2023

Module guide (Modulhandbuch) NHRE

Bauhaus-Universität Weimar

01.04.2023

Study Regulations - Supplement 1 Master's degree programme "Natural Hazards and Risks in Structural Engineering"				1st semester (winter semester)	2nd semester (summer semester)	3rd semester (winter semester)	4th semester (summer semester)
Modules		Credits		Credits	Credits	Credits	Credits
Applied mathematics and stochastics for risk assessment	**Prof. Rüffer,** Prof. Lahmer	6		**6**			
Geographical Information Systems (GIS) and building stock survey	**Prof. Rodehorst,** Dr. Beinersdorf, Dr. Schwarz	6		**6**			
Primary hazards and risks Part I: Seismic Monitoring + Regional Ground Motion Part II: Wind engineering	**Dr. Schwarz,** Prof. Morgenthal, Prof. Höffer	6		**6**			
Finite element methods and structural dynamics	**Prof. Rabczuk,** Dr. Zabel	6		**6**			
Structural engineering Part I: Reinforced and post-tensioned concrete structures Part II: Steel structures	**Prof. Kraus,** Prof. Morgenthal	6		**3**	**3**		
Elective module ** (recommendation: German language)		**6**		**3**	**3**		
Structural parameter survey and evaluation Part I: Systems and data processing Part II: Data evaluation	**Prof. Morgenthal,** Prof. Rodehorst, Prof. Illge	6			**6**		
Earthquake engineering and structural design	**Dr. Schwarz,** Prof. Abrahamczyk	6			**6**		
Geo- and hydrotechnical engineering Part I: Geotechnical Engineering Part II: Flood Hazard and Vulnerability Assessment	**Prof. Staubach**, Dr. Maiwald	6			**6**		
Elective compulsory module *		6			6		
Disaster management and mitigation strategies	**Prof. Melzner,** Prof. Eckardt	6				**6**	
Life-lines engineering	**Prof. Morgenthal**	6				**6**	
Elective compulsory module *		6				6	
Special project		12				12	
Elective module **		6					6
Master's Thesis		24	4 months				24
Total		120		30	30	30	30

* see NHRE module catalogue (updated annually, to be confirmed by the head of the NHRE program and the examination committee)

** see NHRE module catalogue - additionally any master course at the Bauhaus University (German language courses for 6 credits are valid too)

Compulsory modules

Compulsory modules 1st semester (winter semester):

- Applied mathematics and stochastics for risk assessment
- Geographical Information Systems (GIS) and building stock survey
- Finite element methods and structural dynamics
- Structural engineering - Reinforced and post-tensioned concrete structures

Compulsory modules 2nd semester (summer semester):

- Structural engineering - Steel structures
- Structural parameter survey and evaluation
- Earthquake engineering and structural design
- Geo- and hydrotechnical engineering

Compulsory modules 3rd semester (winter semester):

- Disaster management and mitigation strategies
- Life-lines engineering
- Special Project

Bauhaus-Universität Weimar / Faculty of Civil Engineering M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]						
Applied mathematics and stochastics for risk assessment						**Module-No.: 2301012**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1	annually in Winter Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 68hs Attendance time, 82hs Self-study time 30hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.	NHRE	**1 written exam** “Applied mathematics and stochastics for risk assessment” / 180 min (100%) / **WiSe** + SuSe	Lecture (L) Exercise (E) Tutorial (T)	Prof. Dr. rer. nat. Björn Rüffer

Course aim
Students will be prepared for mathematical requirements in Computer Aided Engineering (CAE), Signal Processing and Engineering lectures. Introduction to Computer Science based on Computer Algebra Systems for analysis and equation solving. Provision of basic concepts in probability theory and statistics for the assessment of risks of both single components and complex systems. Emphasis on the theory and application of extreme-value distributions.

Course content
Applied mathematics: Fundamentals of linear algebra, eigenvalue problems, fixed point principles, solvers; Fourier series, convergence, Fourier transform, Laplace transform; Solution of initial value problems, boundary value problems and eigenvalue problems for ordinary differential equations; All topics are discussed from the mathematical point of view and their implementation will be studied. **Stochastics for risk assessment:** Introduction to probability theory with focus on situations characterized by low probabilities. Random events, discrete and continuous random variables and associated distributions. Descriptive statistics, parameter estimation. Risk Assessment by means of FORM and Monte Carlo Simulations. Introduction to reliability theory: Extreme value distributions; stochastic modelling with software tools e.g. MATLAB, Octave, Excel, R. Reliability Analysis of Systems. Catastrophic events + risk problems, Applications

Course literature
Will be announced.

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Rüffer, Dr. Gorban	Applied mathematics (L)	2
Dr. Gorban	Applied mathematics (E)	1
Prof. Lahmer	Stochastics for risk assessment (L)	2
Prof. Lahmer	Stochastics for risk assessment (E)	1
--	Tutorial: Computer Algebra Systems (T)	

Bauhaus-Universität Weimar / Faculty of Civil Engineering
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Geographical Information Systems (GIS) and building stock survey						Module-No.: 2904002
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1	annually in Winter Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 45hs Attendance time, 45hs Project work 60hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE	**1 written exam** “Geographical Information Systems (GIS) and building stock survey” / 90 min (50%) / **WiSe** + SuSe **1 written report** “Geographical Information Systems (GIS) and building stock survey” (50%) / **WiSe**	Lecture (L) Exercise (E) Project (P)	Prof. Dr.-Ing. Volker Rodehorst

Course aim

Students will be trained to reproduce existing natural hazard and risk related data in GIS format using GIS Software Solutions and Tools, will be able to create basic layers for hazard and risk assessment and to establish relevant links and to solve simple example tasks.
Students will be trained in building stock survey, vulnerability assessment, damage interpretation and handling of tools for detailed empirical and instrumental elaboration.
Training in instruments, equipment, and technologies for advanced detailed building survey (geodetic, photogrammetric, satellite data).

Course content

Fundamentals of three-dimensional positioning, photogrammetry, GIS/cartography, land management / cadastre; earthwork computation; spatial data in daily life; instruments, equipment, and technologies for advanced detailed building survey (geodetic, photogrammetric, satellite data).

Training in:
Coordinate systems; global maps for the natural hazard phenomena; quality and availability of input data; layers for natural hazard related parameters (topography, geology, and subsoil); reproduction of historical events and associated parameters; layers for risk assessment and loss estimation procedures; link between layers and risk mapping procedures. In parallel, necessary foundations in scientific working are taught and trained.

Course literature

Textbooks (to be announced); publication from the lecturers; results from recent projects

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Rodehorst	Geographical Information Systems (GIS) and building stock survey (L)	1
Dr. Beinersdorf / Dr. Schwarz	Geographical Information Systems (GIS) and building stock survey (E, P)	3

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Primary hazards and risks						**Module-No.: NHM-2010**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1	annually in Winter Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 68hs Attendance time, 30hs Project work 57hs Self-study time 25hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.	NHRE	**1 Project report** “Regional Ground Motion” (17%) / **WiSe** **2 written exams** “Seismic Monitoring” / 120 min (50%) / **WiSe** + SuSe “Wind Engineering” / 90 min (33%) / **WiSe** + SuSe	Lecture (L) Exercise (E) Project (P)	Dr.-Ing. Jochen Schwarz

Course aim

Students will be able to define the seismic and wind action being related to design concepts and practical applications. They will be familiar to use ground and wind recordings and building response data and they will be trained in practical realization and handling of data, different types of sensors and data acquisition instruments. The students should be able to interpret dynamic building response characteristics and define input parameters for calculations.

