CURRICULUM OF THE **POSTGRADUATE** UNIVERSITY STUDY IN **CIVIL ENGINEERING**

In Rijeka, September 2020

CURRICULUM

Postgraduate University Study in CIVIL ENGINEERING
for obtaining a PhD in Technical Sciences

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1 Introduction

During the implementation of the Bologna Process, the Faculty of Civil Engineering in Rijeka (hereinafter: the Faculty) reformed the existing study programs (of university, vocational and postgraduate studies) according to the principles of the Bologna Declaration of 1999 and the Berlin Communiqué of 2003, that is, adopted the European credit transfer system (ECTS) principles in order to enable student mobility in the single European knowledge area.

The adopted scheme by education cycle is "3 + 2 + 3", i.e.:

- a three-year undergraduate university study in civil engineering
- a two-year graduate university study in civil engineering with different courses of study
- a three-year postgraduate university study with field of study Technical Sciences within subject area of civil engineering and other basic technical sciences.

The Faculty began organizing and implementing the study of civil engineering in 1976. From the academic year 1998/1999 until the academic year 2010/2011 The Faculty has also been delivering the Postgraduate scientific study in Civil Engineering (course of study Structural Mechanics) for obtaining the degree of Master of Technical Sciences. Program structure of the Postgraduate University Study in Civil Engineering for obtaining the degree of PhD in Technical Sciences (hereinafter: the Study) was adopted at the session of the Scientific and Educational Council of the Faculty in December 2004. It should be noted that the launch of the postgraduate university study was an imperative for the Faculty as one of constituents of the University of Rijeka, whose mission includes conducting scientific, artistic and developmental research, and especially programs of strategic interest to the Republic of Croatia, artistic creation and professional work, which are the base of the undergraduate, graduate and postgraduate education. The study for obtaining the degree of PhD in Technical Sciences has been delivered by the Faculty since the academic year 2005/2006.

Intensive construction activity, especially in the field of infrastructure, inevitably indicates the need for staff educated in the wake of the latest scientific knowledge and trained not only for independent scientific research, but also for original contribution to scientific thought in scientific fields of construction and other basic technical sciences, especially in the scientific branches of geotechnics, structural engineering, hydraulic engineering, transportation engineering, materials, fluid mechanics and engineering mechanics (mechanics of solid and deformable bodies). The proposed Study aims to educate an expert whose expertise would contribute to and expedite the transfer of the scientifically based technological solutions into engineering practice, and also be actively involved in scientific research. The scientific staff certainly needs to be educated not only for the stated existing needs but also for the planned development of the region that gravitates to the University of Rijeka. Given the specific scientific research orientation of the Study, there is interest from related institutions from other backgrounds.

During development of the Study curriculum, the Faculty actively cooperated with related faculties of civil engineering in Croatia and Slovenia, and took into account the experiences of other faculties, primarily from Europe and beyond (Eidgenossiche Technische Hochschule Zürich, Stanford University, University of Cambridge, Chalmers Institute of Technology, University of Maryland, University of Colorado at Boulder). Both domestic and foreign experts were included in the study program development, which opens the possibility of intensifying international scientific research cooperation (University of Split, University of Zagreb, Univerza v Mariboru, Univerza v Ljubljani, University of Lancaster). The program is based on research projects funded by the Croatian Science Foundation, European funds, the University of Rijeka, but also faculty development projects and projects based on business cooperation between the Faculty and the economy.

Following the relevant provisions of the general act on studies of the University of Rijeka, the proposed Study elaborates the application for moving to another domestic or foreign university and scientific institution for a limited period of time in order to stimulate the mobility of doctoral students. The Faculty has established scientific research cooperation with related faculties in the country and abroad. Encouraged by the need to enable its doctoral students to move to another domestic and foreign institution, but also by the reciprocal use of human and material resources for the development of scientific research and doctoral studies, this cooperation is contractually regulated and expands from year to year.

2 General information

2.1 Name of study

The postgraduate university study "Civil Engineering" is organized for obtaining a PhD in the scientific fields of Civil Engineering (2.05) and Basic Technical Sciences (2.15) within the scientific field of study of Technical Sciences. Teaching courses from the scientific field of Construction include the scientific branches: Geotechnics (2.05.01), Structural Engineering (2.05.02), Hydraulic Engineering, (2.05.03), Transportation Engineering (2.05.04) and Construction Organization and Technology (2.05.05.). Teaching courses from the scientific field of Basic Technical Sciences include the scientific branches: Materials (2.15.03), Fluid Mechanics (2.15.04) and Engineering Mechanics (mechanics of solid and deformable bodies) (2.15.06).

2.2 Holder and deliverer of study program

Holder and deliverer of the study program is the Faculty of Civil Engineering in Rijeka with its basic teaching organizational units: Department of Geotechnics, Department of Hydraulic Engineering, Department of Computer Modelling of Materials and Structures, Department of Structures, Department of Construction Organization and Technology, Department of Architecture and Urbanism, Department of Transportation Engineering, Department of Technical Mechanics, Department of Mathematics, Department of Physics and other courses.

2.3 Length of study

The study is performed full-time or part-time. The maximum length of study is regulated by the Ordinance on Postgraduate University Study in Civil Engineering (hereinafter: the Ordinance). In both delivery models, the program includes the same study responsibilities, but there is a difference in the time required to fulfil them. The study is delivered in six semesters.

2.4 Objectives of PhD study and study program

The main objective of the Study is to provide students with effective education through the proposed teaching and research elements and to expand their prior knowledge and expertise through the implementation of original scientific research work. Such work must meet internationally accepted high quality standards and significantly contribute to the development of scientific thought within one of the research areas of the Faculty. Therefore, monitoring the quality of postgraduate university study is essential and is carried out by accepting objective quality criteria.

General objectives of the study program are education and development of researchers for whom there is a social need, and who will be able (i) to conduct independent research work at the level of internationally accepted quality standards, (ii) to actively contribute to the development of humane and sustainable society and (iii) to transfer the acquired knowledge to future generations of students and present it to the public in general.

The study aims to offer the students flexibility in creating study requirements and thus recognize the diversity of student experiences and approaches. These objectives provide structured education, including mandatory courses that provide the student with a scientific background, research at the level of international competitiveness with quality mentoring and the possibility of developing knowledge transfer skills through possible engagement in university study programs, participation in research and teaching seminars organized by the Faculty, and participation at international and domestic conferences.

2.5 Quality of study program

The quality of the study program, its parts and courses is ensured by:

- carefully selecting the best candidates
- contractual relations between the student and the Faculty
- appointing student advisors, mentors and commentators
- flexibility of the study program

- facilities and staff required for conducting research work and for acquiring the ECTS credits prescribed by the program
- staying at other university and scientific institutions
- publishing the obtained results in scientific publications cited in the world's most prestigious databases
- involving students in scientific research projects.

The quality of the study program, its parts and courses is supervised by continuous monitoring of student program delivery throug various forms of evaluation and self-evaluation of teachers, students and support staff by the Faculty.

The key faculty body in charge of conducting the Study and controlling its quality is the Committee for Doctoral Study, whose existence is provided by Art. 56 of the Ordinance on Studies at the University. Members of the Committee are the Vice Dean, who is also the chairman of the Committee, five teachers at the study and a student representative. Members of the Committee are elected for a term of three years. The tasks of the Committee are regulated by the Ordinance.

Through its secretary, the Committee for Doctoral Studies carries out the following activities:

- conducts a survey among students and teachers on all aspects of the teaching process
- after conducting a survey among students and teachers on all aspects of the teaching process, presents the results to teachers and students and, if necessary, also to the Faculty Council and the University Senate
- keeps record on teachers – a teacher portfolio (student opinions, work on improving scientific research and teaching, additional teacher education, sabbaticals, etc.)
- conducts analyses on taking exams (success, transparency, objectivity, etc.),
- conducts analyses of mentoring performance,
- conducts analyses on studying performance at the study in general (pass rate by year of study and the like),
- evaluates professional and support staff at the Faculty.

The quality of mentoring performance is monitored within the activities that monitor the implementation of the entire study program, as well as by analysis and acceptance or rejection of regular quarterly reports on student work by the dean or the Faculty Council, as well as student response to a potential negative report. In the four-month report, the mentor/advisor conducts the following: (i) assesses the work of the student work during the past period (ii) assesses the progress at the study, (iii) assesses the further course of studying, (iv) emphasizes the student's special achievements, (v) points out student's shortcomings and proposes measures for their elimination, (vi) points out possible non-compliance with general acts on ethical and disciplinary accountability. Mentoring performance is evaluated by an assistant at the postgraduate university study in the manner prescribed by the general act on the evaluation of the work of assistants, postdoctoral students and mentors. The quality of mentoring performance is ultimately objectively proven by publishing the results of doctoral research in the relevant scientific databases, as defined by the Ordinance. The student has the right to change the mentor in the manner prescribed by the general act on postgraduate university (doctoral) studies at the University of Rijeka.

Students are integrated into the activities of the Faculty, and, in addition to reports of their mentors, their progress is ensured through the following activities:

- by presenting the work of the doctoral student and transferring knowledge (in teaching, at professional conferences, at faculty series of scientific research and teaching meetings)
- by their involvement and active cooperation in scientific research projects of the Faculty
- by public defense of the topic of the doctoral thesis
- by a written consent of the mentor approving the public defense of the doctoral thesis
- by actively encouraging the students to publish the obtained results, as well as their doctoral thesis, in English or another generally accepted language.

2.6 Enrollment requirements

The application for enrollment in the Study is carried out based on an open call for applications announced by the Faculty Council. The requirements for enrollment in the study, the documentation required for the application to the study, and the criteria of selecting the candidates for enrollment are regulated by the Ordinance.

Prerequisite for applying to the Study is a completed university graduate study at which the candidate gained 300 ECTS credits, including an undergraduate cycle at one of the faculties of civil engineering or another completed university graduate study if the share of acquired competencies in other basic technical sciences is equivalent to the same share at the study of civil engineering, which is determined by the Committee for Doctoral Studies and committees and faculty commissions responsible for postgraduate studies and academic evaluation and evaluation of the length of study based on the diploma supplement.

Candidates with completed graduate studies in other subject areas of the scientific field of technical sciences, as well as in the scientific field of natural sciences, can also apply for enrolment in the Study. Given the acquired competencies, the Committee for Doctoral Studies may require such students to enroll a certain number of relevant courses taught at graduate study in civil engineering at the Faculty and take the exams. The acquired competencies are determined based on the diploma supplement.

If it can be established that certain candidates, who have enrolled in the Study, have previously acquired additional knowledge based on published scientific research papers or by attending and taking exams as part of the postgraduate master's study started before the higher education reform in 2005, such candidates may be exempted from attending classes and taking exams from courses taught in the first and/or the second semester. The exact number of ECTS credits, which are granted to the candidate as equivalent to the acquired knowledge, is adopted by the Faculty Council for each candidate individually. The costs of study are reduced in proportion to the number of ECTS credits, which was reduced as a result of granted courses.

Depending on the needs, the enrolment quota is defined at the beginning of the academic year.

2.7 Completion of PhD study and acquired competencies

The study is completed after the student has successfully passed the exams, met all the Study requirements, written and held a public defense of the doctoral thesis before the Commission for the Defense of the Doctoral Thesis. Upon completion of the study, at least 180 ECTS credits are earned.

Upon completion of the study, the student earns the title of **doctor of technical sciences** and acquires the following competencies:

- conducting research using scientific methodology
- conducting research in the spirit of generally accepted research ethics
- conducting independent advanced scientific research and professional work in modelling, calculation, analysis and design of systems in certain scientific branches
- having ability and knowledge to solve specific problems in an interdisciplinary manner, especially in the context of the interrelationship of construction projects, systems and their environment
- conducting critical analysis, evaluation and synthesis of new and complex concepts
- applying the results in a context different from the one in which they were obtained
- developing new methodological procedures
- critically assessing one's own research and research of others
- having ability to present one's own work
- conducting transfer of knowledge in a pedagogic manner
- conducting a discussion with logical argumentation of positive scientific facts (related to information, ideas, challenges, possible solutions)
- conducting research activities
- showing further independent development and improvement in the field of research, planning, design, execution and management of the most complex construction projects and related systems
- promoting technological progress in a knowledge-based society
- taking independent action within the academic community.

Learning outcomes for each course are listed in Chapter 3.3.

2.8 Language

All mandatory and elective courses can be delivered in English.

The doctoral thesis can be written in Croatian or English, or another accepted language of communication in the field of technical sciences.

2.9 Rights and responsibilities of students

Contractual relations, rights and responsibilities of students are defined by the Ordinance.

3 Description of study program

3.1 Structure and organization of study

Student requirements are regulated by the applicable regulations, especially the general acts of the University on studies and postgraduate (doctoral) study, the Ordinance, and the curricula of the subjects defined in Chapter 3.3.

Study requirements include:

- curricular requirements, which earns at least 30 ECTS credits
- scientific research, which earns at least 138 ECTS credits
- additional requirements in teaching and transfer of knowledge, which earns at least 12 ECTS credits.

The student is required to collect at least 20 ECTS credits by fulfilling curricular requirements or by research activities while spending at least three months at university or scientific institutions outside the University.

The pace of studying and the requirements for enrollment in each semester are regulated by the applicable Ordinance. The student is guided through the study by an advisor, a mentor and a co-mentor. The evaluation system and guidance through the study are regulated by the Ordinance.

3.1.1 Curricular requirements

Teaching obligations consist of:

- listening and taking exams in mandatory subjects, which earns at least 12 ECTS credits
- listening to and taking exams in elective subjects, which earns at least 18 ECTS credits.

In cooperation with the advisor, the student selects three elective courses with a total of 18 ECTS credits. A student may enroll in more than three elective courses if, in agreement with the advisor, he/she estimates that enrolling in elective courses will not interfere with the performance of study requirements. Within elective courses, the student is offered topics related to the subject area of the teacher delivering the course. Topics within elective courses may change depending on the current research activity of the teacher. At the proposal of the Committee, the Faculty Council may approve the implementation of new elective courses.

The student may enroll in elective courses at another corresponding doctoral study. The student, who enrolls in a course at another postgraduate doctoral study inside or outside the University and meets all student requirements related to that course, which are based on the study contract between the Faculty and the institution where the other study is implemented, will be recognized as many ECTS credits as would be earned by the doctoral student of that institution after enrolling that very same course and meeting student requirements.

Students of other institutions may be allowed to participate in the Study in accordance with the conditions defined in this program, the general acts on postgraduate studies at the University and the Ordinance.

3.1.2 Scientific research

Scientific research paper includes defining the original hypothesis of the paper, determining the relationship between the hypothesis and previous knowledge in the field of research, detailed elaboration of the hypothesis which logically shows its applicability in the field of research and proof of hypothesis viability.

Scientific research paper is evaluated through mandatory and elective activities.

Mandatory scientific research activities are the following:

- preparation and proposal of the topic of the doctoral thesis, which earns 15 ECTS credits,
- public defense of the topic of the doctoral thesis, which earns 5 ECTS credits,
- preparation and proposal of the doctoral thesis, which earns 40 ECTS credits,

- adoption of a positive report of the Expert commission for the evaluation of the doctoral thesis, which earns 10 ECTS credits
- preparation of an original scientific paper with the student as the main author and its publication in a foreign scientific journal cited in the database Current Contents, Science Citation Index or Science Citation Index Expanded, which earns 30 ECTS credits,
- public defense of the doctoral thesis, which earns 10 ECTS credits.

The procedure for proposing the topic of the doctoral thesis, evaluation and defense of the doctoral thesis, proposal, evaluation and defense of a doctoral thesis is regulated in more detail by the Statute of the University of Rijeka, general acts of the University on studies and postgraduate (doctoral) study and the Ordinance.

Elective scientific research activities are the following

- preparation and publication of an article in the proceedings of a domestic scientific conference, which earns 3 ECTS credits, i.e. up to 6 ECTS credits
- presentation of an article published in the proceedings of a domestic scientific conference at the conference itself and as part of the Faculty scientific meetings, which earns 2 ECTS credits, i.e. up to 4 ECTS credits
- preparation and publication of an article in the proceedings of an international scientific conference, which earns 4 ECTS credits, i.e. up to 8 ECTS credits
- presentation of an article, which was published in the proceedings of an international scientific conference, at that conference in English and its presentation at Faculty scientific meetings, which earns 4 ECTS credits, i.e. up to 8 ECTS credits
- preparation and publication of a peer-reviewed article in an unindexed journal, which earns 5 ECTS credits, i.e.up to 10 ECTS credits
- preparation and publication of an article in a journal indexed outside the citation databases Current Contents, Science Citation Index and Science Citation Index Expanded, which earns 10 ECTS credits
- preparation and publication of an article in a journal indexed within the citation databases Current Contents, Science Citation Index or Science Citation Index Expanded, which earns 30 ECTS credits.

At least 138 ECTS credits are earned through mandatory and elective scientific research activities.

3.1.3 Additional requirements in teaching and transfer of knowledge

Teaching methods and methods of transfer of knowledge are the following:

- cooperation in teaching university undergraduate or graduate study courses, which earns 1 ECTS credit for every 20 active teaching classes, up to a maximum of 12 ECTS credits
- participation in one of the one-day workshops organized by the University on the topic of improving teaching competencies, which earns 1 ECTS credit for each participation, up to a maximum of 3 ECTS credits
- one-time teaching process improvement or introduction of new teaching methods, which earns 2 ECTS credits
- participation in the popularization of technology and construction profession through lectures or presentations at appropriate events, which earns 3 ECTS credits for each lecture or presentation, up to a maximum of 12 ECTS credits
- participation in workshops related to improving the teaching quality and obtaining a certificate with the number of hours of participation, which earns 1 ECTS credit for every 20 hours of participation, up to a maximum of 4 ECTS credits
- one-time analysis of measures by which student work organizations stimulate their scientific research training during part-time work, which earns 2 ECTS credits.

