "Operation and Maintenance of Tunnels and Pipelines," • will be enabled to prepare procedures for more complex and demanding projects. • will have the opportunity to establish a wide range of contacts with representatives from the field and thus begin to build a professional network. • will deepen their skills in technical discussions with representatives of the most important planning offices and construction companies in the field of underground construction.					
Contents a) Participation in a 2-day international symposium including accompanying trade fair in cooperation with the Study Association for Tunnels and Traffic Facilities (STUVA e.V.). The symposium presentations by experts from the field cover current topics in underground construction, in particular tunnel construction and tunnel operation: • Major international projects • BIM, digitization, monitoring • Innovations in regulations • Combined construction methods • Mechanical tunnel boring • New developments in segmental lining • Ground freezing • Tunnel construction in swelling soils • Safety in road tunnels • Tunnel planning, renovation • Commissioning and energy saving					
Educational form / Language a) Excursion / German					

Examination methods

- Seminar 'Building process and management in practice' (30 h., ungraded, Participation in a 2-day conference including trade fair (e.g., STUVA conference))
- PowerPoint presentations, supplementary handouts

Requirements for the award of credit points

- Verified attendance at the seminar

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 0, ungraded

Further Information

In addition to the lectures, a trade fair will be held at the same time. Travel arrangements will be organized by the department.

Concrete Applications in Practice Betone für besondere Anwendungen in der Praxis					
Module number BI-W27	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Concrete Applications in Practice			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. habil. Iurie Curosu a) Prof. Dr.-Ing. habil. Iurie Curosu					
Admission requirements Recommended previous knowledge: Knowledge of construction materials and building physics					
Learning outcome, core skills The students • have advanced application-orientated knowledge of concretes with special properties that are used in various engineering structures. • can evaluate the special features of such structures in terms of concrete technology and processes. • can examine engineering problems and develop solutions. • can name special aspects of large international construction projects. • can assess their knowledge of construction materials from an international perspective.					
Contents a) This module covers detailed information on the special requirements for concrete in the various applications in the construction of roads, tunnels, water-impermeable components and much more. In addition to the many possible uses of concrete, the compositions needed to meet a wide range of requirements and exploitation conditions are explained. It not only deals with concrete concepts, but also with technological processes and framework conditions from practice. Typical topics include: • Large international construction projects • Concreting under special climatic conditions • Concretes in hydraulic engineering• Concretes for pavement applications • Concretes in tunnelling • Concretes in high-rise construction • Waterproof concrete • Textile and fiber-reinforced concretes					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Oral exam 'Concrete Applications in Practice' (30 min., ungraded) Attendance (min. 80% during classes)					
Requirements for the award of credit points					

• Attendance (min. 80% during classes) • Passed oral examination
Module applicability • M.Sc. Civil Engineering
Weight of the mark for the final score Percentage of total grade [%] = 0, ungraded
Further Information

Earthworks – Soil mechanical background and practice Bodenmechanik und Baupraxis des Erdbaus					
Module number BI-WP61/UI-WPD8	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Soil-water interaction and its practical significance for earthworks b) Site investigation and earthworks c) Behaviour of innovative retaining structures and foundations			Contact hours a) 2 WLH (30 h) b) 1 WLH (15 h) c) 1 WLH (15 h)	Self-study a) 60 h b) 30 h c) 30 h	Frequency a) each winter b) each winter c) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. Wiebke Baille b) Dr.-Ing. Wiebke Baille, Dr.-Ing. Henning Wolf c) Dr.-Ing. Oliver Detert					
Admission requirements Recommended previous knowledge: Completed modules in soil mechanics and foundation engineering					
Learning outcome, core skills The students - are familiar with the behaviour of soil under partially saturated conditions, have in-depth knowledge of soil investigation and description, and are familiar with earthwork methods and the load-bearing behaviour of innovative retaining and foundation structures, - have the ability to engage with innovative ideas, research results, and current and changing regulations, - are able to assess the effects of changes in soil water content and develop and evaluate innovative solutions for ground improvement.					
Contents a) The course covers the principles of soil mechanics of partially saturated soils and phenomena in soils that can be caused by changes in water content, as well as their practical significance in construction. The following topics are covered: - Saturated and partially saturated soils - Soft cohesive and organic soils, consolidation behavior - Swelling and shrinking cohesive soils and their physicochemical properties - Collapsible soils - Compaction and structure of compacted soils - Structures on problematic soils / case studies - Laboratory experiments to illustrate the above phenomena b)					

The course covers strategies for investigating building sites and the planning, execution, and monitoring of earthworks:

- Concepts for site investigation and preparation of site reports
- Earthwork classifications
- Appropriate and economical construction of earthworks (e.g., dams, cuts for transport routes, dikes)
- Testing methods
- Methods for soil improvement and soil stabilization
- Soil management concepts

c)

The course covers the description of load-bearing behaviour and the design of innovative support and foundation structures:

- Detailed retaining structures - construction methods and special features (e.g. geotextile reinforcement, gabion walls, ...)
- Detailed foundation structures - construction methods and special features (e.g. stone columns, vibro compaction piles, ...)
- Geotextiles: types, areas of application, properties
- Load-bearing behaviour and design of retaining structures with geosynthetics
- Foundations on soft soils – examples and design approaches

Educational form / Language

a) Lecture (2 WLH) / German

b) Lecture (1 WLH) / German

c) Lecture (1 WLH) / German

Examination methods

- Written exam 'Earthworks – Soil mechanical background and practice' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed final module examination: written examination

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

Bridges- Conceptual Design and Structural Detailing					
Brückenbau - Entwurf, Konstruktion und Bemessung					
Module number BI-WP03	Credits 9 CP	Workload 270 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Steel and composite bridges b) Reinforced concrete and prestressed concrete bridges			Contact hours a) 3 WLH (45 h) b) 3 WLH (45 h)	Self-study a) 90 h b) 90 h	Frequency a) each winter b) each winter
Module coordinator and lecturer(s) Vertr.-Prof.'in Dr.-Ing. Rebekka Winkler a) Vertr.-Prof.'in Dr.-Ing. Rebekka Winkler b) Prof. Dr.-Ing. Peter Mark, Dr.-Ing. David Sanio					
Admission requirements Recommended previous knowledge: Modules BI-WP1 and BI-WP2					
Learning outcome, core skills The students • possess fundamental knowledge of the design, structural detailing, and analysis of bridges. • can transfer their understanding of how bridges carry applied loads and determine which primary and secondary structural systems are appropriate design options, depending on local boundary conditions. • are capable of independently evaluating load-bearing principles. • can independently solve design, analysis, and construction tasks related to bridge structures.					
Contents a) The lectures provide foundational knowledge for the design, structural analysis, and detailing of bridges in reinforced concrete, prestressed concrete, steel, and composite construction. • Primary and secondary structural systems • Load-bearing principles • Typical bridge cross-sections • Steel and concrete road-way deck slabs • Construction and structural depths • Structural detailing • Effective flange widths • Fatigue and service life • Fundamentals of design • Basic types of longitudinal and transverse systems • Bridge-specific actions (loads and influences) • Prestressing and reinforcement • Calculation principles for longitudinal and transverse systems • Design for ultimate and serviceability limit states b)					

The course teaches the basic knowledge required for design, dimensioning, and structural engineering of bridges made of reinforced and prestressed concrete, steel, and composite materials.

- Primary and secondary structures
- Load transfer principles
- Typical cross-sections of bridges
- Steel and solid deck slabs
- Construction and structural heights
- Structural design
- Load-effective widths
- Fatigue and fatigue strength
- Fundamentals of design
- Basic types of longitudinal and transverse systems
- Bridge-specific action effects
- Prestressing and reinforcement
- Calculation principles for longitudinal and transverse systems
- Ultimate and serviceability limit state design

Educational form / Language

a) Lecture with tutorial / German

b) Lecture with tutorial / German

Examination methods

- Term paper 'Bridge building - design, construction and measurement' (35 h., Part of modul grade 0 %)
- Written exam 'Bridges- Conceptual Design and Structural Detailing' (150 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: Written exam
- Passed term paper

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $9 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

Communication for civil engineers Communication for civil engineers					
Module number W14	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration Semester[s]	Group size 20
Courses a) Communication for civil engineers (128404)			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) M.A. Julia Salzinger a) M.A. Julia Salzinger					
Admission requirements Recommended previous knowledge: Level B2 (Common European Framework of Reference for Languages)					
Learning outcome, core skills Students • enhance their language skills in technical areas. • practise expressing technical content using appropriate technical vocabulary for experts. • learn to express technical contexts in simple language for non-specialists. • will be enabled to act in the foreign language with a view to their future professional activities. • can work on a manageable task conceptually and independently in technical English within a given time frame. • can discuss subject-related content.					
Contents a) In the seminar, participants practice talking about specialist topics with experts and non-experts in regard to their future professional life. Pair and group work, TED talks and discussions integrated in the course.					
Educational form / Language a) Seminar / German / English					
Examination methods • Compulsory attendance 'Communication for civil engineers - Compulsory attendance' (ungraded, Attendance at least 75% of the appointments, Preliminary requirement for participation in the oral examination) • Oral exam 'Communication for civil engineers' (15 min., Part of modul grade 100 %, Presentation)					
Requirements for the award of credit points • Passed module final exam: Written exam • Attendance at at least 75% of the appointments					
Module applicability • BSc. Civil Engineering • MSc. Civil Engineering • BSc. Environmental Engineering • MSc. Environmental Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Additional material will be provided on Moodle.

Computational Modeling of Membranes and Shells Computational Modeling of Membranes and Shells					
Module number BI-WP57/CE-WP16	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Computational Modeling of Membranes and Shells (127506)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Roger A. Sauer a) Prof. Dr. Roger A. Sauer					
Admission requirements Recommended previous knowledge: Basic knowledge of continuum mechanics (CE-P07) and linear Finite Element Methods (CE-P05) is strongly recommended.					
Learning outcome, core skills After successfully completing the module the students • can identify the elements of the numeric models for membranes and shells and explain their mathematic-physical background • are able to describe the presented numerical discretization methods • can transfer the formulations used for membranes and shells to other constitutive laws and implement them into an existing software application • are able to estimate the accuracy of those applications					
Contents a) The module includes the following topics: 1. Kinetics of membranes under large deformations 2. Constitutive laws for membranes 3. Membrane equilibrium for the strong form and the weak form 4. Summarization of the isogeometric finite element methods 5. Numerical discretization methods for membranes 6. Shell theory 7. Rotation-free discretization methods for Kirchhoff-Love Shells 8. Implementation of the presented discretization methods					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / English					
Examination methods • Oral exam 'Computational Modeling of Membranes and Shells' (30 min., Part of modul grade 100 %) • Term paper 'Computational Modeling of Membranes and Shells - Homework' (40 h., ungraded, Deadline will be announced at the beginning of the semester)					
Requirements for the award of credit points					

• Passed oral test • Passed Homework
Module applicability • M.Sc. Civil Engineering • M.Sc. Computational Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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

Computational Structural Optimization Computational Structural Optimization					
Module number CE-WP35/BI-W74/SE-O-19	Credits 6 CP	Workload 180 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Computational Structural Optimization (127517)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Roger A. Sauer a) Prof. Anupam Saxena					
Admission requirements Recommended previous knowledge: Basics knowledge in Mathematics, Programming, FEM and Structural Analysis					
Learning outcome, core skills After successfully completing the module, the students • have advanced knowledge regarding topology optimization and its integration in computational models • are able to independently implement topology optimization code in FE-Analysis frameworks • can perform computational topology optimization and apply it to any engineering problem • can critically interpret the results of a topology optimization					
Contents a) The course covers the basic knowledge of topology optimization and its implementation in computational frameworks. In particular, the following topics are taught in the course: • Introduction in finite-element theory and the development of code to perform FE-Analysis • Theory of topology optimization with code implementation • Application of topology optimization in computational models with different complexity levels					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / English					
Examination methods • Project report 'Computational Structural Optimization' (30 h., Part of modul grade 100 %, Project work with coding assignments and a written report (90%), optional presentation, with Oral examination (10%))					
Requirements for the award of credit points					
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 [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$ FAK: The weighting factors can be taken from the table of contents.					

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Further Information

Conventional and Mechanised Tunneling: Design – Engineering – Technologies					
Conventional and Mechanised Tunneling: Design – Engineering – Technologies					
Module number BI-WP11/SE-CO-2	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Design, engineering and technologies in Tunneling and Pipeline Construction (128009)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus Thewes a) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. Britta Schößler					
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) Lecture (3 WLH) / Tutorial (1 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 [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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

Data Analysis and Simulation in Traffic Engineering					
Datenanalyse und Simulation im Verkehrswesen					
Module number BI-W46	Credits 2 CP	Workload 60 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size 30
Courses a) Data Analysis and Simulation in Traffic Engineering			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Justin Geistefeldt a) Prof. Dr.-Ing. Justin Geistefeldt					
Admission requirements Recommended previous knowledge: Traffic engineering					
Learning outcome, core skills Students have in-depth knowledge of • in processing and analyzing traffic-related data, • in the use of simulation tools for traffic engineering applications.					
Contents a) In the lecture, relevant methods of data analysis and simulation in traffic engineering are presented, which are then applied by the students in computer exercises using practical examples. The focus is on the use of relevant programs to simulate the flow of traffic on motorways and urban roads, taking into account modern traffic control systems (route control systems and traffic lights) as well as the computer-aided processing and analysis of the underlying traffic data. Structure of the lecture: • Data analysis with Excel / VBA (Visual Basic for Applications) • Traffic simulation with VISSIM and Aimsun • Planning of traffic signal controls with CROSSIG					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Term paper 'Data Analysis and Simulation in Traffic Engineering' (10 h., ungraded)					
Requirements for the award of credit points • Passed module final exam: written exam					
Module applicability • M. Sc. Environmental Engineering • M. Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = 0, ungraded					
Further Information					

Durability and Repair of Concrete Structures Dauerhaftigkeit und Instandsetzung von Betonbauwerken					
Module number BI-WP13/UI-WPC6	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Durability and Repair of Concrete Structures			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. habil. Iurie Curosu a) Prof. Dr.-Ing. habil. Iurie Curosu					
Admission requirements Recommended previous knowledge: Knowledge of construction materials and building physics					
Learning outcome, core skills The students • can explain the diverse effects of the environment on the durability of concrete structures. • can derive prophylactic measures and illustrate approaches to service life assessment. • are able to develop suitable measures to increase the durability of new structures in advance, to investigate any damage that occurs and to design suitable repair concepts.					
Contents a) The physical and chemical effects from the environment and their possible effects on concrete structures are presented (exposure classes, concrete and reinforcement corrosion). In particular, the transport processes within the microstructure and the corrosion processes are discussed. • Potential impacts • Transport of pollutants • Corrosion processes • Prophylactic measures • Probabilistic lifetime design In the event of damage, the structural analyses required for a diagnosis, including suitable test methods, are first presented. Furthermore, appropriate repair measures, in particular the choice of suitable construction materials and repair systems, including their application limits, are explained. Design aspects of the repair and upgrading of concrete structures are also discussed. • Structural investigations and testing methods • Development of repair concepts and repair measures for special design features, e.g. reinforcements In the laboratory exercises, the durability-relevant examination methods and selected repair concepts developed in the lectures are carried out and explained.					
Educational form / Language a) Lecture (3 WLH) / Tutorial (1 WLH) / German					
Examination methods					

• Written exam 'Durability and Repair of Concrete Structures' (90 min., Part of modul grade 100 %)
Requirements for the award of credit points • Passed written examination of the module
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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

Digitalisation in road construction and the basics of railway engineering					
Digitalisierung im Straßenbau und Grundlagen des Schienenverkehrs					
Module number BI-WP29	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Railway Engineering b) Environmental aspects and sustainability in road construction c) Management systems in road construction d) Digitalisation in the planning processes of road infrastructure			Contact hours a) 2 WLH (30 h) b) 1 WLH (15 h) c) 1 WLH (15 h) d) 1 WLH (15 h)	Self-study a) 30 h b) 15 h c) 15 h d) 45 h	Frequency a) each summer b) each summer c) each summer d) each summer
Module coordinator and lecturer(s) Vertr.-Prof.'in Dr.-Ing. Nina Nytus a) Vertr.-Prof.'in Dr.-Ing. Nina Nytus b) Vertr.-Prof.'in Dr.-Ing. Nina Nytus c) Vertr.-Prof.'in Dr.-Ing. Nina Nytus d) Vertr.-Prof.'in Dr.-Ing. Nina Nytus					
Admission requirements Recommended previous knowledge: Road construction and maintenance or environmental technology in road planning and construction					
Learning outcome, core skills After successfully completing the module, students will be able to • design and assess the geometric, mechanical and driving dynamic properties that are important for the routing, construction and operation of railways, • select and evaluate the criteria necessary for the sustainability of a road, • select and check the engineering aspects necessary for management-supported systematic maintenance, • generate the steps necessary for the digitisation process of road planning using computer software.					
Contents a) The course deals with the basic knowledge of railway engineering. In detail, it deals with • legal fundamentals, • economic and social significance of railways in the transport sector, • the superstructure, • the switches, • design of routes, • aspects of driving dynamics, • and the fundamentals of railway operation b) In this course, sustainability in road construction is considered against the background of comprehensive resource conservation. The following topics are covered in detail					

- Legal principles of environmental protection and sustainability
- Life cycle assessment
- Suitability of recycled construction materials and industrial by-products for road construction
- Use of sustainable construction materials
- Environmental compatibility of construction materials
- Aspects of life cycle assessment
- Sustainability assessment criteria

c)

The course deals with the determination of road conditions and road network management in the context of maintenance planning. In detail, it deals with

- Meaning and purpose of management systems
- Data bases and collection of road data
- Systematic condition survey and assessment of roads
- Forecast of maintenance and financial requirements
- Planning of maintenance measures on road pavements
- Work site/construction site management
- Current developments in recording and evaluation technology

d)

This course aims to impart practical skills in the field of digital road planning through the targeted implementation of software training. In detail, the following topics are covered

- Application of typical software tools used in road planning
- Building Information Modelling in road construction.