Course content

Seismic Monitoring
Description of seismic action; recording instruments, input parameters for seismic hazard assessment; EQ-Action for building design; Measurements for site response evaluation; Building Monitoring Systems: tasks and developments, analysis of instrumental data; identification of dynamic and structural parameters
Regional Ground Motion
Identification of hazard describing parameters; seismic networks, availability/ elaboration of ground motion data and records; Ground Motion Prediction Equations (GMPEs); application of ground motions models and tools to the study area and target site; re-interpretation of national code background; site categorization and response studies.
Wind Engineering
Meteorology related wind effects on structures, quantification of wind effects and wind loading after wind loading standards: extreme value analysis and wind maps, aerodynamic and aeroelastic effects on structures, phenomena of wind-induced dynamic response, basics of wind resistant design, wind tunnel technology, numerical simulations of aerodynamic effects, wind risk mitigation; examples

Course literature

Textbooks (to be announced); publication from the lecturers

Courses

Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Dr. Schwarz, DI Ch. Kaufmann	2202001: Seismic Monitoring (L)	3
Dr. Schwarz, DI Ch. Kaufmann	2202001: Regional Ground Motion (E)	1
Prof. Morgenthal / Prof. Höffer	2204017: Wind Engineering (L, E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Finite element methods and structural dynamics						Module-No.: NHM-2050
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1	annually 1st half Winter Semester	1/2 Semester weekly	Compulsory	6	English	180hs, thereof 90hs Attendance time, 60hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE other	**1 written exam:** "Fundamentals of finite element methods" / 90 min (50%) / **WiSe** + SuSe **1 written exam:** "Fundamentals of structural dynamics" / 90 min (50%) / **WiSe** + SuSe	Lecture (L) Exercise (E)	Prof. Dr.-Ing. Timon Rabczuk, Dr.-Ing. Volkmar Zabel

Course aim

TR: Students will obtain the ability to analyse complex structural engineering problems applying numerical simulation techniques, to establish numerical approximation methods for structural engineering problems starting with the PDE and ending in a discretized form of a weak formulation. They will be able to assess the quality of FEM solutions.
VZ: The students will obtain basic knowledge of structural dynamics, become able to understand the concepts of analyses in time and frequency domain for SDOF systems as well as the extension of these analyses to MDOF systems. Further, they will be able to solve simple problems of structural dynamics by means of a numerical tool.

Course content

Finite element methods: (50% of semester course time)
strong and weak form of equilibrium equations in structural mechanics, Ritz and Galerkin principles, shape functions for 1D, 2D, 3D elements, stiffness matrix, numerical integration, Characteristics of stiffness matrices, solution methods for linear equation systems, post-processing and error estimates, defects of displacements based formulation, mixed finite element approaches,
Structural Dynamics: (50% of semester course time)
SDOF systems: free vibrations, harmonic, impulse and general excitation for undamped and damped systems, Impulse response function, frequency response function, base excitation, time step analysis: central difference and Newmark methods; MDOF systems: modal analysis, modal superposition, modal damping, Rayleigh damping, Frequency response functions, state-space models

Course literature

K.J. Bathe: Finite Element Procedures, O.Zienkiewicz: Finite Element Methods
Clough, Penzien: Dynamics of Structures, 2010 / Chopra: Dynamics of Structures, 2015

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Rabczuk	2401015: Finite element methods (L)	2
Prof. Rabczuk / et al.	2401015: Finite element methods (E)	1
Dr. Zabel	2401014: Structural dynamics (L)	2
Dr. Zabel / et al.	2401014: Structural dynamics (E)	1

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Structural engineering						Module-No.: NHM-2020
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1	Start annually in Winter Semester	2 Semester weekly	Compulsory	6	English	180hs, thereof 68hs Attendance time, 82hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE	**2 written exams** “Reinforced and post-tensioned concrete structures” / 90 min (50%) / **WiSe** + SuSe “Steel structures” / 90 min (50%) / **SuSe** + WiSe	Lecture (L) Exercise (E)	Prof. Dr.-Ing. Matthias Kraus

Course aim
Students will be familiar with the history of structures and structural forms, with building materials and building methods. They will understand the concepts of structural engineering design, including safety concepts, loads and structural design codes. They will be able to convert a structural concept into a mechanical model to determine internal demand and to design and detail the components of the structure, with an emphasis on reinforced concrete and post-tensioned concrete structures as well as steel and steel-concrete composite structures.

Course content
Structural Engineering – Reinforced and post-tensioned concrete structures (winter semester) (formerly Standard systems): History of structures; building materials; structural form and structural behaviour; actions on structures; structural reliability and codes of practice; mechanical modelling of structures; design of reinforced concrete and post-tensioned concrete structures – design and detailing. **Structural Engineering – Steel structures (summer semester) (formerly Advanced systems):** Elastic and plastic cross sectional capacity; Design of steel members – Stability modes of flexural and lateral torsional buckling, Design of welded and bolted steel connections – Structural detailing; Fire design of members susceptible to stability

Course literature
Textbooks (to be announced)

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Morgenthal	205032 Structural engineering – Reinforced and post-tensioned concrete structures (L)	2
Prof. Morgenthal / et al.	205032: Structural engineering – Reinforced and post-tensioned concrete structures (E)	1
Prof. Kraus	205033: Structural engineering – Steel structures (L)	2
Prof. Kraus / et al.	205033: Structural engineering – Steel structures (E)	1

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Structural parameter survey and evaluation						**Module-No.: 2204018**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2	annually in Summer Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 45hs Attendance time, 60hs Project work 55hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
Prim. Hazards and Risks, Appl. Mathem.	NHRE	**1 written exam** “Structural parameter survey and evaluation “/ 120 min (100%) / **SuSe** + WiSe	Lecture (L) Exercise (E) Project (P)	Prof. Dr. Guido Morgenthal

Course aim
The students will be familiar with methods to determine properties of structural systems by means of modern measurement techniques. They will be familiar with the concepts, the application and the limitations of these techniques. They understand the data obtained and the methods to condition, analyse and interpret the data to extract information about structures and structural members and components. They will be able to apply the concepts to develop measurement setups and analysis procedures to problems encountered in structural engineering.

Course content
Signal Analysis Trigonometric polynomials (TP); amplitude-phase and complex representation; approximation of arbitrary periodic functions by TP using method of least squares, calculation of Fourier coefficients and error estimation; Fourier series. Discussion of spectra and Fourier transform and its basic properties; Convolution and its properties and applications; random variables and central limit theorem; applications of Fourier transforms such as filtering of signals and solving differential equations **Sensor-based Monitoring and System Analysis** Types and principles of sensors; important sensor properties; data acquisition techniques; spectral and stochastic analysis of sensor data; properties of structural systems important in experimental testing and structural health monitoring; relevant limit states; structural analysis, modelling and model calibration; applications to static and dynamic response, load determination, physically nonlinear structural behaviour and optimization of sensor system setups **Geo-spatial Monitoring** Preparation and planning of three-dimensional measurement tasks; application of tacheometry, satellite-based positioning (GNSS), terrestrial laser scanning and photogrammetry for monitoring; image-based sensor orientation and surface reconstruction; spatial transformations, georeferencing, distance measures, pointcloud registration and geometric deformation analyses

Course literature
Baher: Signal Processing and Integrated Circuits, Wiley 2012; Blinder: Guide to Essential Math, Elsevier 2013; Further literature to be announced

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Morgenthal	Sensor-based Monitoring and System Analysis (L,E+P)	1.5
Prof. Rodehorst / et al.	Geo-spatial Monitoring (L,E+P)	1.5
Prof. Illge	Signal Analysis (L/E)	1.5

Bauhaus-Universität Weimar / Faculty of Civil Engineering
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Earthquake engineering and structural design						**Module-No.: 2202002**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2	annually in Summer Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 68hs Attendance time, 45hs Project work 47hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
Primary Hazards and Risks	NHRE	**1 written exam** “Earthquake engineering” / 150 min (67%) / **SuSe** + WiSe **1 Project report + Project presentation** “Structures in Earthquake Regions/Design of RC frames” / (33%) / **SuSe**	Lecture (L) Exercise (E) Project (P)	Dr.-Ing. Jochen Schwarz

Course aim

Students are trained and qualified in tasks of earthquake engineering, natural hazard and risk determining parameters. Students will be able to process input data, to realize design decision for structures of different building type and risk potential, to apply modern building codes and design concepts, to develop earthquake resistant structures and to evaluate structural design.