In addition to cooperation in teaching, all of the listed activities should be followed by a presentation as part of the faculty series of scientific and teaching meetings.

At least 12 ECTS credits are earned through additional teaching and knowledge transfer duties.

3.2 List of mandatory and elective courses and teachers

The study curriculum consists of mandatory and elective courses. In the first semester, the student attends mandatory course classes and then takes the exams. Mandatory courses taught in the first semester are listed in Table 1.

Table 1. First semester mandatory courses

Teacher	Mandatory courses	Code
asst. prof. dr. sc. Ivan Marović	Methodology of Scientific Research Work	O-01
assoc. prof. dr. sc. Bojan Crnković and prof. dr. sc. Boris Podobnik	Applied Higher Mathematics	O-02

In the second semester, the student chooses three elective courses, each of which corresponds to a load of 6 ECTS credits. Elective courses are delivered in scientific branches: Geotechnics (Table 2), Load-Bearing Structures (Table 3), Hydraulic Engineering (Table 4), Transportation Engineering (Table 5), Materials (Table 6), Fluid Mechanics (Table 7), Engineering Mechanics (mechanic of solid and deformable bodies) (Table 8).

Table 2. Courses in the scientific branch of Geotechnics (2.05.01)

Teacher	Elective courses	Code
prof. dr. sc. Željko Arbanas	Advanced Theoretical Soil Mechanics	I-G01
prof. dr. sc. Željko Arbanas asst. prof. dr. sc. Martina Vivoda Prodan	Observation Methods in Geotechnical Engineering	I-G02
assoc. prof. dr. sc. Sanja Dugonjić Jovančević	Hazard in Geotechnical Engineering	I-G03
asst. prof. dr. sc. Vedran Jagodnik	Soil Consolidation and Creep	I-G04
assoc. prof. dr. sc. Leo Matešić	Geotechnical Aspects of Waste Disposal	I-G05
assoc. prof. dr. sc. Leo Matešić	Geotechnical Aspects of Seismic Engineering	I-G06
assoc. prof. dr. sc. Leo Matešić	Geotechnical Modelling	I-G07
prof. emeritus Ivan Vrkljan	Advanced Rock Mechanics	I-G08

Table 3. Courses in the scientific branch of Structural Engineering (2.05.02)

Teacher	Elective courses	Code
assoc. prof. dr. sc. Adriana Bjelanović	Analysis and Improvement of Timber Structures	I-NK01
assoc. prof. dr. sc. Mladen Bulić	Selected Chapters of Steel Structures	I-NK02
prof. dr. sc. Davor Grandić	Models of Bearing Capacity and Usability of Concrete Structures Affected by Reinforcement Corrosion	I-NK03
prof. dr. sc. Davor Grandić	Earthquake Engineering	I-NK04

prof. dr. sc. Davor Grandić, prof. dr. sc. Ivana Štimac Grandić, assoc. prof. dr. sc. Adriana Bjelanović, assoc. prof. dr. sc. Mladen Bulić, asst. prof. dr. sc. Paulina Krolo	Experimental Methods in Condition Assessment and Analysis of Structural Behaviour	I-NK05
prof. dr. sc. Ivica Kožar	Modelling of Structures	I-NK06
asst. prof. dr. sc. Paulo Šćulac	Crack Analysis in Reinforced Concrete Members	I-NK07
prof. dr. sc. Ivana Štimac Grandić	Structural Damage Assessment Using Nondestructive Methods	I-NK08
asst. prof. dr. sc. Neira Torić Malić	Modelling and Analysis of Structures under the Influence of Moving Loads	I-NK09
prof. dr. sc. Goran Turk	Structural Reliability	I-NK10
asst. prof. dr. sc. Željko Smolčić	Analysis and Design of Concrete Cross Sections	I-NK11
asst. prof. Paulina Krolo, D.Sc.	Analysis of Connection Behaviour in Steel Constructions	I-NK12

Table 4. Courses in the scientific branch of Hydraulic Engineering (2.05.03)

Teacher	Elective courses	Code
prof. dr. sc. Suzana Ilić	Coastal Processes and Engineering	I-H01
prof. dr. sc. Barbara Karleuša	Contemporary Approaches to Water Resources Management	I-H02
prof. dr. sc. Nevenka Ožanić	Analysis and Modelling of Hydrological Processes	I-H03
prof. dr. sc. Nevenka Ožanić	Management of Hydro-Melioration Systems	I-H04
prof. dr. sc. Nevenka Ožanić, asst. prof. dr. sc. Ivana Sušanj Čule	Karst Hydrology	I-H05
asst. prof. dr. sc. Bojana Horvat	Principles and Application of Remote Sensing	I-H06
asst. prof. dr. sc. Josip Rubinić	Eco-Hydrology	I-H07
assoc. prof. dr. sc. Vanja Travaš	Groundwater and Surface Water Interaction Modelling	I-H08
asst. prof. dr. sc. Goran Volf	Aquatic Ecosystem Modelling	I-H09

Table 5. Courses in the scientific branch of Transportation Engineering (2.05.04)

Teacher	Elective courses	Code
prof. emeritus Mate Sršen	Pavement Management Systems	I-P01
prof. dr. sc. Aleksandra Deluka-Tibljaš, asst. prof. dr. sc. Sanja Šurdonja	Experimental Analyses of Asphalt Mixtures	I-P02
prof. dr. sc. Aleksandra Deluka-Tibljaš	Advanced Analysis of Pavement Structures	I-P03
prof. dr. sc. Aleksandra Deluka-Tibljaš	Traffic Flow Analysis	I-P04

asst. prof. dr. sc. Sanja Šurdonja	Transport Infrastructure and Traffic Safety – selected chapters	I-P05

Table 6. Courses in the scientific branch of Materials (2.15.03)

Teacher	Elective courses	Code
asst. prof. dr. sc. Silvija Mrakovčić	Development of Modern Cement Composites	I-M01

Table 7. Courses in the scientific branch of Fluid Mechanics (2.15.04)

Teacher	Elective courses	Code
asst. prof. dr. sc. Igor Ružić	Modelling of Hydrodynamic and Transport Processes in Marine Environment	I-MF01
assoc. prof. dr. sc. Vanja Travaš	Numerical Hydrodynamics	I-MF02
asst. prof. dr. sc. Elvis Žic	SPH Method for Fluid Dynamics Simulation	I-MF03
asst. prof. dr. sc. Nino Krvavica	Modelling Coupled Systems of Shallow Water Flows	I-MF04

Table 8. Courses in the scientific branch Engineering Mechanics (Mechanics of Solid and Deformable Bodies) (2.15.06)

Teacher	Elective courses	Code
prof. dr. sc. Gordan Jelenić	Algorithmic Preservation of Mechanical Properties	I-TM01
prof. dr. sc. Gordan Jelenić	Fixed-Pole Approach for Geometrically Non-Linear Beams	I-TM02
prof. dr. sc. Gordan Jelenić	Tensor Mechanics of Elastic Continuum	I-TM03
prof. dr. sc. Gordan Jelenić	Plasticity Theory in Construction Simulations	I-TM04
prof. dr. sc. Vedrana Kozulić	Meshless Numerical Methods	I-TM05
prof. dr. sc. Ivica Kožar	Numerical Methods in Engineering	I-TM06
prof. dr. sc. Joško Ožbolt	Mechanics of Quasi-Brittle Materials	I-TM07
asst. prof. dr. sc. Edita Papa Dukić	Configuration-Dependent Interpolation in Non-Linear Beam Elements	I-TM08
prof. dr. sc. Zoran Ren	Fracture Mechanics	I-TM09
assoc. prof. dr. sc. Dragan Ribarić	Convergence and Error Estimation in Finite Element Method	I-TM10
assoc. prof. dr. sc. Dragan Ribarić	Plates and Shells	I-TM11
asst. prof. dr. sc. Leo Škec	Modelling of Layered Beam Structures	I-TM12
asst. prof. dr. sc. Leo Škec	Introduction to Non-Linear Mechanics – One-Dimensional Problems	I-TM13
asst. prof. dr. sc. Nina Čeh	Experimental Dynamics of Solid and Deformable Systems	I-TM14
asst. prof. dr. sc. Teo Mudrić	Basics of Peridynamics	I-TM15

3.3 Course description

Courses are divided into **mandatory courses**, which are taught in the first semester, and elective courses, which are taught in the second semester.

MANDATORY COURSES

Course: Methodology of Scientific Research Work					Status: mandatory		Code: 0-01	
Lecturer: asst. prof. Ivan Marović								
Course delivery		Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours		15						
Allocation of ECTS credits		0.4	0.6	1.5			1.5	
A total of ECTS credits: 4.0								
Course objectives	Development of general competences, knowledge and skills in the evaluation of knowledge related to the methodology of scientific research and scientific research work.							
Learning outcomes	- Describe and interpret: (1) basic developmental features of science and scientific research; (2) research skills in scientific research. - Distinguish and / or successfully justify: (1) scientific fields, fields and branches; (2) scientific and scientific-teaching titles; (3) types of scientific papers; (4) relevant characteristics of the scientific, scientific and professional work; (5) methodological approaches when designing scientific and professional work; (6) scientific methods; (7) forms of intellectual property. - Define and / or develop: (1) the subject of scientific research; (2) the structure of the scientific work (seminars, articles, thesis); (3) hypotheses; (4) scientific research plan; (5) ability to search bibliographic and other databases; (6) ability to shape scientific research work as a project application. - Analyze, categorize and evaluate: (1) scientific journals; (2) a plan for scientific research; (3) a bibliography (Cooper's taxonomy of literature reviews); (4) results of the conducted research; (5) project application for scientific research work.							
Topics	- Theory of science: concept, development, relationship between science and technology, tendencies of development of modern science. - Division of Science. - Scientific categories. - Scientific activity: scientific research: experimental research, theoretical research, relationships. - Scientific research methodology: the concept and division of scientific methods. - Scientific research technology: identifying a scientific problem and its formulation, hypothesizing, developing an orientation plan for scientific research, collecting and studying literary material, preparing a scientific work structure, solving a scientific problem, writing the research results, applying the research results, controlling the application of research results. - Fundamentals of Intellectual Property Management. - Communication of the scientific research results: written works, types and significance. - Shaping the results of the research work as a project application. - Fundamentals of proposing and implementing scientific projects. - Scientific-research work in economy and industry and at the university.							
Student obligations	Creation of two seminar papers.							
Exam	Seminar paper presentation and oral exam.							
Assessment	Seminar: 50%, oral exam: 50%.							
Required literature	- Zelenika, R.: Metodologija i tehnologija izrade znanstvenog i stručnog djela, 4. ed., Ekonomski fakultet u Rijeci, Rijeka, 2000. - Zelenika, R.: Metodologija i tehnologija izrade znanstvenog i stručnog djela – Pisana djela na poslijediplomskim doktorskim studijima, IQ Plus, Kastav, Univerzitet Vitez, Travnik, Rijeka-Travnik, 2012. - Zelenika, R.: Metodologija i tehnologija izrade znanstvenog i stručnog djela – Znanstvene međusobno povezane metode, IQ Plus, Kastav, 2013. - Zelenika, R.: Metodologija i tehnologija izrade znanstvenog i stručnog djela – Znanstvene kvalitativne metode, IQ Plus, Kastav, 2014. - Zelenika, R.: Metodologija i tehnologija izrade znanstvenog i stručnog djela – Znanstvene kvantitativne metode, IQ Plus, Kastav, 2015.							

	- Zelenika, R.: Metodologija i tehnologija izrade znanstvenog i stručnog djela – Dobrim znanjem do akademske karijere i znanstvene karijere, peto izmijenjeno i dopunjeno izdanje, Naklada Kvarner, Novi Vinodolski, Rijeka, 2020.
Recommended literature	- Tkalac Verčić, A., Sinčić Ćorić, D., Pološki Vokić, N.: Priručnik za metodologiju istraživačkog rada – Kako osmisliti, provesti i opisati znanstveno i stručno istraživanje, MEP, Zagreb, 2010. - Silobrčić, V.: Kako sastaviti, objaviti i ocijeniti znanstveno djelo, 5. dop. izd., Medicinska knjiga, Zagreb, 2003. - Ivanović, Z.: Metodologija znanstvenog istraživanja, Saiva, Kastav, 2011. - Marczyk, G., DeMatteo, D., Festinger, D.: Essentials of Research Design and Methodology, John Wiley & Sons, Hoboken, 2005.

Course: Applied Higher Mathematics				Status: mandatory		Code: 0-02	
Lecturer: assoc. prof. Bojan Crnković and prof. Boris Podobnik							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	30						
Allocation of ECTS credits	0.75	2.25	4.0			0.5	0.5
A total of ECTS credits: 8.0							

Course objectives	Introduce students to statistical assessments and determine the parameters of the appropriate statistical hypotheses.
Learning outcomes	- Define basic concepts in probability theory. - Conduct statistical analysis of data collected through measurement. - Define basic concepts in the theory of partial differential equations. - Analyze partial equations of the second order: parabolic, elliptic and hyperbolic. - Analyze methods for solving these equations.
Topics	- Averaging, median, and other measures of central tendency. - Standard deviation, higher moments and other measures of dispersion. - Elementary probability theory, binomial, Poisson and GEV distributions. Pattern theory. - Statistical theory of estimates. Parameter rating, point estimates and rating intervals. - Estimates of confidence intervals. Statistical Decision Theory --- Hypothesis Tests. - Sample theory, student t-distribution, hi-square test and F-distribution. - Least squares method, multiple regression. Correlation theory. Variance analysis. - Non-parametric tests. Random processes, ARMA processes. Time series analysis. - Evaluation of dynamic models. Non-stationarity testing in time series. - Multiple variable functions, continuity, partial derivations - Vector spaces, norm, scalar product, Euclidean metric. - Basic concepts of partial differential equations, order, linearity. - Examples of partial differential equations in physics (wave equation, Laplace equation, conductivity equation, Kortweg de Vries equation). - Systems of partial differential equations, reduction of nonlinear differential equation to quasilinear. - Initial problems, boundary problems, mixed problems. - Classification of partial differential equations of the 2nd order, an equation with functions of two variables. - Elliptic, parabolic, hyperbolic equation. - 2^{nd} order hyperbolic equations (one-dimensional wave equation, Cauchy problem for 1D wave equation, inhomogeneous wave equation, Fourier method of separating equations). - 2^{nd} order elliptic equations (boundary value problems and maximum principle, Poisson formula and separation method) - 2^{nd} order parabolic equations
Student obligations	Creation of a seminar paper from a selected part of the course.
Exam	The exam consists of the presentation of a seminar paper, and a written and oral part.
Assessment	Assessment is based on the written and oral exam and seminar paper and its presentation.
Required literature	- M. Spiegel and L. Stephens, Schaum's Outline of Statistics McGraw-Hill, New York, 1998. ISBN: 0071167668 - J.E. Marsden, T.J.R. Hughes, Mathematical Foundations of Elasticity, Dover, New York, 1994.
Recommended literature	- S. Bernstein, R. Bernstein, Elements of Statistics II: Inferential Statistics, Schaum's Series, McGraw-Hill, New York, 1999.

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF CIVIL ENGINEERING (2.05) AND THE SCIENTIFIC BRANCH OF GEOTECHNICS (2.05.01)

Course: Advanced Theoretical Soil Mechanics				**Status:** elective		**Code:** I-G01	
Lecturer: prof. Željko Arbanas							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	3.0			2.0	
A total of ECTS credits: 6.0							

Course objectives	Prepare a PhD student to understand the application of nonlinear continuum mechanics and constitutional equations in describing real soil behaviour. Describe the theory of critical states in the mechanical behaviour of real soils. Explain theoretical behaviour for different soil models. Introduce the student to the application of theoretical models of soil behaviour in practical application.
Learning outcomes	- Correctly describe different advanced models of soil behaviour. - Define laboratory experiments and conditions for performing experiments that determine soil behaviour in accordance with the assumptions of advanced soil models. - Analyze soil behaviour based on the results of laboratory experiments and based on the conducted behavioural comparisons. Define the parameters of the adopted soil model. - Independently analyze the results of laboratory soil tests and justify the necessary improvements in soil behaviour models. - Use and explain the need to use soil behaviour models in certain practical phenomena in the behaviour of geotechnical structures.
Topics	Theory of critical states and mechanical behaviour of real soils. Nonlinear continuum mechanics and constitutional equations. Elasticity and elastoplasticity. Yield surfaces and plastic potentials. Isotropically hardening models. Complex nonlinear soil models and their limitations: Duncan and Chang model, Cam clay and variants, Pastor and Zinekiewicz model and variants, models with multiple yield surfaces. Application to models in various geotechnical problems.
Student obligations	Creation of a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 60 %, seminar paper presentation 20%, seminar paper explanation 20%.
Required literature	- ISSMFE: Constitutive Laws of Soils, Report of ISSMFE Subcommittee on Constitutive Laws of Soils and Proceedings of Discussion Session 1A, ed.: S. Murayama, XI International Conference on Soil Mechanics and Fundation Engineering, San Francisco, Japanese Society of Soil Mechanics and Fundation Engineering, Tokyo, 1985, p. 175. - Desai, C. S., Siriwardane, H.J.: Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials, Prentice-Hall, In., Englewood Cliffs, New Jersey, 1984, p. 468. - Atkinson, J.H., Bransby, P.L.: The Mechanics of Soil - An Introduction to Critical State Soil Mechanics, McGraw-Hill Book Company (UK) Limited, London, 1978, p. 376. - Schofield, A.N., Worth, C.P.: Critical State Soil Mechanics, McGraw-Hill Book Company, London, 1968, p. 310. - Wood, D.M.: Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, Cambridge, 1990, p. 462.
Recommended literature	- Desai, C. S., Siriwardane, H.J.: Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials, Prentice-Hall, In., Englewood Cliffs, New Jersey, 1984, p. 468. - Atkinson, J.H., Bransby, P.L.: The Mechanics of Soil - An Introduction to Critical State Soil Mechanics, McGraw-Hill Book Company (UK) Limited, London, 1978, p. 376.