Educational form / Language

- a) Lecture (1 WLH) / Tutorial (1 WLH) / German
 b) Lecture (1 WLH) / German
 c) Lecture (1 WLH) / German
 d) Seminar / German

Examination methods

- Written exam 'Digitalisation in road construction and the basics of railway engineering' (120 min., Part of modul grade 100 %, written examination on a), b) and c))
- Term paper 'Digitalization in the planning processes of road infrastructure' (30 h., Part of modul grade 0 %, d) Seminar paper (30 hours, submission deadline will be announced at the beginning of the semester)

Requirements for the award of credit points

- Passed final module examination: written examination
- Passed seminar paper

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 roads, material models and practical aspects in road construction technology Dimensionierung, Stoffmodelle und Praxisaspekte in der Straßenbautechnik					
Module number BI-WP28/UI-WPC1	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Design and material models in road construction b) Road construction internship c) Seminar on road construction			Contact hours a) 3 WLH (45 h) b) 1 WLH (15 h) c) 1 WLH (15 h)	Self-study a) 60 h b) 15 h c) 30 h	Frequency a) each winter b) each winter c) each winter
Module coordinator and lecturer(s) Vertr.-Prof.'in Dr.-Ing. Nina Nytus a) Vertr.-Prof.'in Dr.-Ing. Nina Nytus b) Vertr.-Prof.'in Dr.-Ing. Nina Nytus c) Vertr.-Prof.'in Dr.-Ing. Nina Nytus					
Admission requirements Recommended previous knowledge: Pavement Construction and Maintenance or Environmental Engineering in Pavement Construction					
Learning outcome, core skills After successfully completing the module, students will be able to • select, apply and evaluate the material models required for the dimensioning of a road superstructure, • apply the experimental laboratory tests required for the material models themselves and verify and evaluate the test results obtained, • generate and defend the construction contract processes (specifications, quotation and post-calculation) that are important for the practical handling of road construction measures in small groups.					
Contents a) In this lecture series, basic knowledge of mix design and the dimensioning of traffic routes is imparted. The following aspects are highlighted as essential components: • Fundamentals of traffic loads, construction methods and load-bearing capacity • Material models for predicting asphalt performance based on mix properties • Dimensioning of the subgrade and unbound layers • Dimensioning of asphalt roads • Dimensioning of concrete roads • Dimensioning of paving and slab pavements • Special features of airfield construction b) In the form of a laboratory practical lasting several days, students are taught elementary knowledge of asphalt testing technology. The laboratory tests shown in the road construction practical course serve as a					

basis for the dimensioning of asphalt and thus illustrate the elements learnt in the course Dimensioning and material models in road construction. The following content is covered during the practical course:

- Determination of specific parameters of aggregates
- Conventional and performance-orientated test methods for binders
- Requirements for asphalt and asphalt mix production in the laboratory
- Test methods for determining asphalt performance
- Proctor and CBR tests and aggregate composition of unbound layers

c)

After the presentation of the necessary work steps for the realisation of a road construction project by external experts, the students should work on the following contents in small working groups during the seminar:

- Preparation of a bill of quantities based on a practical example
- Carrying out work preparation for a practical example
- Partial calculation of a construction site
- Preparation of a final report
- Presentation of the results

Educational form / Language

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

b) Internship / German

c) Seminar / German

Examination methods

- Written exam 'Design of roads, material models and practical aspects in road construction technology' (120 min., Part of modul grade 100 %, written examination on a) and b) (120 minutes))
- Internship 'Practical training for road construction' (15 h., Part of modul grade 0 %, minutes of the practical course)
- Term paper 'Traffic Infrastructure Engineering - Seminar' (30 h., Part of modul grade 0 %, seminar paper (submission deadline will be announced at the beginning of the semester))

Requirements for the award of credit points

- Passed final module examination: Written examination on a) and b)
- b) Three passed protocols
- c) Passed seminar paper

Module applicability

- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Introduction to Structural Health Monitoring Einführung in Structural Health Monitoring					
Module number BI-WP46	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Introduction to Structural Health Monitoring			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Inka Mueller a) Prof. Dr.-Ing. Inka Mueller					
Admission requirements Recommended previous knowledge: Knowledge of mechanics and mathematics					
Learning outcome, core skills After completion of the module • students will have internalized the concept underlying structural health monitoring. • they will be able to explain and evaluate various methods of structural health monitoring, the physical principles, and the advantages and disadvantages of each method. • Students will be able to place approaches to structural health monitoring in the broader context of engineering and life cycle analysis and validate them. • In particular, they will be able to independently select suitable methods for structural monitoring problems, • outline the basic procedure, and • evaluate existing structural health monitoring concepts.					
Contents a) The concept underlying Structural Health Monitoring (SHM) is introduced and SHM methods are classified according to objectives and physical phenomena. The basic structure and necessary steps for a meaningful SHM system are discussed. At the beginning, mathematical and mechanical fundamentals that are essential for understanding various SHM methods are reviewed and elaborated upon. In particular, there is an introduction to vibrations and waves, as well as an overview of ill-posed inverse problems and possible solutions to these problems. Building on this, various SHM methods are discussed in detail. In particular, this concerns vibration-based methods, strain-based methods, acoustic emission, load monitoring, active wave-based methods, and methods based on electromechanical impedance. In addition to explaining the physical fundamentals and method-specific features, approaches to data processing and metrological implementation are developed using numerical and experimental application examples. Students' own developments and implementations in small groups and as part of study-related tasks enable them to deepen their understanding of the theoretical content. The knowledge acquired and the stumbling blocks in practical implementation are placed in the larger context of condition monitoring and life cycle analysis.					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German / English					

Examination methods

- Oral exam 'Introduction to Structural Health Monitoring' (30 min., Part of modul grade 100 %)
- Term paper 'Development of own SHM solutions' (60 h., Part of modul grade 0 %, Semester project as a study-related task for developing your own SHM solutions in a team, including a final presentation and discussion)

Requirements for the award of credit points

- Passed module final exam: oral exam
- Passed semester assignment with presentation
- Participation in experimental trials in small groups (three dates)

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Exercises in small groups

Introduction to materials modeling Einführung in die Materialmodellierung					
Module number BI-WP49	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Introduction to materials modeling			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Daniel Balzani a) Prof. Dr.-Ing. Daniel Balzani					
Admission requirements Recommended previous knowledge: Mechanics, Foundations of the FEM					
Learning outcome, core skills The students • have basic knowledge of the physical principles of solids and their consequences on the stress-strain response • are able to describe materials from different material classes mathematically using simple material models • understand the concept of internal variables and their evolution equations • are able to derive and implement algorithmic methods for the numerical integration of evolution equations					
Contents a) • Recapitulation of the 3D theory of elasticity • Rheological modeling • Visco-elasticity • Elasto-plasticity • Modeling of damage • Algorithmic treatment of material models • Implementation in Finite-Element programs					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Written exam 'Introduction to materials modeling' (120 min., Part of modul grade 100 %, or oral exam (30 minutes). The form of examination is determined at the beginning of each semester depending on the number of participants)					
Requirements for the award of credit points • Passed final module examination: written or oral examination					
Module applicability • M.Sc. Civil Engineering • B.Sc. Mechanical Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Actions on structures and safety concepts Einwirkungen auf Tragwerke und Sicherheitskonzepte					
Module number BI-P07	Credits 6 CP	Workload 180 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Actions on structures and safety concepts			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Rüdiger Höffer a) Prof. Dr.-Ing. Rüdiger Höffer					
Admission requirements Recommended previous knowledge: Recommended prior knowledge: From bachelor's degree: Mechanics, advanced mathematics, statics and structural engineering, building construction, reinforced concrete and prestressed concrete construction, steel and timber construction Recommended: Participation in the master's module Statistics					
Learning outcome, core skills Students • can explain the background of the first-order reliability method and the partial safety concept, • can apply structural dynamics fundamentals, • can apply the standards for determining effects covered in the lecture in practice, • are able to develop design loads for the ultimate limit state and serviceability limit state of structures.					
Contents a) The course covers applied knowledge for safety concepts primarily used in structural engineering. This includes: • Introduction to the partial safety concept with partial safety factors and combination factors • Characteristic values and design values • Damage consequence classes • First-order reliability method (FORM) for calculating the reliability index beta • Statistical background The course covers the application of the exposure standards introduced by the building authorities as well as other selected regulations. These include: • Loads due to dead weight • Live loads and their application to primary and secondary load-bearing elements • Snow loads on various roof shapes, at height differences, on row roofs, etc. • Wind effects from extreme design winds in wind zones: Design-relevant gust pressure for various terrain categories, extreme value analyses, pressure coefficients for walls and roofs as well as internal pressures, force coefficients for various component cross-sections. • Unusual effects including impact loads • Traffic loads and climatic effects on bridges					

- Bulk material loads on silos

The course covers selected fundamentals of structural dynamics and loads acting on structures. These include:

- Structural dynamic amplification and resonance factors in the time and frequency domain
- Earthquake effects according to DIN EN 1998
- Wind excitation of vibration-prone cantilever structures

Educational form / Language

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

Examination methods

- Term paper 'Actions on structures and safety concepts - Homework' (30 h., Part of modul grade 0 %)
- Written exam 'Actions on structures and safety concepts' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: Written exam
- Term papers

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

Railway engineering Eisenbahnwesen					
Module number BI-W53	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Railway engineering			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Vertr.-Prof.'in Dr.-Ing. Nina Nytus a) Vertr.-Prof.'in Dr.-Ing. Nina Nytus					
Admission requirements The module cannot be selected if BI-WP29 " Digitalisation in road construction and the basics of railway engineering" is taken.					
Learning outcome, core skills After successfully completing this module, students will be able to design and assess the geometric, mechanical and dynamic properties that are important for the routing, construction and operation of railway tracks.					
Contents a) The course deals with the basic knowledge of railway engineering. In detail, it deals with • the legal foundations, • the economic and social significance of railways in the transport sector, • the superstructure, • the switches, • route design, • aspects of driving dynamics, • and the basics of railway operation					
Educational form / Language a) Lecture (1 WLH) / Tutorial (1 WLH) / German					
Examination methods • Written exam 'Railway engineering' (60 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final examination: written exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $2 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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					

Geotechnical calculations and foundation engineering Erdstatik und Grundbau					
Module number BI-WP41	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Calculation Methods in Geotechnics			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. D. König					
Admission requirements Recommended previous knowledge: completed modules in mathematics, mechanics, soil mechanics and foundation engineering					
Learning outcome, core skills The students • have advanced knowledge of calculation methods in soil mechanics and their application to the design of foundation structures, • are able to assess and solve practical geotechnical problems against this background, • can recognize the limits of application of the methods and extend or adapt them to specific boundary conditions.					
Contents a) The course covers the theories of classical calculation methods in soil mechanics and the application of these methods to the design of common foundation structures: • Limit equilibrium calculations, bound theorems of plasticity • Application to stability problems and the calculation of plane and spatial earth pressure • Dependence of shear strength, earth pressure, and earth resistance on deformation • Calculation of excavation pits • Calculation of shallow foundations using the subgrade reaction method					
Educational form / Language a) Lecture (3 WLH) / Tutorial (1 WLH) / German					
Examination methods • Term paper 'Geotechnical calculations and foundation engineering' (45 h., Part of modul grade 100 %, Homework with oral examination)					
Requirements for the award of credit points • Passed module examination: Homework with oral examination					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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

Maintenance and lifetime management for bridges Erhalt und Lebensdauermanagement im Brückenbau					
Module number BI-W29	Credits 2 CP	Workload 60 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Maintenance and lifetime management for bridges			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Prof. Dr.-Ing. Gero Marzahn					
Admission requirements Recommended previous knowledge: Completed modules in fundamentals of Reinforced and Prestressed Concrete Structures, Structural Analysis, Bridge Construction					
Learning outcome, core skills The Students: • Know the challenges of structural maintenance in bridge construction and strategic concepts for dealing with them • Are familiar with the scope, documentation obligations and activities required in the course of structural inspections in accordance with DIN 1076 • Know the guidelines for the recalculation of existing bridges • Knowledge of the requirements of maintenance, rehabilitation and reinforcement and know suitable concepts for this					
Contents a) The course provides an overview of maintenance and service life management in bridge construction. Thematically this includes: • Maintenance management of road bridges - Strategy for the maintenance of road bridges - Life cycle considerations and sustainability - Bridge management system (BMS) • Structural inspection according to DIN 1076 - Legal aspects - Content and scope of the structural inspection - Inspection types, inspection scenarios and inspection documents - Test reports and condition grades • Repair and rehabilitation of road bridges - Typical cases of damage (superstructure, substructure, bearings and transition structures) - Repair techniques (concrete, steel and masonry construction) - Examples of the repair of concrete bridges					

- Examples of the repair of masonry bridges
- Examples of the repair of steel and composite bridges
- Repair of bearings and expansion joints
- Planning steps and tenders for repair procedures
 - Refurbishment of road bridges
- Strategy for long-term refurbishment
- Recalculation of road bridges
- Technology of structural reinforcement (focus on bridge superstructures)
- Realised examples of strengthening measures

Educational form / Language

a) Lecture (2 WLH) / German

Examination methods

- Oral exam 'Maintenance and lifetime management for bridges' (30 min., Part of modul grade 100 %)
- At least 75% attendance

Requirements for the award of credit points

- Oral Exam 'Maintenance and lifetime management for bridges' (30 min., Part of module grade 100%)
- At least 75% attendance

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

Experimental based analysis of structural members Experimentelle Untersuchungen an Tragkonstruktionen					
Module number BI-W08	Credits 2 CP	Workload 60 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Experimental based analysis of structural members			Contact hours a) 2 WLH (30 h)	Self-study a) 0 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing Helen Bartsch a) Dr.-Ing. Hussein Alawieh					
Admission requirements Recommended previous knowledge: Knowledge of steel construction					
Learning outcome, core skills The students • possess in-depth knowledge of the load-bearing behavior of structural components, as well as bolted and welded structural elements. • are capable of designing, conducting, and interpreting experiments to solve engineering-related tasks. • can select appropriate measurement techniques for recording relevant mechanical quantities. • have the ability to transfer their knowledge to independently developed experimental questions.					
Contents a) In the course, experimental investigations are carried out on current research topics, particularly in the following areas: • Bolted connections • Welded connections • End plate joints • Stability failure • Fatigue behavior of components and notch details					
Educational form / Language a) Internship / Tutorial (2 WLH) / German					
Examination methods • Oral exam 'Experimental based analysis of structural members' (30 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final exam: oral exam					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$ 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					
Felsbau					
Module number BI-WP23/SE-CO-24	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Rock Mass Mechanics (177269) b) Rock Engineering (177222) c) Rock Mechanical Lab Training (177251)			Contact hours a) 2 WLH (30 h) b) 2 WLH (30 h) c) 1 WLH (15 h)	Self-study a) 45 h b) 45 h c) 15 h	Frequency a) each summer b) each summer 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 Recommended previous knowledge: Completed modules in mechanics, soil mechanics and foundation engineering					
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 und Versagen von Gestein; Einführung in die Versuchstechnik; Deformation und Versagen von Trennflächen; Gebirgsklassifikationen; Deformation und Versagen von Fels; Charakteristika von Tunneln, Stollen und Felskavernen; Prinzipien des Hohlraumbaus; Gründungen auf Fels und Böschungen aus Fels; Aufgabenstellungen und Messgrößen bei der geotechnisch/geomechanischen Überwachung; felsmechanische numerische Simulation 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 'Felsbau' (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
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

German-language lecture materials will be provided.

Finite Element Methods in Linear Structural Mechanics					
Finite Element Methods in Linear Structural Mechanics					
Module number CE-P05/BI-P08/SE-C-2/ FEM-I	Credits 6 CP	Workload 180 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Finite Element Methods in Linear Structural Mechanics (125507/127012)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency 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) Lecture (2 WLH) / Tutorial (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 [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Finite Element Technology Finite Elemente Technologie					
Module number BI-WP19	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Finite Element Technology			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Daniel Balzani a) Dr.-Ing. Christian Gierden, Prof. Dr.-Ing. Johanna Waimann					
Admission requirements Recommended previous knowledge: Fundamentals of FEM					
Learning outcome, core skills The students • acquire advanced knowledge of finite element methods, particularly with regard to the derivation of reduced integrated and mixed element formulations • are able to design their own element routines or competently use or modify commercial finite element software					
Contents a) • the boundary value problem of linear elastostatics • variational principle, Galerkin method • single- and multifield variational formulations • FEM (basic equations, locking, adaptivity) • reduced integrated elements (hourglassing) • elements with incompatible modes • mixed element formulations • aspects of nonlinear FEM • coupled problems					
Educational form / Language a) Lecture (3 WLH) / Tutorial (1 WLH) / German					
Examination methods • Written exam 'Finite Element Technology' (120 min., Part of modul grade 100 %, or oral examination (30 minutes). The type of examination is determined at the beginning of each semester depending on the number of participants)					
Requirements for the award of credit points • Passed module final exam: written or oral exam					
Module applicability • M.Sc. Civil Engineering • B.Sc. Mechanical Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Zienkiewicz, Taylor, Zhu: The Finite Element Method. Vol.1, Vol. 2

Johnson,: Numerical Solution of Partial Differential Equations by the Finite Element Method

Braess: Finite elements

Brenner, Scott: The Mathematical Theory of Finite Element Methods

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

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

Module number BI-WP10/SE-CO-1	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Design, engineering and technologies in Foundation Engineering and Utility Pipe Construction			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus Thewes a) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. Britta Schößler					
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) Lecture (2 WLH) / Tutorial (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 [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Geotechnics Geotechnik					
Module number BI-P05	Credits 5 CP	Workload 150 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Calculation Methods in Geotechnics			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. D. König					
Admission requirements Recommended previous knowledge: completed modules in mathematics, mechanics, soil mechanics and foundation engineering					
Learning outcome, core skills The students • have advanced knowledge of calculation methods in soil mechanics and their application to the design of foundation structures, • are able to assess and solve practical geotechnical problems against this background, • can recognize the limits of application of the methods and extend or adapt them to specific boundary conditions.					
Contents a) The course covers the theories of classical calculation methods in soil mechanics and the application of these methods to the design of common foundation structures: • Limit equilibrium calculations, bound theorems of plasticity • Application to stability problems and the calculation of plane and spatial earth pressure • Dependence of shear strength, earth pressure, and earth resistance on deformation • Calculation of excavation pits • Calculation of shallow foundations using the subgrade reaction method					
Educational form / Language a) Lecture (3 WLH) / Tutorial (1 WLH) / German					
Examination methods • Term paper 'Geotechnics' (35 h., Part of modul grade 100 %, Homework with oral examination)					
Requirements for the award of credit points • Passed module examination: Homework with oral examination					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $5 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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

Global Water Resources Globale Wasserressourcen					
Module number BI-W37	Credits 3 CP	Workload 90 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Global Water Resources			Contact hours a) 1 WLH (15 h)	Self-study a) 75 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Martina Flörke a) Prof. Dr.-Ing. Martina Flörke					
Admission requirements Recommended previous knowledge: Knowledge of deterministic hydrology, water management					
Learning outcome, core skills Students • learn how to work with scientific publications in the English language and develop an in-depth understanding of descriptive and analytical concepts relating to the issue of global water resources • evaluate knowledge of water availability, shortages or surpluses in terms of their temporal and spatial distribution in different regions of the world and are able to critically discuss the concepts used • analyse global, large-scale interrelationships between climate, globalization, and water budget and can classify small- and large-scale differences • present their findings in summaries and presentations in English (optionally in German) to the other participants and learn scientific discourse.					
Contents a) The overuse of global water resources is already presently shaping the earth's appearance. The seminar deals with the descriptions and developments of approaches for a consistent and comprehensive evaluation of the state of global water resources and the associated ecosystems. The topics are addressed under the aspects of water management and political relevance and are intended to complement the courses "Hydrology" and "Sustainable Water Resources Management." The seminar will focus on topics that change annually. The following content will be covered: • Introduction to Internet-based literature research and computer-assisted literature management • Compilation of fundamental scientific publications on current water management topics (e.g., conflicts of use, transboundary river basins, long-distance effects) • Conducting literature research individually • Leading a scientific discussion, as is customary at conferences, for example.					
Educational form / Language a) Seminar / German					
Examination methods • Seminar 'Global Water Resources' (30 h., Part of modul grade 100 %)					

- Writing a summary of the topic (max. 2 pages) in English (15 hours, deadline to be announced at the beginning of the semester)
- Presentation on the topic (20 minutes) and Discussion (10 minutes) (15 hours, date to be announced at the beginning of the semester)
- Summary of the discussion (Report)

Requirements for the award of credit points

- Passed module final exam (writing a summary of the topic, presentation on the topic, discussion, and summary of the discussion)

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

Individual or group work (2 people) depending on the number of participants

Fundamentals of automation technology Grundlagen der Automatisierungstechnik					
Module number BI-WP53	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Fundamentals of automation technology			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Bernd Kuhlenkötter a) Prof. Dr.-Ing. Bernd Kuhlenkötter					
Admission requirements					
Learning outcome, core skills Objective: - Students should be able to explain current developments and trends in automation technology, describe development processes for automated technical systems, and apply the corresponding development methods. - By completing the course, they should be able to explain the functional principle and hardware structure of a PLC and work on automation tasks in the field of PLC and NC programming using a methodical approach. - In addition, they should acquire the knowledge to critically evaluate robot systems for use in various automation tasks, select suitable systems, and assess the safety risks of automation technology. Knowledge: - Students are familiar with the essential methods and procedures of engineering/mechanical engineering, have the relevant technical vocabulary, and know examples of applications. - Students have in-depth knowledge of the fundamentals of engineering in their area of specialization. Skills: - Students have the ability to think critically and in a networked manner. - Students practice initial approaches to scientific learning and thinking. - Students can model and solve engineering problems. - Students can solve complex mathematical problems in physical systems (interdisciplinary if necessary) using appropriate methods. - Students have developed their ability to think critically and in a networked manner and are able to select and apply established methods and procedures. Competencies: - Students have interdisciplinary methodological competence. - Students can transfer knowledge/skills to specific mechanical engineering/engineering problems.					
Contents a) The lecture "Fundamentals of Automation Technology" (GdA) presents topics related to industrial automation with a focus on industrial robotics. Basic areas of application, such as the use of industrial robotics in painting lines or welding applications, are presented alongside the historical development of					

automation technology. One focus of the lecture is on PLC and NC/CNC controllers, which are frequently used for automation tasks. In addition to explaining the hardware structure and operating principle of a PLC, students create their own PLC programs in exercises accompanying the lecture. Within the control systems, signal processing plays an essential role, from the acquisition of sensor signals to processing and output, as well as the type of communication between the data. Furthermore, project processes and plans for exemplary automated processes are developed with the students during the lecture. Another focus of the lectures and exercises is on teaching the fundamentals of industrial robotics. The course begins by presenting the development of industrial robotics. It then goes on to teach the essential components of a robot system and introduces various types of industrial robots and their areas of application in automation technology. The basic functioning of robot controllers is explored in greater depth in further lectures and practical sessions. The course concludes with an introduction to the fundamentals of communication technology, sensor technology, and safety technology in the field of automation. The content of the lecture prepares students for work as automation engineers. Lectures by guest speakers from industry and research highlight practical application examples from automation technology, thus complementing the course. Exercises serve to further deepen the material covered in the lectures.