Course content

Earthquake engineering
Seismic Code development and generations; simplified analysis methods; design of structures and regularity criteria for earthquake resistance; performance and experience-based design concepts; rules for engineered buildings (R/C, steel, masonry) and non-engineered buildings; interaction effects between structure and soil, equipment and filling media; special and high risk structures
Structures in Earthquake Regions
Description of National code development; recent code situation; determination of seismic forces for an idealized RC frame system; comparison of different international code levels
Design of RC frames with masonry infill walls in earthquake regions: Application of modern software tools
Training of modelling and calculation with different software tools; interpretation of structural systems in terms of earthquake resistance design (ERD); design and analysis of structural systems for given and modified building layouts; comparison of the results with outcome of damage surveys. Tools: ETABS, SAP2000

Course literature

Publication and Textbooks from the lecturers

Courses

Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Dr. Schwarz, Prof. Abrahamczyk, DI Kaufmann	Earthquake engineering and structural design (L)	4
Dr. Schwarz, Prof. Abrahamczyk	Structures in Earthquake Regions (E)	0,5
Prof. Abrahamczyk et al.	Design of RC frames with masonry infill walls in earthquake regions (E + P)	1,5

Bauhaus-Universität Weimar / Faculty of Civil Engineering M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]						
Geo- and hydrotechnical engineering						**Module-No.: NHM-2030**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2	annually in Summer Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 68hs Attendance time, 30hs Project work 62hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.	NHRE	**1 written exam** “Flood Hazard and Vulnerability Assessment” / 90 min (50%) / **SuSe** + WiSe **1 written exam** “Geotechnical Engineering” / 90 min (50%) / **SuSe** + WiSe	Lecture (L) Project (P)	Vert.-Prof. Dr.-Ing. Patrick Staubach

Course aim
The objective of this module is focused on deepening the basics of soils mechanics, the fundamentals of analysis in applications for static and dynamic analysis as well as the basics of soil-structure interaction analysis. The students should be able to apply the strategies and methods to arbitrary engineering problems in the given fields. To fix the theoretical background the student has to apply the methods independently at given tasks during several projects.

Course content
Geotechnical Engineering Classification and identification of soils; Description of soil state; Water in the soil; Hydraulic conductivity and seepage flow; Distribution of vertical stress in the soil; Stress-strain relationships; Settlement analysis; Consolidation theory; Shear strength; Earth pressure; Basics of Soil Dynamics (wave propagation, laboratory and field testing, soil-structure interaction under dynamic loading); Soil Liquefaction (phenomenon, consequences, estimation of liquefaction risk, prevention) **Flood Hazard and Vulnerability Assessment** Flood Management; Fundamentals of flood defence; Management of low-lying areas; Design of river dikes, channels and dams; Design concepts for the defence of structural objects and buildings; Forecasting, management and maintenance in flood defence; Hydrology, hydraulic calculations, flood routing; Characteristics of tsunami action, forces and loads on structures; Structural damage and loss prediction, damage scenarios; Re-interpretation of recent events.

Course literature
Wichtmann, T. & Staubach, P. Lecture Notes for Geotechnical Engineering, 2023

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Staubach	2906014: Geotechnical Engineering (L+E)	3
Dr. Maiwald	2202003: Flood Hazard and Vulnerability Assessment (L+E)	3

Bauhaus-Universität Weimar / Faculty of Civil Engineering
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Disaster management and mitigation strategies						**Module-No.: NHM-2040**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
3	annually in Winter Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 60hs Attendance time, 105hs Self-study time 15hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.	NHRE	**1 written exam** “Project and disaster management“ or “sociology of disaster”/ 60 min (50%) / **WiSe** + SuSe **1 Presentation + presentation paper** “sociology of disaster” or “project and disaster management“ (50%) / **WiSe**	Lecture (L)	Prof. Dr.-Ing. Jürgen Melzner

Course aim

Being trained in selected main aspects of project management. Students learn special demands and procedures in situations of disaster prevention and are able to develop appropriate organizational measures. Students learn basic assumptions on the social behaviour in crisis situations with main focus on the urban dimension on social actions.

Course content

Project and disaster management:
Introduction to Project management: work breakdown structure; time scheduling; cost control measures; types of company and project organization; documentation; communication in projects; fee structure and fees for construction project management services.
Fundamentals in disaster management: examples of methods and procedures in situations of crisis and catastrophe; introduction into critical incident management systems in Germany and internationally.
Sociology of disaster:
The sociology of disaster focuses on the precipitating event to the social structure of critical mass within community that leads to the changing routine of social structure. The past decade alone has seen multiple disasters around the world, few studies have been available on how to reconstruct the cities. Historical attempts to interpret disaster in sociological terms are necessary in order to raise questions about the social order and resilience after disaster. Recent research on social networks and organisational forms of association related to disasters from European and International cases are highlighted.

Course literature

H. Schelle, R. Ottmann, A. Pfeiffer: **Project Manager** (GPM 2006) and **Projekt Manager** (3. Aufl. Ottmann & Partner 2018) ● **ICS 100**, Incident Command system, Handbook, FEMA, 2018 ● **DV100**, Leadership and Command In Emergency Operations, German Regulation 100 ● UN Disaster Assessment and Coordination (UNDAC), **Field Handbook** (7th Edition, 2018)
F. Eckardt: **Landscapes of Disaster**. Symb. Spaces of Orientation. Topos – int.rev.of landscape archit.a.urban design, 76 (2011), 51-55.
M. Kammerbauer. **Planning Urban Disaster Recovery**. Spatial, institutional, and social aspects of urban disaster recovery in the U.S.A. – New Orleans after Hurricane Katrina. (2013) VDG Weimar. ISBN 978-3-89739-745-3
E.L Quarantelli. **Urban vulnerability** to disasters in developing countries: Managing risks, Book Chapter 15 (2003) 211-231. World Bank.

Courses

Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Bargstädt/Prof. Koch/Azimian	2901005: Project- and disaster management (L)	2
Prof. Eckardt, Dr. Podlaszewska	2901033: Sociology of disaster (L)	2

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Life-lines engineering						**Module-No.: 2204019**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
3	annually in Winter Semester	1 Semester weekly	Compulsory	6	English	180hs, thereof 68hs Attendance time, 82hs Self-study time 30hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.	NHRE	**1 written exam** “Life-lines Engineering “/ 180 min (100%) / **<u>WiSe</u>** + SuSe	Lecture (L) Exercise (E)	Prof. Dr. Guido Morgenthal

Course aim

The students will be familiar with bridges in the context of their functions as critical infrastructure. They will be familiar with the design objectives with specific emphasis on risks associated with natural hazards and with strategies to limit damage and to ensure operability after a major natural disaster. They will be able to develop structural concepts and to carry out detailed design of such structures, including the application of relevant codes of practice.