Course: Observational Methods in Geotechnical Engineering				**Status:** elective		**Code:** I-G02	
Lecturer: prof. Željko Arbanas, asst. prof. Martina Vivoda Prodan							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Educate PhD students to understand the behaviour of real soil and rock mass in practical problems and their solution by numerical methods. Point out an active approach to design in geotechnical engineering based on methods of observation and monitoring. Introduce in detail the available software packages for numerical solution of geotechnical problems and their use in active design.
Learning outcomes	- Describe the application of different observational methods and define their role in the construction of geotechnical structures. - Analyze the results of measurements with different observational methods and justify the reasons for the deviation from the expected measured values. - Compare the results obtained by different methods of observation and measurement on a geotechnical structure and interpret the behaviour of a geotechnical structure. - Independently develop appropriate models of structural behaviour and define the needs of using measuring devices for a defined model of structural behaviour. - Independently analyze the needs of the intervention on the geotechnical structure and justify the needs of structural change due to unexpected occurrences on the structure.
Topics	- Principles of the observation method. - Numerical modelling methods in geotechnical engineering. - Methods of observation and monitoring. - Numerical modelling of reinforced soil and rock mass. - Modelling of geotechnical structures. - Feedback analyses in soil and rock mass. - Influence on the behaviour of the building during construction. - Condition analyses of constructed geotechnical structures (case studies).
Student obligations	Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 70 %, seminar paper presentation 15 %, seminar paper defense 15 %.
Required literature	- Nicholson, D.P., Tse, C.M., Penny, C.: The Observational Method in Ground Engineering: Principles and Applications, Report 185, CIRIA, London, 1999 - Dunnicliff, J. Geotechnical instrumentation for monitoring field performance. John Wiley & Sons, Inc., New York, 1988 - Arbanas, Ž.: Prediction of Supported Rock Mass Behaviour by Analysing Results of Monitoring of Constructed Structures, Ph.D. Thesis, Faculty of Civil Engineering, University of Zagreb (in Croatian), 2004 - Wood, D.M.: Geotechnical Modelling, Spoon Press, Taylor & Francis Group, London, 2004 - Potts, D.M., Zdravković, L.: Finite Element Analysis in Geotechnical Engineering, Theory, Thomas Telford, London, 1999 - Potts, D.M., Zdravković, L.: Finite Element Analysis in Geotechnical Engineering, Application, Thomas Telford, London, 2001
Recommended literature	- Sakurai, S.: Back analysis in rock engineering, Volume 4, CRC Press, London, 2017 - Rocscience Inc. User's guide RS2 9 Modeler, online help, Toronto, Canada, 1990-2018 - GEO-SLOPE Int. Ltd.: Stress-Deformation Modeling with SIGMA/W/ An Engineering Methodology, Calgary, 2013 - Itasca Consulting Group: FLAC, Fast Lagrangian Analysis of Continua, FLAC 8 Basics, Minneapolis, 2015

	- Plaxis: Plaxis, Finite Element Code for Soil and Rock Analysis, Delft, 2019 - Desai, C. S., Siriwardane, H.J.,: Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials, Prentice-Hall, In., Englewood Cliffs, New Jersey, 1984 - Naylor, D.J., Pande, G.N., Sompson, B., Tabb, R.: Finite Elements in Geotechnical Engineering, Pineridge Press Ltd., Swansa (UK), 1981

Course: Hazard in Geotechnical Engineering				**Status:** elective		**Code:** I-G03	
Lecturer: assoc. prof. Sanja Dugonjić Jovančević							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Basic understanding of the relationship between endodynamic and exodynamic processes and the phenomenon of geohazard, as well as natural and artificial types of hazard. Students will be introduced to the impact of spatial planning and construction on changing levels of hazard and risk. The course includes the impact of geotechnical engineering in reducing and avoiding geohazards.
Learning outcomes	- Describe the connections between endodynamic and exodynamic processes and geohazard phenomena. - Define the basic types of natural and artificial hazards. - Analyze the impact of spatial planning and construction on changing the level of hazards and risks. - Analyze the impact of geotechnical engineering in reducing and avoiding geohazards.
Topics	- Natural and anthropogenic hazard and risk. - Seismotectonic activity. - River erosion and accumulation. - Marine erosion and accumulation. - Mass movements and slope stability. - Hazard assessment and zoning. - The impact of construction on the level of hazards and risks. - The role of geotechnical engineering in reducing and avoiding hazards and risks.
Student obligations	Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 80 %, seminar paper presentation 10%, seminar paper defense 10%.
Required literature	- Bell, G.F., Geological hazard. Their Assessment, Avoidance and Mitigation. Spon Press, 2003. - Bell, G.F., Environmental Geology, Principles and Practice. Blackwell Science, 1998. - Turner, A.K., Schuster, R.L., Landslides, Investigation and Mitigation, Special report 247, Transportation Research Board, National Research Council, National Academy Press, 1996. - Smith, K., Environmental Hazards: Assessing Risk and Reducing Disaster 3. ed. Routledge, 2001.
Recommended literature	- Van Westen, C.J., Application of Geographic Information Systems to Landslide Hazard Zonation. Vol. 1: Theory - ITC Publication No. 15, 1993. - Keller, A.E., Environmental Geology. 8. ed. Prentice Hall, 2000. - Allen, P. A., Earth Surface Processes. Blackwell, 1997. - Bobrowsky, P. T. (ed.), Geoenvironmental Mapping. Balkema, 2002. - Morris, P. & Therivel, R. (ed.): Methods of Environmental Impact Assessment. 2. ed. Spon Press, 2001.

<table>
<tr><td colspan="4">Course: Soil Consolidation and Creep</td><td colspan="2">Status: elective</td><td colspan="2">Code: I-G04</td></tr>
<tr><td colspan="8">Lecturer: asst. prof. Vedran Jagodnik</td></tr>
<tr><td>Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Assignments</td><td>Exercises</td><td>Exam</td><td>W. exam</td></tr>
<tr><td>Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>4.0</td><td></td><td></td><td>1.0</td><td></td></tr>
<tr><td colspan="8">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="7">Detailed introduction to understanding the process of flow and consolidation in soil with the application of nonlinear mechanics of continuum and constitutional equations in describing the process of consolidation and creep in real soil. Indication of consolidation models and numerical modelling of the subject process. Introduction to software packages that enable solving the problem of consolidation in the soil.</td></tr>
<tr><td>Learning outcomes</td><td colspan="7">- Distinguish stages of consolidation.
- Describe the deformation of a single-phase relation.
- Distinguish primary from secondary consolidation.
- Describe and analyze the process of creeping in the soil.
- Compare models of constitutive creep behaviour.</td></tr>
<tr><td>Topics</td><td colspan="7">- Basic principles of flow through saturated soil as an anisotropic porous medium.
- Related flow and consolidation process.
- Pore pressure.
- Constitutive models.
- Numerical modelling of flow and consolidation processes.
- Determination of characteristics and measurement in situ.
- Applications and examples.</td></tr>
<tr><td>Student obligations</td><td colspan="7">Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.</td></tr>
<tr><td>Exam</td><td colspan="7">After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.</td></tr>
<tr><td>Assessment</td><td colspan="7">Seminar paper preparation 80 %, seminar paper presentation 10%, seminar paper defense 10%.</td></tr>
<tr><td>Required literature</td><td colspan="7">- Šuklje, L.: Rheological Aspects of Soil Mechanics, Wiley–Interscience, London, 571 p., 1979.
- Bathe, K.J.: Finite Element Procedures in Engineering Analysis, Prentice-Hall, Englewood Cliffs, New Jersey, 1984.
- GEO-Slope Int. Ltd.: User's Guide Sigma/W for Finite Element / Deformation Analysis, Version 4, Calgary, 1998.</td></tr>
<tr><td>Recommended literature</td><td colspan="7">- Nonveiller, E.: Mehanika tla i temeljenje građevina, Školska knjiga, Zagreb, p.780, 1979.
- Desai, C. S., Siriwardane, H.J.: Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials, Prentice-Hall, In., Englewood Cliffs, New Jersey, 1984, p. 468.
- Itasca Consulting Group: FLAC, Fast Lagrangian Analysis of Continua, Manual, Minneapolis: Itasca Consulting Group Inc., 1993, 1995, 2000.
- Plaxis: Plaxis, Finite Element Code fo Soil and Rock Analyses, R.B.J. Brinkgreve and P.A. Vermeer Eds., Rotterdam/Brookfield: A.A. Balkema, 1998.</td></tr>
</table>

Course: Geotechnical Aspects of Waste Disposal	**Status:** elective	**Code:** I-G05

Lecturer: assoc. prof. Leo Matešić

Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	

A total of ECTS credits: 6.0

Course objectives	Through a series of lectures, students are introduced to the theory of geotechnics in environmental protection. Geotechnics in environmental protection includes the application of geotechnical principles in solving environmental problems, especially in the design of landfills.
Learning outcomes	- Define the role of geotechnics in the design of landfills. - Define a geotechnical soil model. - Define geotechnical solutions in the construction of landfills. - Apply geotechnical solutions in the construction of landfills.
Topics	- Environmental protection regulations. - Geohazards in waste disposal. - Characteristics of waste material (solid waste, liquid waste, hazardous waste). - Design of landfills. - Hydrogeology of polluted environment. - Processes of flow and pollution of porous media. - Flow process in unsaturated materials in landfills. - Processes of improvement and stabilization of waste materials. - Geosynthetics and landfills. - Leakage and gas monitoring and removal systems. - Closure of landfills. - Waste management.
Student obligations	Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 80 %, seminar paper presentation 10%, seminar paper defense 10%.
Required literature	- Qian, X., Koerner, R.M. and Gray, D.H.(2002), Geotechnical Aspects of Landfill Design and Construction, Prentice Hall - McBean, E.A., Rovers, F.A. and Farquhar, G.J. (1995), Solid Waste Landfill Engineering and Design, Prentice-Hall.
Recommended literature	- Babić, B et al., Geosintetici u graditeljstvu, Hrvatsko društvo građevinskih inženjera, 1995. - Bell, G.F., Environmental geology, Principles and Practice. Blackwell Science, Cambridge, 1998. - C.W. Fetter, Contaminant Hydrogeology, 2. ed., Prentice Hall, 1998. - Proske, H., Vlcko, J., Rosenbaum, M.S., Dorn, M., Culshaw, M. and Marker, B., Special purpose mapping for waste disposal sites. Report of IAEG Commission 1: Engineering Geological Maps. Bulletin of Eng. Geol. Environ., 64 (1), 2005.

Course: Geotechnical Aspects of Seismic Engineering				**Status:** elective		**Code:** I-G06	
Lecturer: assoc. prof. Leo Matešić (asst. prof. Vedran Jagodnik)							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Through a series of lectures, students are introduced to geotechnical aspects of seismic engineering, with the aim of a higher level of safety in the design of structures in seismic conditions.
Learning outcomes	- Define the role of geotechnics in seismic engineering. - Define a geotechnical soil model. - Define geotechnical solutions in seismic engineering. - Apply geotechnical solutions in seismic engineering.
Topics	- Earthquake and vibrations in the soil. - Behaviour of the soil under the action of random vibrations. - Dynamic soil characteristics. - Active soil pressure in dynamic conditions. - Seismic slope stability. - Soil liquefaction and determination of liquefaction potential. - Interaction of foundation and soil in dynamic conditions. - Monitoring the behaviour of foundations and soil in dynamic conditions. - Hazard analysis by deterministic and probabilistic methods.
Student obligations	Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 80 %, seminar paper presentation 10%, seminar paper defense 10%.
Required literature	- Das, B. M. (1992) Principles of Soil Dynamics. PWS-KENT - Ishihara, K., (1996): Soil Behaviour in Earthquake Geotechnics. Clarendon Press - Oxford University Press - Itasca Consulting Group: FLAC, Fast Lagrangian Analysis of Continua, Manual, Minneapolis: Itasca Consulting Group Inc., 1993, 1995, 2000. - Kramer, S. L. (1996) Geotechnical Earthquake Engineering, Prentice Hall
Recommended literature	- Plaxis: Plaxis, Finite Element Code of Soil and Rock Analyses, R.B.J. Brinkgreve and P.A. Vermeer Eds., Rotterdam/Brookfield: A.A. Balkema, 1998.

Course: Geotechnical Modelling					**Status:** elective		**Code:** I-G07
Lecturer: assoc. prof. Leo Matešić (asst. prof. Vedran Jagodnik)							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Educating PhD students to understand the application of nonlinear continuum mechanics and constitutional equations in describing the behaviour of real soil in practical problems and their solution by numerical methods. Introduce students to the available software packages for numerical solution of geotechnical problems.
Learning outcomes	- Apply continuum mechanics and constitutional equations in describing the behaviour of real soil in practical problems. - Define a geotechnical soil model. - Get familiar with appropriate computer programs. - Analyze geotechnical problems by numerical methods.
Topics	- Static and dynamic loads of saturated soil. - Analysis of stress and strain states in various geotechnical problems. - Analysis of related flow and deformation processes. - Analysis of dynamic problems. - Feedback analyses and analyses of the condition of constructed geotechnical structures (case studies). - Software packages in geotechnical modelling (FLAC, Plaxis, GEO-Slope).
Student obligations	Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 80 %, seminar paper presentation 10%, seminar paper defense 10%.
Required literature	- Desai, C. S., Siriwardane, H.J.: Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials, Prentice-Hall, In., Englewood Cliffs, New Jersey, 1984, p. 468. - GEO-Slope Int. Ltd.: User's Guide Sigma/W for Finite Element / Deformation Analysis, Version 4, Calgary, 1998. - Itasca Consulting Group: FLAC, Fast Lagrangian Analysis of Continua, Manual, Minneapolis: Itasca Consulting Group Inc., 1993, 1995, 2000. - Plaxis: Plaxis, Finite Element Code for Soil and Rock Analyses, R.B.J. Brinkgreve and P.A. Vermeer Eds., Rotterdam/Brookfield: A.A. Balkema, 1998. - Wood, D.M.: Geotechnical Modelling, Spoon Press, Taylor & Francis Group, London, 2004, p. 488.
Recommended literature	- Naylor, D.J., Pande, G.N., Sompson, B., Tabb, R.: Finite Elements in Geotechnical Engineering, Pineridge Press Ltd., Swansa (UK), 1981, p. 245. - Bathe, K.J.: Finite Element Procedures in Engineering Analysis, Prentice-Hall, Englewood Cliffs, New Jersey, 1984. - Desai, C.S., Abel, J.F.: Introduction to The Finite Element Method, A Numerical Method for Engineering Analysis, Van Nostrand Reinchold Company, New York, 1972, p.477.

Course: Advanced Rock Mechanics				**Status:** elective		**Code:** I-G08	
Lecturer: prof. emeritus Ivan Vrkljan							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Introduce PhD students to the theoretical foundations of engineering rock mechanics, which will deepen the knowledge acquired in undergraduate and graduate studies. In this way, a PhD student will get familiar with the latest knowledge in the field of rock mechanics as well as the trends in rock mechanics and related geosciences in the near future.
Learning outcomes	- Analyze and solve complex problems of rock mechanics and rock engineering by applying different constitutional relations and strength criteria. - Distinguish the behaviour of rocks and rock masses during the construction of underground structures. - Describe variations in the stress state due to the presence of discontinuity, inhomogeneity and anisotropy on various scales. - Define the parameters of the rock mass when applying the method of discrete elements.
Topics	- Constitutive models for intact rock, discontinuities and rock mass. Rock rheology. Swelling of rocks. Numerical modelling. Fracture process modelling. Discontinuum modelling. - Development of tunnel primary support philosophy. Tunnel deformations. - Foundation on rock mass and slope stability. - Mechanisms of rock destruction by blasting. Mechanisms of cutting and destruction by water blast. - Stresses and methods of their measurement. - Design methodology in rock engineering. - Storage of oil, gas and waste in the rock mass. Large underground structures.
Student obligations	Attending lectures. Selecting a topic for the seminar paper. Preparing a seminar paper. Presentation and defense of the seminar paper.
Exam	After its completion, the seminar paper is presented to the subject teacher and the results of the seminar paper are explained orally by the student at teacher's request.
Assessment	Seminar paper preparation 80 %, seminar paper presentation 10%, seminar paper defense 10%.
Required literature	- Hudson, J. A., (editor-in-chief), 1993, Comprehensive Rock Mechanics, Vol.1, 2, 3, 4 and 5. - Hoek, E.: Rock Engineering, A Course Notes, http://www.rocscience.com - Hudson, J.A. and Harrison J.P., 2000., Engineering Rock Mechanics, An introduction to the principles, Pergamon, 444 p.
Recommended literature	- Harrison, J.P., Hudson, J.P., 2000, Engineering Rock Mechanics, Illustrative Worked Exsamples, Pergamon, 506. p. - Hudson, J.A., (editor-in-chief), 1993., Comprehensive Rock Engineering, Volume 1,2,3,4 i 5 - Bell, F.G., 1995. Engineering Geology. Blackwell Science, Cambridge. - Hoek, E., Bray, J.W.: Rock Slope Engineering, 2nd. Ed., The Institute of Mining and Metallurgy, London, 527 p., 1977. - Desai, C. S., Siriwardane, H.J.: Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials, Prentice-Hall, In., Englewood Cliffs, New Jersey, 1984, p. 468. - GEO-Slope Int. Ltd.: User's Guide Sigma/W for Finite Element / Deformation Analysis, Version 4, Calgary, 1998. - Itasca Consulting Group: FLAC, Fast Lagrangian Analysis of Continua, Manual, Minneapolis: Itasca Consulting Group Inc., 1993, 1995, 2000. - Plaxis: Plaxis, Finite Element Code fo Soil and Rock Analyses, R.B.J. Brinkgreve and P.A. Vermeer Eds., Rotterdam/Brookfield: A.A. Balkema, 1998.