Educational form / Language

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

Examination methods

- Written exam 'Fundamentals of automation technology' (180 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: Written exam

Module applicability

- M.Sc. Civil Engineering
- B.Sc. MEchanical Engineering
- B.Sc. Sales Engineering and Product Management

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

Foundations of dynamics Grundlagen der Dynamik					
Module number BI-WP18	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Foundations of dynamics			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Johanna Waimann a) Prof. Dr.-Ing. Daniel Balzani, Prof. Dr.-Ing. Johanna Waimann					
Admission requirements Recommended previous knowledge: knowledge of Engineering Mechanics (statics and elastostatics) and Mathematics from the Bachelor studies					
Learning outcome, core skills The students • are familiar with the terminology and ways of thinking regarding the dynamics of rigid bodies that are essential for advanced courses, • are able to describe and mathematically analyze the state of motion of particles and spatially extended bodies based on the forces and moments acting on them.					
Contents a) • Kinematics of particles: representation in different coordinate systems • Kinetics of particles: one-dimensional and general free and guided movements • Kinematics of rigid bodies: combination of translation and rotation, instantaneous center of rotation • Kinetics of rigid bodies: mass moments of inertia, principle of linear and angular momentum, balance of energy • Planar motion of rigid bodies: kinematics, motion around a fixed axis, general motion • Elementary theory of impact: central impact, general impact processes • Spatial motion of rigid bodies including gyroscopic theory • Oscillations with one and two degrees of freedom • Hamilton's principle The lecture is supplemented by numerous applications and examples					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Written exam 'Foundations of dynamics' (120 min., Part of modul grade 100 %, or oral examination (30 minutes). The type of examination is determined at the beginning of each semester depending on the number of participants) • Term paper 'Foundations of dynamics - Homework' (30 h., Part of modul grade 0 %)					
Requirements for the award of credit points					

- Passed module final exam: written or oral exam
- Passed term paper

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Fundamentals of System Dynamics Grundlagen der Dynamik von Systemen					
Module number BI-WP20	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Fundamentals of System Dynamics			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Tamara Nestorovic a) Prof. Dr. Tamara Nestorovic					
Admission requirements Recommended previous knowledge: Knowledge of advanced mathematics (e.g., from a bachelor's degree); advanced knowledge of mechanics (dynamics)					
Learning outcome, core skills Students have acquired basic knowledge and are able to • calculate dynamically stressed structures • analyze phenomena occurring in such structures • approximate important parameters • understand and independently work on standard tasks • apply their knowledge to specific engineering problems					
Contents a) Formulation of differential equations of motion for discrete and continuous structures; eigenvalue problem; harmonic analysis; Rayleigh and Grammel quotients; Dunkerley method; vibration damping; phenomena occurring in dynamically stressed systems (critical speeds, imbalance); Fundamentals of measurement data acquisition and processing for experimental modal analysis of vibrating structures.					
Educational form / Language a) Lecture (3 WLH) / Tutorial (1 WLH) / German					
Examination methods • Written exam 'Fundamentals of System Dynamics' (180 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final exam: Written exam					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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					

High-Performance Computing on Clusters High-Performance Computing on Clusters					
Module number BI-WP55/SE-O-9	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) High-Performance Computing on Clusters			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency 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) Lecture (2 WLH) / Tutorial (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. Civil Engineering • M.Sc. Applied Computer Science • M.Sc. Subsurface Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 BI-WP56/CE-WP25/SE-O-8	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) High-Performance Computing on Multicore Processors (126509)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency 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) Lecture (2 WLH) / Tutorial (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 [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Buildings and industrial structures Hoch- und Industriebau					
Module number BI-WP04	Credits 9 CP	Workload 270 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Industrial, environmental protection and building structures made of concrete b) Building and industrial construction in steel and composite construction			Contact hours a) 3 WLH (45 h) b) 3 WLH (45 h)	Self-study a) 90 h b) 90 h	Frequency a) each winter b) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Dr.-Ing. Markus Obel, Prof. Dr.-Ing. Peter Mark b) Vertr.-Prof.'in Dr.-Ing. Rebekka Winkler					
Admission requirements Recommended previous knowledge: Completed modules 'Prestressing and non-linear calculations of concrete structures', 'Nonlinear Design Methods of Steel and Composite Structures'					
Learning outcome, core skills The Students: • have a basic knowledge of the design and construction of buildings and industrial structures, • know characteristic components and common load-bearing systems consisting of beam, frame and wall-like load-bearing elements, • are aware of the importance of cores, walls and bracing to stiffen buildings and systems, • are able to independently solve design, calculation and dimensioning tasks in the field of structural and industrial engineering.					
Contents a) The course on industrial, environmental protection and building structures provides the basic knowledge for the design, dimensioning and structural design of buildings in concrete construction. This includes: • Hall buildings • Administrative buildings • WU structures • Liquid-tight containment structures for environmental protection • Fundamentals of design • Types of support systems • Bracing systems, spatial stiffness and stability • Prestressing and reinforcement, structural detailing • Design and verification in the serviceability and ultimate limit states b)					

The course on building and industrial construction in steel and composite construction provides the basic knowledge for the design, dimensioning and structural design of buildings in steel and composite construction. This includes:

- Multi-storey / office buildings
- Long-span truss girders
- Grandstand and platform roofs
- Aircraft hangars
- Design and construction of composite beams
- Car parks/car dealerships
- Power stations/power houses
- Load transfer, design, dimensioning and structural realisation

Educational form / Language

a) Lecture with tutorial / German

b) Lecture with tutorial / German

Examination methods

- Written exam 'Buildings and industrial structures' (150 min., Part of modul grade 100 %)
- Term paper 'Buildings and industrial structures - Homework' (35 h., Part of modul grade 0 %, deadline will be announced at the beginning of the semester)

Requirements for the award of credit points

- Passed final module examination: written examination
- Passed homework

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $9 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

Hydrology Hydrologie					
Module number BI-WP34/UI-WPD2	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Deterministic hydrology/modeling technology b) Hydrometry practical seminar			Contact hours a) 3 WLH (45 h) b) 1 WLH (15 h)	Self-study a) 60 h b) 60 h	Frequency a) each summer b) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Martina Flörke a) Prof. Dr.-Ing. Martina Flörke b) Prof. Dr.-Ing. Martina Flörke					
Admission requirements Recommended previous knowledge: Knowledge of advanced mathematics, fluid mechanics, fundamentals of hydrology, and water management					
Learning outcome, core skills Students • acquire fundamental knowledge of the most important procedures and methods for establishing hydrological statements on a deterministic basis • learn the methodological basics of modelling using exemplary applications and design mathematical models to solve hydrological and water management problems • evaluate independently collected data using measurement methods for hydrological and hydraulic variables in the laboratory and in the field • independently adopt a professional perspective and devise application-oriented problems and solutions.					
Contents a) The course deals with procedures and methods for determining the available water supply and for recording and describing the runoff process in catchment areas and river sections on a causal-deterministic basis. Furthermore, deterministic models from the field of hydrological engineering and water management are discussed. The following topics are covered in detail: • Recording and describing the spatial heterogeneity of climatic factors • Physical principles for describing the groundwater balance • Accounting for the combined effects of soil and vegetation in evaporation calculations • Methods for calculating the regional water budget and groundwater recharge • Description of runoff formation during flooding • Runoff concentration models: translation approaches, storage-translation models, • Flood wave propagation models for river courses: translation-diffusion models, numerical solution with simplified Saint-Venant equations (kinematic wave) • Methodology for flood assessment on a deterministic basis • Scaling problems: measurement scales, process scales and model scales					

- Examples of precipitation-runoff models, water balance models
- Methods for model calibration and validation
- Model and parameter uncertainties.

b)

The practical course focuses on the use of hydrological measuring instruments in the laboratory and in the field. The course takes place in groups that carry out and evaluate measurements several times during the semester under supervision.

Specifically, these include:

- Flow measurements: use of the current meter for flow velocity measurements, salt dilution measurements
- Soil moisture measurements with TDR probes
- Permeability measurements, Darcy experiment
- Measurement of infiltration capacity using the double ring infiltrometer
- Operation and evaluation of rain gauges.

The lecture is divided into two main areas: the description of the water balance, considering the complex interactions of climatic, pedological and vegetation-specific factors, and methods for calculating floods in catchment areas and river sections.

In the practicals, the various methods are studied using practical examples. Computer exercises are necessary to master the modelling techniques. Various models with corresponding data sets are available for this purpose, which can be used by students in the faculty's CIP pool.

Educational form / Language

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

b) Internship / German

Examination methods

- Term paper 'Hydrometry practical seminar' (30 h., Part of modul grade 0 %, submission deadline to be announced at the beginning of the semester)
- Written exam 'Hydrology' (90 min., Part of modul grade 100 %)

Optional Moodle online test to assess learning progress and earn bonus points (5 hours, starting halfway through the semester)

Optional online Moodle quiz to assess learning progress and earn bonus points (5 hours, halfway through the semester)

Requirements for the award of credit points

- Passed module final exam: Written exam
- Passed term paper (hydrometry practical)

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

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Further Information

Hydrological Processes Hydrologische Prozesse					
Module number BI-W38	Credits 3 CP	Workload 90 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Hydrological Processes			Contact hours a) 1 WLH (15 h)	Self-study a) 75 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Martina Flörke a) Dr. rer. nat. Hans Dürr					
Admission requirements Recommended previous knowledge: Knowledge of deterministic hydrology, mass transport in catchment areas					
Learning outcome, core skills Students • learn how to work with scientific publications in English and develop an in-depth understanding of concepts for describing and analyzing hydrological processes • evaluate knowledge from various subject areas and can critically discuss the methods used • present their findings in summaries and lectures in English (optionally in German) to the other participants and learn scientific discourse.					
Contents a) The seminar deals with hydrological theories and process descriptions in addition to the courses 'Hydrology' and 'Material Transport in Catchment Areas'. The topics change annually. The following content will be covered: • Introduction to internet-based literature research and computer-assisted literature management • Development of fundamental scientific publications on different theories (benchmark papers) • Conducting literature research individually • Leading a scientific discussion, as is customary at conferences, for example.					
Educational form / Language a) Seminar / German / English					
Examination methods • Seminar 'Hydrological Processes' (30 h., Part of modul grade 100 %) • Writing a summary of the topic (max. 2 pages) in English (15 hours, Deadline to be announced at the beginning of the semester) • Presentation on the topic (20 minutes) and Discussion (10 minutes) (15 hours, date to be announced at the beginning of the semester) • Summary of the discussion (Report)					
Requirements for the award of credit points • Passed module final exam (writing a summary of the topic, presentation on the topic, discussion, and summary of the discussion)					

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Individual or group work (2 people) depending on the number of participants

Advanced Mechanics of Materials Höhere Festigkeitslehre					
Module number BI-WP17	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Advanced Mechanics of Materials			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Johanna Waimann a) Prof. Dr.-Ing. Johanna Waimann, Dr.-Ing. Ulrich Hoppe					
Admission requirements Recommended previous knowledge: Knowledge of mechanics from bachelor's degree program					
Learning outcome, core skills The students acquire the required basic knowledge to mathematically formulate and analytically or numerically solve mechanical problems of elastostatics in general and for plates and panels					
Contents a) - stress state and equilibrium condition - deformation und strain - law of elasticity, anisotropy, isotropy - plane stress state, plane strain state, stress functions, plate equation, rotation symmetrical problems, examples of application - plate theory, examples of application - torsion: fundamental equation, warp function, examples of application - shape change energy, principle of work and energy, principle of virtual displacements, Ritz method, examples of application					
Educational form / Language a) Lecture (3 WLH) / Tutorial (1 WLH) / German					
Examination methods Written exam 'Advanced Mechanics of Materials' (120 min., Part of modul grade 100 %, or oral examination (30 minutes). The type of examination is determined at the beginning of each semester depending on the number of participants). The examination is during the semester.)					
Requirements for the award of credit points Passed module final exam: written or oral exam					
Module applicability - M.Sc. Civil Engineering - B.Sc. Mechanical Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$					

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

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

Industrialised construction Industrielles Bauen					
Module number BI-W13	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Industrialised construction			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Dr.-Ing. Julian Meyer					
Admission requirements Recommended previous knowledge: Completed modules in fundamentals of Reinforced and Prestressed Concrete Structures, Structural Analysis					
Learning outcome, core skills The Students: • have basic knowledge of industrial construction • gain initial orientation with regard to their own future fields of activity in the construction industry					
Contents a) The course provides basic knowledge of industrial construction. This includes: • Definition and delimitation of the term 'industrial construction' • Presentation of modern technical manufacturing processes • Boundary conditions and characteristics of production in plants or factories, series and mass production • Requirements of performance and growth orientation • Division of labour and work processes in organisational structures • Product design according to technical, economic, functional and aesthetic aspects					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Oral exam 'Industrialised construction' (30 min., Part of modul grade 100 %) • At least 75% attendance					
Requirements for the award of credit points • At least 75% attendance • Passed final module examination: oral examination					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$ 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	
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Inelastic Finite Element Methods for Structures					
Inelastic Finite Element Methods for Structures					
Module number BI-WP59/CE-WP06/SE-CO-20	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Inelastic Finite Element Methods for Structures (127518)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
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 Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Innovations in Urban Water Management and Mathematical Simulation Innovationen in der Siedlungswasserwirtschaft und mathematische Simulation					
Module number BI-WP38/UI-WPD6	Credits 6 CP	Workload 180 h	Semester[s] 2./3. Sem.	Duration 2 Semester[s]	Group size no limitation
Courses a) Innovations in Urban Water Management b) Simulation of Wastewater Treatment Plants c) Computer Lab: Simulation Models			Contact hours a) 2 WLH (30 h) b) 1 WLH (15 h) c) 2 WLH (30 h)	Self-study a) 60 h b) 15 h c) 30 h	Frequency a) each winter b) each summer c) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Marc Wichern a) Prof. Dr.-Ing. Marc Wichern b) Dr.-Ing. Manfred Lübken c) Dr.-Ing. Manfred Lübken					
Admission requirements Recommended previous knowledge: Siedlungswasserwirtschaft					
Learning outcome, core skills The students • are familiar with new procedures and methods for planning and optimisation of systems in urban water management. • have the ability to define relevant measures for climate protection, energy issues and sustainability in the context of urban water management, • have the ability to critically assess these systems and to evaluate and reflect on research findings in this area, • are able to transfer findings from urban water management to specific and new problems, • know the basics of dynamic simulation in wastewater treatment and can relate their knowledge to practical applications in wastewater treatment, • know how established mathematical models are used to model key processes and process variables in biochemical wastewater treatment, • have an overview of the possibilities of using simulation and dimensioning models in biochemical wastewater treatment, • are able to create model plants and validate them based on practical case studies.					
Contents a) The course deals with research-relevant topics such as • Energy consumption and greenhouse gases on wastewater treatment plants • Sustainable systems and closed cycles • Energy generation from wastewater and renewable raw materials • new processes of nitrogen elimination (deammonification) • pathways from wastewater to drinking water • Aerobic granules and the use of biofilm processes					

- Elimination of trace substances

b)

The course focuses on

- a detailed understanding of the chemical, physical and microbiological processes of modern wastewater treatment, which are realised by efficient technical engineering systems.
- the presentation of methods required for the development of simulation models.

c)

In the course

- static and dynamic simulation models for wastewater treatment plants are explained.
- the SIMBA# programme is used as simulation software for this purpose.
- the relevant biochemical processes and hydraulic aspects of municipal wastewater treatment are described in the mathematical models.
- the implementation and calibration of models and sample calculations support the understanding of wastewater treatment processes.

Educational form / Language

a) Lecture (2 WLH) / German

b) Lecture (1 WLH) / German

c) Tutorial (2 WLH) / German

Examination methods

- Oral exam 'Innovations in Urban Water Management and Mathematical Simulation' (60 min., Part of modul grade 100 %, Oral exam every semester)
- Term paper 'Computer exercise Simulation models' (15 h., Part of modul grade 0 %, Submission each semester)

Requirements for the award of credit points

- Passed module final exam: oral exam
- Passed report on computer exercise
- Attendance: for c) will be announced at the beginning of the semester

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

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Further Information

This module can be recognized as part of the RUB sustainability certificate.