Course content

<u>Life-lines Engineering</u>
History of bridge engineering; types of bridges; structural concepts and articulation; planning and design; construction methods; structural modelling and analysis; elastic and plastic design approaches; performance-based design; structural detailing; dynamic characteristics and behaviour under dynamic loading; seismic response and isolation; response to wind loading

<u>Training in:</u>
Structural modelling and Finite Element Analysis; design of post-tensioning systems in bridges; design and detailing of girders and piers; seismic response; wind response, analysis of cable stayed bridges

Course literature

Textbooks (to be announced)

Courses

Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Morgenthal	Life-lines Engineering (L)	4
Prof. Morgenthal / et al.	Life-lines Engineering (E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Elective compulsory module						Module-No.: NHM-3000
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1 to 4	annually in Winter Semester and Summer semester	1 Semester weekly	Elective Compulsory	12	English	depend on the chosen module Total workload: 540hs

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE other	depend on the chosen module	depend on the chosen module	depend on the chosen module

Course aim
The students are using the possibility to sharpen their individual profile of free choice of at least two modules from a list with NHRE-elective compulsory modules. * see NHRE module catalogue (updated annually, to be confirmed by the examination committee)

Course content
depend on the chosen module

Course literature
depend on the chosen module

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
	depend on the chosen module	

Bauhaus-Universität Weimar / Faculty of Civil Engineering M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Elective module	**Module-No.: NHM-4000**

Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1 to 4	annually in Winter Semester or Summer semester	1 Semester weekly	Elective	12	English or German	depend on the chosen module Total workload: 360hs

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.	NHRE other	depend on the chosen module	depend on the chosen module	depend on the chosen module

Course aim
The students are using the possibility to sharpen their individual profile of free choice of modules from a list with NHRE-elective compulsory modules as well as from all master's degree programs of the Bauhaus-Universität Weimar. ** any course at the Bauhaus university is valid (recommendation: "German language courses")

Course content
depend on the chosen module

Course literature
depend on the chosen module

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
	depend on the chosen module	

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Special project

Module-No.: NHM-5000

Semester No.	Frequency of the module offering	Duration	Type of module	Credit points (ECTS)	Language(s)	Student workload
3	annually in Winter Semester or Summer semester	1 Semester weekly	Compulsory	12	English	Total workload: 360hs

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE	**1 Project report (written paper) + optional oral presentation** Title of “Special project” (100%) / **WiSe** and **SuSe**	Project (P)	all NHRE lectures depend on the chosen project

Course aim
Demonstration of student’s ability to apply methods commonly used in their professional field to recognize a problem, evaluate it in a reflective, analytical-critical manner, and come up with ways of solving it within a limited period of time

Course content
Special problems derived from demanding engineering tasks in the areas of planning, construction and realization of structures under specific conditions, integrating research and practical applications; site- or structure-specific risk analysis using modern tools to estimate the threat of natural hazards; contributions to modelling, simulation and application of performance-based design, including field work and laboratory investigation, engineering-related topics with focus on the support by natural sciences, social sciences and economics; derived from on-going planned projects at both regional and global level, sub-tasks reflect the reached progress in training of the general course content.

Course literature
depend on the chosen project

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
	Title of “Special project” (P)	4

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Master's Thesis						Module-No.: NHM-8000
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
4	annually in Winter Semester or Summer semester	4 months (continuously in the semester or term-overlapping)	Compulsory	24	English	Total workload: 720hs, thereof 690hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
passed module totalling at least 78 ECTS (including the Special project)	NHRE	one digital and two printed copies of the master's thesis in English (75%) + Presentation of the master's thesis (25%)	independent research, consultations	depend on the chosen subject

Course aim
The master's examination should demonstrate that the candidate has the ability to independently assess and solve a problem in his/her discipline using scientific methods.

Course content
depend on the chosen subject

Course literature
depend on the chosen subject

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**

Elective compulsory modules

Modules	Lecturers	winter semester (credits)	summer semester (credits)
1st / 3rd Semester / 2nd Semester			
Applied finite element methods and structural dynamics	Prof. Rabczuk, Prof. Könke, Dr. Zabel	3 ECTS	3 ECTS
2nd / 4th Semester (see module description)			
Advanced building information modeling	Prof. Koch		6 ECTS
Complex dynamics	Prof. Rüffer		6 ECTS
Computational and Experimental Wind Engineering	Prof. Morgenthal		6 ECTS
Experimental structural dynamics	Dr. Zabel		6 ECTS
Introduction to optimization / Optimization in applications	Prof. Lahmer		6 ECTS
Introduction to Optimization / Stochastic Simulation Techniques and Structural Reliability	Prof. Lahmer		6 ECTS
Mathematics for data science	Prof. Rüffer		6 ECTS
Modelling of steel structures and numerical simulation	Prof. Kraus		6 ECTS
Multi-hazard and risk assessment (incl. Excursion GFZ)	Dr. Schwarz, Dr. Beinersdorf, Prof. Cotton,		6 ECTS
Stochastic simulation techniques and structural reliability	Prof. Lahmer		6 ECTS
Stochastic simulation and optimization	Prof. Lahmer		6 ECTS
3rd Semester			
Assessment of structural performance (under extreme loading conditions)	Prof. Abrahamczyk, Dr. Maiwald	6 ECTS	
Design and interpretation of experiments (incl. signal processing II)	Prof. Kraus, Prof. Lahmer	6 ECTS	
Object-oriented modeling and programming in engineering	Prof. Koch	6 ECTS	
Risk projects and evaluation of structures	Dr. Schwarz, Dr. Maiwald	6 ECTS	
Secondary hazards and risks (land-use, site studies)	Prof. Staubach, Dr. Aselmeyer	6 ECTS	

Additional modules as elective compulsory modules are not allowed!

Legend: Applied Mathematics and informatics Structural Mechanics Structural engineering + hazard and risks

Bauhaus-Universität Weimar / Faculty of Civil Engineering M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]	
Applied finite element methods and structural dynamics	**Module-No.: NHM-3000**

Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
1 or 3 and 2	annually 2nd half Winter Semester (Applied SD) and annually in Summer Semester (Applied FEM)	1/2 Semester weekly (WiSe) and 1 Semester weekly	Elective compulsory	3 + 3	English	180hs, thereof 90hs Attendance time, 60hs Self-study time 30hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc. Structural dynamics & FEM	NHRE other	**1 written exam:** "Fundamentals of finite element methods" / 90 min (50%) / <u>WiSe</u> + **SuSe** **1 written exam:** "Fundamentals of structural dynamics" / 90 min (50%) / **<u>WiSe</u>** + SuSe	Lecture (L) Exercise (E)	Prof. Dr.-Ing. Timon Rabczuk, Prof. Dr.-Ing. habil. Carsten Könke, Dr.-Ing. Volkmar Zabel

Course aim
Appl. FEM (summer semester): Students will obtain the ability to analyse geometrical and nonlinear structural engineering problems and to establish numerical models for static and dynamic problems in structural engineering. They will be able to assess the quality of numerical solutions by error estimation concepts and will understand how to solve large equation systems by efficient solution techniques. Appl. SD (winter semester): The students will become able to apply the concepts of SDOF and MDOF system analysis to practical problems, understand the principles of action of different kinds of dynamic loading on structures, and obtain knowledge about the design of remedial measures. Further, they will be able to solve more complex problems by means of a numerical tool.