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF CIVIL ENGINEERING (2.05) AND THE SCIENTIFIC BRANCH OF STRUCTURAL ENGINEERING (2.05.02)

Course: Analysis and Improvement of Timber Structures				**Status:** elective		**Code:** I-NK01	
Lecturer: assoc. prof. Adriana Bjelanović							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	5.0				
A total of ECTS credits: 6.0							

Course objectives	Acquire advanced knowledge about timber structures. Scientific research and analysis are the basis for improving knowledge on the design and engineering of modern wooden structures with emphasis on innovation in the field of joints, special load-bearing systems made of timber / timber-based materials and composite systems based on timber, as well as improving knowledge on evaluating the impact of external influences on the material behaviour and the load-bearing system in special circumstances and environments.
Learning outcomes	- Analyze the problem (selected topic of seminar paper / research from those offered in the field of improving the condition or behaviour of timber structures). - Define the objectives, outcomes and methodology of the research in the context of proposals for improving behaviour and constructional properties. - Apply an appropriate problem-solving method (analytical, numerical, experimental or a combination). - Analyze and compare the obtained results with the results of similar research. - Analyze the achievements and contributions of the conducted independent research.
Topics	Safety analysis of elements and modern joints of timber structures from the point of view of mechanical resistance and stability, durability and fire resistance. Modern and innovative joints of elements in timber structures: theoretical and numerical models of behavioural simulation (with emphasis on joints with glued steel bars and rods reinforced with polymer fibers and glued elements), laboratory tests, fracture mechanics, safety assessment methods, element safety analysis and joints of timber structures under dynamic loads. Reinforcements of timber structural elements with insufficient load-bearing capacity - application of glued bars (steel and FRP) and strips based on polymer and glass fibers: theoretical and numerical models of behaviour, laboratory tests, fracture mechanics, methods of assessing the effects of reinforcement. Timber-based composite systems: composite mechanics, new timber-based materials and adhesives, mechanical resistance and stability, behaviour in fire conditions, coupling of timber / timber-based materials with other materials (composite ceiling beams - concrete, lightweight concrete, glass, plastic) - bond yield analysis and analysis of glued joints in composite beams timber / timber-based materials - glass / plastic and timber / timber-based materials / steel. Timber structures in aggressive environments: modelling of external influences - exposures, modelling of material / load-bearing system responses, analysis of consequences of degradation of mechanical properties on usability, durability, mechanical resistance and stability. Application of AI techniques in calculation and safety assessment of timber structures: numerical models, expert systems, neural networks: problem modelling, problem solving by searching, problem solving by consulting, optimization and forecasts, knowledge and reasoning.
Student obligations	Preparation of a seminar paper from one of the proposed thematic areas under the mentorship of the subject lecturer.
Exam	Defense of seminar paper by discussing it with the subject lecturer.
Assessment	The grade is the result of the seminar paper quality.

Required literature	- Blass, H. J., Aune, P., Choo, B. S., Gorlacher, R., Griffits, D. R., Hilson, B. O., Racher, P., Steck, G.: Timber Engineering STEP 1, Basis of design, Material properties, structural components and joints, 1st, Edition, Centrum Hout, The Netherlands, 2004. - Blass, H. J., Aune, P., Choo, B. S., Gorlacher, R., Griffits, D. R., Hilson, B. O., Racher, P., Steck, G.: Timber Engineering STEP 2, Design, Details and Structural Systems, 1st, Edition, Centrum Hout, The Netherlands, 2004. - Blass, H. J., Kreuzinger, …, Steck, G., Ehlbeck, …, Görlacher, R.: Erläuterungen zur DIN 1052: 2004-08, Beuth-Verlag, Berlin, 2005. - Felkel, A., Hemmer, K., Libner, K., Radovic, B., Rug, W., Steinmetz, D.: Praxishandbuch Holzbau – DIN 1052:2004, Beuth-Verlag, Berlin, 2005. - Becker, k., Blass H.J.: IngenieurHolzbau nach DIN 1052, Ernst& Sohn, Berlin, 2006. - Scheer, C., Peter M., Stohr, S.: Holzbau Tachenbuch Bemessungbeispiele nach DIN 1052, Ausgabe 2004, Ernst& Sohn, Berlin, 2006. - COST ACTION E55: Modelling of the performance of Timber Structures (System identification and exposures, Vulnerability of components, Robustness of systems – Technical documents, 2007–2010. - CIB W18 Publication (compiled by Goerlacher, R.): Proceedings of the International Council for Research and Innovation in Building and Construction, Working Commission W 18 – Timber Structures, Meeting Thirty Eight, Karlsruhe, Germany, 29-31, August, 2005., Meeting Thirty Nine, Florence, Italy, 29-31, August, 2006 and Meeting Thirty Ten, Bled, Slovenia, 29-31, August, 2007.
Recommended literature	- Aune, P.: Timber Structures Example, Tapir Publisher, Trondheim, 1994. - Kordina, K., Mayer-Ottens, C.: Holz Brandschutz Handbuch, 1994. - Droge, G.: Holzmastenbauart Kap. 20 aus Holzbau Taschenbuch, 8. Auflage, Band 1, Verlag Ernst & Sohn, Berlin, 1986. - Stalnaker, J. J., Harris, E. C.: Structural Design in Wood, Van Nostrand Reinhold, 115 Fifth Avenue, NY, 1989. - Halas, R. Scheer, C.: Holzbau-Taschenbuch, IES, Verlag, Berlin, 2000. - Götz, K., Hoor, D., Möhler, K., Natterer, J.: Holzbau Atlas, Institute für International Architecture - Dokumentation, GmbH, München, 1999. i 2004. - Bjelanović, A., Rajčić, V.: Drvene konstrukcije prema europskim normama, Građevinski fakultet Sveučilišta u Zagrebu, Hrvatska sveučilišna naklada i Zagora-Zagorje d.o.o, Zagreb, 2005., reizdanje, 2007.

Course: Selected Chapters of Steel Structures				**Status:** elective		**Code:** I-NK02	
Lecturer: assoc. prof. Mladen Bulić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4			1.0	
A total of ECTS credits: 6.0							

Course objectives	Acquisition of advanced knowledge in the field of steel structures.
Learning outcomes	- Analyze the aerodynamic stability of steel structures. - Analyze special types of steel structures. - Analyze the stability of plated steel girders.
Topics	- Aerodynamic stability of steel structures. - Special types of steel structures. - Stability of plated steel girders.
Student obligations	Preparation of the seminar paper from one of the proposed topics under the mentorship of the subject lecturer.
Exam	Preparation and oral presentation of the seminar paper.
Assessment	Based on the seminar paper quality, its presentation and discussion.
Required literature	- Čaušević, M., Bulić, M., Stabilnost konstrukcija, Tehnička knjiga, Zagreb, 2013. - Čaušević, M., Dinamika konstrukcija – Potresno inženjerstvo, Aerodinamika, Konstrukcijske euronorme, Golden marketing – Tehnička knjiga, Zagreb, 2010. - Androić, B., Čaušević, M., Dujmović, D., Džeba, I., Markulak, D., Peroš, B., Čelični i spregnuti mostovi, IA Projektiranje, Zagreb, 2006. - Bulić, M., Čaušević, M., Androić, B., Reliability of Short Seismic Links in Shear, Bulletin of Earthquake Engineering, 2013, DOI 10.1007/s10518-012-9419-y (objavljen Online, u tisku). - Bulić, M., Čaušević, M., Ponašanje i konstruiranje čeličnih okvira s ekscentričnim dijagonalama, GRAĐEVINAR 2005;57(9):687-697. - Bulić, M., Pouzdanost seizmičkih spona kod čeličnih okvira s ekscentričnim dijagonalama, Disertacija, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 2009.
Recommended literature	- Čaušević, M., State-of-the-Art on Aerodynamics of Steel Long-Span Bridges at the End of the Second Millennium, Informatologia, 34 (2001) 3-4, pp. 252-258. - Larsen, A., Aerodynamics of the Tacoma Narrows Bridge – 60 Years Later, Structural Engineering International, Vol. 10, 4 (2001), pp. 243-248. - Larsen, A., Esdahl, S., Andersen, J.E., Vejrum, T., Storebaelt Suspension Bridge – Vortex Shedding Ecitation and Mitigation by Guide Vanes, Journal of Wind Engineering and Industrial Aerodynamics, 88 (2000), pp. 283-296. - Wyatt, T.A., Walshe, D.E., Bridge Aerodynamics 50 Years after the Tacoma Narrows: The Tacoma Failure and after, Journal of Wind Engineering and Industrial Aerodynamics, 40 (1992), pp. 317-326. - Richards, P., Uang, C. M. Development of Testing Protocol for Short Links in Eccentrically Braced Frames, Report No. SSRP-2003/08, University of California, San Diego, 2003.

Course: Models of Bearing Capacity and Usability of Concrete Structures Affected by Reinforcement Corrosion				**Status:** elective		**Code:** I-NK03	
Lecturer: prof. Davor Grandić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	The assessment of the remaining level of load-bearing capacity and usability of concrete structures affected by reinforcement corrosion should be carried out to determine the remaining service life of the structure and to assess when it is necessary to repair or replace the structure or structural element. Appropriate residual capacity and usability assessment models are used for the systematic and sufficiently reliable implementation of such assessments. The objectives of the Course are to get familiar with the existing level of knowledge achieved in the field of research of concrete structures exposed to environmental actions that cause steel reinforcement corrosion, and to understand the model for assessing the remaining load-bearing capacity and usability of such structures. The acquired knowledge is the basis for further student's independent scientific research work.
Learning outcomes	- Define the harmful effects of corrosion of reinforcement in concrete. - Predict the progress of corrosion of steel reinforcement over time. - Investigate and use constitutional models of materials as a function of reinforcement corrosion state. - Calculate the limit states of usability of reinforced concrete elements affected by corrosion of reinforcement. - Determine the remaining load-bearing capacity of concrete structures affected by corrosion of reinforcement. - Predict the ductility of concrete structures depending on the state of corrosion of reinforcement.
Topics	- Concrete reinforcement corrosion, corrosion parameters in general. - Progression of steel reinforcement corrosion over time. - Adverse effects on concrete structures caused by reinforcement corrosion. - Introductory prediction of the remaining service life of concrete structures affected by corrosion of reinforcement. - Review of the results of experimental research conducted so far and ways of conducting experiments. - Existing condition assessment procedures and models for determining the residual load-bearing capacity and usability of concrete structures affected by reinforcement corrosion. - Constitutional models of materials as a function of the reinforcement corrosion state. - Procedures for calculating the serviceability limits (deflections and cracks) of reinforced concrete elements affected by corrosion of reinforcement. - Remaining load-bearing capacity of concrete structures affected by reinforcement corrosion. - Ductility of concrete structures affected by corrosion of reinforcement.
Student obligations	Preparation and presentation of the seminar paper on one of the proposed topics.
Exam	Preparation and oral presentation of the seminar paper.
Assessment	Based on the seminar paper quality, its presentation and topic discussion.

Required literature	- CONTECVET, A Validated User Manual for Assessing the Residual Life of Concrete Structures – Manual for Assessing Corrosion-Affected Concrete Structures, Instituto Eduardo Toroja, EC innovation program IN30902I, Madrid, 2000. - Service-Life Prediction – State-of-the-Art Report, ACI 365.R-00, ACI Committee 365, American Concrete Institute, 2000. - Broomfield, J. P.: Corrosion of Steel in Concrete, Understanding, Investigation and Repair, E&FN Spon, London, 1997. - CEB-FIP Model Code 1990 (MC-90), Design Code, Comité Euro-International du Béton (CEB), Thomas Telford Services Ltd., London, 1993. - CEB Design Manual on Cracking and Deformations, Bulletin D'Information Nº 158-E, Comité Euro-International du Béton (CEB), Laussanne 1985.
Recommended literature	- Li, C. Q.: Initiation of Chloride-Induced Reinforcement Corrosion in Concrete Structural Members– Experimentation, ACI Structural Journal, 98 (2001) 4, 502-510. - Mangat, S.P.; Elgarf, M.S.: Flexural Strength of Concrete Beams with Corroding Reinforcement, ACI Structural Journal 96 (1999) 1, 149-159. - Al-Sulaimani, G. J.; Kaleemullah, I. A.; Basunbul, I. A.; Rasheeduzzafar: Influence of Corrosion and Cracking on Bond Behaviour and Strength of Reinforced Concrete Members, ACI Structural Journal, 87 (1990) 2, 220-231. - Bjegović, D.; Durability design for reinforced concrete structures, sixth CANMET/ACI International Conference on Durability of Concrete / V.M. Malhotra (ur.), ACI Inernational, Geece, Thessaloniki, 2003, 737-75. - Shimomura, T.; Maruyama, K.: Constitutive models for prediction of performance of deteriorated concrete structures, 2nd International RILEM Workshop on Life Prediction and Aging Management of Concrete Structures, Paris, 2003, 3-12. - Cairns, J.; Plizzari, G. A.; Du, Y.; Law, D. W.; Franzoni, C.: Mechanical Properties of Corrosion-Damaged Reinforcement ACI, Materials Journal, 102 (2005) 4, 256-264. - Palsson, R.; Mirza, S.: Mechanical Response of Corroded Steel Reinforcement of Abandoned Concrete Bridge, ACI Structural Journal, 99 (2002) 2, 157-161. - Grandić, D.; Bjegović, D.; Banić, D. I.: Residual Structure Service Life Depending on Steel Corrosion Rate, Global Construction: Ultimate Concrete Opportunities, Application of Codes, Design and Regulations, Dundee, Scotland, 2005, 195-202. - Grandić, D., Bjegović, D.: Structural Deterioration due to Chloride-Induced Reinforcement Corrosion, Seventh CANMET/ACI International Conference on Durability of Concrete, Montreal, Canada 2006.

Course: Earthquake Engineering				**Status:** elective			**Code:** I-NK04
Lecturer: prof. Davor Grandić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	5.0				
A total of ECTS credits: 6.0							

Course objectives	The need to change existing methodologies applied in regulations for structural calculations due to seismic loads is widely recognized. Based on scientific research, a new generation of procedures is being developed for the design of new and remediation of damaged buildings, which contain engineering concepts based on the structure behaviour (performance base engineering concept). The objective of the Course is to master these procedures. It was realized that more attention should be paid to damage control during design. This can only be achieved by introducing some nonlinear analysis into the seismic calculation methodology. It was concluded that the most appropriate approach is to combine nonlinear static analysis (pushover) with spectral response methodology. Seismic protection of steel structures using shear clamps as elements of energy consumption (experimental analysis, numerical modelling, probabilistic representation of the reliability index β).
Learning outcomes	- Apply principles and methods to ensure the ductile behaviour of elements and structures. - Select the appropriate construction system for the earthquake-resistant structure. - Determine the hierarchy of elements according to the load-bearing capacity for complex structures. - Calculate the structure on seismic action using nonlinear methods. - Define requirements for the behaviour of structural elements and materials in earthquakes. - Develop a proposal and budget for seismic insulation systems. - Carry out procedures for assessment and renovation of the existing structure.
Topics	Nonlinear methods based on the behaviour of structures in earthquakes (N2 method: combination of nonlinear static analysis (pushover) with response spectrum methodology, in which two mathematical models are applied; Modal pushover analysis for estimating seismic demand in buildings according to Chopra and Goel; Seismic analysis of bridges). Experimental tests and numerical analysis on models of steel structures with eccentric diagonals under conditions of seismic action.
Student obligations	Attendance at lectures.
Exam	Written part of the exam; Selection of a certain topic and preparation of a seminar paper.
Assessment	Assessment is based on the results of the written part of the exam and the seminar paper quality.
Required literature	- Chopra, A. K., and Goel, R. K., 2002. A Modal Pushover Analysis Procedure for Estimating Seismic Demands for Buildings, Earthquake Eng. Struct. Dyn. 31 (3), 561-582 - Goel, R. K., and Chopra, A. K., 2004. Evaluation of Modal and FEMA Pushover Analysis: SAC Buildings, Earthquake Spectra, 20, (1), 225-254 - Fajfar, P., 2000, A Nonlinear Method for Performance Based Seismic Design, Earthquake Spectra, 16, (3), 573-592 - Gupta, B., and Kunnath, S. K., 2000. Adaptive Spectra–Based Pushover Procedure for Seismic Evaluation of Structures, Earthquake Spectra 16 (2), 367-392 - Dusicka, P., Itani, A. M. and Buckle, I. G., Cyclic Behaviour of Shear Links and Tower Shaft Assembly of San Francisco-Oakland Bay Bridge Rower, Report CCEER 02-06, Centre for Civil Engineering Earthquake Research, University of Nevada, Reno, Nevada, 2002. - Čaušević, M., Zehentner, E., Nelinearna seizmička analiza konstrukcija prema europskoj normi EN 1998-1:2004 (Eurokod 8-1), GRAĐEVINAR 59 (2007), 9. - Androić, B., Bulić, M., Čaušević, M., Pouzdanost seizmičkih spona kod čeličnih okvira s ekscentričnim dijagonalama, GRAĐEVINAR 59 (2007), 8, 675-683. - Čaušević, M., Fajfar, P., Fischinger, M., Isaković, T., Proračun vijadukta na djelovanje sila potresa prema Eurokodu 8/2, GRAĐEVINAR 55 (2003) 3.