International Wastewater Treatment, Industrial Wastewater Treatment and River Water Quality Internationale Siedlungswasserwirtschaft, industrielle Abwasserreinigung und Gewässergüte					
Module number BI-WP37/UI-WPD4	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) International Wastewater Treatment b) Industrial wastewater treatment c) River Water Quality			Contact hours a) 2 WLH (30 h) b) 1 WLH (15 h) c) 1 WLH (15 h)	Self-study a) 60 h b) 30 h c) 30 h	Frequency a) each summer b) each summer c) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Marc Wichern a) Prof. Dr.-Ing. Marc Wichern b) Prof. Dr.-Ing. Burkhard Teichgräber c) Prof. Dr.-Ing. Marc Wichern					
Admission requirements Recommended previous knowledge: Urban water management					
Learning outcome, core skills The students • have a comprehensive overview of the current state of technology and science in the field of international urban water management, • know adapted technical solutions for drinking water treatment and wastewater treatment in other European countries as well as the basics for calculating and operationally optimising these processes, • are familiar with integrated processes for wastewater treatment and know why cycle-orientated processes play an important role. • are familiar with the special features of industrial wastewater and have a comprehensive overview of the current state of the art in the field of biological wastewater treatment, • are familiar with processes for pre-treatment and chemical treatment of industrial wastewater, • are able to develop solutions and plan holistic concepts. • know the characteristics of the material balance of water bodies and understand the biochemical turnover processes involved, • know what influence selective and diffuse discharges of wastewater have on water quality • are able to assess water quality on the basis of the EU-WRRL • are familiar with models to describe the condition of water bodies and are able to critically assess the results, • are able to recognise water body problems, develop integrative solutions and improve the status of water bodies in accordance with the EU-WRRL					
Contents a) The course addresses the development of solutions for drinking water treatment and wastewater purification in the context of challenges faced in non-European countries. These include:					

- Development of sustainable concepts and utilisation of wastewater as a resource
- Utilisation of methods for the evaluation of sustainable solutions
- In-depth consideration and operational optimisation of various internationally used process technologies such as activated sludge processes, anaerobic technology, soil filters and pond systems.
- Development of solutions for drinking water treatment and resource-conserving waste management

b)

The course provides an overview of processes in industrial wastewater treatment. Topics include:

- Special features of biological treatment including the pre-treatment of industrial wastewater for discharge into the public sewerage system
- Chemical treatment of special industrial wastewater
- Explanation of special aerobic and anaerobic wastewater treatment options using selected examples.

c)

The course provides an insight into the ecological principles of water bodies, water characteristics and the material balance. The following topics are covered in detail:

- Impairment of water bodies through the discharge or impact of pollutants
- Modelling the quality of water bodies and developing solutions to improve water quality
- Methods for the integrative consideration of water bodies, sewers, sewage treatment plants and agriculture and the development of solutions

Educational form / Language

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

b) Lecture (1 WLH) / German

c) Lecture (1 WLH) / German

Examination methods

- Written exam 'International Wastewater Treatment, Industrial Wastewater Treatment and River Water Quality' (150 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: Written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

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Further Information

Introduction to advanced numerical methods for particulate media					
Introduction to advanced numerical methods for particulate media					
Module number SE-O-16	Credits 3 CP	Workload 90 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Introduction to advanced numerical methods for particulate media (125817)			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency 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 [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

Climate-Resilient Urban Planning Klimaresilienter Städtebau					
Module number BI-W76	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Climate-Resilient Urban Planning			Contact hours a) 1 WLH (15 h)	Self-study a) 45 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Justin Geistefeldt a) Dr.-Ing. Sandra Hohmann					
Admission requirements Recommended previous knowledge: Design of transportation facilities					
Learning outcome, core skills Students are able to • develop a qualitative understanding of the impacts of climate change on urban areas and the underlying relationships and processes, • demonstrate in-depth knowledge of the role of urban greening for microclimate regulation and of water-sensitive urban design as an approach to climate adaptation, • understand the challenges of soil sealing and apply techniques for de-sealing urban surfaces, • become familiar with concepts such as Blue-Green Streets as well as sustainable and participatory urban planning approaches, • examine practical case studies to understand different urban planning and mobility concepts and transfer these insights to other contexts.					
Contents a) The course provides strategies for how cities can adapt to the impacts of climate change. It focuses on nature-based solutions such as urban greening, water-sensitive urban design, and the de-sealing of surfaces to improve the urban climate and enhance resilience. In addition, innovative concepts such as Blue-Green Streets and sustainable mobility strategies are addressed. A key aspect of the module is interdisciplinary and participatory urban planning, which promotes active community involvement. International case studies are used to illustrate successful implementations in different cities.					
Educational form / Language a) Lecture (1 WLH) / German					
Examination methods • Term paper 'Climate-Resilient Urban Planning' (30 h., Part of modul grade 100 %, Term paper with presentation and final discussion)					
Requirements for the award of credit points • Passed module final exam: Term paper with presentation and final discussion					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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:

- Richtlinien für die Anlage von Stadtstraßen (RASt). Forschungsgesellschaft für Straßen- und Verkehrswesen (Hrsg.), 2006.
- Ergänzende Handlungsanleitungen zur Anwendung der RASt 06. Forschungsgesellschaft für Straßen- und Verkehrswesen (Hrsg.), 2024.

Contact-Based Sensors for Structural and Environmental Monitoring					
Kontaktierende Sensorik für Bauwerks- und Umweltmonitoring					
Module number BI-W77	Credits 3 CP	Workload 90 h	Semester[s] ab dem 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Contact-Based Sensors for Structural and Environmental Monitoring			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each winter
Module coordinator and lecturer(s) Dr.-Ing. Christoph Baer a) Dr.-Ing. Christoph Baer					
Admission requirements Recommended previous knowledge: Basic knowledge of mathematics, physics, and engineering fundamentals at bachelor's level is recommended. Prior knowledge of electrical engineering or measurement technology is helpful but not required.					
Learning outcome, core skills Students acquire fundamental knowledge of the design, operating principles, and applications of contact-based sensor systems in civil and environmental engineering. Upon successful completion of the module, students will be able to: • describe and analyse measurement chains from the physical quantity being measured to digital data processing, • understand fundamental principles of signal conditioning and signal digitization, • assess typical error sources, uncertainties, and interference effects in measurement systems, • select appropriate sensors for different monitoring tasks in structural and environmental applications, • critically interpret measurement results with regard to their significance and limitations, • apply contact-based sensors for measuring mechanical, thermal, and environmental parameters in structures and infrastructure systems.					
Contents a) • Fundamentals of measurement chains and instrumentation systems • Electrical fundamentals of sensor systems • Signal conditioning and digitization of measurement signals • Measurement errors, uncertainty analysis, calibration, and long-term stability • Strain gauges for strain and stress measurements • Pressure sensors for monitoring structures, pipelines, and water infrastructure • Flow sensors for applications in water and environmental systems • Temperature and humidity sensors for structural and environmental monitoring • Inductive and capacitive displacement sensors for deformation and settlement measurements • MEMS-based acceleration and inclination sensors for vibration and structural condition monitoring • Selection, design, and evaluation of sensor systems for monitoring applications					
Educational form / Language					

a) Lecture with tutorial / German

Examination methods

- Oral exam 'Contact-Based Sensors for Structural and Environmental Monitoring' (30 min., Part of modul grade 100 %, Participation in the expert-group format may be considered as a bonus component.)

Requirements for the award of credit points

- Successful completion of the oral module examination

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

- Lectures with integrated problem-solving and conceptual exercises
- Demonstration experiments using selected sensor technologies
- Analysis and interpretation of exemplary measurement data

Optionally, an expert-group format is offered in which student teams work on an advanced sensor topic and present their topic at the end of the semester.

Continuum Mechanics Kontinuumsmechanik					
Module number BI-WP16	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Continuum Mechanics			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Daniel Balzani a) Prof. Dr.-Ing. Daniel Balzani					
Admission requirements Recommended previous knowledge: Mechanics B					
Learning outcome, core skills The students • can describe deformations of general, three-dimensional, deformable material bodies • are able to describe the internal stress states of material bodies • have a sound knowledge of the basic laws of physics for the description of solids • can derive closed equation systems for the solution of thermo-mechanical boundary value problems on the basis of these principles					
Contents a) • Foundations of tensor calculus • Kinematic relations • Deformation and rates of deformation • Stress concept • Balance laws • Foundation of material modeling					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Written exam 'Continuum Mechanics' (120 min., Part of modul grade 100 %, or oral exam (30 minutes). The form of examination is determined at the beginning of each semester depending on the number of participants)					
Requirements for the award of credit points • Passed final modul examination: written or oral examination					
Module applicability • M.Sc. Civil Engineering • M.Sc. Mechanical Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$					

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

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

Artificial Intelligence Künstliche Intelligenz					
Module number BI-WP51	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size 300
Courses a) Introduction to Artificial Intelligence			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr. Laurenz Wiskott a) Prof. Dr. Laurenz Wiskott					
Admission requirements Recommended previous knowledge: Basic knowledge of calculus and linear algebra					
Learning outcome, core skills After successful completion of this course, students will be able to • summarize a number of fundamental methods in artificial intelligence, • explain their mathematical basis and algorithmic nature, • apply them to simple problems, • decide which methods are suitable for which problems, and • communicate about the all that in English.					
Contents a) This course gives an overview over representative methods in artificial intelligence: formal logic and reasoning, classical methods of AI, probabilistic reasoning, machine learning, deep neural networks, computational neuroscience, neural dynamics, perception, natural language processing, robotics.					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / English					
Examination methods • Written exam 'Artificial Intelligence' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passing grade on final written exam					
Module applicability • MSc Bauingenieurwesen					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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 This course is given with the flipped/inverted classroom concept. The students work through online material beforehand and this will then be deepened in the contact sessions, which will be used for an interactive exchange between students and with the lecturer in a flexible format.					

Master Thesis Masterarbeit BI					
Module number BI-MA	Credits 30 CP	Workload 900 h	Semester[s] 4. Sem.	Duration 6 Monate	Group size no limitation
Courses a) Master Thesis			Contact hours	Self-study a) 900 h	Frequency a) each sem.
Module coordinator and lecturer(s) Alle Professorinnen und Professoren des Studiengangs a) Alle Professorinnen und Professoren des Studiengangs					
Admission requirements Those who can verify that they have successfully completed modules worth at least 70 LP may be admitted to the master's thesis.					
Learning outcome, core skills Students • can independently develop a topic from the field of civil engineering using scientific methods within a specified period of 6 months (900 working hours), • are able to research and understand international literature, • can overview the interrelationships of the subject • have the ability to work on problems in their specialized field using scientific methods and apply scientific findings, • can prepare technical topics appropriately and present them in a comprehensible manner during the corresponding presentation, • will acquire the necessary specialist knowledge for the transition to professional life while working on their master's thesis.					
Contents a) The master's thesis can be theoretical, practical, constructive, or organizational in nature. The topic is determined by the examiner. The results must be presented in detail in written and visual form. This includes, in particular, a summary, an outline, and a list of the literature used in the thesis.					
Educational form / Language a) Final thesis / German / English					
Examination methods • Final thesis 'Master Thesis' (900 h., Part of modul grade 100 %, with final presentation)					
Requirements for the award of credit points • Passed thesis • Completed presentation					
Module applicability • M.Sc. Civil 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

Mathematical Statistics Mathematische Statistik					
Module number BI-P02/UI-P1	Credits 5 CP	Workload 150 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Mathematical Statistics			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Holger Dette a) Prof. Dr. rer. nat. N. Bissantz					
Admission requirements Recommended previous knowledge: Knowledge of advanced mathematics					
Learning outcome, core skills Students acquire in-depth knowledge of essential methods of mathematical statistics closely related to engineering applications.					
Contents a) The lecture begins with a brief review of the fundamentals of probability theory and statistics taught in the Mathematics C lecture. The most important probability distributions and parameter estimation methods are presented. Other topics include goodness-of-fit tests and confidence intervals. From multivariate statistics, multivariate regression and model selection, analysis of variance, principal component analysis, and factor analysis are covered. From the field of extreme value theory, the most important extreme value distributions and the associated parameter estimation methods will be presented. Another chapter covers the fundamentals of time series analysis, including trend and seasonal effect estimation, ARMA models, and spectral analysis. Since the focus is on the practical application of the methods, exercises will be combined with homework assignments, some of which will be completed using the statistical program R.					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods - Written exam 'Mathematical Statistics' (90 min., Part of modul grade 100 %, inklusive Multiple Choice Fragen, für die ein Anteil von maximal 50% der Punkte vergeben wird) - Homework (optional): 30 hours of independent study					
Requirements for the award of credit points Passed module final exam: Written exam					
Module applicability - M.Sc. Civil Engineering - M.Sc. Environmental Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$ 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

Mechanics C Mechanik C					
Module number BI-P03	Credits 5 CP	Workload 150 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Mechanics C			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Johanna Waimann a) Prof. Dr.-Ing. Daniel Balzani, Prof. Dr.-Ing. Johanna Waimann					
Admission requirements Recommended previous knowledge: knowledge of Engineering Mechanics (statics and elastostatics) and Mathematics from the Bachelor studies					
Learning outcome, core skills The students • are familiar with the terminology and ways of thinking regarding the dynamics of rigid bodies that are essential for advanced courses, • are able to describe and mathematically analyze the state of motion of particles and spatially extended bodies based on the forces and moments acting on them.					
Contents a) • Kinematics of particles: representation in different coordinate systems • Kinetics of particles: one-dimensional and general free and guided movements • Kinematics of rigid bodies: combination of translation and rotation, instantaneous center of rotation • Kinetics of rigid bodies: mass moments of inertia, principle of linear and angular momentum, balance of energy • Planar motion of rigid bodies: kinematics, motion around a fixed axis, general motion • Elementary theory of impact: central impact, general impact processes • Spatial motion of rigid bodies including gyroscopic theory • Oscillations with one and two degrees of freedom • Hamilton's principle The lecture is supplemented by numerous applications and examples.					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Written exam 'Mechanics C' (120 min., Part of modul grade 100 %, or oral examination (30 minutes). The type of examination is determined at the beginning of each semester depending on the number of participants)					
Requirements for the award of credit points • Passed module final exam: written or oral exam					

Module applicability
• M.Sc. Civil Engineering • B.Sc. Mechanical Engineering
Weight of the mark for the final score Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$ 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

Stormwater Treatment Misch- und Regenwasserbehandlung					
Module number BI-W36	Credits 3 CP	Workload 90 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Stormwater Treatment			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Marc Wichern a) Dr.-Ing. Klaus Hans Pecher					
Admission requirements Recommended previous knowledge: Urban water management I					
Learning outcome, core skills The students • know the functions and different elements of a sewer network for the discharge of wastewater, • are familiar with analytical and numerical methods for rainfall-runoff-calculations, • are able to name the functions of decentralised and near-natural rainwatertreatment and to dimension the structures, • have a basic understanding of sustainable processes in wastewater treatment.					
Contents a) The course deals with concepts for the planning of sewer networks and stormwater treatment systems. This includes: • Function and structure of individual elements of the sewerage system • Sewer calculation methods • Hydraulic rehabilitation of existing sewer networks • Methods and concepts of decentralised rainwater treatment • Economic efficiency calculations					
Educational form / Language a) Lecture (1 WLH) / Tutorial (1 WLH) / German					
Examination methods • Written exam 'Stormwater Treatment' (60 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final exam: Written exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $3 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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

Sustainable Water Resources Management Nachhaltige Wasserbewirtschaftung					
Module number BI-WP33/UI-WPD1	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) River basin management b) Water budget modeling			Contact hours a) 2 WLH (30 h) b) 2 WLH (30 h)	Self-study a) 30 h b) 90 h	Frequency a) each winter b) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Martina Flörke a) Prof. Dr.-Ing. Martina Flörke b) Prof. Dr.-Ing. Martina Flörke					
Admission requirements Recommended previous knowledge: Completed module in Fundamentals of Hydrology and Water Management, Hydrology module					
Learning outcome, core skills Students • apply the fundamentals of water management planning as part of the administration of water resources • demonstrate an interdisciplinary understanding of problems and methodological competence in relation to the application of water budget modelling • independently develop solutions for challenging water management tasks and assess the water balance, considering the complex interactions of climatic, pedological and vegetation-specific factors • can assign and further develop procedures for determining and considering the technical, economic and ecological dimensions of water management measures.					
Contents a) The strain and utilization of water resources and regionally and temporally variable requirements of society for water-dependent conditions require specific procedures and methods for planning, managing and controlling water management facilities. The concept of sustainability, particularly in the context of the UN Sustainable Development Goals, is of growing importance. In detail, the course covers the following topics: • Fundamentals of integrative planning in river basins • Securing water supply (long-term demand planning, assessment of water availability, sustainable water use) • Flood protection planning, structural flood protection, flood prevention, flood damage assessment • Planning fundamentals of low flow management, determination of minimum water flow • Agriculture and water management (agrochemical pollution of water resources, planning of protected areas and reservoirs) • Ecological assessment of water bodies, measures to improve structural quality, ecosystem services • Conflicts of interest, prioritisation of water use • Risk assessment and risk management of extreme events					

- Determination of technical, economic, ecological and social evaluation criteria for water management assessment
- Principles of water law and institutional framework conditions.

b)

The course aims to provide an in-depth understanding of water budget modelling on different scales (from single-reservoir models to 2D approaches). Topics covered include:

- Fundamentals of model development and parameterization
- Fundamentals of model error and uncertainty diagnostics
- Practicals with a hydrological model (e.g., HBV light)
- Preparation and plausibility check of model input data
- Methods for and practical implementation of model calibration and validation
- Quantification of model uncertainty and sensitivity
- Model evaluation.

Computer exercises are required to master the modelling techniques. Various models with corresponding data sets are available for this purpose, which can be used by students in the CIP pool of the faculty. In the practicals, the various methods are explained and applied using real-world examples.

Educational form / Language

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

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

Examination methods

- Term paper 'Sustainable Water Resources Management' (60 h., Part of modul grade 100 %, Presentation of results (20-minute presentation))

Requirements for the award of credit points

- Passed module final exam: Term paper and final presentation of results

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

This module can be recognized as part of the RUB sustainability certificate.

Sustainable operation and resource conservation with urban water management facilities Nachhaltiger Betrieb und Ressourcenschutz bei siedlungswasserwirtschaftl. Anlagen					
Module number BI-WP40/UI-WPB6	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Sustainable operation of urban water management facilities b) Water reuse			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.-Ing. Marc Wichern a) Prof. Dr.-Ing. Marc Wichern b) Dr.-Ing. Manfred Lübken					
Admission requirements Recommended previous knowledge: Urban water management					
Learning outcome, core skills The students • have a comprehensive overview of various technical purification processes in urban water management, • are familiar with various options for operating technical systems for water and wastewater treatment, • know the expected emissions and greenhouse gases that are produced during the operation of urban water management facilities, • know measures to reduce these emissions and GHG in terms of sustainable operation, • are familiar with ways of protecting and reusing recyclable materials, • are able to develop solutions and plan holistic concepts, • know the relevant wastewater treatment strategies in the national and international context of water reuse, • know the hygienic standards and other requirements for irrigation water, • are able to assess possible areas of application for the reuse of treated wastewater, e.g. agricultural, urban or industrial, • can assess risks to the environment and people, taking into account legal requirements, and derive measures to minimise risks.					
Contents a) The course deals with the development of solutions for the sustainable operation of drinking water and wastewater treatment processes. The contents include: • In-depth knowledge and operational optimisation of various process technologies used, such as activated sludge processes, filtration and anaerobic processes, mechanical processes, new technologies • Effect of different operating modes of purification technologies on water-related emissions • Estimation of indirect emissions and GHG depending on the process and mode of operation • Possibilities for sustainable plant operation					

• Solutions for new, holistic process concepts and their operating modes
b) The course deals with the principles and possible applications of water reuse for different users. The contents include: • Relevance of water reuse on a national and international level • In-depth knowledge of the nutrient cycle, resource efficiency and efficient water utilisation • Institutional requirements and risk management • Requirements for proceeding wastewater treatment with the aim of downstream reuse as irrigation water
Educational form / Language a) Lecture (1 WLH) / Tutorial (1 WLH) / German b) Lecture (1 WLH) / Tutorial (1 WLH) / German
Examination methods • Oral exam 'Sustainable operation and resource conservation with urban water management facilities' (40 min., Part of modul grade 100 %)
Requirements for the award of credit points • Passed module final exam: oral exam
Module applicability • M.Sc. Environmental Engineering • M.Sc. Civil Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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 This module can be recognized as part of the RUB sustainability certificate.

Sustainable Building Nachhaltiges Bauen					
Module number BI-WP47/UI-WPB3	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size 12
Courses a) Resource-efficient construction b) Sustainability assessment for buildings			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.-Ing. Annette Hafner a) Prof. Dr.-Ing. Annette Hafner b) Prof. Dr.-Ing. Annette Hafner					
Admission requirements Recommended previous knowledge: Knowledge of building construction, knowledge of building physics					
Learning outcome, core skills Students • have basic knowledge in the field of resource-efficient construction and can explain this independently, • have basic knowledge of the environmental considerations of buildings and their demolition options, • can illustrate specific knowledge for engineering and environmental tasks in this field, • independently test and solve common problems related to resource efficiency, taking into account life cycle analysis, • investigate the return of materials to the material cycle and its effects • after successfully completing the module, have basic knowledge of sustainability aspects in construction, • can explain evaluation systems for sustainable buildings • have a basic understanding of the environmental, economic, and socio-functional aspects of buildings, • can establish connections between building structures and sustainability as well as service life • are able to use sustainability assessment systems and apply them to buildings					
Contents a) The course provides a general introduction to the topic of resource-efficient construction and related topics, such as: • Observation and analysis of built examples with regard to resource efficiency criteria • Resource-efficient use of materials • Special consideration of modern timber construction • In-depth investigation of the return of building materials to the material cycle during the demolition phase • Demolition and recycling options in the building sector b)					

A newly constructed building is examined on sustainability aspects. The focus here is on specific evaluation systems

- First, the individual profiles are worked on in small groups
- After a general introduction to the evaluation system and the profiles, they are applied to the specific building (weekly supervision by the chair)
- The aim is to determine the current status quo for a building that was not familiar with the criteria during the planning/construction phase
- At the end of the semester, an overall evaluation of the real building should have been prepared and discussed

Educational form / Language

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

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

Examination methods

- Oral exam 'Sustainable Building' (30 min., Part of modul grade 100 %)
- Term paper 'Resource efficient building' (45 h., Part of modul grade 0 %)
- Term paper 'Sustainability assessment for buildings' (45 h., Part of modul grade 0 %)

Requirements for the award of credit points

- Passed assignments
- Passed oral module final exam

Module applicability

- MSc Environmental Engineering
- MSc Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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

This module can be recognized as part of the RUB sustainability certificate.