Course content
Appl. FEM (summer semester): Finite element formulation for geometrical and physical nonlinear problems in structural engineering, incremental-iterative concepts, quality assessment of numerical results via error estimates, efficient solver techniques for large linear and nonlinear equation systems resulting from the FE concepts, application of FE-methods for typical engineering problems (50 % of course time) Appl. SD (winter semester): Continuous systems: free and forced vibrations, travelling loads; machinery induced vibrations, earthquake excitation wind induced vibrations human induced vibrations (50 % of course time)

Course literature
K.J. Bathe: Finite Lement Procedures / Johnson, Hansbo: Computational Differential Equations Clough, Penzien: Dynamics of Structures, 2010 / Chopra: Dynamics of Structures, 2015

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Rabczuk	2401012: Applied Finite element methods (L)	2
Prof. Rabczuk / Prof. Könke / et al.	2401012: Applied Finite element methods (E)	1
Dr. Zabel	2401011: Applied Structural dynamics (L)	2
Dr. Zabel / et al.	2401011: Applied Structural dynamics (E)	1

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Advanced building information modeling

Module-No.: 2303001

Semester No.	Frequency of the module offering	Duration	Type of module	Credit points (ECTS)	Language(s)	Student workload
2 or 4	annually in Summer Semester, at least 5 participants	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 105hs Project work 30hs Self-study time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc., Basic knowledge of Computer-Aided Design, BIM concepts, and object-oriented programming	NHRE other	**1 Project report + 1 presentation** “Advanced building information modeling” (70% report + 30% presentaion) / **SuSe**	Lecture (L) Exercise (E) Project (P)	Prof. Dr.-Ing. Christian Koch

Course aim

This module introduces advanced concepts of Building Information Modelling (BIM) to provide students with advanced knowledge in order to understand, analyze and discuss scientific research approaches related to BIM. Within the frame of the module project (coursework) the students will choose a topic from a pre-defined list or come up with their own topic. Based on that they will do detailed research, implement a representative concept in a software prototype and discuss findings and limitations. Also, the students acquire skills of scientific working and presentation.

Course content

Advanced geometric and parametric modelling, Interoperability and collaboration concepts (IFC, IDM, BEP), Advanced use cases (e.g. clash detection, as-built mod-eling), BIM programming (incl. visual programming)

Course literature

Eastman, C., Teichholz, P., Sacks, R., Liston, K. (2011), BIM Handbook: A guide to Building Information Modelling, 2nd edition, Wiley.
Borrmann, A., König, M., Koch, C., Beetz, J. (2018), Building Information Modeling: Technological Foundations and Industry Practice, Springer Vieweg.
Mortenson, M.E. (2006), Geometric Modeling, 3rd edition, Instustrial Press.
Shah, J.J., Mäntylä, M. (1995), Parametric and feature-based CAD/CAM – Concepts, Techniques and Applications.
Liebich, T. (2009), IFC 2x Edition 3 Model Implementation Guide, Version 2.0."

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Koch / et al.	Advanced building information modeling (L)	2
Prof. Koch / et al.	Advanced building information modeling (E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Complex dynamics						Module-No.: 301016
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 60hs Attendance time, 90hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc., knowledge in Matlab or Python	NHRE other	**1 written exam** “Complex dynamics” 120 min (100%) / **SuSe** + WiSe	Lecture (L) Exercise (E)	Prof. Dr. rer. nat. Björn Rüffer

Course aim
After the course the students will be able to analyse mathematical models that describe dynamic behaviour, as they occur in engineering (e.g. mechanical coupling of building structures), in biology and in physics, but also in multi-agent systems in computer science, or as opinion dynamics in psychology. Based on examples from different disciplines, students learn to build simplified models that allow to answer questions on their long-term behaviour. Students will be able to apply methods of feedback design that help shape the dynamics of a given system, along with the relevant stability concepts. As several topics lend themselves for computer simulation, students of this course will develop a proficiency to both implement and analyse mathematical models using computational tools and software.

Course content
Examples of complex dynamics. Models for dynamical systems in continuous and discrete time. Computer simulation. Control and Feedback. Stability, stabilization, and Lyapunov functions. Coupled systems: Disturbance or Cooperation? Networks of systems. Consensus. Synchronization. The topics will be presented in a lecture, deepened by exercises. Some of the exercise include computer programming and simulation.

Course literature
Will be announced

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Rüffer	Complex dynamics (L)	2
Prof. Rüffer	Complex dynamics (E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Computational and Experimental Wind Engineering						Module-No.: 2204031
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English	depend on the chosen module Total workload: 180hs

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE	**1 Intermediate presentation** “Theoretical background and work update (20%)“ / **SuSe** **1 Final presentation** “Presentation of final outcome (30%)“ / **SuSe** **1 Final report** “Computational and Experimental Wind Engineering” (50%) / **SuSe**	Lecture (L) Exercise (E) Project (P)	Prof. Dr. Guido Morgenthal

Course aim

The course aims to introduce the students to the fundamentals and state-of-the-art methods of wind engineering and different aerodynamic phenomena that are relevant to the design of long-span cable-supported bridges. To characterize and quantify aerodynamic and aeroelastic effects, students will understand the concepts of computational fluid dynamics (CFD) simulations and experimental wind tunnel tests, along with their advantages and limitations. Students will be able to model complex bridge structures using Finite Element Analysis methods and simulate dynamic response due to wind. Different combinations of analytical, numerical and experimental analysis approaches are employed to investigate dynamic wind excitations with a focus on identifying serviceability issues and ultimate limit scenarios of the structure.

Participating students are tasked with practical bridge design-oriented challenges and work in groups to address them. Group organization and goal-oriented work are an important aspect to the project work. Results are reported periodically in presentations. Results are to be summarized in a report following scientific writing standards and presented orally.

Course content

Literature review on aerodynamic phenomena in long-span bridges; Fundamentals of computational wind engineering; Aerodynamic loads; Self-excited or motion-induced forces; Aerodynamic instabilities; Finite Element modelling and dynamic simulation of long-span bridges (arches, cable-stayed bridges, suspension bridges); Model Validation; Analytical and semi-analytical aerodynamic models; 2D and pseudo-3D CFD simulations; Developing experimental scaled models; Experimental wind tunnel testing; Comparison of results from different methods; Strategies for vibration mitigation; Aerodynamic optimization; Scientific writing and design-focused reporting.

Course literature

Textbooks and relevant articles (to be announced)

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Morgenthal	Computational and Experimental Wind Engineering (L)	2
Prof. Morgenthal / et al.	Computational and Experimental Wind Engineering (E, P)	4

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Experimental structural dynamics						**Module-No.: 2401009**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 60hs Attendance time, 80hs Project work 40hs Self-study time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc. Applied FEM & Structural dynamics	NHRE other	**1 Project report + intermediate and final presentations** “Experimental structural dynamics” (100%) / **SuSe**	Project (P)	Dr.-Ing. Volkmar Zabel

Course aim
The students obtain deepened knowledge in structural dynamics, structural dynamic analysis, data processing, dynamic test equipment and its handling. They learn to analyse the dynamic behaviour of a structure utilizing both numerical and experimental state-of-the-art methods. Furthermore, the students have to develop strategies and concepts of investigation. The work in small groups enhances the social competence of the students.

Course content
Operational modal analysis, sensor types, sensor positioning, data analysis and assessment, assessment of structural changes, structural modelling, model updating

Course literature
Ewins, D.J.: Modal Testing: Theory, Practice and Application, 2nd edition, 2000 / Maia, N.M.M., Silva, J.M.M. (eds.): Theoretical and Experimental Modal Analysis, 1997 / Rainieri, C. & Fabbrocino, G.: Operational Modal Analysis of Civil Engineering Structures, 2014 / Clough, R.W., Penzien, J.: Dynamics of Structures, 2010

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Dr. Zabel	Experimental structural dynamics and Structural monitoring (P)	4

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Introduction to optimization / Optimization in applications						Module-No.: NHM-3020
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English (German)	180hs, thereof 45hs Attendance time, 60hs Project work 55hs Self-study time 20hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE other	**1 written or oral exam** (depending on the number of participants) “Introduction to Optimization” (3 credits) / **SuSe** + WiSe **1 project** “Optimization in Applications” (3 credits) / **SuSe** + WiSe	Lecture (L) Exercise (E) Project (P)	Prof. Dr. rer. nat. Tom Lahmer

Course aim

In engineering science, we are often faced with problems having potential for optimization. We learn how to formulate this in mathematical terms, and we will study techniques how to improve the situations, generally by involving numerical models. We will discuss classical optimization problems in the field of linear and nonlinear optimization, e.g. optimization of the use of resources, routing problems, calibration problems and structural optimization. In particular in structural optimization we learn techniques like dimensioning, shape and topology optimization. Optimized structures are discussed also in the context of additive manufacturing techniques.