	- Mackie, K. and Stojadinovic, B., Seismic Demands for Performance-Based Design of Bridges, PEER Report 2003/16, Berkeley: Pacific Earthquake Engineering Center, College of Engineering, University of California, Berkeley, 2003 - Pinto, A. V., Pseudodynamic and Shaking Table Tests on R. C. Bridges, Report No. 5, ISPRA: The European Laboratory for Structural Assessment (ELSA), 1996.
Recommended literature	- Čaušević, M., 2005. Dinamika konstrukcija, Školska knjiga, Zagreb - Chopra, A. K., 2001. Dynamics of Structures: Theory and Applications to Earthquake Engineering, 2nd Edition, Prentice Hall, Englewood Cliffs, NJ

<table>
<tr><td colspan="5">Course: Experimental Methods in Condition Assessment and Analysis of Structural Behaviour</td><td colspan="2">Status: elective</td><td>Code: I-NK05</td></tr>
<tr><td colspan="8">Lecturers: prof. Davor Grandić, prof. Ivana Štimac Grandić, assoc. prof. Adriana Bjelanović, assoc. prof. Mladen Bulić, asst. prof. Paulina Krolo</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Laboratory</td><td>Research</td><td>Exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>5</td><td></td><td>30</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.9</td><td>1.1</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td colspan="8">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="7">Mastering the basic principles of experimental methods and methodology of their application in condition assessment and analysis of structural behaviour. Application of knowledge acquired in complementary Doctoral Courses and previously completed studies. Developing the ability to develop a methodology and conduct testing within the context of expected outcomes and fulfill the purpose of the experimental program. Understanding the procedures for processing test results and analyzing compatibility with results collected by analytical or numerical methods.</td></tr>
<tr><td>Learning outcomes</td><td colspan="7">- Application of basic principles of experimental methods in methodology development.
- Elaboration of the methodology of their targeted application in the assessment of the condition and analysis of the structural behaviour.
- Analysis of effectiveness regarding the purpose of application and the expected result.
- Development of test programs and their implementation.
- Evaluation and analysis of results.</td></tr>
<tr><td>Topics</td><td colspan="7">- Generic methodology in the assessment of the existing structures condition and the analysis of the behaviour of load-bearing structures in general, the significance and purpose of the application of experimental methods.
- Peculiarities of the methodological approach with regard to the material, construction system, and the expected outcome of the experimental research program application.
- Development of the experimental research program and special features with regard to:
a) purpose of testing (assessment of the condition of existing structures and the impact of damage on their behaviour, verification of numerical models describing the behaviour of structures, development and evaluation of technological solutions, improvement of analytical and numerical models, methods and procedures related to research, etc.)
b) type of testing (laboratory, field, combination) and sampling
c) limitations (available equipment, availability and number of test samples, areas of application of the experimental method / reliability of the collected results, etc.)
d) general feasibility (when, for example, the use of destructive tests is not allowed, etc.).
- Selection of test methods, techniques and equipment.
- Complementarity of testing techniques.
- Conducting tests.
- Analysis of test results and applications.</td></tr>
<tr><td>Student obligations</td><td colspan="7">Attended lectures of a consultative nature, preparation and presentation of a seminar paper.</td></tr>
<tr><td>Exam</td><td colspan="7">Preparation and presentation of a seminar paper, discussion.</td></tr>
<tr><td>Assessment</td><td colspan="7">In the overall assessment, 80% of the grade is awarded for the seminar paper and 20% for its presentation, defense and discussion.</td></tr>
<tr><td>Required literature</td><td colspan="7">- Harris, H.G, Sabnis, G.M., Structural Modeling and Experimental Techniques, 2nd edition, CRC Press, 1999.
- R. Vukotić: Ispitivanje konstrukcija, Naučna knjiga, Beograd, 1998.
- V. Brčić, R. Čukić: Eksperimentalne metode u projektiranju konstrukcija, Građ. knjiga, Beograd, 1988.
- Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard: Mechanical Measurements, Addison-Weslwy Publishing Company, New York, 1995.
- John P. Bentley: Principles of Measurement Systems, Pearson education, Edinburgh, 1995.
- J. H. Bungey: The Testing of Concrete in Structures, Blackie and Son Ltd, 1989.
- B. Kasal, Th. Tannert: In Situ Assessment of Structural Timber, Springer, 2010.</td></tr>
</table>

Course: Modelling of Structures				**Status:** elective		**Code:** I-NK06	
Lecturer: prof. Ivica Kožar							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	2.0	2.0		1.0	
A total of ECTS credits: 6.0							

Course objectives	Application of computer modelling methods in the analysis of buildings in complex conditions.
Learning outcomes	- Distinguish possible building models. - Describe the interaction of models and measurements. - Define the measurements required for the implementation of the building model.
Topics	- Modelling of multi-physical problems that occur in the analysis of structures. - Influence of temperature and humidity on the durability of structures. - Interaction of the structure with the ground. - Interaction of the structure with the fluid (primarily water). - Interaction of the structure with the load (vehicle passage). - Contact problems with some types of construction. - Modelling of structures at different levels. - Examples of isoparametric elements for the plane state of stresses and strains, axially symmetric finite elements, plate and shell problems. - Instabilities in isoparametric elements, reduced numerical integration, incompatible shape functions. - Formulation of geometrically nonlinear problems. - Formulation of material nonlinear problems. - Finite elements in dynamic analysis.
Student obligations	Two assignments to be done with software by prof. I. Kožar and programs MathCAD and MatLab.
Exam	Two assignments and oral examination.
Assessment	In the overall assessment, 80% of the grade is awarded for the two assignments and 20% is awarded for oral examination. Minimum required points is 70% (70% - 80% = good, 81% - 90% = very good, > 91% = excellent).
Required literature	- Wilson E.L. Three-Dimensional Static and Dynamic Analysis of Structures, CSI, Berkeley, California, 2003. - Zienkiewitz, O.C., Taylor, R.L.: The Finite Element Method Vol. I i II, McGraw-Hill 1989 and 1991. - Cook, R.D., Malkus, D.S., Plesha, M.E., Witt, R.J., Concepts and Applications of Finite Element Analysis, Wiley, 2002. - Sorić J. Metoda konačnih elemenata, Golden marketing – Tehnička knjiga 2004.
Recommended literature	- Štimac I, Meštrović D, Kožar I 2004, Analiza mostovnih konstrukcija pobuđenih pokretnim opterećenjem, GRAĐEVINAR vol. 56, no. 6, p. 347-353 - Ožbolt J, Kožar I, Eligehausen R, Periškić G 2005, Three-Dimensional FE Analysis of Headed Stud Anchors Exposed to Fire", Computers and Concrete, vol. 2, no. 4, p. 249-266. - Lozzi-Kožar D, Kožar I, Holjević D 2005, Djelovanje topline na zid bujice, GRAĐEVINAR, vol. 57, no.11, p. 879 – 887. - Ožbolt J, Meštrović D, Kožar I 2006, Tridimenzijski proračun prearmiranih betonskih greda, GRAĐEVINAR, vol. 58, no.2, p. 95 – 101.

Course: Crack Analysis in Reinforced Concrete Members				**Status:** elective		**Code:** I-NK07	
Lecturer: asst. prof. Paulo Šćulac							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15						
Allocation of ECTS credits	0.4	0.6	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Understand crack formation and development in reinforced-concrete members. Acquire knowledge for numerical modelling of the cracking process. Study factors influencing bond performances between concrete and reinforcement bars. Enable students for independent critical analysis of existing engineering procedures for crack evaluation.
Learning outcomes	- Get familiar with the mechanism of formation and development of cracks in reinforced concrete elements. - Acquire the knowledge needed for numerical modelling of cracking. - Understand the factors that affect the connection between concrete and reinforcing bars.
Topics	Application of the finite element method in modelling crack formation and development. Finite elements with embedded discontinuities. Nonlinear constitutive bond-slip models. Experimental procedures used for determination of bond-slip constitutive models. Tension stiffening. Analytical and numerical procedures for crack distance and crack width evaluation, engineering procedures for crack prediction based on experimental results. Measurement and monitoring of cracks.
Student obligations	Preparation of a seminar paper.
Exam	Submission and presentation of a seminar paper.
Assessment	Based on the quality of the seminar paper, its presentation and discussion.
Required literature	- FIB Bulletin 10, Bond of Reinforcement in Concrete, (2000.), State-of-Art Report, International Federation for Structural Concrete, Lausanne, Switzerland. - Bažant, Z.P., Planas, J. (1998.), Fracture and Size Effect in Concrete and Other Quasibrittle Materials, CRC Press LLC. - Shi, Z. (2009.), Crack Analysis in Structural Concrete: Theory and Applications, Butterworth Heinemann. - Hofstetter, G., Meschke, G. (2011.), Numerical Modelling of Concrete Cracking (CISM Courses and Lectures, Vol. 532), Springer Wien NewYork.
Recommended literature	- Hsu, T.T.C., Mo, Y.L. (2010.), Unified Theory of Concrete Structures, Wiley. - Computational Modelling of Concrete Structures (2014.), Proceedings of EURO-C 2014, ed.: Bićanić, N., Mang, H., Meschke, G., de Borst, R., London: Taylor and Francis Group.

Course: Structural Damage Assessment Using Nondestructive Methods				**Status:** elective		**Code:** I-NK08	
Lecturer: prof. Ivana Štimac Grandić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Nondestructive damage detection (NDD) is an important subproblem of damage assessment and should form the basis of any decision to repair, rehabilitate, or replace a structure. The main course objectives are to give an insight into nondestructive methods for locating and evaluating damage severity and point out advantages and disadvantages of the methods.
Learning outcomes	- Describe the possibilities of measuring static and dynamic quantities by non-destructive methods. - Describe the methods of static and dynamic parametric identification based on data measured by non-destructive procedures. - Define the basic settings of methods for determining damage to structures (e.g. the theory of natural frequency perturbation, comparison of basic forms of oscillations of eigenvectors, methods of changing the energy of deformation of eigenvectors, etc.). - Carry out the determination of damage from the data of static and dynamic measurements on the structure. - Compare the effectiveness of individual methods (static and dynamic).
Topics	- Nondestructive techniques and equipment for measuring static and dynamic parameters. - Review of static and dynamic parametric identification methods based on data measured by non-destructive procedures. - Theory of linear perturbation (first-order perturbation) of natural frequencies. - Theory of nonlinear natural frequency perturbation. - Comparison of eigenvector oscillation basic forms - Method of changing the eigenvector deformation energy. - A combination of eigenvectors and eigenfrequencies. - Flexibility matrix change method. - Analysis of construction frequency response functions. - Improving the analytical stiffness matrix from static measurements without the influence of noise. - Numerical analysis of slab structure deflection sensitivity to local damage. - Damage detection using deflection influence lines and deflection influence surfaces.
Student obligations	Preparation and presentation of a seminar paper.
Exam	Submission and presentation of a seminar paper.
Assessment	Based on the quality of the seminar paper, its presentation and discussion.
Required literature	- Cawley, P., Adams, R. D.; The Location of Defects in Structures from Measurements of Natural Frequencies, Journal of Strain Analysis, Vol. 14, No 2, pp. 49-57, 1979. - Štimac, I., Uporaba utjecajnih linija progiba u otkrivanju oštećenja konstrukcija, Disertacija, Split, 2006. - Pandey, A. K., Biswas, M., Samman, M.: Damage Detection from Changes in Curvature Mode Shapes, Journal of Sound and Vibration, Vol. 145, No. 2, pp. 321-332, 1991. - Abdo, M. A.-B., Hori, M. A Numerical Study of Structural Damage Detection Using Changes in the Rotation of Mode Shapes, Journal of Sound and Vibration, Vol. 251, No. 2, pp. 227-239, 2002. - Maia, N. M. M., et al., Damage Detection in Structures: from Mode Shape Frequency Response Function Methods, Mechanical Systems and Signal Processing, Vol. 17, No. 3, pp. 489-498, 2003. - Cornwell, P, et al., Application of the Strain Energy Damage Detection Method to Plate-Like Structures, Journal of Sound and Vibration, Vol. 224, No. 2, pp. 359-374, 1999. Radić, J., Mekjavić, I.; Identifikacija oštećenja mostova primjenom teorije nelinearne preturbacije, Građevinar, No. 57, p. 11-19, 2005.

Recommended literature	- Hassiotis, S., Jeong, G. D; Assessment of Structural Damage from Natural Frequency Measurements, Computers & Structures, Vol. 49, No 4, pp. 679-691, 1993. - Abdel Wahab, M. M., Damage Detection in Bridges Using Modal Curvatures: Application to a Real Damage Scenario, Journal of Sound and Vibration, Vol. 226, No. 2, pp. 217-235, 1999. - Bicanic, N., Chen, H. P.: Damage Identification in Framed Structures Using Natural Frequencies, International Numerical Methods in Engineering, Vol.40, No. 23, pp. 4451-4468, 1997.

<table>
<tr><td colspan="5">Course: Modelling and Analysis of Structures under the Influence of Moving Loads</td><td colspan="2">Status: elective</td><td colspan="2">Code: I-NK09</td></tr>
<tr><td colspan="9">Lecturer: asst. prof. Neira Torić Malić</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Assignments</td><td>Exercises</td><td>Exam</td><td>W. exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>4.0</td><td></td><td></td><td>1.0</td><td></td></tr>
<tr><td colspan="9">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="8">Understanding the basic concept of the moving loading dynamics. Introduction to the traditional and some novel moving load models in dynamic analysis of structures and numerical procedures for solving moving load problem.
The students are expected to be able to recognize, describe and analyse the basic types of moving loads on simple structures and apply the appropriate numerical procedure for solving moving load problems.</td></tr>
<tr><td>Learning outcomes</td><td colspan="8">- Identify and describe the basic types of moving loads.
- Be able to make a numerical model of moving loads on simple structures.
- Describe a mathematical model of load-structure coupling.
- Analyze the interaction of moving load and the structure.
- Be able to select and apply appropriate numerical methods to solve the problem of moving loads.</td></tr>
<tr><td>Topics</td><td colspan="8">- The basic concept of dynamic influence of moving loads on the structure.
- Different types and models of moving loads.
- Analytical solutions. Beam vibrations induced by a moving force.
- Semianalytical solutions. Fourier solution. The Lagrange equation.
- Beam vibrations induced by an inertial force (moving mass with force).
- Numerical procedures for solving moving load problems.
- Beam vibrations induced by a moving oscillator with multiple degrees of freedom.
- The Newmark method for a moving load analysis.
- The impulse acceleration method.
- Influence of the surface irregularities.
- The critical speed.
- Coupling of the moving load model and the structure model.
- Loading-structure interaction (moving vehicle on the structure).
- The contact forces.
- The low energy impact loading.</td></tr>
<tr><td>Student obligations</td><td colspan="8">Preparation and presentation of a seminar paper on the chosen topic.</td></tr>
<tr><td>Exam</td><td colspan="8">Preparation and presentation of the seminar on the chosen topic.</td></tr>
<tr><td>Assessment</td><td colspan="8">Based on the quality of prepared seminar paper, its presentation and discussion on the topic.</td></tr>
<tr><td>Required literature</td><td colspan="8">- Fryba, L. Vibration of Solids and Structures under Moving Loads, Prague: Thomas Telford, 1999, 94-156.
- Timoshenko, S.P., Young, D.H., Weaver, W., Vibration Problems in Engineering, Wiley, New York, 1974.
- Torić Malić, Neira. Analiza fleksibilnih konstrukcija pod utjecajem pokretnog opterećenja metodom konačnih traka / disertacija. Rijeka: Građevinski fakultet, 09. 07. 2012, p. 138. Voditelj: Kožar, Ivica.
- Bajer, C.I., Dyniewicz, B. Numerical Analysis of Vibrations of Structures under Moving Inertial Load, Springer, Berlin, 2012.
- Yang, Y.B., Yau, J.D., Wu, Y.S. Vehicle-Bridge Interaction Dynamics with Application to High Speed Railways, World Scientific Publishing, London, 2004.
- Weaver, W., Johnston, P.R., Structural Dynamics by Finite Elements, Prentice-Hall, Inc., New Jersey, 1987.
- Clough, R.W., Penzien J. Dynamics of Structures, McGraw-Hill, New York, 1975.</td></tr>
</table>

Recommended literature	- Ibrahimbegovic A. Nonlinear Solid Mechanics. Springer; 2009. - Torić Malić, Neira; Kožar, Ivica. Vehicle Strip Element in the Analysis of Stiffened Plate under Realistic Moving Loads. // Proceedings of the Institution of Mechanical Engineers part K-Journal of Multi-Body Dynamics. 226 (2012), 4; 374-384 (scientific paper). - Kožar, Ivica; Torić Malić, Neira. Spectral Method in Realistic Modelling of Bridges under Moving Vehicles. // Engineering Structures. 50 (2012); 149-157 (scientific paper). - Kožar, Ivica. Security Aspects of Vertical Actions on Bridge Structure: Comparison of Earthquake and Vehicle Induced Dynamical Forces. // Engineering Computations. 26 (2009), 1; 145-165 (scientific paper). - Kožar, I.; Torić Malić, N. Spectral Method in Moving Load Analysis of Kirchhof-Love Plates. // Tehnicki Vjesnik-Technical Gazette. 20, 1 (2013); 79-84 (scientific paper).