Nonlinear Design Methods of Steel and Composite Structures Nichtlineare Berechnungsverfahren im Stahl- und Verbundbau					
Module number BI-WP02	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Nonlinear design methods of steel and composite structures			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing Helen Bartsch a) Vertr.-Prof.'in Dr.-Ing. Rebekka Winkler					
Admission requirements Recommended previous knowledge: Steel constructions, structural analysis, finite element methods					
Learning outcome, core skills The students • possess in-depth knowledge and theoretical background in the computer-aided analysis of the nonlinear load-bearing and deformation behavior, as well as the fatigue strength and fracture mechanics of steel and composite structures • are familiar with advanced design methods and can develop targeted and specific solutions for practical construction tasks • understand the application limitations of the methods, can assess the consequences and implications of modeling and simplifications, and can interpret the results					
Contents a) The course focuses on advanced knowledge and skills for the design and analysis of the load-bearing, deformation, damage, and fracture behavior of steel and composite structures, particularly through the use of computer-based methods. Specifically, the following topics are covered: • Fundamentals of computer-aided analysis of the load-bearing and deformation behavior of cross-sections, members, and structures • Suitable finite elements and simulation methods for practical construction tasks and structural modeling • Geometrically and materially nonlinear analysis of members and structures • Second-order bending and torsion theory • Computer-based investigations of plate buckling • Computer-based methods in fatigue strength and fracture mechanics					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Term paper 'Nonlinear design methods of steel and composite structures - Homework' (60 h., ungraded) • Written exam 'Nonlinear design methods of steel and composite structures' (120 min., Part of modul grade 100 %)					

Requirements for the award of credit points
• Passed module final exam: Written exam • Passed term paper
Module applicability
• M.Sc. Civil Engineering
Weight of the mark for the final score
Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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

Non-motorized traffic Nichtmotorisierter Verkehr					
Module number BI-W67	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Non-motorized traffic			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Justin Geistefeldt a) Dr.-Ing. Sandra Hohmann					
Admission requirements Recommended previous knowledge: Design of transportation systems					
Learning outcome, core skills Students • will be able to independently implement design specifications for pedestrian and bicycle facilities, • have in-depth knowledge of calculation and evaluation methods for pedestrian and bicycle traffic, • recognize the interrelationships between design, cost-effectiveness, and safety of pedestrian and bicycle traffic facilities, • are able to understand various pedestrian and bicycle traffic concepts using practical examples, • are able to reflect on the interaction between the promotion of non-motorized traffic and the intended resource-saving and sustainable handling of traffic.					
Contents a) Non-motorized transport is an effective component of environmentally friendly mobility. Students learn about the design specifications and the calculation and evaluation procedures of the technical regulations for the two most common forms of non-motorized individual transport—walking and cycling. In addition, they learn about tried-and-tested walking and cycling concepts and gain insights into the economic efficiency and safety aspects of walking and cycling facilities.					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Oral exam 'Non-motorized traffic' (30 min.ungraded)					
Requirements for the award of credit points • Passed module final exam: Oral exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					
Weight of the mark for the final score Percentage of total grade [%] = 0, ungraded					
Further Information					

Nonlinear Finite Element Methods for Structures Nonlinear Finite Element Methods for Structures					
Module number BI-WP05/CE-WP04/SE-CO-23	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Nonlinear Finite Element Methods for Structures (126515)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency 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) Lecture (2 WLH) / Tutorial (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					

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

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 (128018)			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. Mohammad Salimi					
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 [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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 Mathematics Numerische Mathematik					
Module number BI-P01/UI-M01	Credits 5 CP	Workload 150 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Numerical Mathematics			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Markus Reinecke a) Dr. Mario Lipinski					
Admission requirements Recommended previous knowledge: Advanced mathematics					
Learning outcome, core skills After successfully completing the module • students will be familiar with the most important methods of engineering mathematics • students will be able to identify and solve mathematical problems in physical systems • students will practice initial approaches to scientific learning and thinking • students will have interdisciplinary methodological skills					
Contents a) • Fundamental methods of numerical mathematics: • Methods for solving large linear systems of equations (Gauss method, L-R decomposition, Cholesky method, and related methods), • Methods for solving nonlinear equations and systems of equations, in particular Newton's method with modifications, • Methods for calculating eigenvalues and eigenvectors, Lagrange, Hermite, and spline interpolation, • Methods for numerical integration, • Numerical solution of ordinary differential equations, initial value problems (one-step methods, in particular Runge-Kutta methods, order and convergence, importance of stability and application to stiff systems, step size control, multi-step methods).					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Written exam 'Numerical Mathematics' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed module final exam: Written exam					
Module applicability • M.Sc. Civil Engineering • B.Sc. Environmental Engineering • B.Sc. Mechanical Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Operation and Maintenance of Tunnels and Utility Pipes					
Operation and Maintenance of Tunnels and Utility Pipes					
Module number BI-WP26/SE-CO-5	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Facility management of under-ground transportation infrastructure (129021) b) Pipeline maintenance and network management (129022)			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.-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 %, optionally 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 [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$

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Further Information

b) Digital teaching within the meaning of the HDVO

Operations Research and Databases Operations Research und Datenbanken					
Module number BI-P10/UI-P3	Credits 6 CP	Workload 180 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Operations Research (127020) b) Databases			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.-Ing. Markus König a) Prof. Dr.-Ing. Markus König b) Prof. Dr.-Ing. Markus König					
Admission requirements					
Learning outcome, core skills Upon completion of the course, students will be able to: • mathematical optimization strategies and structured data management concepts to solve practice-oriented problems in civil and environmental engineering, • familiar with current optimization software and employ it purposefully to address engineering problems, • the necessary knowledge to implement data management concepts computationally and to apply them both theoretically and practically to engineering challenges.					
Contents a) • Linear optimization • Queueing theory • Fuzzy-Control • Evolutionary algorithms • Multi-criteria decision-making methods b) • Database models • Database implementation • Database queries					
Educational form / Language a) Lecture (1 WLH) / Tutorial (1 WLH) / German b) Lecture (1 WLH) / Tutorial (1 WLH) / German					
Examination methods • Written exam 'Operations Research and Databases' (150 min., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed final module examination: Written exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Planning, Speaking, Writing : project management and scientific work in engineering Planen, Sprechen, Schreiben: Projektmanagement und wissenschaftliches Arbeiten im Ingenieurwesen					
Module number BI-W28	Credits 3 CP	Workload 90 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Planning, Speaking, Writing : project management and scientific work in engineering			Contact hours a) 3 WLH (45 h)	Self-study a) 45 h	Frequency a) each sem.
Module coordinator and lecturer(s) Dr.-Ing. Sandra Greassidis a) Dr.-Ing. Sandra Greassidis, Vertr.-Prof.'in Dr.-Ing. Nina Nytus, Dr.-Ing. Christian Jolk					
Admission requirements					
Learning outcome, core skills In addition to their technical training, students who complete this module will have acquired knowledge of project planning and independent project management to prepare them for upcoming projects and final theses. After successfully completing the module • students will plan their final theses according to the rules of efficient time and project management • students will have acquired techniques for scientific work and presentation • students will write scientific texts with the help of learned writing techniques • students will research, manage, and organize literature with the help of current software					
Contents a) In cooperation with the Project Office for Construction and Environment, the course treats the topics of project management and scientific working techniques as a "simulated engineering office" and with the involvement of experts. This includes, among other things: • Time and project management • Structure of an exposé • Structure and characteristics of a scientific paper • Literature research and management • Writing training • Presentation techniques and criteria for a professional oral presentation The content is not only taught "theoretically," but also tested and practiced under realistic conditions.					
Educational form / Language a) Lecture (3 WLH) / German					
Examination methods • Term paper 'Planning, Speaking, Writing : project management and scientific work in engineering' (15 h., ungraded, with final oral exam (30 min.))					
Requirements for the award of credit points • Passed module final exam: Term paper with oral exam					
Module applicability					

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering
- B.Sc. Civil Engineering
- B.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 0, ungraded

Further Information

Block seminar at the end of the semester

Plasticity and Damage Plastizität und Materialschädigung					
Module number BI-WP21	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Plasticity and Damage			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Daniel Balzani a) Prof. Dr.-Ing. Daniel Balzani					
Admission requirements Recommended previous knowledge: Stereostatics and Elastostatics					
Learning outcome, core skills the students • are able to derive the mathematical equations to describe the elastic-plastic material behavior within the framework of a geometrically linear description • can mathematically describe softening processes using phenomenological damage models • are able to derive an algorithmic implementation within the framework of the FEM					
Contents a) • Continuum mechanical and thermodynamic foundations • Concept of internal variables and associated dissipation • Elasto-plastic constitutive models (yield functions and flow rules) • Algorithmic implementation of elasto-plastic material models • Aspects of material damage • Continuum mechanical damage models • Algorithmic treatment of damage models and implementation					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Written exam 'Plasticity and Damage' (120 min., Part of modul grade 100 %, or oral examination (30 minutes). The form of examination is determined at the beginning of each semester depending on the number of participants.)					
Requirements for the award of credit points • Passed final modul examination: written or oral examination					
Module applicability • M.Sc. Civil Engineering • M.Sc. Mechanical Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$					

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Further Information

Practical Training on Tunneling and Pipeline Construction Techniques					
Practical Training on Tunneling and Pipeline Construction Techniques					
Module number BI-W03/SE-O-1	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Week Semester[s]	Group size 20
Courses a) Practical Training on Tunneling and Pipeline Construction Methods (128202)			Contact hours a) 3 WLH (45 h)	Self-study a) 15 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus Thewes a) Prof. Dr.-Ing. Markus Thewes					
Admission requirements					
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.					
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					
Educational form / Language a) Block seminar / Internship / English					
Examination methods • Internship 'Practical Training on Tunneling and Pipeline Construction Methods' (60 h., ungraded, Regular participation)					
Requirements for the award of credit points • Full time participation					
Module applicability • M.Sc. Civil Engineering • M.Sc. Subsurface Engineering					
Weight of the mark for the final score					

Percentage of total grade [%] = 0, ungraded

Further Information

This module usually takes place in the first week of the lecture-free period in the summer semester. The number of participants is limited.

Registration for participation as well as information about date/location at the Chair for Tunnelling and Construction Management (Lehrstuhl für Tunnelbau, Leitungsbau und Baubetrieb).

Practical Geotechnics: Laboratory and Computing					
Praktikum Geotechnik: Labor und computergestützte Berechnungen					
Module number BI-WP27	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Soil mechanics laboratory course b) Software-based analysis of geotechnical structures			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.-Ing. Torsten Wichtmann a) Dr.-Ing. Wiebke Baille b) Prof. Dr.-Ing. Torsten Wichtmann					
Admission requirements Recommended previous knowledge: Completed module in soil mechanics and foundation engineering					
Learning outcome, core skills The students • are familiar with the essential tests of soil mechanics, their principles, the equipment technology, and the necessary measuring equipment, • have an overview of sample preparation and the time required to carry out the tests, • are able to independently design experimental strategies for solving application-oriented problems and analyse their results, • are able to solve practical problems in soil mechanics and foundation engineering using geotechnical calculation programs, • have the ability to abstract more complex problems to such an extent that they can be calculated using geotechnical programs and can interpret the results.					
Contents a) The laboratory practical course introduces the essential soil mechanics testing techniques and selected tests are carried out independently: • Measurement methods in geotechnical laboratory and field tests • Carrying out classification tests (including grain size distribution curve, water content, densities at loosest and densest packing, grain density) • Tests for shear strength, compressibility, permeability b) The course demonstrates how to use commercial geotechnical software: • Introduction to the program structure • Essential calculation strategies • Examples, variant studies (including slope stability, shallow foundations, settlement calculation, pile foundations, excavation pits)					
Educational form / Language					

a) Internship / German

b) Seminar / German

Examination methods

- Written exam 'Practical Geotechnics: Laboratory and Computing' (90 min., Part of modul grade 50 %)
- Term paper 'Soil mechanics laboratory course' (15 h., Part of modul grade 50 %, with oral examination)

Requirements for the award of credit points

- Homework and oral exam for a)
- Passed final module examination for b): written examination

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Applied Structural Dynamics Praktische Probleme der Baudynamik					
Module number BI-W12	Credits 2 CP	Workload 60 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Applied Structural Dynamics			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Prof. Dr.-Ing. Peter Mark, Prof. Dr.-Ing. Dieter Heiland					
Admission requirements Recommended previous knowledge: Completed modules in fundamentals of Reinforced and Prestressed Concrete Structures, Structural Analysis					
Learning outcome, core skills The Students: • have basic knowledge in the field of structural dynamics					
Contents a) The course imparts basic knowledge using examples from construction practice. These include: • Vibration-sensitive buildings in nanotechnology • Vibrations and their reduction in railway traffic • Vibration isolation • Monitoring (continuous measurement) of vibrations at the world's tallest cooling tower • Vibration prediction during construction work (at the example of a court report)					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Oral exam 'Applied Structural Dynamics' (30 min., Part of modul grade 100 %) • At least 75% attendance					
Requirements for the award of credit points • At least 75% attendance • Passed final module examination: oral examination					
Module applicability • M.Sc. Civil Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$ 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					

Programming					
Programming					
Module number BI-P04	Credits 5 CP	Workload 150 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Programming (127002)			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency 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 presented content, employing the Python programming language for selected scientific applications.					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / English					
Examination methods • Term paper 'Programming' (90 h., Part of modul grade 100 %)					
Requirements for the award of credit points • Passed final module examination					
Module applicability • M.Sc. Civil 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

Programming the Finite Element Method Programming the Finite Element Method					
Module number BI-W39/CE-WP10	Credits 3 CP	Workload 90 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Programming the Finite Element Method (128047)			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr. Roger A. Sauer a) Prof. Dr.-Ing. Matthias Baitsch, Prof. Dr. Roger A. Sauer					
Admission requirements Recommended previous knowledge: Finite Element Methods in Linear Structural Mechanics and Modern Programming Concepts in Engineering					
Learning outcome, core skills The seminar connects the theory of finite element methods (FEM) and object-oriented programming. After successfully completing the module, the students • can implement the theories and methods of the course 'Finite Element Methods in Linear Structural Mechanics' in an object-oriented finite element program and apply this program for the analysis of engineering structures, • have developed a program for the computation of spatial truss structures, • can verify the program using benchmark examples, • gained deep insight into the most relevant aspects for the implementation within the FEM and possibilities of using object-oriented programming for numerical approaches.					
Contents a) The main topics of the course are: • short summary of the basics of FEM and project-oriented programming • preparing a project with two parts - Part 1: students individually develop and verify an object-oriented finite element program for the linear analysis of spatial truss structures - Part 2: students can choose between different options, either, the application developed in the Part 1 is extended to more challenging problems (nonlinear analysis, other element types, etc.) or students switch to an existing object-oriented finite element package (e.g. Kratos) and develop an extension of that software (e.g. material models, element formulations)					
Educational form / Language a) Seminar / English					
Examination methods • Term paper 'Object-oriented Modelling and Implementation of Structural Analysis Software' (60 h., Part of modul grade 100 %, with final student presentation)					
Requirements for the award of credit points					

- Passed project work and final student presentation

Module applicability

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

Weight of the mark for the final score

Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Project "Geotechnics and Tunneling" Projekt Geotechnik und Tunnelbau					
Module number BI-PA03	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Project "Geotechnics and Tunneling"			Contact hours	Self-study a) 180 h	Frequency a) each sem.
Module coordinator and lecturer(s) Siehe Lehrende a) Prof. Dr.-Ing. Markus Thewes, Prof. Dr.-Ing. Torsten Wichtmann, Prof. Dr.-Ing. habil. Iurie Curosu, Prof. Dr. Roger A. Sauer					
Admission requirements					
Learning outcome, core skills Students • can structure complex tasks, devise solutions to problems, and work on them in teams, with the students themselves defining the responsibilities for the individual areas of work. • are able to present the results of the entire project work in a report and in the subsequent presentation. • possess creativity, imagination, teamwork, and social skills, and thus the ability and competence for networked thinking					
Contents a) Students are assigned project work, which is carried out in project teams on a collaborative basis. The project teams organize and coordinate the distribution of tasks independently. The lecturers act as supervisors and advisors for the project work and review the results at regular intervals, making suggestions for improvement where necessary. At the end of the project work, the students document and present their results. The content of the project work varies from semester to semester, allowing students to address current issues in geotechnical and tunnel construction, geotechnical assessment, process selection, design, and control of the construction of geotechnical structures and tunnels. The projects focus on complex tasks from the field of geotechnical engineering and tunnel construction. The project work is generally designed in such a way that interdisciplinary aspects are incorporated into the task. This means that at least two departments are responsible for supervising the project. The content defined by the task is formulated in such a way that the following aspects are taken into account • identifying and describing problems • Formulating objectives • Distributing and coordinating tasks • Group dynamic problem solving • Organizing and optimizing time and work allocation • Interdisciplinary problem solving • Literature procurement and evaluation as well as expert interviews • Documentation, presentation, and presentation of work results					
Educational form / Language					

a) Project / German / English

Examination methods

- Term paper 'Project "Geotechnics and Tunneling"' (180 h., Part of modul grade 100 %, with presentation)

Requirements for the award of credit points

- Completed project work
- Completed presentation

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Project "KIB - Design and Construction" Projekt KIB - Bemessung und Konstruktion					
Module number BI-PA01	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Project "KIB - Design and Construction"			Contact hours	Self-study a) 180 h	Frequency a) each sem.
Module coordinator and lecturer(s) Siehe Lehrende a) Prof. Dr.-Ing. Annette Hafner, Prof. Dr.-Ing. Helen Bartsch, Prof. Dr.-Ing. Daniel Balzani, Prof. Dr.-Ing. Markus Thewes, Prof. Dr.-Ing. Rüdiger Höffer, Prof. Dr.-Ing. Peter Mark, Prof. Dr.-Ing. Johanna Waimann, Prof. Dr.-Ing. habil. Iurie Curosu, Prof. Dr.-Ing. Markus König, Prof. Dr. Roger A. Sauer					
Admission requirements					
Learning outcome, core skills Students • are able to structure civil engineering tasks, solve them in teams, translate them into structural designs including implementation planning, and present their results in written form and oral presentation. • are able to apply appropriate analytical methods to abstract structural engineering problems, interpret and constructively implement numerical analyses, design construction-ready plans, and adapt structures to their function, their environment, and ecological requirements. • possess social skills and the ability to work in a team.					
Contents a) The contents of the project work is re-newed each semester. It covers issues relating to planning, dimensioning, and construction for structural engineering tasks. The project work is generally designed in such a way that interdisciplinary aspects are incorporated into the task. This means that at least two departments are responsible for supervising the work. The content defined by the task is formulated in such a way that the following aspects are taken into account: • Identifying and describing problems • Formulating objectives • Distributing and coordinating tasks • Team-oriented problem solving • Organizing time and work • Interdisciplinary problem solving • Literature procurement and evaluation as well as expert interviews • Documentation, presentation, and presentation of work results					
Educational form / Language a) Project / German / English					
Examination methods • Term paper 'Project "KIB - Design and Construction"' (180 h., Part of modul grade 100 %, with presentation)					
Requirements for the award of credit points					