Course content

Introduction to Optimization (summer semester):
Definitions, Classification of Optimization Problems,
Linear Problems, Simplex Method, Nonlinear Problems: Constrained and unconstrained continuous problems, descent methods and variants. (Robust) Structural Optimization (including Shape and Topology Optimization)

Optimization in Applications (summer semester):
Optimization in Applications is generally a project assigned to the students including own programming and modelling. E.g. innovative optimization strategies are to be implemented in Matlab, Python or similar. Alternatively, engineering models could be subjected to optimization software.

Course literature

C.T. Kelley- Iterative methods for Optimization
Forst, Wilhelm, Hoffmann, Dieter: Optimization—Theory and Practice
I. M. Bomze, W. Grossmann: Optimierung - Theorie und Algorithmen - Eine Einführung in Operations Research für Wirtschaftsinformatiker

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Lahmer	2451002: Introduction to Optimization (L+E)	3
Prof. Lahmer	2451006: Optimization in Applications (P)	3

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Mathematics for data science						Module-No.: 301017
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 45hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B. Sc.; Analysis and Linear Algebra at Bachelor level, knowledge of Matlab or Python	NHRE DE CS4MI	**1 written exam** “Complex dynamics” 120 min (100%) / **SuSe** + WiSe	Lecture (L) Exercise (E) Project (P)	Prof. Dr. rer. nat. Björn Rüffer

Course aim

After the course the students will be familiar with the fundamental concepts of data science. The participants can analyse given data sets with respect to dimensionality reduction and clustering. They also know the basic structure of neural networks and support vector machines to solve classification tasks. The participants know relevant methods from linear algebra and optimization and can apply these techniques. This embraces the design of appropriate algorithms and the implementation of different numerical methods to solve the corresponding problems.

Course content

Singular value decomposition, generalized eigenvalue problems, Max-min theorem, convex optimization, KKT conditions, strong duality, kernel methods, reproducing kernel Hilbert spaces, Linear Discriminant Analysis, Principle Component Analysis, Regression, Classification, K-means Clustering, Neural networks, deep networks, training deep neural networks, backpropagation
The topics will be presented in a lecture, deepened by exercises.

Course literature

R.A. Horn, C. R. Johnson Matrix Analysis, Cambridge Univ. Press 2013
D.A Simovici. Mathematical Analysis For Machine Learning And Data Mining-World Scientific, 2018. M.P. Deisenroth, A. A. Faisal, C. S. Ong, Mathematics for Machine Learning. Cambridge University Press 2021. D.A Simovici. Linear Algebra Tools for Data Mining. World Scientific, 2013. C.C. Aggarwal. Neural networks and deep learning: a textbook. Springer 2018.

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Rüffer	Mathematics for data science (L)	2
Dr. Schönlein	Mathematics for data science (E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]						
Modelling of steel structures and numerical simulation						**Module-No.: 2205007**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 105hs Self-study time 30hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc. Mechanics	NHRE other	**1 Project report** “Modelling of steel structures and numerical simulation” (0%) / **SuSe** **1 written exam** “Modelling of steel structures and numerical simulation”/ 120 min (100%) / **SuSe** + WiSe	Lecture (L) Exercise (E)	Prof. Dr.-Ing. Matthias Kraus

Course aim
The students will be familiar with skills and expertise in the field of nonlinear structural analyses. Extensive knowledge of theoretical basics and modern modelling methods including numerical representations are the aim of the course. The students will acquire skills in handling advanced tools for the analysis and the design of structures.

Course content
Design of steel structures using finite element methods; basics of the design; modelling of structures and loads; nonlinear material behaviour, numerical analyses of steel-members and structures regarding geometric and physical nonlinearities; stability behaviour of members including flexural and lateral torsional buckling

Course literature
Internal lecture notes

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Kraus	Modelling of steel structures and numerical simulation (L)	2
Prof. Kraus / et al.	Modelling of steel structures and numerical simulation (E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Multi-hazard and risk assessment						**Module-No.: 2202004**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2	annually in Summer Semester	1 Semester weekly	Elective compulsory (Compulsory for DAAD scholarship-holders)	6	English	180hs, thereof 45hs Attendance time, 60hs Project work 55hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
Primary Hazards and Risks	NHRE	**1 written exam** "Multi-hazard and risk assessment "/ 90 min (50%) / **SuSe** + WiSe **1 Project report (SYMULTHAN)** (50%) / **SuSe**	Lecture (L) Exercise (E) Project (P)	Dr.-Ing. Jochen Schwarz

Course aim
The students will be familiar with the probability of natural hazard and risk determining parameters. They will be able to recognize procedures of single and multi-hazard assessment and to process input data and to apply tools to study areas. Students will be introduced in further advanced geotechnologies and existing or on-going research as well as global projects conducted by GFZ.

Course content
Hazard Assessment and Applications Primary input and output parameters for EQ (and other natural) hazard; Earthquake statistics and occurrence probability; Methodology of seismic hazard assessment; Seismicity models; Examples of seismic hazard and risk studies; Synopses of natural hazards; procedures and developments in multi-hazard assessment; Case studies of multi-hazard, vulnerability, and risk considerations. **Workshop** "Natural Hazards and Advanced Geotechnologies" **Compilation of EQ hazard-related data** Treatment of long-term seismicity data files; elaboration of earthquake data to get harmonized input for PSHA; earthquake catalogues; creation of shakemaps; data pre-processing; Hazard Description for the Project regions Excursion to GeoResearchCenter Potsdam

Course literature
Textbooks (to be announced); Textbooks from the lecturers

Courses		
Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Cotton et al. / Dr. Schwarz / Dr. Beinersdorf	Hazard Assessment and Applications (L)	2
Prof. Cotton / Dr. Beinersdorf	Workshop (L)	1
Dr. Schwarz et al. / Dr. Beinersdorf	"Compilation of hazard related data" and „Synopsis of Multi-Hazard Assessment Normatives" (E)	3

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Stochastic simulation techniques and structural reliability						**Module-No.: NHM-3040**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English (German)	180hs, thereof 45hs Attendance time, 60hs Project work 55hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc. Basics in Probability Theory	NHRE other	**1 written or oral exam** (3 credits) / **SuSe** + WiSe **1 project** (3 credits) / **SuSe** + WiSe	Lecture (L) Exercise (E) Project (P)	Prof. Dr. rer. nat. Tom Lahmer

Course aim

Soils, rocks and materials like concrete are in the natural state among the most variable of all engineering materials. Engineers need to deal with this variability and make decisions in situations of little data, i.e. under high uncertainties. The course aims in providing the students with techniques state of the art in risk assessment (structural reliability) and stochastic simulation.

Course content

The course topics comprise
- (a very brief review) of probability theory
- discrete and continuous random processes and fields
- estimation of statistical parameters
- stochastic simulation techniques (Monte Carlo Simulation)
- reliability-based design
- sensitivity analysis
- structural reliability (FORM, FOSM, Subset Simulation, …)
- Risk assessment and stochastic modelling in practice

The project (extra 3 credits) involves own programming of stochastic simulation algorithms, e.g. generators of random fields, methods to assess structural reliability, and combination of stochastic simulation techniques with engineering models.