<table>
<tr><td colspan="4">Course: Structural Reliability</td><td colspan="2">Status: elective</td><td colspan="2">Code: I-NK10</td></tr>
<tr><td colspan="8">Lecturer: prof. Goran Turk</td></tr>
<tr><td>Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Assignments</td><td>Exercises</td><td>Exam</td><td>W. exam</td></tr>
<tr><td>Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>4.0</td><td></td><td></td><td>1.0</td><td></td></tr>
<tr><td colspan="8">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="7">Learn the basics of reliability of structures.</td></tr>
<tr><td>Learning outcomes</td><td colspan="7">- Define the importance of reliability methods in engineering structures.
- Distinguish the connections between stochastic methods in commonly used deterministic methods.
- Distinguish the importance of safety factors and characteristic quantities.
- Conduct structural reliability analysis.
- Analyze and prepare data for reliability analysis.
- Describe available reliability analysis programs.
- Calculate the safety factor based on stochastic analysis.
- Conduct structural analysis in accordance with reliability theory.</td></tr>
<tr><td>Topics</td><td colspan="7">- Probabilistic models of load and strength variables.
- Order statistics and extreme value theory – important probability distribution in structural analysis such as Gumbel, Weibull and Frechet distributions.
- Basic analysis of structural safety: the definition of characteristic values, safety factors, reliability index and probability of failure.
- Basic structural reliability problem: determination of probability of failure, i.e. probability that the load variable exceeds the resistance variable.
- First-order second-moment method (uncorrelated variables, correlated normally distributed variables, arbitrary multivariate distribution), Hasofer-Lind method, Rosenblatt transformation.
- Monte Carlo methods, basic (naive) simulations, variance reduction techniques, e.g. importance sampling, correlated variables, antithetic variables, etc.
- System reliability (serial and parallel systems), bounds on reliability of systems, first and second order bounds.
- Time-dependent reliability analysis, stochastic random process, stationary process, Poisson process, stochastic fields.</td></tr>
<tr><td>Student obligations</td><td colspan="7">Preparation of a seminar paper. The seminar paper includes explanation of the problem, methods used, numerical examples and conclusions.</td></tr>
<tr><td>Exam</td><td colspan="7">Oral presentation/defence of the seminar paper.</td></tr>
<tr><td>Assessment</td><td colspan="7">Based on the quality of the seminar paper and its presentation.</td></tr>
<tr><td>Required literature</td><td colspan="7">- R.E. Melchers, Structural reliability Analysis and Prediction, John Wiley and Sons, 1999.
- P. Thoft-Christensen, M.J. Baker, Structural Reliability Theory and its Applications, Springer-Verlag, 1982.
- J. Benjamin, C.A. Cornell, Probability, Statistics, and Decision for Civil Engineers, McGraw-Hill, 1970.</td></tr>
<tr><td>Recommended literature</td><td colspan="7">- A. H.-S. Ang, W. Tang, Probability Concepts in Engineering Planning and Design, John Wiley and Sons, 1975.
- R. Y. Rubinstein, Simulation and the Monte Carlo Method, John Wiley and Sons, 1981.
- P. Thoft-Christensen, Y. Morotsu, Application of Structural Systems Reliability Theory, Springer-Verlag, 1986.</td></tr>
</table>

Course: Analysis and Design of Concrete Cross Sections				**Status:** elective			**Code**: I-NK11
Lecturer: asst. prof. Željko Smolčić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							
Course objectives	Get acquainted with fundamental numerical analysis and design of concrete cross section.						
Learning outcomes	- Understand the problem of numerical analysis of the (pre-stressed) concrete cross section. - Understand the problem of numerical design of the (pre-stressed) concrete cross section.						
Topics	- Design of (pre-stressed) concrete T-section. - Design of reinforced concrete (hollow) circular section. - Optimal design of reinforced concrete T-section. - Diagram of bending moment-curvature of the cross section. - Ultimate moment of resistance for (pre-stressed) concrete T-section. - Stress analysis of (non)cracked (pre-stressed) concrete T-section. - Interactions diagrams of rectangular section. - Interactions diagrams of (hollow) circular section. - Tables for design of rectangular section.						
Student obligations	Preparation of a seminar paper. Presentation and defense of seminar papers.						
Exam	At seminar classes, the paper is presented to the subject teacher and its results are explained in oral form at teacher's request.						
Assessment	Seminar paper preparation 60%, seminar paper presentation 20%, seminar paper defense 20%.						
Required literature	- Materials handed out at lecture classes. - Ž. Smolčić, D. Grandić: Dijagrami interakcije za AB kružni poprečni presjek, Građevinar 64 (2012)1, 23-31. - Ž. Smolčić, K. Blašković: Dijagrami interakcije za armiranobetonski šuplji kružni poprečni presjek, Zbornik radova Građevinskog fakulteta Sveučilišta u Rijeci, Rijeka, 2017, XX, 111-126. - Ž. Smolčić, K. Blašković: Dijagrami interakcije za armiranobetonske (šuplje) kružne poprečne presjeke, MB&ton (2019), 116-126.						
Recommended literature	- Anvar, N., Najam, F. A.: Structural Cross Sections: Analysis and Design, Butterworth-Heinemann, 2016. - Hulse, R., Mosley, W. H.: Reinforced Concrete Design by Computer, MACMILLAN EDUCATION LTD, 1986.						

Course: Analysis of Connection Behaviour in Steel Constructions	**Status:** elective	**Code**: I-NK12

Lecturer: asst. prof. Paulina Krolo						
Course delivery	Lectures	Office hours	Seminars	Modelling	Research	Exam
Number of teaching hours	15		10			
Allocation of ECTS credits	0.6	0.4	1.5	1.5	1.0	1.0
A total of ECTS credits: 6.0						

Course objectives	Educate PhDs to understand the behaviour of connection in steel constructions under the monotonic and cyclic loading. Introduce students with available numerical methods to describe the real behaviour of connection.
Learning outcomes	- Define the basic connection concept. - Identify and describe the effects of monotonic and cyclic loading on the connection behaviour. - Distinguish the influence of certain connection parameters on the connection behaviour. - Calculate the resistance of the connections according to the conventional methods. - Make a numerical model of steel connection of a certain typology. - Critically analyze the results obtained by numerical calculations.
Topics	- General terms about steel connections. - Classification of connections. - The basic concept for the connection analysis. - Connection ductility. - The resistance of the bolts and welds. - Effect of the model material on the connection behaviour. - Distribution of forces in connection. - The behaviour of connection under seismic loading. - Analytical and numerical methods for determining connection behaviour.
Student obligations	Preparation of seminar paper. Presentation and defense of seminar paper.
Exam	Preparation and presentation of a seminar paper.
Assessment	Seminar paper preparation 80%, seminar paper presentation 10%, seminar paper defense 10%.
Required literature	- L. Martin and J. Purkiss, Structural Design of Steelwork to EN 1993 and EN 1994, London: Elsevier, 2008. - L. Simoes de Silva, R. Simoes and H. Gervasio, Design of Steel Structures, Portugal: Ernst & Sohn, 2010. - F. M. Mazzolani and V. Piluso, Theory and Design of Seismic Resistant Steel Frames, London: E&FN Spon, 1996. - R. Kindmann and M. Kraus, Steel Structures - Design Using FEM, London: Ernst & Sohn, 2011. - V. Gioncu and F. M. Mazzolani, Ductility of Seismic Resistant Steel Structures, London: Spon Press, 2002. - P. Rugarli, Steel Connection Analysis, India: Wiley Blackwell, 2018.
Recommended literature	- Design of Structural Connections to Eurocode 3 – Frequently asked questions, Building Research Establishment Ltd., Watford, 2003. - P. Krolo, D. Grandić and M. Bulić, The Guidelines for Modelling the Preloading Bolts in the Structural Connection Using Finite Element Method, *Journal of Computational Engineering,* vol. 2016, 2016. - P. Krolo, M. Čaušević and M. Bulić, Nonlinear Seismic Analysis of Steel Frame with Semi-Rigid Joints, *Građevinar,* vol. 67, no. 6, pp. 573-583, 2015. - P. Krolo, M. Čaušević and M. Bulić, The Extended N2 Method in Seismic Design of Steel Frames Considering Semi-Rigid Joints, in *Proceedings of the Second European Conference on Earthquake Engineering*, Istanbul, Turkey, 2014.

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF CIVIL ENGINEERING (2.05) AND THE SCIENTIFIC BRANCH OF HYDRAULIC ENGINEERING (2.05.03)

<table>
<tr><td colspan="4">Course: Coastal Processes and Engineering</td><td colspan="2">Status: elective</td><td colspan="2">Code: I-H01</td></tr>
<tr><td colspan="8">Lecturer: prof. Suzana Ilić</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Class activity</td><td>Exam</td><td>W. exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>1.5</td><td>1.0</td><td>2.5</td><td></td></tr>
<tr><td colspan="8">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="7">- Introduction to the laws of water phenomena in the coastal area.
- Acquisition of knowledge and adoption of methodological procedures for independent processing and modelling of water phenomena and processes in the coastal area, as well as the development of structural coastal solutions in order to protect the shores and encourage their formation.</td></tr>
<tr><td>Learning outcomes</td><td colspan="7">- Distinguish key coastal processes in different coastal conditions.
- Describe key coastal hydrodynamic processes and sediment transport process using the laws of physics and mathematical equations.
- Analyze and solve problems in coastal processes and coastal engineering.
- Gain experience in modelling coastal processes and coastal changes.
- Present the paper orally and in writing on a professional level.</td></tr>
<tr><td>Topics</td><td colspan="7">- Tides, historical and recent dynamics.
- Wave theories, wave deformations, wave refraction processes, currents caused by waves in shallow sea.
- Coastal geomorphology, sediment transport, shallow formation sediments, changes in shore profiles, coastal areas and units.
- Coastal walls, feathers, breakwaters, embankments, artificial embankments.
- Monitoring, modelling.
- Coastal zone management, coastal zone management plans, coastal habitat protection plans.</td></tr>
<tr><td>Student obligations</td><td colspan="7">Attending lectures and preparing a seminar paper.</td></tr>
<tr><td>Exam</td><td colspan="7">The exam consists of the preparation and verification of a seminar paper (and both the written and the oral part of the exam)</td></tr>
<tr><td>Assessment</td><td colspan="7">Exercises 20%, seminar paper 80% (exam 60%)</td></tr>
<tr><td>Required literature</td><td colspan="7">- Abbot, M.B., Price, W.A.: Coastal, Esturial and Harbor Engineers Reference Book, Spon, London, 1994.
- Dean, R.G., Dalrymple, R.A.: Coastal Processes with Engineering Applications, Cambridge University Press, 2001.
- Komar, P.D.: Beach Processes and Sedimentation, Oregon State University, 1998. (essential)
- Reeve, D., Chadwick, A. J., Fleming, C.: Coastal Engineering: Processes, Theory and Design Practice E & FN Spon, 2004. (good start)</td></tr>
</table>

Recommended literature	- Carter, R.W.G.; Woodroofe, C.D.: Coastal Evolution, Cambridge University Press, Cambridge, 1997. - Dean, R.G: Beach Nourishment Theory and Practice, World Scientific, Singapore, 2003. - Dean, R.G., Dalrymple, R.A.: Water Wave Mechanics for Engineers adn Scientists, World Scientific, Singapore, 1997. - Dingemans, M.W.: Water Wave Propagation over Uneven Bottoms (In 2 Parts), World Scientific, Singapore, 1997. - Fredsoe, J., Deigaard, R: Mechanics of Coastal Sediment Transport, World Scientific, Singapore, 1992. - Goda, Y.: Random Seas and Design of Maritime Structures (2nd Edition), World Scientific, Singapore, 2000. - Kamphuis, J.W.: Introduction to Coastal Engineering & Management, World Scientific, Singapore, 2000. - Komar, P.D.: CRC Handbook of Coastal Processes and Erosion, CRC Press, Boca Raton, 1983. - Massel, S.R.: Ocean Surface Waves: Their Physics and Prediction, World Scientific, Singapore, 1996. - Mei, C.C.: The Applied Dynamics of Ocean Surface Waves, World Scientific, Singapore, 1989. - Nielsen, P.: Coastl Bottom Boundary Layers and Sediment Transport, World Scientific, Singapore, 1992. - Silvester, R., Hsu, J.R.C: Coastal Stabilization, World Scientific, Singapore, 1997. - U.S. Army Engineer Research and Development Centers Coastal & Hydraulics Laboratory (CHL): Coastal Engineering Manual, (http://chl.erdc.usace.army.mil/CHL.aspx?p=s&a=ARTICLES;104)

Course: Contemporary Approaches to Water Resources Management				**Status:** elective		**Code:** I-H02	
Lecturer: prof. Barbara Karleuša							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercise	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	3.0			2.0	
A total of ECTS credits: 6.0							

Course objectives	Enable the students to solve complex water resources management problems implementing modern methods ad approaches (system analysis, multi-criteria optimisation, expert systems and neural networks).
Learning outcomes	- Analyze and solve complex problems in the field of water management using scientific methodology, modern methods and approaches (e.g. systematic analysis, multi-criteria optimization, expert systems, neural networks, etc.) - Present the results of analyses to the scientific, professional and general public in a clear and effective way.
Topics	- Water resources management and water management systems. - Integrated water resources management and sustainable development. - Planning, designing, construction, management and control of water management systems. - Models in water resources management. - System analysis in solving water management problems. - Multi-criteria optimisation methods in water management (technical, economic, social, environmental and other criteria/aspects). - Artificial intelligence in water management (expert systems and neural networks). - Possibilities for water management improvement.
Student obligations	Attending lectures, preparing and presenting a seminar paper, oral exam.
Exam	The exam consists of the preparation, presentation and verification of the seminar paper and the written and oral exam.
Assessment	70% of the grade is obtained at classes and 30% at the oral exam.
Required literature	- Karleuša, B.: Primjena postupaka višekriterijske optimalizacije u gospodarenju vodama, magistarski rad, Građevinski fakultet u Zagrebu, 2002. - Karleuša, B.: Unapređenje gospodarenje vodama korištenjem ekspertnog sustava, disertacija, Građevinski fakultet u Zagrebu, 2005. - Grigg, N.S.: Water Resources Management, McGraw-Hill, New York, 1996. - Đorđević, B.: Cybernetics in Water Resources Management, Water Resources Publications, 1994.
Recommended literature	- Margeta, J.: Osnove gospodarenja vodama, Građevinski fakultet u Splitu, 1992. - Margeta, J.: Smjernice za integralni pristup razvoju, gospodarenju i korištenju vodnih resursa, Split 1999. - Nikolić, I., Borović, S.: Višekriterijumska optimizacija, Beograd, 1996. - Kompare, B.: The Use of Artificial Intelligence in Ecological Modelling, PhD Thesis, University of Ljubljana and Royal Danish School of Pharmacy, 1995.

Course: Analysis and Modelling of Hydrological Processes					**Status:** elective		**Code:** I-H03
Lecturer: prof. Nevenka Ožanić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	2.0			1.5	1.5
A total of ECTS credits: 6.0							

Course objectives	- Introduce students to the complex mechanisms of conversion of precipitation into runoff, and interactions with the soil, as well as the hydrological laws of flow through and through different media and train them for their modelling. - Ensure the adoption of methodological procedures for independent processing of more complex problems of time series hydrological analyses. Ensure the adoption of methodological procedures for self-treatment and hydrological modelling of the functions of natural water systems, as well as the analysis of the functions and impacts of structural structures and systems.
Learning outcomes	- Analyze and solve complex problems and mechanisms of hydrological processes (relationship of precipitation and runoff, hydrological laws of flow through and through different media, multivariate analysis of time series, etc.) using recent scientific methodology, modern methods and approaches (regionalization, multi-criteria optimization, mathematical and physical modelling, etc.). - Give a critical review of the results of the analysis and present it to the scientific and professional public through lectures and publication of papers.
Topics	Conceptual hydrological models, algorithms for calibration of model parameters, sensitivity and errors of model parameters. Genetic theory and modelling of runoff, analysis of interactions: - meteorological parameters - infiltration - soil - surface, subsurface and underground flow. Stochastic analyses and distribution functions of unrepresentative hydrological time series and their modelling. Multivariate time series analysis: stationary and seasonal models; frequency analysis of hydrological processes, spectral density analysis.
Student obligations	Attending lectures and preparing a seminar paper from one of the following topics: analysis of transient components in hydrological series, analysis of intermittent (occasional) hydrological processes, random functions: generation and analysis of synthetic time series, analysis of dynamic hydrological series, Kalman filters, nonlinear models , linearization of nonlinear systems, decomposition of seasonal components.
Exam	Preparation and verification of a seminar paper, and the written and oral exam.
Assessment	Total grade is composed of seminar paper grade (1/3), written exam grade based on the concept of answers (1/3) and oral exam with detailed explanation of the concept together with an open discussion with the examiner on selected questions (1/3).
Required literature	- Sing, V.P. (ed.) (1995): Computer Models of Watershed Hydrology, Water Resources Publications, Colorado. - Salas, J.D.; Delleur, J.W.; Yevjevich, V.; Lane, W.L. (1980): Applied Modeling of Hydrologic Time Series, Water Resources Publications, Littleton, Colorado. - Bras,R. L.; Rodrigez-Iturbe, I. (1993): Random Functions and Hydrology, Dover Publications, Inc., New York.
Recommended literature	- Beven, J.K. (2003): Rainfall-Runoff Modelling – The Primer, John Wiley & Sons, Ltd., Chichester. - Limić, N. (2002): Monte Carlo simulacije slučajnih veličina, nizova i procesa. Element, Zagreb. - Ožanić, N. (2003): Hidrogrami velikih voda. U: Priručnik za hidrotehničke melioracije – III kolo/knjiga 1 (ur. Ožanić, N.). Građevinski fakultet Sveučilišta u Rijeci, Rijeka, 197-237. - Ožanić, N. (2005): Statističke obrade velikih voda hidromelioracijskih sustava. U: Priručnik za hidrotehničke melioracije – III kolo/knjiga 2 (ed. Ožanić, N.). Građevinski fakultet Sveučilišta u Rijeci, Rijeka, 33-75. - Marić, N. (1991): Modeliranje vremenskih serija, Savezni zavod za statistiku, Beograd. - Jevđević, V. (1974): Stohastički procesi u hidrologiji, Zavod za hidrotehniku Građevinskog fakulteta, Sarajevo.