- Successful completion of project work
- Completed presentation

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Project "KIB - Digital Design and Construction" Projekt KIB - Digital Design and Construction					
Module number BI-PA02	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Project "KIB - Digital Design and Construction"			Contact hours	Self-study a) 180 h	Frequency a) each sem.
Module coordinator and lecturer(s) Siehe Lehrende a) Prof. Dr.-Ing Helen Bartsch, Prof. Dr.-Ing. Daniel Balzani, Prof. Dr.-Ing. Peter Mark, Prof. Dr.-Ing. Johanna Waimann, Prof. Dr.-Ing. Markus König, Prof. Dr. Roger A. Sauer					
Admission requirements					
Learning outcome, core skills Students • are able to structure civil engineering tasks, solve them in teams, translate them into a structural design including implementation planning, and present their results in report form and in a presentation. • are able to apply appropriate analytical methods to abstract structural engineering problems, interpret and constructively implement numerical analyses, design construction-ready plans, and adapt structures to their function, their environment, and ecological requirements. • possess social skills and the ability to work in a team.					
Contents a) As part of the elective modules, students are assigned project work, which is carried out in project teams on a collaborative basis. The project teams organize and coordinate the distribution of tasks independently. The lecturers act as supervisors and advisors for the project work and review the results at regular intervals. At the end of the project work, students present their results. The content of the project work varies from semester to semester, so that issues relating to the planning and assessment of structural engineering tasks can be addressed using modern numerical methods, taking into account various influences. The project work is generally designed in such a way that interdisciplinary aspects are incorporated into the task processing. This means that at least two chairs are responsible for supervision. The content defined by the task is formulated in such a way that the following aspects are taken into account: • Identifying and describing problems • Formulating objectives • Distributing and coordinating tasks • Team-oriented problem solving • Organizing and optimizing time and work allocation • Interdisciplinary problem solving • Literature procurement and evaluation as well as expert interviews • Documentation, presentation, and presentation of work results					
Educational form / Language a) Project / German / English					
Examination methods					

- Term paper 'Project "KIB - Digital Design and Construction"' (180 h., Part of modul grade 100 %, with presentation)

Requirements for the award of credit points

- Successful completion of project work
- Completed presentation

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Project "Road and Traffic Engineering" Projekt Verkehrswesen					
Module number BI-PA05	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Project "Road and Traffic Engineering"			Contact hours	Self-study a) 180 h	Frequency a) each sem.
Module coordinator and lecturer(s) Siehe Lehrende a) Vertr.-Prof.'in Dr.-Ing. Nina Nytus, Prof. Dr.-Ing. habil. Iurie Curosu, Prof. Dr.-Ing. Justin Geistefeldt					
Admission requirements Recommended previous knowledge: Course content of modules BI-WP 28 to BI-WP 33					
Learning outcome, core skills Students • can structure complex tasks, devise solutions to problems, and work on them in teams, with the students themselves defining the responsibilities for the individual areas of work. • are able to present the results of the entire project work in a report and in the subsequent presentation. • possess creativity, imagination, teamwork, and social skills, and thus the ability and competence for networked thinking					
Contents a) Each year, a topic area is selected for the elective modules that includes tasks from several of the modules covered. Preferably, this topic is linked to a practical task. The scope of the task depends on the number of participants. The participants work on the problem analysis and the project tasks in several teams. The students organize the teams and divide up the tasks themselves under the guidance of the project manager. The lecturers preferably act as supervisors and advisors for the project work and check the results at regular intervals, making suggestions for improvement where necessary. During the project, several meetings are held between the participants and the project managers to coordinate the work. Where appropriate, experts from the field who are involved in the underlying real-life case are also invited to these meetings. At the end of the project work, the students document and present their results. The content of the project work varies from semester to semester so that current tasks relating to transport planning and construction engineering (transport infrastructure construction) issues can be addressed. Complex tasks from the field of transport are selected as the subject of the projects. The project work is generally designed in such a way that interdisciplinary aspects are incorporated into the task. This means that at least two departments are responsible for supervising the project. The content defined by the task is formulated in such a way that the following aspects are taken into account: • Identifying and describing framework conditions and problems • Formulating objectives • Distributing and coordinating tasks • Group dynamic problem solving • Organizing time and work allocation (project management)					

- Interdisciplinary problem solving
- Literature procurement and evaluation as well as expert surveys
- Documentation, presentation, and presentation of work results

Educational form / Language

a) Project / German / English

Examination methods

- Term paper 'Project "Road and Traffic Engineering"' (180 h., Part of modul grade 100 %, with presentation)

Requirements for the award of credit points

- Completed project work
- Completed presentation

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Project " Water Management and Environmental Technology" Projekt Wasserwesen und Umwelttechnik					
Module number BI-PA04	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Project " Water Management and Environmental Technology"			Contact hours	Self-study a) 180 h	Frequency a) each sem.
Module coordinator and lecturer(s) Siehe Lehrende a) Prof. Dr.-Ing. Annette Hafner, Prof. Dr.-Ing. Martina Flörke, Prof. Dr.-Ing. Marc Wichern					
Admission requirements					
Learning outcome, core skills The students • are able to structure complex tasks, design solutions to problems and develop them in a team, whereby the responsibilities for the individual areas of work are to be defined by the students themselves. • are able to present the results of the entire project work in a report and in the subsequent presentation. • possess creativity, imagination, teamwork and social skills and thus the ability and competence for networked thinking.					
Contents a) On the content of the compulsory elective modules, students are assigned project work that is carried out collaboratively in project teams with a division of tasks. The project teams organise and coordinate the distribution of tasks independently. The lecturers act as supervisors and advisors during the project work and check the results at regular intervals. At the end of the project work, the students present their results. The content of the project work varies from semester to semester so that current problems relating to hydrological issues, the dimensioning and control of water management systems, wastewater disposal and water supply as well as environmental planning and ecology can be dealt with. Complex tasks from the practice of water management and environmental technology are chosen as the subject of the projects. The project work is generally designed to incorporate interdisciplinary aspects into the task processing. This means that at least two chairs are responsible for supervision. The content defined in the assignment is formulated in such a way that the following aspects are taken into account: • Recognise and describe problems • Formulate objectives • Distributing and coordinating tasks • Group dynamic problem solving • Design and optimize time and workload distribution • Interdisciplinary problem solving • Obtaining and analysing literature and interviewing experts • Documentation, visualisation and presentation of work results					
Educational form / Language a) Project / German / English					

Examination methods

- Term paper 'Project " Water Management and Environmental Technology"' (180 h., Part of modul grade 100 %, with presentation)

Requirements for the award of credit points

- Completed project work
- Completed presentation

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Recent Advances in Numerical Modelling and Simulation					
Recent Advances in Numerical Modelling and Simulation					
Module number BI-W35/CE-W04	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Recent Advances in Numerical Modelling and Simulation (129224)			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each sem.
Module coordinator and lecturer(s) Prof. Dr. Roger A. Sauer a) Prof. Dr. Roger A. Sauer					
Admission requirements Recommended previous knowledge: Finite Element Methods in Linear Structural Mechanics (CE-P05)					
Learning outcome, core skills After successfully completing the module, the students • gain insight into the current research in the field of numerical methods in structural mechanics based on selected research topics, • have skills on selected numerical simulation approaches and its application in engineering, • have tested research-oriented working					
Contents a) During the course, selected topics in the field of numerical modeling and simulation in structural mechanics will be presented. The range of topics will be continuously updated to fit with the relevance of current research topics, e.g.: • the Extended Finite Element Method • Finite Cell methods • Isogeometric Analysis • Peridynamics For each topic, the theory will be offered in the compact form with emphasis on the algorithms and specific numerical methods. Selected application examples will be demonstrated					
Educational form / Language a) Seminar / English					
Examination methods • Seminar 'Recent Advances in Numerical Modelling and Simulation' (30 h., Part of modul grade 100 %, Seminar presentation)					
Requirements for the award of credit points • Passed seminar presentation					
Module applicability • M.Sc. Computational Engineering					

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Spatial data analysis and environmental modelling Räumliche Datenanalyse und Umweltmodellierung					
Module number BI-WP35/UI-WPB5	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Methodological fundamentals of environmental modelling b) Big data in environmental sciences			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.-Ing. Martina Flörke a) Prof. Dr.-Ing. Martina Flörke b) Dr.-Ing. Henning Oppel					
Admission requirements Recommended previous knowledge: Knowledge from bachelor's degree in advanced mathematics and computer science					
Learning outcome, core skills Students - describe the fundamentals of common data sources, data types and data formats, as well as relevant model concepts in the context of environmental modelling - can prepare, analyse and present (large) spatial data sets and time series using geographic information systems (GIS) and scripting languages (Python and R) - can evaluate the model results and uncertainties and thus assess the validity of the methods, - can understand standard tasks and independently develop solution strategies for environmentally relevant issues.					
Contents a) The course covers the basic knowledge of the methodological fundamentals of environmental modelling. This includes: - Sources of spatial information for environmental modelling, importing and processing large data sets - Use of various data formats and model concepts from the fields of hydrology, urban water management, traffic planning, etc. - Working with and developing in GIS, Python and R - Spatial statistics (variogram), geostatistics (spatial interpolation) - Time series analysis (trend tests, autocorrelation). b) The lecture focuses on the use of modern data sources and modelling approaches to solve environmentally relevant issues and the presentation of results. The following topics will be covered in detail: - Machine learning and data mining					

- Model uncertainty and validity criteria
- Ensemble forecasting and ensemble analysis
- Evaluation and processing of remote sensing data
- Presentation of results.

The methodological and technical fundamentals of analyzing, evaluating and presenting environmentally relevant data are covered in the lectures and discussed in terms of their validity, uncertainty and decision support.

Computer exercises are necessary to master the modelling and programming techniques. Various programmes and models with corresponding data sets are available for this purpose, which can be used by students in the CIP pools of the faculty.

The various methods are applied using real-world examples in the practicals.

Educational form / Language

- a) Lecture (1 WLH) / Tutorial (1 WLH) / German
- b) Lecture (1 WLH) / Tutorial (1 WLH) / German

Examination methods

- Term paper 'Spatial data analysis and environmental modelling' (60 h., Part of modul grade 100 %, term paper with presentation of results (20 minutes) (deadline to be announced at the beginning of the semester))

Requirements for the award of credit points

- Passed term paper and final presentation of results

Module applicability

- M.Sc. Environmental Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Welding technology for constructional engineers Schweißtechnik für Bauingenieure					
Module number BI-W06	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Welding technology for constructional engineers			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing Helen Bartsch a) Dipl.-Ing. Jörg-Werner Mortell					
Admission requirements Recommended previous knowledge: Steel and Timber Structures					
Learning outcome, core skills The students: • can assess the process-related advantages and disadvantages of various welding methods and appropriately select methods based on specific projects and tasks. • can evaluate the factors affecting the weldability of steels and the types of failure in welded joints. • possess the ability to design in a welding-appropriate manner, especially for structures subjected to dynamic loads. • have the necessary knowledge to identify execution defects in weld seams and determine their possible causes. • are familiar with the regulatory quality assurance system in welding technology.					
Contents a) The following topics are covered in the course: • Welding methods • Weldability of steels • Structural design of welded joints • Failure of welded joints • Defects and inspection of weld seams • Quality assurance in steel construction • Practical exercises (welding workshop)					
Educational form / Language a) Lecture (2 WLH) / German					
Examination methods • Written exam 'Welding technology for constructional engineers' (30 min., Part of modul grade 100 %) • Attendance at at least 75% of the sessions • Verified participation in the welding practicum					
Requirements for the award of credit points					

- Passed module final exam: Written exam
- Attendance at at least 75% of the sessions
- Verified participation in the welding practicum

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Digital examinations within the meaning of the HDVO

Seminar for transportation and traffic engineering Seminar für Verkehrswesen					
Module number BI-W61	Credits 2 CP	Workload 60 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Seminar for Transportation and Traffic Engineering			Contact hours a) 1 WLH (15 h)	Self-study a) 45 h	Frequency a) each sem.
Module coordinator and lecturer(s) Prof. Dr.-Ing. Justin Geistefeldt a) Prof. Dr.-Ing. Justin Geistefeldt					
Admission requirements					
Learning outcome, core skills Students • have expanded their knowledge in the field of transport to include a current topic, • have learnt how to work in a team to solve a complex task in the field of transport, • have learnt to present the results of their work in a short presentation.					
Contents a) Sub-areas of a given framework topic are worked on in small groups. Finally, an overall report is compiled. Participants are required to present and discuss the results.					
Educational form / Language a) Lecture (1 WLH) / German					
Examination methods • Term paper 'Seminar for Transportation and Traffic Engineering' (30 h., Part of modul grade 100 %, seminar report with presentation)					
Requirements for the award of credit points • Passed module final exam: written exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$ 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					

Simulation Technology Simulationstechnik					
Module number BI-WP09	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Simulation Technology			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Markus König a) Prof. Dr.-Ing. Markus König					
Admission requirements					
Learning outcome, core skills Students • are able to use computer-aided simulation concepts to solve practical problems in civil engineering and environmental engineering, • learn about current simulation software and can use it in a targeted manner to solve simulation tasks, • have the necessary knowledge to implement simulation techniques in terms of computing technology and apply them to engineering problems both theoretically and practical					
Contents a) • System analysis and modeling • System dynamics • Event-driven simulation • Agent-based simulation • Stochastic simulation • Simulation-based optimization					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Term paper 'Simulation Technology' (90 h., Part of modul grade 100 %, with presentation)					
Requirements for the award of credit points • Passed module final exam: Presentation of term paper					
Module applicability • M.Sc. Civil Engineering • M.Sc. Applied Computer Science					
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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					

Special Concrete Technologies Sondergebiete der Betontechnologie					
Module number BI-WP12	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Special Concrete Technologies			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. habil. Iurie Curosu a) Prof. Dr.-Ing. habil. Iurie Curosu					
Admission requirements Recommended previous knowledge: Knowledge of construction materials and building physics					
Learning outcome, core skills The students • have in-depth knowledge of the concrete raw materials and can assess the demand and design requirements for special concretes. • can design concretes for special applications and evaluate their application limits. • are able to independently develop solutions for special concrete technology issues.					
Contents a) The appropriate areas of application of special concrete constituents and the associated changes in the concrete structure are explained. These include (among others): • Special cements • Secondary and recycled products • Hydration process • Concrete properties • Phase products • Porosity / pore size distribution • Hydration heat and strength development The characteristics of special concretes and the procedure for special concreting methods are explained. In particular, the advantages, but also the application limits and special detection methods are shown. These include (among others): • Lightweight concrete • High-performance concrete • Self-compacting concrete • Exposed concrete • Fiber-reinforced concrete • Special concreting methods, e.g. underwater concreting and shotcrete.					

In the theoretical exercises, concrete designs are conducted based on real practical examples and conformity verifications are carried out.

In the laboratory exercises, the examination methods developed in the lectures are carried out and explained.

Educational form / Language

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

Examination methods

- Written exam 'Special Concrete Technologies' (90 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed written examination of the module

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Prestressing and non-linear calculations of concrete structures					
Spannbeton und nichtlineare Berechnungsmethoden im Massivbau					
Module number BI-WP01	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Prestressed Concrete Member b) ,Non-lilnear calculation of concrete structures			Contact hours a) 2 WLH (30 h) b) 2 WLH (30 h)	Self-study a) 60 h b) 60 h	Frequency a) each summer b) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Peter Mark a) Dr.-Ing. Mark Alexander Ahrens, Prof. Dr.-Ing. Peter Mark b) Dr.-Ing. Mark Alexander Ahrens, Prof. Dr.-Ing. Peter Mark					
Admission requirements Recommended previous knowledge: Knowledge of the fundamentals of Reinforced and Prestressed Concrete Structures, Structural Analysis					
Learning outcome, core skills The Students: • have basic knowledge of prestressed concrete construction of beam-shaped and planar structures, • they are familiar with the types of prestressing, the terminology, technical systems and necessary components, • plan, calculate and analyse tendon layout idependently • understand the effect of prestressing and design prestressed structures in accordance with recent standards, technical regulations and approvals • are familiar with the special design features in areas of force introduction and deviations • know the limits of linear calculations in concrete construction • are able to take material and geometric non-linearities into account in the calculation and assess their necessity • understand the load and stiffness-dependent material behaviour when predicting deformations • are able to assess the stability risk of compression members • design and reinforce slender columns on the basis of recent standards					
Contents a) The course deals with the basic knowledge of plane prestressed structures, their calculation, planning, detailing and structural design. This includes: • Fundamentals, prestressing systems, equipment, bond types • Tendon guidance and anchoring (planning, calculation and evaluation) • Determination of imaginary cross-section quantities (plausibility checks) • Friction and slip losses, elastic losses, time-dependent losses from KSR • Deviation and anchorage forces method • Determination of internal forces of statically determinate and indeterminate systems under prestress • Design and verification in the limit states of serviceability and ultimate bearing capacity • Special features of the structural design					

b) The course deals with physical and geometric non-linearities in the calculation and design of reinforced concrete structures, in particular compression members (slender columns) and beams at risk of tilting. It imparts the knowledge to use non-linear methods for truss structures or the yield line theory to design special cases of concrete construction. The course covers the following in detail: • Fundamentals of non-linear calculations • Redistribution of forces • Stiffness of cracked concrete (state II) • Moment-curvature relationships • Nonlinear computation of deformations (state II) • Stability problems in reinforced concrete construction • Design of compression members and beams at risk of tilting • Yield line and fracture line theory
Educational form / Language a) Lecture (1 WLH) / Tutorial (1 WLH) / German b) Lecture (1 WLH) / Tutorial (1 WLH) / German
Examination methods • Term paper 'Pre-stressed concrete structures' (40 h., Part of modul grade 0 %, term paper) • Term paper 'Non-linear processes for concrete constructions' (40 h., Part of modul grade 0 %, term paper) • Written exam 'Prestressing and non-linear calculations of concrete structures' (120 min., Part of modul grade 100 %)
Requirements for the award of credit points • Passed final module examination: written examination • Passed homework 'Prestressed Concrete Member' (40h) • Passed homework 'Non-linear calculation of concrete structures' (40h)
Module applicability • M.Sc. Civil Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 \cdot 100 \cdot \text{FAK} / \text{DIV}$ 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

Material Flow Management Stoffstrommanagement					
Module number BI-WP54/UI-WPB2	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Material flow analysis in construction with life cycle assessment tool			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Annette Hafner a) Prof. Dr.-Ing. Annette Hafner					
Admission requirements Recommended previous knowledge: Knowledge of life cycle assessment, knowledge of building physics, knowledge of building construction					
Learning outcome, core skills Students • After successfully completing the module, students will have a basic understanding of material flows in construction and their interactions, • can explain environmental considerations of building constructions and determine references to sustainability and service life, • acquire the ability to independently perform a building life cycle assessment using the eLCA tool (or possibly another tool), • can compare and evaluate the results of building life cycle assessments.					
Contents a) The lecture provides an overview of life cycle assessment (LCA) methods. The lecture is based on national and international standards. Specific topics covered include: • LCA processes and procedures (system boundaries, functional unit, life cycle inventory, life cycle impact assessment, etc.) • Special requirements of life cycle assessment in construction (manufacturing, construction, use, and demolition) and conclusions regarding national and international assessment methods for sustainable buildings • Basic knowledge for creating an LCA with the eLCA tool (or possibly another tool) for the independent creation of a building LCA • Structural analysis of different building structures and their influence on the LCA					
Educational form / Language a) Lecture (2 WLH) / Tutorial (2 WLH) / German					
Examination methods • Term paper 'Material Flow Management' (30 h., Part of modul grade 100 %, with a final oral exam (15 min). The scope and deadline will be announced at the beginning of the semester.)					
Requirements for the award of credit points					

- Passed term paper

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Transport and fate of substances in river basins Stofftransport in Einzugsgebieten					
Module number BI-WP36/UI-WPD3	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Mass transport and mass transport equations b) Modeling and assessment of water quality			Contact hours a) 2 WLH (30 h) b) 2 WLH (30 h)	Self-study a) 60 h b) 60 h	Frequency a) each summer b) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Martina Flörke a) Prof. Dr.-Ing. Martina Flörke b) Prof. Dr.-Ing. Martina Flörke					
Admission requirements Recommended previous knowledge: Completed module in Fundamentals of Hydrology and Water Management, Hydrology module, knowledge of R					
Learning outcome, core skills Students - characterize the fundamentals of sources and sinks as well as the transport of the most important dissolved and particulate, organic and inorganic substances, such as nutrients, BOD, pesticides, fertilizers, heavy metals and nanoparticles from a catchment area perspective - differentiate between pollutant dispersion and substance behaviour in the aquatic environment based on processes such as sorption, volatilisation, transformation and degradation - olve standard tasks with the aid of analytical transport equations with initial and boundary conditions - interpret the quality of calculation methods and model results in the given context - prepare analyses and assessments of substance input in aquatic systems.					
Contents a) The course covers the basics of mass transport in aquatic systems and the theoretical principles for solving mass transport equations. Specifically, the course addresses the following topics: - Water pollution and its consequences - Sources of substances and the determination of substance loads and substance balances - Conservative and reactive transport (processes, flow paths) - Consideration of specific pollutants (BOD, nutrients, pesticides, fertilizers, heavy metals, nanoparticles) - Sediment and heat transport - Tracer experiments and breakthrough curves - Analytical solution of the transport equation for 1D and 2D with different boundary and initial conditions - Presentation of common numerical solution methods for mass and heat transport - Water management measures for water pollution control. b)					

The course covers the collection of water quality data and the introduction and use of water quality models for describing, analyzing and evaluating substance inputs into aquatic systems.