Course literature

Gordon A. Fenton, D. V. Griffiths, Risk Assessment in Geotechnical Engineering
Ch. Bucher, Computational Analysis in Structural Mechanics,

Courses

Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Prof. Lahmer	2451007: Stochastic Simulation Techniques and Structural Reliability (L+E)	3
Prof. Lahmer	2451011: Stochastic Simulation Techniques and Structural Reliability (P)	3

Bauhaus-Universität Weimar / Faculty of Civil Engineering M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]						
Stochastic simulation and optimization						**Module-No.: NHM-3030**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
2 or 4	annually in Summer Semester	1 Semester weekly	Elective compulsory	6	English (German)	180hs, thereof 90hs Attendance time, 70hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc. Basics in Probability Theory	NHRE other	**1 written or oral exam** (depending on the number of participants) "Introduction to Optimization" (3 credits) / **SuSe** + WiSe **1 written or oral exam** "Stochastic simulation techniques and structural reliability" (3 credits) / **SuSe** + WiSe	Lecture (L) Exercise (E)	Prof. Dr. rer. nat. Tom Lahmer

Course aim

In engineering science, we are often faced with problems having potential for optimization. We learn how to formulate this in mathematical terms, and we will study techniques how to improve the situations, generally by involving numerical models. We will discuss classical optimization problems in the field of linear and nonlinear optimization, e.g. optimization of the use of resources, routing problems, calibration problems and structural optimization. In particular in structural optimization we learn techniques like dimensioning, shape and topology optimization. Optimized structures are discussed also in the context of additive manufacturing techniques.
Soils, rocks and materials like concrete are in the natural state among the most variable of all engineering materials. Engineers need to deal with this variability and make decisions in situations of little data, i.e. under high uncertainties. The course aims in providing the students with techniques state of the art in risk assessment (structural reliability) and stochastic simulation.

Course content

Introduction to Optimization (L+E):
Definitions, Classification of Optimization Problems,
Linear Problems, Simplex Method, Nonlinear Problems: Constrained and unconstrained continuous problems, descent methods and variants. (Robust) Structural Optimization (including Shape and Topology Optimization)
Stochastic simulation techniques and structural reliability (L+E)
The course topics comprise
- (a very brief review) of probability theory
- discrete and continuous random processes and fields
- estimation of statistical parameters
- stochastic simulation techniques (Monte Carlo Simulation)
- reliability-based design
- sensitivity analysis
- structural reliability (FORM, FOSM, Subset Simulation, …)
- Risk assessment and stochastic modelling in practice

Course literature

Gordon A. Fenton, D. V. Griffiths, Risk Assessment in Geotechnical Engineering
Ch. Bucher, Computational Analysis in Structural Mechanics,

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Lahmer	2451002: Introduction to Optimization (L+E)	3
Prof. Lahmer	2451007: Stochastic Simulation Techniques and Structural Reliability (L+E)	3

Bauhaus-Universität Weimar / Faculty of Civil Engineering
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Assessment of structural performance (under extreme loading conditions)						**Module-No.: 2202011**
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
3	annually in Winter Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 60hs Project work 55hs Self-study time 20hs Exam-preparation time

Recommended course requirements	**Course program**	**Form of examination / Duration of examination**	**Teaching and learning methods**	**Responsible for the module**
B.Sc.; Seismic Monitoring/ Earthquake Engineering	NHRE other	**1 Project report**: „Damage assessment of unreinforced masonry structures" (33%) / **WiSe** **1 written exam:** „Assessment of structural performance (under extreme loading conditions)"/ 120 min (67%) / **WiSe** + SuSe	Lecture (L) Exercise (E) Project (P)	Jun.-Prof. Dr.-Ing. L. Abrahamczyk, Dr.-Ing. J. Schwarz Dr.-Ing. H. Maiwald

Course aim

Students will be familiar with the existing building typologies, the methods of structural performance assessment and design rules for traditional and engineered building types. Students should be able to evaluate the quality of structural systems, to interpret the performance of masonry and steel structures under horizontal action, to derive appropriate models and to decide upon the applicability of equivalent or simplified ones. Students will be informed about on-going research projects and recent code developments which are linked to the course topics and options for further graduation (master thesis). Training of student's ability to apply methods and current state in natural hazard and risk assessment. Students will be able to apply modern software tools to transfer buildings into dynamic models and to evaluate the seismic response characteristics in dependence on design situation and performance directed concepts; they will be trained to identify failure mechanism and design defects, and to evaluate appropriateness of strengthening measures. Students will be familiar with different analysis methods, techniques, and tools of empirical and analytical vulnerability assessment.

Course content

Structural performance of traditional and engineered building types (L)
Reinterpretation of observed response for different building types; building taxonomies; empirical and analytical vulnerability assessment; damage classification and fragility functions; design principles and structural solutions for traditional (masonry) and engineered (steel) type structures, basic rules for non-engineered buildings (with locally available materials); building assessment criteria for strengthening; evaluation of applied strengthening and rehabilitation measures.
Damage assessment of unreinforced masonry structures (E, P)
Search for typical building representatives of the target regions (home countries of the participants); derivation of structural layout and simplified models of representative building types; modelling and assessment of masonry structures applying equivalent frame approach; determination of characteristic building response parameters; determination of fragility function; risk scenario for a virtual city.

Course literature

Publication from the lecturers, thesis, etc. on moodle/ Grünthal, G. (ed.), Musson, R., Schwarz, J., Stucchi, M. (1998): European Macroseismic Scale 1998. / Maiwald, H., Schwarz, J. (2019): Unified damage description and risk assessment of buildings under extreme natural hazards, Europ. J. of Masonry 23, 2, 95-111. / Schwarz, J., Abrahamczyk, L., Leipold, M., Wenk, T. (2015): Vulnerability assessment and damage description for R.C. frame structures following the EMS-98 principles. Bull. Eq. Eng. Vol. 13 (4), 1141-1159. / WHE (2004): World Housing Encyclopedia. http://www.world-housing.net/ / FEMA 440: Improvement of Nonlinear Static Seismic Analysis Procedures, ATC (ATC-55 Project), 2005. / Ghiassi B., Milani G. (ed.) (2019): Numerical Modeling of Masonry and Historical Structures. In Woodhead Publishing Series in Civil and Structural Engineering, Woodhead Publishing, ISBN 9780081024393

Courses

Lecturer	**Title of the course**	**Semester periods per week (SPW)**
Dr. Schwarz / Dr. Maiwald / et al.	Structural performance of traditional and engineered building types (L, E)	2
Jun.-Prof. Dr.-Ing. L. Abrahamczyk / et al.	Damage assessment of unreinforced masonry structures (E, P)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
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Design and interpretation of experiments						Module-No.: 2205014
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
3	annually in Winter Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 56hs Attendance time, 94hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.	NHRE other	**1 written exam / 120 min** / **WiSe** + SuSe including "Experiments in Structural Engineering" and "Signal Processing, Design of Experiments and System Identification"	Lecture (L) Exercise (E)	Prof. Dr.-Ing. Matthias Kraus

Course aim

Students will be familiar with following: Design and setup as well as evaluation and interpretation of experimental testing in structural engineering. Provision of techniques linking experimental and mathematical / numerical modelling. Parallel assessment of steps being part of any verification and validation procedure. Discussion of common techniques of optimal experimental designs

Course content

The course gives an overview on experiments and their evaluation regarding different tasks and scopes of structural engineering. Next to different testing techniques applied for diverse aims, the equipment and measuring devices employed for testing are treated as well. Besides the experiment itself, it is an important question, how we can use the experimental data for the calibration and validation of models in engineering. In this course, we give insights to techniques called parameter and system identification.
As often signals are not useable directly, transforms are necessary, like filtering, Fourier Transform, Wavelet Transform and, in particular for signals with noise, averaging techniques. Having models at hand, the experiment can be designed virtually by means of nonlinear optimization.