Course: Management of Hydro-Melioration Systems				**Status:** elective		**Code:** I-H04	
Lecturer: prof. Nevenka Ožanić (asst. prof. Ivana Sušanj Čule)							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	2.0			1.5	1.5
A total of ECTS credits: 6.0							

Course objectives	- Introduction to problems of hydro-melioration system planning and management and interactions of these systems with the surroundings. - Adoption of knowledge about plant–water–soil processes modelling in hydro-melioration systems. - Adoption of knowledge about independent tasks solving in the domain of hydro-melioration systems planning and management with special emphasis on such systems in karst areas.
Learning outcomes	- Analyze and solve complex problems and mechanisms of hydromelioration systems (planning and management of hydromelioration systems, interactions of these systems with the environment, modelling of plant-water-soil processes in hydromelioration systems, etc.) using recent scientific methodology, modern methods and approaches, multi-criteria optimization, mathematical modelling, etc.). - Give a critical review of the results of the analysis and present it to the scientific and professional public through lectures and publication of papers.
Topics	- Processes plant–water–soil (water in nature, hydro-pedology, soil humidity, porosity, infiltration, permeability and capillary characteristics of the soil). - Water balance in soil, deficits and water demands. - Dynamics of water movements in saturated and unsaturated conditions, modelling of water movements in soil. - Planning of the systems for drainage and irrigation (concepts, hydraulics, economics, ecology). - Water springs, water reservoirs and acceptors. - Mathematical modelling of spatial components and transport systems of hydro-melioration systems. - Mathematical modelling of the investment policy. - Development of hydro-melioration systems and systems for irrigation in karst areas (problems, principles and possibilities). - Management of hydromelioration systems (monitoring, informatization, water management, economic and environmental aspects).
Student obligations	Attending lectures and preparing a seminar paper.
Exam	Preparation and verification of a seminar paper and written and oral examination.
Assessment	Total grade is composed of seminar paper grade (1/3), written exam grade based on the concept of answers (1/3) and oral exam with detailed explanation of the concept together with an open discussion with the examiner on selected questions (1/3).
Required literature	- Jensen, M. E.: Design and Operation of Farm Irrigation Systems; ASAE, 1981. - Đorđević, B.: Vodoprivredni sistemi. Naučna knjiga - GF Beograd, 1990. - Kos, Z.: Hidrotehničke melioracije tla. Navodnjavanje. Zagreb. Školska knjiga, 1987. - Kos, Z.: Hidrotehničke melioracije tla. Odvodnjavanje. Zagreb. Školska knjiga, 1989. - Kos, Z.: Hidrotehničke melioracije tla. Kvaliteta vode za navodnjavanje. Zagreb. Školska knjiga, 1991.
Recommended literature	- Priručnici za hidrotehničke melioracije I, II i III kolo; Društvo za odvodnjavanje i navodnjavanje Hrvatske, GF Rijeka; 1983.-2005.

Course: Karst Hydrology				**Status:** elective		**Code:** I-H05	
Lecturer: prof. Nevenka Ožanić, asst. prof. Ivana Sušanj Čule							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	2.0			1.5	1.5
A total of ECTS credits: 6.0							

Course objectives	- Introduction to specific regularities and methodological basis of researches of flow processes in karst areas. - Application of knowledge adopted during undergraduate study and during first semester of doctoral study on researches of hydrological processes in karst areas. - Adoption of methodological procedures for independent elaborations and hydrological modelling of water appearances and processes in karst.
Learning outcomes	- Analyze and solve complex problems and mechanisms of the flow process in karst environments using recent scientific methodology, modern methods and approaches (regionalization, multi-criteria optimization, mathematical and physical modelling, etc.). - Give a critical review of the results of the analysis and present it to the scientific and professional public through lectures and publication of papers.
Topics	- Geological and hydro-geological characteristics and specificities of karst areas. - Parameters and models of water flowing in karst areas. - Conceptualization of water systems in karst areas, numeric and stochastic approaches to modelling. - Karst aquifers, dynamics of fluctuation of underground water and mutual connection with the regime of discharge from the aquifer, flowing processes in surface and underground water appearances. - Karst water springs, separation of discharge hydrograms, discharge modelling. - Mechanisms of salinization of karst water springs, modelling of interrelation between sea and fresh water in littoral karst aquifers. - Parameters and modelling of water quality in karst aquifers and water appearances. - Water quality protection in karst areas.
Student obligations	Attending lectures and preparing a seminar paper.
Exam	The exam consists of preparation and verification of a seminar paper and written and oral examination.
Assessment	Total grade is composed of seminar paper grade (1/3), written exam grade based on the concept of answers (1/3) and oral exam with detailed explanation of the concept together with an open discussion with the examiner on selected questions (1/3).
Required literature	- Bonacci, O.: Karst Hydrology, Springer Verlag, 1987. - Clarke, R.T.: Statistical Modelling in Hydrology. John Wiley and Sons, 1994. - Dreybrot, W.: Processes in Karst System: Physic, Chemistry and Geology. Springer, Berlin, Heildelberg, New York, 1998.
Recommended literature	- Bonacci, O., Roje-Bonacci, T. (2004): Posebnosti krških vodonosnika. U: Građevinski godišnjak '03/'04 (ed. Simović, V.), Hrvatski savez građevinskih inženjera, Zagreb, 89-187. - Mayer, D. (1993): Kvaliteta i zaštita podzemnih voda. Hrvatsko društvo za zaštitu voda i mora, Zagreb. - Rubinić, J. (2007): Problemi zaslanjenja, korištenja i precrpljivanja priobalnih krških izvora i vodonosnika – primjeri Sjevernojadranskog područja. U: Priručnik za hidrotehničke melioracije – III kolo/knjiga 3 (ur. Ožanić, N.). Građevinski fakultet Sveučilišta u Rijeci, Rijeka, 321-387. - Ford, D., Williams, P. (2007). Karst Hydrogeology and Geomorphology. Wiley. Chichester. - Bögli, A.: Karst Hydrology and Physical Speleology, Berlin Heidelberg New York, 1980. - Dingman, L.S.: Physical Hydrology. Macmillan Publishing Company, New York, 1994. - Stanford, J; Gilbert, J; Danielopol, D. (ed.) Groundwater Ecology, Academic Press, Inc. San Diego, 1994.

	- Abrahart, R., Kneale, P. E. i See, L. M., (editors), (2004). Neural Networks for Hydrological Modelling, CRC Press. - Govindaraju, R. S., i Rao, A. R., (editors), (2013). Artificial Neural Networks in Hydrology (36), Springer Science & Business Media

<table>
<tr><td colspan="3">Course: Principles and Application of Remote Sensing</td><td colspan="3">Status: elective</td><td colspan="2">Code: I-H06</td></tr>
<tr><td colspan="8">Lecturer: asst. prof. Bojana Horvat</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Research</td><td>Exam</td><td>W. exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.6</td><td>0.3</td><td>1.2</td><td>1.0</td><td>1.4</td><td>1.5</td></tr>
<tr><td colspan="8">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="7">- Introduction to remote sensing data acquisition types (aerial photography, satellite imagery).
- Conceptual understanding of remote sensing.
- Developing skills in image processing, classification and interpretation of remote sensing imagery for solving various water management related tasks.</td></tr>
<tr><td>Learning outcomes</td><td colspan="7">- Generate variant solutions to problems related to construction using GIS and remote sensing.
- Define and explain the types of remote sensing.
- Describe the geospatial problem and select the appropriate sensor accordingly.
- Explain and apply appropriate methodological approaches in defining the concept and creating a model based on the processing, classification and interpretation of images.
- Apply field research for verifying the results obtained from remote sensing.</td></tr>
<tr><td>Topics</td><td colspan="7">- Theoretical settings of remote sensing (electromagnetic radiation, electromagnetic spectrum, interaction with the atmosphere).
- Sensors and characteristics of images acquired by remote sensing.
- Preparation and processing of images acquired by remote sensing.
- Geometric aspects of data acquired by remote sensing.
- Visual interpretation of images.
- Classification of sensed data.
- Visualization and presentation.</td></tr>
<tr><td>Student obligations</td><td colspan="7">- Attending lectures and exercises according to faculty regulations.
- Completion and delivery of all assignments.
- Completion and delivery of a seminar paper.</td></tr>
<tr><td>Exam</td><td colspan="7">Written and oral exam. The passing grade in the written exam is a prerequisite for the oral exam.</td></tr>
<tr><td>Assessment</td><td colspan="7">20% exercises, 20% seminars, 60% exam</td></tr>
<tr><td>Required literature</td><td colspan="7">- Lillesand, T.M., Kiefer, R.W., Chipman (2015): Remote Sensing and Image Interpretation. John Wiley & Sons Inc., USA.
- Tolpekin, V., & Stein, A. (2012). The Core of GIScience: a Process-Based Approach. (ITC Educational Textbook Series). Enschede: University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC).</td></tr>
<tr><td>Recommended literature</td><td colspan="7">- Marinko Olujić (2001): Snimanje i istraživanje zemlje iz Svemira – sateliti, senzori, primjena. HAZU i Geosat. Zagreb
- Hengl T., 2004. Geoinformacijski sustavi u inventarizaciji prirodnih resursa. Sveučilište u Osijeku, Osijek, p. 350.
- Mather, P.M., Mather, P. (2010): Computer Processing of Remotely Sensed Images: An Introduction, Wiley, John & Sons, Incorporated, USA.
- Jensen, J.R. (2004): Introduction to Digital Image Processing, Prentice Hall, New Jersey, USA, 2004.
- Jensen, J.R. (2000): Remote Sensing of the Environment: An Earth Resource Perspective, Prentice Hall, Upper Saddle River, New Jersey, 2000.
- Lyon, J.G. (2003): GIS for Water Resources and Watershed Management. Taylor & Francis, London, 266 pp. (bookshop.blackwell.com)</td></tr>
</table>

Course: Eco-Hydrology					**Status:** elective		**Code:** I-H07
Lecturer: asst. prof. Josip Rubinić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	3.0			2.0	
A total of ECTS credits: 6.0							

Course objectives	Introduce the principles of sustenance of ecological systems connected with water resources. Enable students for planning of ecologically accepted activities on open water streams and for the projects of water stream reconstruction. Enable students for inter-disciplinary approach to solving the problems of environment protection and management of water resources.
Learning outcomes	- Describe the influencing factors of aquatic ecosystem. - Analyze the interrelationships of environmental factors and hydrological cycle. - Form and apply mathematical models from the domain of machine learning methods. - Model possible changes in aquatic ecosystems depending on the forecasted climate changes as well as anthropogenic conditioned changes in the water regime.
Topics	- Concept of sustainable development, definition of eco-hydrology. - Habitats, open water streams as habitats. - Hydrological cycle as support to biological diversity. - Eco-hydrology of the karst. - Hyporheic zone. - Alluvium in open water streams as food and habitat. - Eco-remediation, open streams reconstruction. - Principles and methods of determination of ecologically accepted runoffs.
Student obligations	- Attending lectures according to faculty's regulations. - Preparation and delivery of a seminar paper.
Exam	Preparation and verification of a seminar paper and oral examination.
Assessment	60% seminar paper, 40% exam
Required literature	- Bonacci O (2003): Ekohidrologija vodnih resursa i otvorenih vodotoka. Građevinsko-arhitektonski fakultet Split. - Gordon ND, McMahon TA, Finlayson BL (2004): Stream Hydrology – an Introduction for Ecologists. CRC Press, Boca Raton.
Recommended literature	- Allan JD (1996): Stream Ecology – Structure and Function of Running Waters. Chapman & Hall, London. - Eagleson PS (2002): Ecohydrology – Darwinian Expression of Vegetation Form and Function. Cambridge University Press, Cambridge.

Course: Groundwater and Surface Water Interaction Modelling				Status: elective		Code: I-H08	
Lecturer: assoc. prof. Vanja Travaš							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	1.4	4.0				
A total of ECTS credits: 6.0							

Course objectives	- Introduce students to methods of numerical modelling of surface water flow on intergranular porous media. - Introduce students to methods of numerical modelling of groundwater flow in intergranular porous media. - Introduce students to methods of modelling the interaction of surface and groundwater present within the integral aquifers.
Learning outcomes	- Explain the importance of surface water flow modelling. - Explain the importance of groundwater flow modelling. - Explain the importance of modelling the interaction of surface and groundwater. - Define the parameters of surface water flow numerical model. - Define the parameters of groundwater flow numerical model. - Define boundary and initial flow conditions for saturated and unsaturated porous medium. - Define the mechanisms of substance transport and the parameters of the transport model. - Define the mechanisms of interaction between groundwater and surface water. - Define boundary and initial conditions of the groundwater and surface water interaction model.
Topics	- Purpose and goal of surface water flow numerical modelling. Definition of shallow waters. 1D flow analysis: conservation of momentum equation, conservation of mass equation. Integration of Saint-Venant equations (characteristic method, Preissmann scheme, Q-scheme). Defining boundary and initial conditions. 2D flow analysis: a system of differential equations for in-plane flow. Friction impact modelling. Finite volume method (cell-centered FVM). Time discretization. Generating a network and defining boundary and initial conditions. Visualization and interpretation of results. - Purpose and goal of numerical modelling of groundwater flow. Conceptual flow models. Geological models of aquifers. REV and the continuum hypothesis. Darcy's law and the theory of laminar filtration. Elements of the theory of potential flow. Fundamentals of numerical modelling of stationary and nonstationary flow in an intergranular porous medium. Discretization of the spatial domain of the flow (finite difference method, finite element method, finite volume method). Defining boundary and initial conditions. - Modelling of substance transport (convection and molecular diffusion). Hydrodynamic dispersion. Numerical integration of Bear's equations. Tracer retardation and decay models. Regional flow models. - Unsaturated porous medium. Richards equation (m, h and θ form). Capillary diffusivity models. Numerical integration of the Richards equation. Defining boundary and initial conditions. Review of the mechanism of interaction of surface and groundwater (hyporheic zone). Setting boundary conditions. Visualization, interpretation and validation of results.
Student obligations	Creating a program task.
Exam	Program task presentation and discussion.
Assessment	Based on the program task.
Required literature	- W. Tan: Shallow Water Hydrodynamics, Elsevier, Amsterdam, 1992. - J. Bear, A. Cheng: Modeling Groundwater Flow and Contaminant Transport, Springer, 2010. - A. Szymkiewicz: Modeling Water Flow in Unsaturated Porous Media, Springer, 2013. - C. Abesser, T. Wagener, G. Nuetzmann: Groundwater-Surface Water Interaction: Process Understanding, Conceptualization and Modelling, Selected papers from a symposium on A New Focus on Integrated Analysis of Groundwater-Surface Water Systems, held during the International Union of Geodesy and Geophysics XXIV General Assembly in Perugia, Italy, 11-13 July 2007.
Recommended literature	- S. Družeta: Utjecaj parametara numeričke mreže na rezultat simulacija strujanja u plitkim vodama, Magistarski rad, Tehnički fakultet u Rijeci, 2013. - J. Bear: Dynamics of Fluids in Porous Media, American Elsevier Publishing Company, New York, 1988.

Course: Aquatic Ecosystem Modelling					**Status:** elective		**Code:** I-H09
Lecturer: asst. prof. Goran Volf							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Learning about and overcoming basic mathematical models describing aquatic ecosystems.
Learning outcomes	- Distinguish types of mathematical models for describing aquatic ecosystems. - Describe and define basic bio-geo-chemical processes in the aquatic environment. - Describe and define the growth of microorganisms and the population dynamics of higher organisms. - Describe and define basic chemical and biochemical reactions and their reactors. - Use basic and advanced tools to create mathematical models. - Develop basic mathematical models of aquatic ecosystems. - Describe and define the processes of transport and transformation of nutrients in the aquatic environment. - Describe and define models of standing and running water quality. - Develop basic mathematical models of wastewater treatment plants.
Topics	- Types of the mathematical models (statistical, conceptual, hybrid); static and dynamic models. - Basic tools for building the models (statistics, ODE and PDE, machine learning). - Advanced tools for building the models (Stella, Matlab, Aquasim, Weka, Cubist). - Basic bio-geo-chemical processes in the aquatic ecosystems. - Microbial growth and population dynamic of higher organisms. - Chemical reactions and reactors; biochemical reactions and reactors. - Water quality models for standing waters: 0D, 1D, 2D i 3D. - Water quality models for streams and rivers: 1D, 2D i 3D. - Models of water treatment devices (for both waste and drinking water). - Models of transport and transformation of nutrients and/or phytopharmaceuticals products.
Student obligations	Attending lectures, studying according to the lectures, individual work using modern techniques, preparation and oral presentation of the seminar paper.
Exam	Seminar paper presentation.
Assessment	Based on the quality of the seminar paper and its presentation.
Required literature	- Jørgensen SE & Bendoricchio G.: Fundamentals of Ecological Modelling, 3rd Ed., Elsevier, 2001. - Chapra SC.: Surface Water-Quality Modleing, The McGraw-Hill Companies, Inc., 1997. - DeAngelis DL.: Dynamics of Nutrient Cycling and Food Webs, Chapman & Hall, 1992.
Recommended literature	- ILEC: Guidelines of Lake management (http://www.ilec.or.jp/free_download/jpn/index.html) - USEPA: Qual - USEPA: BASINS - USEPA: PRZM - ASM1, ASM2 - ATV A-131 - Henze, Harremoes, La Cour Jansen & Arvin: Wastewater Treatment, 2nd Ed., Springer, 1997 - Schnoor JL: Environmental Modeling; Fate and Transport of Pollutants in Water, Air, and Soil, John Wiley & Sons, 1996. - Orlob GT (Ed.): Mathematical Modeling of Water Quality: Streams, Lakes, and Reservoirs, John Wiley & Sons, 1982 - Ford A.: Modeling the Environment; An Introduction to System Dynamics Modeling of Environmental Systems, Island Press, 1999. - Jørgensen SE.: Integration of Ecosystem Theories: A Pattern, 3rd Ed., Kluwer Academic Publishers, 2002.