This includes:

- Theoretical introduction to measurement methods for various water quality parameters
- Presentation of environmental pressures and environmental protection measures (DPSIR model): Driving forces, Pressures, State, Impact, Response
- Interactions between changes in land use and water quality
- Classification of water quality models
- Scale issues in the analysis and description of processes
- Spatio-temporal analysis of water quality, including long-term problems spanning several decades
- Assessment of potential sources of pollution in catchment areas
- Pollutant classes and guidelines for assessing water quality
- Modelling of various water quality parameters
- Model efficiency measures for evaluating model results
- Presentation of specific models and their application.

Educational form / Language

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

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

Examination methods

- Term paper 'Mass transport in catchment areas - Term paper' (40 h., Part of modul grade 0 %, presentation (max. 20 pages) and final presentation of results at the end of the course (deadline to be announced at the beginning of the semester))
- Written exam 'Transport and fate of substances in river basins' (60 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: Written exam
- Passed presentation with final presentation

Module applicability

- M.Sc. Environmental Engineering
- M.Sc. Civil engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 BI-W51/SE-O-3	Credits 2 CP	Workload 60 h	Semester[s] ab dem 1. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Technologies in Mechanised Tunneling (128228)			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency 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 [%] = $2 * 100 * \text{FAK} / \text{DIV}$

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

Load Bearing Behaviour and Design of Geotechnical Structures					
Tragverhalten und Bemessung von Grundbauwerken					
Module number BI-WP22	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Calculation of foundation structures b) Ground freezing and injection techniques – bearing behaviour and design			Contact hours a) 3 WLH (45 h) b) 1 WLH (15 h)	Self-study a) 90 h b) 30 h	Frequency a) each summer b) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. D. König b) Dipl.-Ing. Sven Keßler					
Admission requirements Recommended previous knowledge: Completed modules in mathematics, mechanics, statics, soil mechanics, and foundation engineering					
Learning outcome, core skills The students • are familiar with the load-bearing behaviour and design approaches of a wide variety of geotechnical structures, • have the ability to engage with innovative ideas, research findings, and current and changing design standards, • are able to reflect on and evaluate practical construction processes and situations in foundation engineering against the background of the knowledge they have acquired.					
Contents a) The course covers the following geotechnical systems, among others: • Grouted anchors • Load-bearing behaviour of anchored systems • Cofferdams • Caissons • Pile foundations • Suspension-supported trenches b) The course covers geotechnical aspects of ground freezing and injection techniques: • Basics of ground freezing technique • Properties of frozen soil and determination of parameters by laboratory testing • Planning of ground freezing applications and design • Technical implementation and monitoring • Injection techniques in foundation engineering • Planning of injection applications, technical implementation and quality management					
Educational form / Language					

- a) Lecture (3 WLH) / German
b) Lecture (1 WLH) / German

Examination methods

- Term paper 'Calculation of Geotechnical Structures - Homework' (30 h., ungraded, homework (30 h) with final discussion)
- Written exam 'Design of Geotechnical Structures' (150 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Homework with final discussion for a)
- Passed final module examination: written examination

Module applicability

- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Structures under climatic loads Tragwerke unter klimatischen Einwirkungen					
Module number BI-W68	Credits 3 CP	Workload 90 h	Semester[s] ab dem 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Structures under climatic loads			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Rüdiger Höffer a) Dr.-Ing. Francesca Lupi					
Admission requirements Recommended previous knowledge: • Bridge construction, building and industrial construction, construction technology for power plants and energy facilities • Fundamentals of dynamics • Effects on structures and safety concepts • Wind effects — civil engineering structures and wind turbines					
Learning outcome, core skills The course complements the compulsory module "Actions on Structures and Safety Concepts" and the elective module "Wind Effects - Civil Engineering Structures and Wind Turbines." Students • can discuss engineering issues relating to the climatic effects on structures, taking into account non-stationary meteorology, • acquire in-depth knowledge of the structural behavior of industrial and infrastructure structures and load-bearing components (bridges, wide-span roofs, high-rise buildings, towers, wind turbines, overhead lines, and pylons) under combined climatic effects (wind, wind and rain, wind and ice/snow), • understand the solution methods for dynamics in DIN EN 1991-1-4 (Eurocode 1: Actions on structures - Part 1-4: Wind loads) and their limitations, and can apply them appropriately to specific problems, • acquire knowledge of experimental methods in boundary layer wind tunnels or climate wind tunnels or numerical simulations for solving scientifically relevant problems, • acquire knowledge of measurements on completed structures for the validation of modeling approaches.					
Contents a) Modeling • Load-bearing behavior of structures and components under climate-related loads • Stochastic climate effects • Vibration calculation using stochastic dynamics • Combination of climatic effects (wind, rain, temperature, ice formation) Applications and examples • Wind excitation of weakly damped structures					

- Vortex-induced vibrations of slender structures (e.g., towers)
- Aeroelastic instabilities of bridge superstructures during construction and in their final state
- Vibrations of bridge hangers under wind and rain
- Icing process in wind for overhead line masts and bridge hangers
- Snow accumulation and displacement on roofs

Educational form / Language

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

Examination methods

- Oral exam 'Structures under climatic loads' (20 min., Part of modul grade 100 %, questions on two topics, approx. 20 minutes per candidate)
- Attendance at at least 60% of the classes

Requirements for the award of credit points

- Passed oral exam
- Attendance at at least 60% of the classes

Module applicability

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

Weight of the mark for the final score

Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Lecture notes and slides will be provided.

Transient Finite Element and Finite Difference Methods					
Transient Finite Element and Finite Difference Methods					
Module number BI-WP60/CE-WP30/TFEM	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Transient Finite Element and Finite Difference Method (126520)			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr. Roger A. Sauer a) Dr.-Ing. Sahir N. Butt, Prof. Dr. Roger A. Sauer					
Admission requirements Recommended previous knowledge: Finite Element Methods in Linear Structural Mechanics					
Learning outcome, core skills After successfully completing the module the students • understand the mathematical formulations of transient problems, including ordinary differential equations (ODEs) and partial differential equations (PDEs) • understand principles of numerical time integration schemes, their stability and accuracy • learn to assess the validity of the simulations, and interpret physical implications • gain hands-on experience in implementing numerical methods for transient problems					
Contents a) a) Introduction to transient problems and analysis • Hamilton's principle and Euler-Lagrange differential equation • Classification of transient problems and applications in engineering • Overview of numerical approaches b) Time integration of ODEs • Explicit and Implicit methods • Time integration of first order ODEs • Stability and accuracy analysis • Time integration of second order ODEs • Error estimates and Adaptive time stepping c) Time integration of PDEs • Finite differences in space and time • Diffusion and wave equation d) Outlook on Advanced topics in transient analysis • Fluid flow problems • Multiphysics problems					

Educational form / Language

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

Examination methods

- Exercises 'Transient Finite Element and Finite Difference Method' (120 h., Part of modul grade 100 %, Classroom quizzes (60h), Homework assignments (60h))

Requirements for the award of credit points

- Passed all quizzes and assignments

Module applicability

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

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Can NOT be combined with CE-WP11 "Applied Computational Simulations of Structures" or BI-WP06 "Angewandte statische und dynamische Tragwerkssimulationen"

Environmental aspects and sustainability in road construction Umweltaspekte und Nachhaltigkeit im Straßenbau					
Module number BI-W42	Credits 1 CP	Workload 30 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Environmental aspects and sustainability in road construction			Contact hours a) 1 WLH (15 h)	Self-study a) 15 h	Frequency a) each summer
Module coordinator and lecturer(s) Vertr.-Prof.'in Dr.-Ing. Nina Nytus a) Vertr.-Prof.'in Dr.-Ing. Nina Nytus					
Admission requirements The module cannot be selected if BI-WP29 or UI-WPC2 is taken. Recommended prior knowledge: Pavement Construction and Maintenance or Environmental Engineering in Pavement Construction Recommended previous knowledge: Straßenbau und -erhaltung bzw. Umwelttechnik in Straßenplanung und -bau					
Learning outcome, core skills After successfully completing the module, students will be able to select and evaluate the criteria necessary for the sustainability of a road.					
Contents a) In this course, sustainability in road construction is considered against the background of comprehensive resource conservation. The following topics are covered in detail • Legal principles of environmental protection and sustainability • Life cycle assessment • Suitability of recycled construction materials and industrial by-products for road construction • Use of sustainable construction materials • Environmental compatibility of construction materials • Aspects of life cycle assessment • Assessment criteria for sustainability					
Educational form / Language a) Lecture (1 WLH) / German					
Examination methods • Written exam 'Environmental aspects and sustainability in road construction' (30 min., Part of modul grade 100 %, or oral examination (15 minutes). The form of examination is determined at the beginning of each semester depending on the number of participants.)					
Requirements for the award of credit points • Passed module final examination: written exam					
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering					

Weight of the mark for the final score
Percentage of total grade [%] = $1 * 100 * \text{FAK} / \text{DIV}$ 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 Umweltgeotechnik					
Module number BI-WP43/UI-WPD7	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Landfill technology b) Dealing with contaminated sites c) Abandoned mining d) Seminar Abandoned mining			Contact hours a) 1 WLH (15 h) b) 1 WLH (15 h) c) 1 WLH (15 h) d) 1 WLH (15 h)	Self-study a) 30 h b) 30 h c) 30 h d) 30 h	Frequency a) each summer b) each summer c) each summer d) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. Hanna Viefhaus b) Dr.-Ing. D. König c) Dr. rer. nat. Ferdinand Stöckhert d) Dr. rer. nat. Ferdinand Stöckhert					
Admission requirements Recommended previous knowledge: Completed module in soil mechanics and foundation engineering					
Learning outcome, core skills The students - are familiar with the legal framework and the concepts and procedures of environmental geotechnics and related design concepts, - can develop solutions for environmental geotechnical problems and identify risks, - are able to adapt the methods learned to specific problems and to further develop them if necessary.					
Contents a) The course covers landfill technology: - Legal framework - Site selection - Construction of a landfill facility - Sealing systems - Monitoring and aftercare b) The course introduces participants to the handling of contaminated sites: - Legal framework - Contaminants relevant to contaminated sites - Decontamination and safety procedures c) The course deals with issues relating to abandoned mines:					

- Issues relating to abandoned mines depending on the mining techniques used
- Impacts and failure mechanisms on the surface of the terrain
- Legal framework
- Exploration techniques
- Securing and remediation procedures
- Monitoring in abandoned mines

d)

In the seminar on abandoned mining, the methods from c) are applied in practice using examples.

Educational form / Language

- a) Lecture (1 WLH) / German
- b) Lecture (1 WLH) / German
- c) Lecture (1 WLH) / German
- d) Seminar / German

Examination methods

- Written exam 'Environmental Geotechnics' (180 min., Part of modul grade 100 %)
- Term paper 'Seminar of abandoned mines' (25 h., Part of modul grade 0 %, homework with presentation (dates for presentation will be announced at the beginning of the semester)

Requirements for the award of credit points

- Homework with presentation for d)
- Passed final module examination: written examination

Module applicability

- M.Sc. Environmental Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Environmental Planning + GIS Umweltplanung und GIS					
Module number BI-P11/UI-WPB1	Credits 6 CP	Workload 180 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Introduction to environmental planning b) Introduction to geoinformation systems (GIS)			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.-Ing. Annette Hafner a) Dr.-Ing. Sandra Greassidis, Prof. Dr.-Ing. Annette Hafner b) Dr.-Ing. Sandra Greassidis, Prof. Dr.-Ing. Annette Hafner					
Admission requirements					
Learning outcome, core skills Students • have an understanding of working methods and methods of spatial and environmental planning with regard to different planning levels (federal, state, city/municipal level) and sectoral planning (e.g. water management planning, nature conservation planning, waste management planning, urban development planning, etc.) • can use the GIS knowledge they have acquired to evaluate various practical issues in environmental planning					
Contents a) Introduction to spatial planning, in particular environmental planning (water, landscape, development, etc.). The students are familiarised with the working methods and procedures of (environmental) planning by means of practical questions, e.g: • Buildings, infrastructure and the environment • Interdependencies between buildings, infrastructure and the environment • Recording the current state and impact prognosis • Planning systems and planning methods • Integrated urban development planning (resilience, climate protection, green spaces, water / flooding, mobility) • Specialised environmental planning (water, nature conservation, waste, etc.) • Environmental impact assessment, strategic environmental impact assessment • Site search for structures and facilities • Line identification for routes • Informal planning processes b) Geoinformation systems (GIS) are modern instruments for processing and utilising spatial data. They are used worldwide for environmental planning, for example, to record and evaluate the diverse effects of buildings on the environment. Different types of information often have to be processed in large quantities					

and visualised spatially.. This can be done effectively and continuously with the help of geographic information systems (GIS). GIS has become an integral part of civil engineering and environmental planning. Students are given an introduction to ArcGIS from ESRI.

The following topics are covered:

- Introduction to ArcMap, Arc Catalog, ArcToolbox
- Factual queries, spatial queries
- Coordinate systems
- Georeferencing
- Digitising
- Attribute tables (field value calculation, field statistics, etc.)
- Geodata processing (spatial join, attribute join, dissolve, summerise)
- Geoprocessing tools (buffer, clip, merge, etc.)
- Layout creation and editing

Educational form / Language

a) Lecture (2 WLH) / German

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

Examination methods

- Written exam 'Environmental Planning + GIS' (90 min., Part of modul grade 100 %)

Optional term paper in the course 'Introduction to Environmental Planning' to achieve a maximum of 10 bonus points for the written exam (30 hours, submission deadline will be announced at the beginning of the semester)

Requirements for the award of credit points

- Passed final module examination: written exam

Module applicability

- M.Sc. Environmental Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Environmental law (excursion) Umweltrecht (Exkursion)					
Module number W10	Credits 1 CP	Workload 30 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Environmental law (excursion)			Contact hours a) 1 WLH (15 h)	Self-study a) 30 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Marc Wichern a) Dr. jur. Till Elgeti					
Admission requirements Recommended previous knowledge: Lecture on environmental law					
Learning outcome, core skills The students • know the main areas of application of general environmental law, • have in-depth knowledge of special environmental law through concrete examples (spatial planning, nature conservation and landscape management, soil protection-, water protection-, pollution control-, water-, mining- and recycling management law).					
Contents a) The course illustrates • the basic requirements for authorisations set out in environmental law. • specific installations which are relevant under environmental law in detail regarding authorisation and monitoring requirements. • these installations under expert lead.					
Educational form / Language a) Excursion / German					
Examination methods • Seminar 'Environmental law (excursion)' (15 h., ungraded, participation in the excursion with prior presentation [ungraded])					
Requirements for the award of credit points • Participation in the excursion and preliminary meeting					
Module applicability • B.Sc. Civil Engineering • B.Sc. Environmental Engineering • M.Sc. Civil Engineering • M.Sc. Environmental Engineering • M.Sc. Geoscience					
Weight of the mark for the final score Percentage of total grade [%] = 0, ungraded					

Further Information

Registration takes place via the Chair of Urban Water Management and Environmental Technology. Students will be informed in good time via the Moodle course "Environmental Law."

Environmental Sustainability and Recycling of Construction Materials					
Umweltverträglichkeit von Baustoffen und Bauen im Bereich Umweltschutz					
Module number BI-WP25/UI-WPB4	Credits 6 CP	Workload 180 h	Semester[s] 2./3. Sem.	Duration 2 Semester[s]	Group size no limitation
Courses a) Environmental Sustainability and Recycling of Construction Materials b) Concrete structures for environmental protection			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 summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. habil. Iurie Curosu a) Prof. Dr.-Ing. Christoph Müller b) Dr.-Ing. Dieter Lehnen					
Admission requirements Recommended previous knowledge: Knowledge in the design of reinforced concrete structures under serviceability limit states as well as in construction materials and building physics					
Learning outcome, core skills The students • can apply advanced knowledge of the structural design and calculation of sealing and barrier structures. • can evaluate the significant effects of construction materials on the environment and their environmentally friendly recycling and reintegration into the material cycle. • are able to develop concrete designs and assess constructive measures for both new buildings and the repair of existing structures.					
Contents a) Principles of sustainable building • Environmentally relevant aspects in the production of construction materials • Influence of construction materials on the environment • Environmentally friendly recycling of construction materials and their reintegration into to the material cycle b) Fundamentals (facets of environmental protection, regulations, laws) • Constructive design (relevant regulations and construction methods) • Selected concrete structures of fossil power plants • Nuclear engineering • Special aspects (including offshore)					
Educational form / Language					

- a) Lecture (2 WLH) / German
- b) Lecture (2 WLH) / German

Examination methods

- Written exam 'Environmental Sustainability and Recycling of Building Materials' (90 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed written examination of the module

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Literature:

- a) Course related transcripts
- b) Slide and link collections

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 (127519) b) Surrogate Modeling (127519)			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 Engineering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Transportation Planning Verkehrsplanung					
Module number BI-WP32/UI-WPC5	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Transport Planning Models b) Evaluation Procedures in Transport			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.-Ing. Justin Geistefeldt a) Prof. Dr.-Ing. Justin Geistefeldt b) Dr.-Ing. Sandra Hohmann					
Admission requirements Recommended previous knowledge: Fundamentals of transportation and traffic engineering					
Learning outcome, core skills Students • have differentiated knowledge of the basic features of handling modern traffic models, • are able to develop simple logit or probit models independently, • are able to subject modelling approaches to critical evaluation and can understand new developments, • have the necessary knowledge and skills to apply transport planning software in their area of responsibility, • are able to assess the effect of the selection of different parameters on the calculation results • have differentiated knowledge of the effects of traffic measures on accidents and noise and pollution levels, • have the ability to independently apply the economic efficiency calculation methods used in practice for transport infrastructure investments and to understand the theoretical background of the methods, • are able to quantify and monetise the traffic effects of various measures and thus evaluate them in economic terms, • are able to judge the quality of the calculation methods and results and to assess the limits of the methods					
Contents a) Traffic modelling comprises four steps: traffic generation, traffic distribution, traffic distribution and traffic reallocation. This process and its variants are presented using examples. In addition to the classic modelling approaches, behaviour-oriented planning models are also considered. These include Route chain models, logit models, nested logit models, probit models, gravity and entropy models as well as reallocation models. The calculation methods of traffic modelling are applied in the exercises. In addition, standard programmes for traffic generation, traffic assignment and simulation are briefly introduced. The background and application of the VISEM and VISUM software is explained in detail as an example of traffic planning software. Concrete planning cases deepen the theory by working on the computer in small groups.					

b)

The economic viability of investments in transport infrastructure is usually examined and economically assessed on the basis of benefit-cost analyses (BCA). To compare the benefits and costs of a measure, the effects on traffic are quantified and monetarised. The effects of traffic on accidents and the environment are analysed in more detail.