Course literature

Internal lecture notes
Farrar, Worden: Structural Health Monitoring: A Machine Learning Perspective, WILEY
Darius Ucinsky: Optimal Measurement Methods for Distributed Parameter System Identification, Taylor and Francis
Further Textbooks (to be announced)

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Kraus	Experiments in Structural Engineering	2
Prof. Lahmer	Signal Processing, Design of Experiments and System Identification	2/1

Bauhaus-Universität Weimar / Faculty of Civil Engineering
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Object-oriented modeling and programming in engineering						Module-No.: 2303005
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
3	annually in Winter Semester, at least 5 participants	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 105hs Project work 30hs Self-study time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc., Basic knowledge of Computer-Aided Design, BIM concepts, and object-oriented programming	NHRE other	**1 written exam** "Object-oriented Modeling and Programming in Engineering" (100%) / **WiSe** + SuSe	Lecture (L) Exercise (E)	Prof. Dr.-Ing. Christian Koch

Course aim

This module covers the basic knowledge needed to develop and implement object-oriented software solutions for engineering problems. This includes the ability to analyse an engineering problem, so that corresponding object-oriented models can be created and suitable algorithms can be selected. The programming language used in this module is Java. However, the since fundamental concepts are described in general, students will be able to program in other modern programming languages.

Course content

Essential programming constructs (alternatives, loops, sequences), Fundamental data structures and algorithms, Principles of object oriented software development (encapsulation, inheritance and polymorphism), The Unified Modeling Language as a tool for software design and documentation, Development of graphical user interfaces using the Model-View-Controller pattern.

Course literature

Meyer, Bertrand Meyer, Touch of class: learning to program well with objects and contracts, Springer, 2013
David J. Barnes, Object-oriented Programming with Java: An Introduction, Prentice Hall, 2000
David Flanagan, Java in a nutshell: a desktop quick reference for java programmers, O'Reilly, 2005

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Koch / et al.	Object-oriented modeling and programming in engineering (L)	2
Prof. Koch / et al.	Object-oriented modeling and programming in engineering (E)	2

Bauhaus-Universität Weimar / Faculty of Civil Engineering
M. Sc. Natural Hazards and Risks in Structural Engineering [NHRE]

Risk projects and evaluation of structures

Module-No.: 2202005

Semester No.	Frequency of the module offering	Duration	Type of module	Credit points (ECTS)	Language(s)	Student workload
3	annually in Winter Semester, not offered in 2022/23	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 60hs Project work 55hs Self-study time 20hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
B.Sc.; Seismic Monitoring / Earthquake Engineering	NHRE other	**1 written exam** "Risk projects and evaluation of structures" 90 min (50%) / **WiSe** + SuSe **1 Project presentation (oral)** "Response estimate for disastrous and recent events" (50%) / **WiSe**	Lecture (L) Exercise (E) Project (P)	Jun.-Prof. Dr.-Ing. L. Abrahamczyk, Dr.-Ing. J. Schwarz Dr.-Ing. H. Maiwald

Course aim

Students will be familiar with the different risk elements in disaster mitigation studies. Students will be able to apply methods and current state in natural hazard and risk assessment integrating research and practical applications to urban settlements or structure-specific risk analysis and planning decisions. Students will be familiar with different analysis methods, knowledge-based techniques, and tools of empirical and analytical vulnerability assessment. Students will be familiar with the existing building typologies and be able to evaluate the quality of structural systems, to interpret the performance under horizontal action. Students are encouraged to contribute reports of regionally particular building types to World Housing Encyclopedia and NHRE database.

Course content

Risk evaluation for buildings and urban settlements (L)
Lessons from recent events and field missions; assessment of hazard phenomena; reinterpretation of observed response for different building types; building taxonomies; knowledge-based exposure modelling; empirical and analytical vulnerability assessment; damage classification and fragility functions; social risk modelling; decision support systems for OEF, EEW and RRE; building assessment criteria for existing and new building stock.
Response estimate for disastrous events (E, P)
Training in risk scenarios: elaboration of input data for the target area (home countries), generation of shake maps; elaboration of fragility functions; generation of risk scenarios and application of decision support system; simulation of mitigation measures.
Studies on Recent Natural Hazard Events (P)
Description and assessment of hazard phenomena; affected regions; building types; reinterpretation of observed damages for different building types; conclusions from rapid response actions; initiated/necessary mitigation measures (consequences of the event); recent developments in design and construction.

Course literature

Publication from the lecturers, thesis, etc. (further announced on Moodle) / Grünthal, G. (ed.), Musson, R., Schwarz, J., Stucchi, M. (1998): European Macroseismic Scale 1998. Cahiers du Centre Européen de Geodynamique et de Seismologie, Volume 15, Luxembourg / Maiwald, H., Schwarz, J. (2019): Unified damage description and risk assessment of buildings under extreme natural hazards, European Journal of Masonry 23, 2, 95-111. / Schwarz, J., Abrahamczyk, L., Leipold, M., Wenk, T. (2015): Vulnerability assessment and damage description for R.C. frame structures following the EMS-98 principles. Bulletin of Earthquake Engineering Vol. 13 (4), 1141-1159. / WHE (2004): World Housing Encyclopedia [Internet]. http://www.world-housing.net/

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Dr.-Ing. H. Maiwald / Jun.-Prof. L. Abrahamczyk	Risk evaluation for buildings and urban settlements (L)	2
Dr.-Ing. H. Maiwald / Ch. Kaufmann	Response estimate for disastrous events (E, P)	2
Jun.-Prof. L. Abrahamczyk / Dr.-Ing. H. Maiwald	Studies on Recent Natural Hazard Events (P)	1

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Secondary Hazards and Risks (land-use, site studies)						Module-No.: 2906016
Semester No.	**Frequency of the module offering**	**Duration**	**Type of module**	**Credit points (ECTS)**	**Language(s)**	**Student workload**
3	annually in Winter Semester	1 Semester weekly	Elective compulsory	6	English	180hs, thereof 45hs Attendance time, 60hs Project work 45hs Self-study time 30hs Exam-preparation time

Recommended course requirements	Course program	Form of examination / Duration of examination	Teaching and learning methods	Responsible for the module
Geo- and hydrotechnical Engineering	NHRE other	**1 Project report** “Secondary Hazards and Risks” (33%) / **WiSe** **1 written exam** „Secondary Hazards and Risks“/ 120 min (67%) / **WiSe** + SuSe	Lecture (L) Project (P)	Vert.-Prof. Dr.-Ing. Patrick Staubach

Course aim

The objective of this module is focused on deepening the skills of the students to judge the risk of a landslide (secondary hazard) in a given sloping ground caused by a primary hazard (e.g. earthquake, heavy rainfall). The students learn advanced methods for the investigation and monitoring of possibly instable soil and rock masses. They deepen their knowledge with respect to different methods of slope stability analysis under static loading and seismic impact. The students are able to study slope stability by means of the finite element method. They know various methods of slope stabilization. They know and can apply basic methods of Geotechnical Earthquake Engineering. To fix the theoretical background the students have to apply the methods learned at given tasks within a project.

Course content

Different methods of slope stability analysis in cases of static and seismic loading (pseudo-static method, Newmark sliding block analysis); Slope investigation and monitoring; Slope stabilization methods; Analysis of slope stability by means of the finite element method (including computer exercise with finite element program Plaxis); Seismic design of retaining structures; Ground response analysis; Stability of rock masses

Course literature

Lecture Notes for this course
Kramer, S.L., Geotechnical Earthquake Engineering, Prentice-Hall, 1996

Courses

Lecturer	Title of the course	Semester periods per week (SPW)
Prof. Staubach, Dr. Aselmeyer	Secondary Hazards and Risks (L)	4