In the lectures, the theoretical background of the procedures for quantifying traffic effects and the individual procedural steps of cost-effectiveness analyses are presented. Accident analyses and safety concepts as well as methods for calculating noise and pollution levels are also dealt with in depth. In the exercises, investment measures are examined and evaluated on the basis of specific planning tasks.

Educational form / Language

a) Lecture (1,5 WLH) / Tutorial (0,5 WLH) / German

b) Lecture (1,5 WLH) / Tutorial (0,5 WLH) / German

Examination methods

- Written exam 'Transportation Planning' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Transportation Systems Verkehrssysteme					
Module number BI-WP31/UI-WPC4	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Public Transport b) Traffic Management c) Air Transport			Contact hours a) 2 WLH (30 h) b) 2 WLH (30 h) c) 1 WLH (15 h)	Self-study a) 60 h b) 30 h c) 15 h	Frequency a) each summer b) each summer c) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Justin Geistefeldt a) Prof. Dr.-Ing. Justin Geistefeldt b) Prof. Dr.-Ing. Justin Geistefeldt c) Prof. Dr. Edmund Krieger					
Admission requirements Recommended previous knowledge: Fundamentals of transportation and traffic engineering					
Learning outcome, core skills Students • have advanced knowledge of planning and operational tasks in the field of public transport, • are able to reflect on the interaction of the individual components of public transport (infrastructure, vehicles, legal framework, economic efficiency, form of operation), • have differentiated knowledge of the methods and systems of transport management and are able to develop and professionally assess transport management measures, • have advanced knowledge of the classic and current technical, legal and economic developments in air traffic. • are able to apply the special planning procedures for air traffic facilities to the various practical and professional fields.					
Contents a) The basics of planning, building and operating local public transport systems are covered. Topics of the lecture are: Legal conditions, tasks and areas of application of transport systems in public transport, requirements for public transport systems, network planning in public transport, stop design, connection points and transfer facilities, operational preparation (operational concepts, timetable design, vehicle and personnel scheduling), operational management (control, security, monitoring), economic efficiency. b) The course covers methods and systems of traffic management in road transport, including new developments in the field of intelligent transport systems. Topics of the lecture are: Fundamentals of road traffic law, signposting, traffic control on motorways, network control, traffic management centres, organisation of traffic management, road works management, traffic safety management, mobility management.					

c)

The lecture primarily deals with the planning and operation of airports. It covers the following topics: Flight operation areas, air traffic control, passenger receiving facilities, cargo terminals and other operational facilities. Environmental aspects are also covered.

Educational form / Language

- a) Lecture (1,5 WLH) / Tutorial (0,5 WLH) / German
- b) Lecture (2 WLH) / German
- c) Lecture (1 WLH) / German

Examination methods

- Written exam 'Transportation Systems' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Traffic Engineering Verkehrstechnik					
Module number BI-WP30/UI-WPC3	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Transportation Engineering			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Justin Geistefeldt a) Prof. Dr.-Ing. Justin Geistefeldt					
Admission requirements Recommended previous knowledge: Advanced mathematics, fundamentals of transportation engineering					
Learning outcome, core skills Students • have a differentiated understanding of the laws governing traffic flow on roads and are able to reflect on scientific methods of describing these laws and recognize their practical applicability. • are able to independently develop extensions or adaptations of traffic flow models, • have an in-depth understanding of the theoretical background and the possible applications and limitations of traffic simulation models, • have up-to-date technical knowledge and advanced knowledge of methods for traffic analysis and intersection control, • are able to understand the planning techniques used in practice for traffic light systems and to design complex systems, including coordination, in a practical manner.					
Contents a) The theoretical principles for describing traffic flow on roads and at intersections are developed using mathematical methods. The underlying laws are derived. The basic methods, control systems, and equipment required for their operation are covered for the traffic analysis and design of road intersections. The methods commonly used in practice are illustrated with examples in the exercises. The following topics are covered in detail: • Parameters of traffic flow and their interrelationships • Fundamental diagram • Capacity • Traffic engineering design • Free traffic flow • Continuum theory • Distance models • Vehicle following theory • Microscopic traffic flow simulation • Waiting time determination at intersections					

- Fixed-time control of traffic signal systems
- Coordination of traffic signal systems
- Traffic-dependent control including signal program formation
- Signal technology
- Right-of-way controlled intersections

Educational form / Language

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

Examination methods

- Written exam 'Traffic Engineering' (120 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed module final exam: written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Water Chemistry and Laboratory Course Wasserchemie und Laborpraktikum					
Module number BI-WP39/UI-WPD5	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Water Chemistry b) Research exercise in urban water management			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.-Ing. Marc Wichern a) Prof. Dr.-Ing. Marc Wichern, Dr. rer. nat. Eva Heinz b) Prof. Dr.-Ing. Marc Wichern, Dr. rer. nat. Eva Heinz					
Admission requirements Recommended previous knowledge: Urban water management I + II					
Learning outcome, core skills The students • have a comprehensive overview of the current state of technology and science in the field of water chemistry. • are able to understand the chemical processes in water and have the ability to combine and apply these in the treatment of water and the purification of wastewater. • are familiar with the determination of relevant test parameters in water and wastewater analysis. • are able to carry out physico-chemical determinations independently. • are able to critically assess the informative value of analytical results and practise scientific learning and thinking by preparing test protocols.					
Contents a) • Chemical basics • the importance of the water cycle in chemistry • Introduction to chemical water treatment b) The research exercise introduces students to • analytics • sampling • conservation of analytical methods relevant to water management and the implementation of special analysis methods regarding wastewater technics, such as the photometric determination of nitrogen parameters.					
Educational form / Language a) Lecture (1 WLH) / Tutorial (1 WLH) / German b) Tutorial (2 WLH) / German					

Examination methods

- Oral exam 'Water Chemistry and Laboratory Course' (60 min., Part of modul grade 100 %, 20 minutes, oral questions: 40 minutes)
- Term paper 'Report on research exercise in urban water management' (15 h., Part of modul grade 0 %)

Requirements for the award of credit points

- Passed module final exam: Written exam
- Passed research exercise report
- Attendance at research exercise

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Wind effects – Engineering Structures and Wind Turbines					
Windwirkungen – Ingenieurbauwerke und Windenergieanlagen					
Module number BI-WP45	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size 30
Courses a) Wind effects – Engineering Structures and Wind Turbines			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Rüdiger Höffer a) Prof. Dr.-Ing. Rüdiger Höffer					
Admission requirements Recommended previous knowledge: Knowledge of fluid mechanics, statics and structural engineering, effects on structures and safety theory, building and industrial construction, bridge construction, structural health monitoring					
Learning outcome, core skills Students will be able to • Use and evaluate statistical analyses of wind data (extreme values and basic ensemble) • Interpret wind effects and impacts on civil engineering structures and wind turbines and apply them in a differentiated manner in structural design • Use and evaluate other relevant regulations for civil engineering structures in addition to technical building regulations introduced by building authorities • Interpret and use results from related wind tunnel tests • Compare, select, and combine wind loads on structures using various methods • Determine aerodynamic forces on a rotor blade of a wind turbine • Use the FE analysis computer program "ASHES" to visualize wind effects on wind turbines • Explain and use the identification of structural dynamic parameters from monitoring data • Demonstrate load cycle counts and fatigue analyses based on monitoring data					
Contents a) • Statistical description of wind fields: - Design wind - Wind as a resource • Wind action models for linear and surface building structures • Static equivalent methods for determining stress for static calculation • Experiments in the boundary layer wind tunnel (partly digital as a "remote access laboratory"): - Physical boundary layer generation in wind tunnel model - Measurement methods and sensor technology - Measurement data evaluation and wind load determination • Applications for linear and flat structures: - Chimneys and masts - Wide-span roofs (e.g., stadium roofs) - Cooling tower shells (structural regulations in cooling tower construction BTR)					

- Container shells (including silos) • Wind turbines: - Structure and design - Wind effects and wave action • Offshore wind energy: - Project development - Current and future situation with example projects • Small wind turbines: - Wind energy in urban areas - Savonius and Darrieus rotors • Solar updraft power plants: - Construction of tower and collector - Wind effects • Simulation of wind effects on wind turbines (onshore and offshore) using the FE program "ASHES" - Model construction, load generation, and visualization of results • Strategies for damage and service life estimation of structural components (including application of structural health monitoring for life cycle management)
Educational form / Language a) Seminar / Lecture (4 WLH) / German / English
Examination methods • Seminar 'Wind effects – Engineering Structures and Wind Turbines' (60 h., Part of modul grade 100 %, poster creation with presentation (30 min))
Requirements for the award of credit points • Creation of a poster and presentation
Module applicability • M.Sc. Civil Engineering • M.Sc. Environmental Engineering (optional module)
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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 Lectures, exercises, and seminars (designed by students), German (and English)

Non-Destructive Testing and Diagnostics of Structures and Environmental Systems Zerstörungsfreie Diagnostik von Bauwerken und Umweltsystemen					
Module number BI-W78	Credits 3 CP	Workload 90 h	Semester[s] ab dem 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Non-Destructive Testing and Diagnostics of Structures and Environmental Systems			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each summer
Module coordinator and lecturer(s) Dr.-Ing. Christoph Baer a) Dr.-Ing. Christoph Baer					
Admission requirements Recommended previous knowledge: Basic knowledge of mathematics, physics, and engineering fundamentals at bachelor's level is recommended. Prior knowledge of electrical engineering or measurement technology is helpful but not required.					
Learning outcome, core skills Students acquire knowledge of modern non-destructive and non-contact measurement techniques for assessing the condition of structures, infrastructure systems, and environmental systems. Upon successful completion of the module, students will be able to: • explain the physical principles of wave- and radiation-based measurement techniques, • understand the operating principles of non-contact sensors and diagnostic systems, • select suitable methods for different inspection, assessment, and monitoring tasks, • interpret and critically evaluate measurement data obtained from non-destructive testing methods, • identify limitations, uncertainties, and environmental influences affecting non-contact measurements, compare different diagnostic techniques with respect to effort, information content, and practical applicability.					
Contents a) • Fundamentals of electromagnetic, acoustic, and optical measurement techniques • Wave propagation, reflection, and time-of-flight measurements • Radar systems for distance, motion, and subsurface sensing • Ground-Penetrating Radar (GPR) for the investigation of structures, soils, and infrastructure systems • Doppler radar for displacement, vibration, and motion monitoring • Ultrasonic testing methods for material characterization and condition assessment • Infrared thermometry for non-contact temperature measurements • Infrared thermography for the detection of thermal bridges, moisture intrusion, and structural defects • Fibre-optic monitoring systems for strain and temperature measurements • Integration and evaluation of non-destructive testing and monitoring techniques • Case studies in structural health monitoring, infrastructure diagnostics, and environmental monitoring					
Educational form / Language					

a) Lecture with tutorial / German

Examination methods

- Oral exam 'Non-Destructive Testing and Diagnostics of Structures and Environmental Systems' (30 min., Part of modul grade 100 %, Presentations given within the expert-group format may be considered as a bonus component.)

Requirements for the award of credit points

- Successful completion of the oral module examination

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

- Lectures with integrated exercises
- Demonstrations of selected non-contact measurement techniques
- Discussion of practical case studies

Optionally, an expert-group format is offered in which student teams independently investigate an advanced sensing topic and present their findings at the end of the semester.

**Master's degree program “Civil Engineering”
Curriculum**

Status 30.07.26

		Module code	Module title	SWS	CP	Semester	Specialization				
							KIB - Design and Construction	KIB - Digital Design and Construction	Geotechnics and Tunneling	Water Managem. and Env. Technology	Road and Traffic Engineering
Compulsory modules of Specialization											
1. Semester	Compulsory modules 28 CP	BI-P01	Numerical Mathematics	4	5	WiSe	X	X	X	X	X
		BI-P02	Mathematical Statistics	4	5	WiSe				X	X
		BI-P03	Mechanics C	4	5	WiSe	X				
		BI-P04	Programming	4	5	WiSe		X			
		BI-P05	Geotechnics	4	5	WiSe			X		
		BI-P06	Construction Operation and Management	4	6	WiSe	X	X	X	X	X
		BI-P07	Actions on structures and safety concepts	4	6	WiSe	X	X			
		BI-P08	Finite Element Methods in Linear Structural Mechanics	4	6	WiSe	X	X	X		
		BI-P09	Physical Geology and Soil Mechanics	4	6	WiSe			X		
		BI-P10	Operations Research and Databases	4	6	WiSe				X	X
		BI-P11	Environmental Planning + GIS	4	6	WiSe				X	X
Compulsory optional modules											
2. / 3. Semester	Compulsory optional modules 24 CP from Category 1 + 12 CP from Category 1 oder 2	BI-WP01	Prestressing and non-linear calculations of concrete structures	4	6	SuSe	1	2	2		
		BI-WP02	Nonlinear Design Methods of Steel and Composite Structures	4	6	SuSe	1	2			
		BI-WP03	Bridges - Conceptual Design and Structural Detailing	6	9	WiSe	1	2			2
		BI-WP04	Buildings and industrial structures	6	9	WiSe	1	2	2		
		BI-WP05	Nonlinear Finite Element Method for Structures	4	6	SuSe	2	1	2		
		BI-WP06	Applied Finite Element Methods	4	6	SuSe	1	2			
		BI-WP09	Simulation Technology	4	6	WiSe	2	2	2	2	2
		BI-WP10	Foundation Engineering and Utility Pipe Construction: Design–Engineering–Technologies	4	6	WiSe	2		1	2	2
		BI-WP11	Conventional and Mechanised Tunneling: Design – Engineering – Technologies	4	6	SuSe	2		1		
		BI-WP12	Special Concrete Technology	4	6	WiSe	1		2		
		BI-WP13	Durability and Repair of Concrete Structures	4	6	SuSe	1		2		
		BI-WP16	Continuum Mechanics	4	6	SuSe	2	2			
		BI-WP17	Advanced Mechanics of Materials	4	6	SuSe	2	2			
		BI-WP18	Foundations of dynamics	4	6	WiSe		1			
		BI-WP19	Finite Element Technology	4	6	SuSe	2	1			
		BI-WP20	Fundamentals of System Dynamics	4	6	WiSe		2			
		BI-WP21	Plasticity and Damage	4	6	SuSe	2	2			
		BI-WP22	Load Bearing Behaviour and Design of Geotechnical Structures	4	6	SuSe			1		
		BI-WP23	Rock Mass Mechanics and Rock Engineering	5	6	SuSe			1		
		BI-WP24	Numerical Simulation in Geotechnics and Tunneling	4	6	SuSe			1		
		BI-WP25	Environmental Sustainability and Recycling of Building Materials	4	6	2 Sem	2		1	2	2
		BI-WP26	Operation and Maintenance of Tunnels and Utility Pipes	4	6	WiSe	2		2		
		BI-WP27	Practical Geotechnics: Laboratory and Computing	4	6	WiSe			1		
		BI-WP28	Design of roads, material models a. practical aspects in road construction technology	5	6	WiSe			2	2	1
		BI-WP29	Digitalization in road construction and the basics of railway engineering	5	6	SuSe			2	2	1
		BI-WP30	Traffic Engineering	4	6	SuSe				2	1
		BI-WP31	Transportation Systems	5	6	SuSe				2	2
		BI-WP32	Transportation Planning	4	6	WiSe				2	1
		BI-WP33	Sustainable Water Resources Management	4	6	WiSe				1	2
		BI-WP34	Hydrology	4	6	SuSe				1	2
		BI-WP35	Spatial data analysis and environmental modelling	4	6	WiSe			2	2	2
		BI-WP36	Transport and fate of substances in river basins	4	6	SuSe				2	
		BI-WP37	Intern. Wastewater Treatment, Industrial Wastewater Treatment a. River Water Quality	4	6	SuSe			2	1	2
		BI-WP38	Innovations in Urban Water Management and Mathematical Simulation	5	6	2 Sem				1	2
		BI-WP39	Water Chemistry and Laboratory Course	4	6	WiSe				2	
		BI-WP40	Sustainable operation a. resource conservation with urban water management facilities	4	6	WiSe				2	
		BI-WP41	Geotechnical calculations and foundation engineering	4	6	WiSe	2				2
		BI-WP42	Soil Dynamics and Geotechnical Earthquake Engineering	4	6	WiSe			1		
		BI-WP43	Environmental Geotechnics	4	6	SuSe			2	2	
		BI-WP44	Advanced Constitutive Models for Geomaterials	4	6	SuSe	2		1		
		BI-WP45	Wind effects – Engineering Structures and Wind Turbines	4	6	SuSe	2	2			
		BI-WP46	Introduction to Structural Health Monitoring	4	6	SuSe	2	2			
		BI-WP47	Sustainable Building	4	6	WiSe	2				
		BI-WP48	Automation in Design and Construction	4	6	WiSe	2	1			
		BI-WP49	Introduction to materials modeling	4	6	SuSe	2	2			
		BI-WP50	Advanced Building Information Modeling	4	6	SuSe		1			
		BI-WP51	Artificial Intelligence	4	6	SuSe		1			
		BI-WP53	Fundamentals of automation technology	4	6	WiSe		2			
		BI-WP54	Material Flow Management	4	6	SuSe		2			
		BI-WP55	High-Performance Computing on Clusters	4	6	WiSe		2			
		BI-WP56	High-Performance Computing on Multicore Processors	4	6	SuSe		2			
		BI-WP57	Computational Modeling of Membranes and Shells	4	6	WiSe	2	2	2		
		BI-WP58	Uncertainty Quantification in FE Analyses with Surrogate Modeling	4	6	WiSe	2	1	2		
		BI-WP59	Inelastic Finite Element Method for Structures	4	6	WiSe	2	1	2		
		BI-WP60	Transient Finite Element and Finite Difference Methods	4	6	SuSe	2	1			
		BI-WP61	Earthworks – Soil mechanical background and practice	4	6	WiSe			1		

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Continuation of the Master's degree program “Civil Engineering” Curriculum

		Module code	Module title	CP		Specialization				
						KIB - Design and Construction	KIB - Digital Design and Construction	Geotechnics and Tunneling	Water Managem. and Env. Technology	Road and Traffic Engineering
Project work of the specializations										
2. / 3. Sem.	Project 6 CP	BI-PA01	Project "KIB - Design and Construction"	6		X				
		BI-PA02	Project "KIB - Digital Design and Construction"	6			X			
		BI-PA03	Project "Geotechnics and Tunneling"	6				X		
		BI-PA04	Project " Water Management and Environmental Technology"	6					X	
		BI-PA05	Project "Road and Traffic Engineering"	6						X
BI										
4. Sem.	Master Thesis 30 CP	BI-MA	Master Thesis	30						
Optional modules										
	Optional modules 20 CP		Further modules from the above list and according to the module handbook	20						
		Foreign languages ¹⁾								
		Modules from other Bachelor's or Master's degree programs ¹⁾								
Total credit points				120						

¹⁾ If similar or equivalent module content was not already part of the Bachelor's examination relevant for admission