	- Patten BC & Jørgensen SE.: Complex Ecology: The Part-Whole Relation in Ecosystems, Prentice Hall Ptr., 1995. - Hannon B. & Ruth M.: Dynamic Modeling, 2nd Ed., Springer, 2001 - Reynolds C.S.: The Ecology of Freshwater Phytoplankton, Cambridge Univ. Press, 1993. - Keen R.E. & Spain J.D.: Computer Simulation in Biology, John Wiley & Sons, 1992. - Levenspiel O.: Chemical Reaction Engineering, 3rd Ed., John Wiley & Sons, 1999. - Barnes R.S.K. & Mann K.H.: Fundamentals of Aquatic Ecology, Blackwell Science, 1991. - Bossel H.: Modeling and Simulation, A.K. Peters & Vieweg, 1994.

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF CIVIL ENGINEERING (2.05) AND THE SCIENTIFIC BRANCH OF TRANSPORTATION ENGINEERING (2.05.04)

Course: Pavement Management Systems				**Status:** elective		**Code:** I-P01
Lecturer: prof. emeritus Mate Sršen						
Course delivery	Lectures	Office hours	Seminars	Laboratory	Exam	Practical work
Number of teaching hours	15		10			
Allocation of ECTS credits	0.6	0.4	2.0	1.0	1.0	1.0
A total of ECTS credits: 6.0						

Course objectives	A pavement management system (PMS) can be defined as a set of procedures or methods that help decision makers find effective strategies for forecasting, assessing, and maintaining a usable condition. PMS covers a wide range of activities that include investment planning or programming, design, construction, maintenance, and periodic performance appraisal. Management levels range from policy decisions (for multiple road projects) to implementation decisions (within individual road projects). The management function at all levels involves comparing alternatives, coordinating activities, deciding and seeing practical implementation in an efficient and cost-effective way. The main purpose of the pavement management system is to achieve the best possible value for the available public funds, and to enable safe, comfortable and economical transport. This can be achieved by comparing financial alternatives both at the level of the road network and at the level of individual projects, coordinating the activities of project solutions, construction, maintenance and evaluation technologies, in order to realize the economical use of existing skills and knowledge. The objective of this course is to acquire knowledge on basic aspects of a systematic approach to pavement management, which means a framework for good pavement design, obtaining the necessary data, pavement assessment, pavement structure design and economic evaluation, and program development and prioritization.
Learning outcomes	- Analyze the parameters important for the systematic management of pavements. - Analyze pavement management models and influencing factors in order to optimize the pavement management process in the background segment.
Topics	Introduction to pavement management. Network-level management functions and tools. Project-level management functions and tools. Tools for analysis and decision making on pavement management. Needs analysis, economic evaluation and programming. Performance prediction models. Need for data and data processing for pavement management. Required data and database functions. Data processing results. Referencing systems. Pavement evaluation. Characterization of inputs for other data. Basic pavement management subsystems. Investment planning, programming and budgeting. Data and databases. Designing. Construction. Maintenance and rehabilitation. Research and special studies. Implementation of pavement management system. Guidelines for the future and necessary research.
Student obligations	Presentation and defense of seminar paper as a final exam.
Exam	The exam consists of the preparation and verification of a seminar paper and an oral part of the exam.
Assessment	- 40% - exercises (laboratory-preparation of measurement reports - interpretation of results). - 40% - seminar paper on a selected topic with the preparation of an article for publication. - 20% - final exam.
Required literature	- Haas, R., W. R. Hudson, and J. P. Zaniewski (1994). Modern Pavement Management. Krieger Publishing Company. Malabar, Florida, USA. - Transportation Association of Canada (1997). Pavement Design and Management Guide. Transportation Association of Canada, Ottawa, Canada. - Hudson, W. R., R. Haas and W. Uddin, (1997). Infrastructure Management: Integrating Design, Construction, Maintenance, Rehabilitation, and Renovation. McGraw Hill. New York, USA. - Huang, Yang H., (1993). Pavement Analysis and Design. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, USA.

Recommended literature	- Robinson, R., U. Danielson, and M. Snaith (1988). Road Maintenance Management - Concepts and Systems. MACMILLAN PRESS LTD, London, UK. - Haas, R., and W.R. Hudson (1978). Pavement Management Systems. McGraw-Hill Book Company, New York, USA. - Roads and Transportation Association of Canada (1977). Pavement Management Guide. Roads and Transportation Association of Canada, Ottawa, Canada.

<table>
<tr><td colspan="4">Course: Experimental Analyses of Asphalt Mixtures</td><td colspan="3">Status: elective</td><td colspan="2">Code: I-P02</td></tr>
<tr><td colspan="9">Lecturer: prof. Aleksandra Deluka-Tibljaš, asst. prof. Sanja Šurdonja</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Laboratory</td><td>Practical w.</td><td>Exam</td><td>W. exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>15</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.4</td><td>0.4</td><td>2.0</td><td>1.0</td><td>1.0</td><td>0.6</td><td>0.6</td></tr>
<tr><td colspan="9">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="8">Prepare students for advanced experimental analyses of asphalt mixtures and analyses on non-standard asphalt mixtures.</td></tr>
<tr><td>Learning outcomes</td><td colspan="8">- Select and apply tests of asphalt mixture according to a predefined criterion.
- Plan, conduct, analyze and interpret testing of asphalt mixtures with the addition of alternative materials.
- Analyze and experimentally examine the interdependence of the installed materials and the operating conditions of the mixture.
- Based on the performed tests, determine the model of behaviour of individual parameters in the mixture.</td></tr>
<tr><td>Topics</td><td colspan="8">- Theoretical analyses of used materials and parameters important for asphalt mixture design.
- Asphalt mixture design according to different criteria (fatigue, rutt, temperature etc.).
- Advanced method for experimental analyses of different types of asphalt mixtures.
- Experimental methods for determination of influence of asphalt mixture characteristics on its performance in exploitation.</td></tr>
<tr><td>Student obligations</td><td colspan="8">Laboratory exercises, seminar paper / article preparation, final exam.</td></tr>
<tr><td>Exam</td><td colspan="8">The exam consists of the preparation and verification of a seminar paper and an oral part of the exam.</td></tr>
<tr><td>Assessment</td><td colspan="8">- 40% - exercises (laboratory-preparation of measurement reports - interpretation of results).
- 40% - seminar paper on a selected topic with the preparation of an article for publication.
- 20% - final exam.</td></tr>
<tr><td>Required literature</td><td colspan="8">- Freddy L. Roberts, Prithvi S. Kandhal, E. Ray Brown, Dah-Yinn Lee and Thomas W. Kennedy: Vruće asfaltne mješavine, Hdgi, 2003.
- Rajib B. Mallick, Tahar El-Korchi: Pavement Engineering: Principles and Practice, Taylor and Francis Group, 2013.
- Athanassios Nikolaides: Highway Engineering: Pavements, Materials and Control of Quality, Taylor and Francis Group, 2013.
- Huang, Shin-che, Di Benedetto, Hervé: Advances in Asphalt Materials, Elsevier Science & Technology 2015.
- Andreas Loizos, Manfred N. Partl, Tom Scarpas, Imad L. Al-Qadi; Advanced Testing and Characterization of Bituminous Materials, Taylor and Francis Group, 2009.
- Selected scientific papers.
- Applicable norms, standards and regulations.
- Applicable COST action reports.</td></tr>
</table>

Course: Advanced Analysis of Pavement Structures				**Status:** elective		**Code:** I-P03	
Lecturer: prof. Aleksandra Deluka-Tibljaš							
Course delivery	Lectures	Office hours	Seminars	Laboratory	Practical w.	Exam	W. exam
Number of teaching hours	15	10					
Allocation of ECTS credits	0.4	0.5	2.0	1.0	1.0	0.5	0.6
A total of ECTS credits: 6.0							

Course objectives	Prepare students for advanced analyses of flexible and rigid pavements, pavement characteristics and parameters influencing pavement performance by using experimental methods.
Learning outcomes	- Apply and analyze methods of structural design of pavement structures and parameters that affect the behaviour of pavement structures. - Analyze and evaluate the parameters important for the design of pavement structures as well as their interrelationships. - Plan, conduct, analyze and interpret experimental field testing of a selected parameter related to the functional or structural properties of pavement structures (friction, load-bearing capacity, flatness, etc.). - Based on the performed tests, determine the model of the behaviour of the pavement structure related to the selected indicator of functional or structural properties of the pavement structures.
Topics	- Parameter influencing pavement design. - Advance methods for analyses of pavement performance. - Structural and functional pavement performance parameters. - Experimental methods for analyses of structural and functional pavement performance (deformations, grip, flatness ...). - Models of behaviour of individual indicators of functionality/load-bearing capacity of pavement structures.
Student obligations	Field/laboratory exercises, seminar paper/journal paper preparation, final exam.
Exam	The exam consists of the preparation and verification of a seminar paper and an oral part of the exam.
Assessment	- 30% - exercises (in the laboratory - preparation of measurement report, including computer work). - 50% - seminar paper on a selected topic with the preparation of a journal paper. - 20% - final exam.
Required literature	- Rajib B. Mallick, Tahar El-Korchi: Pavement Engineering: Principles and Practice, Taylor and Francis Group, 2013. - Federal Highway Administration (FHWA), The Long-Term Pavement Performance Program, Standard Data Release, 2011. - AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, 2000. - Haas, R., Hudson, R., Zaniewski, J.; Modern pavement management, Malabar, Florida, 1994. - Selected scientific papers. - Applicable norms, standards and regulations. - Applicable COST action reports.

Course: Traffic Flow Analysis					**Status:** elective	**Code:** I-P04
Lecturer: prof. Aleksandra Deluka-Tibljaš						
Course delivery	Lectures	Office hours	Seminars	Report	Research	Laboratory
Number of teaching hours	15		15			
Allocation of ECTS credits	0.75		1.5	1.0	2.25	0.5
A total of ECTS credits: 6.0						

Course objectives	Traffic flow analysis is an important precondition in order to satisfy functional requirements of traffic infrastructure inside and out of urban areas, because it assures traffic capacity and indirectly traffic safety level. The goal of this course is to enable students for deeper understanding and analysis of parameters that influence traffic flow, as well as for advanced analysis and research of selected traffic flow parameter. Students will be qualified to develop a traffic simulation model.
Learning outcomes	- Analyse important traffic flow indicators (for both motorised and non-motorised traffic). - Independently investigate a selected traffic flow parameter (conduct analysis of research to date in the field, plan and conduct experimental part of the research process, analyse the results, make relevant conclusions and present them in written and oral form). - Develop a traffic simulation model.
Topics	- Traffic flow theory. - Traffic flow parameters (speed, density, flow, headway, time gap). - Traffic indicator experimental measurements and correlations (e.g. space and time speed). - Analysis of traffic flow parameters for non-motorized traffic. - Influence of traffic flow parameters on traffic safety. - Deterministic and stochastic methods for analysis of traffic flow and capacity of traffic infrastructure. - Traffic simulations (with application on complex traffic situations, including Avs). Defined topics will be tailored according to the research interests of students.
Student obligations	- Active participation in teaching and learning process. - Conduction of independent research on the defined topic. - Presentation of research in written and oral form (seminar paper preparation and presentation). - Scientific paper preparation based on the conducted research.
Exam	The exam consists of the preparation and presentation of a seminar paper and a journal paper.
Assessment	- No final exam. - Seminar paper and presentation – 80% - Scientific paper preparation (for an international conference or a selected journal) – 20%
Required literature	- Roger P. Roess, Elena S. Prassas, William R. McShane: Traffic Engineering, Pearson/Prentice Hall, 2004. - Barcelo, Jaume: Fundamentals of traffic simulation, Springer, 2010. - Dadić, Ševrović, Kos: Teorija prometnog toka, Fakultet prometnih znanosti, Sveučilište u Zagrebu 2014. - Otković, Irena Ištoka; Deluka-Tibljaš, Aleksandra; Šurdonja, Sanja: Validation of the Calibration Methodology of the Micro-Simulation Traffic Model// Transport Infrastructure and Systems in a Changing World. Towards a More Sustainable, Reliable and Smarter Mobility. TIS Roma 2019 Conference Proceedings / Ignaccolo, Matteo; Tiboni, Michela (ur.). Rome, Italy: Elsevier BV, 2020. str. 684-691 doi:10.1016/j.trpro.2020.02.110 - Deluka-Tibljaš, Aleksandra: Giuffre, Tullio; Šurdonja, Sanja; Trubia, Salvatore: Introduction of Autonomous Vehicles: Roundabouts Design and Safety Performance Evaluation // Sustainability, 10 (2018), 4; 1060, 14 doi:10.3390/su10041060

Course: Transport Infrastructure and Traffic Safety - selected chapters			**Status:** elective	**Code:** I-P05	
Lecturer: assist. prof. Sanja Šurdonja					
Course delivery	Lectures	Office hours	Seminars	Laboratory	Research
Number of teaching hours	15		15		
Allocation of ECTS credits	0.75		2.0	1.0	2.25
A total of ECTS credits: 6.0					

Course objectives	Enable students to understand and analyze the parameters that affect the design of transport infrastructure and traffic safety. Students will acquire knowledge and skills on the correlation between the elements of transport infrastructure and parameters of traffic safety and will be able to define the application of appropriate measures and elements of transport infrastructure in order to improve traffic safety.
Learning outcomes	- Analyze the relationship between the elements of transport infrastructure and traffic safety. - Analyze the parameters that affect traffic safety and the design of transport infrastructure. - Independently investigate the selected parameter (conduct an analysis of previous research, plan and conduct independent testing, summarize and present the research results). - Develop a proposal for a model to increase traffic safety, depending on the transport network.
Topics	- Driver - vehicle – environment. - Elements of transport infrastructure from the aspect of traffic safety. - The impact of intersections on traffic safety. - Vulnerable traffic participants. - Traffic in urban and non-urban areas. - Measures to traffic calming. - The impact of various traffic safety factors on the occurrence of traffic accidents. - Traffic safety models; regression models. - The proposed topics are tailored according to the research interest of the student.
Student obligations	Prepare and present a seminar paper on a selected topic.
Exam	The exam consists of the preparation and verification of a seminar paper.
Assessment	- No final exam. - Seminar paper and presentation – 80% - Scientific paper preparation (for an international conference or a selected journal) – 20%
Required literature	- Legac, I. et al.: Gradske prometnice, Sveučilište u Zagrebu Fakultet prometnih znanosti, Zagreb 2011. - PIARC: Road Safety Manual, 2003. - Ištoka Otković, I., Deluka-Tibljaš, A; Šurdonja, S. Validation of the Calibration Methodology of the Micro-Simulation Traffic Model, Transport Infrastructure and Systems in a Changing World. Towards a More Sustainable, Reliable and Smarter Mobility. TIS Roma 2019 Conference Proceedings (Ignaccolo, Matteo; Tiboni, Michela, ed.).Rome, Italy: Elsevier BV, 2020, P. 684-691 doi:10.1016/j.trpro.2020.02.110. - Šurdonja, S., Dragčević, V., Deluka-Tibljaš, A. Analyses of Maximum-Speed Path Definition at Single-Lane Roundabouts, Journal of Traffic and Transportation Engineering (English Edition), 5 (2018), 2; 83-95 doi:10.1016/j.jtte.2017.06.006. - Pranjić, I., Deluka-Tibljaš, A., Cvitanić, D., Šurdonja, S. Analysis of Sight Distance at an At-Grade Intersection, Road and Rail Infrastructure IV, Proceedings of the Conference CETRA 2016 (Stjepan Lakušić ur.). Zagreb: Department of Transportation, Faculty of Civil Engineering, University of Zagreb, 2016, p. 921-928.

Recommended literature	- Dewar RE, Olson PL. Human Factors in Traffic Safety. Tuscon, USA: Lawyers & Judges Publishing Company Co.; 2007. - National Cooperative Highway Research Program REPORT 600: Human Factors Guidelines for Road Systems. Second Edition. Washington: Transportation Research Board of the National Academies; 2012. Available from: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_600Second.pdf - Molugaram K, Shanker Rao, G. Statistical Techniques for Transportation Engineering. Elsevier; 2017. - Teodorović D, Janić M. Transportation Engineering – Theory, Practice and Modeling. Amsterdam, Boston, Heidelberg, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo: Butterworth-Heinemann Elsevier; 2017 (https://ru.b-ok2.org/book/2800861/14413c). - Daniel Hughes. (ed.)Road and Traffic Safety: Practices, Role of Human Behaviour and Effective Programs; 2015.

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF BASIC TECHNICAL SCIENCES (2.15) AND THE SCIENTIFIC BRANCH OF MATERIALS (2.15.03)

Course: Development of Modern Cement Composites				**Status:** elective		**Code:** I-M01
Lecturer: asst. prof. Silvija Mrakovčić						
Course delivery	Lectures	Office hours	Seminars	Laboratory	Exam	W. exam
Number of teaching hours	15		10			
Allocation of ECTS credits	0.6	0.4	2.0	2.0	1.0	
A total of ECTS credits: 6.0						

Course objectives	- Ensure the acquisition of knowledge about the planning and execution of the experiment. - Enable the students to produce samples independently and test the properties of cementitious composites. - Enable the students to analyse independently the parameters of cementitious composites. - Train the students to independently manufacture and test material samples. - Enable the students to optimize the composition of cementitious composites based on the test results obtained.
Learning outcomes	- Define the basic principles and properties of cementitious composites. - Produce comparable mixtures of cementitious composites, and test and analyse individual mechanical and physical properties of the material. - Optimize the composition of the cement composite.
Topics	- Development of modern cementitious composites: Ultra-high performance fiber-reinforced concrete, Self-compacting concrete, Lightweight concretes of high performance, Concretes made with recycled substitutes, Green concrete, Polymer-modified concretes, Injection mixtures, Mortars. - Relationship between technology, structure and properties of cement composites. - Research work in the field of novel cement composites. - Methods for testing the properties of novel cementitious composites.
Student obligations	Preparation of material samples, testing of material properties, analysis of properties and optimization of mixtures. Preparation and presentation of a seminar paper on a selected topic.
Exam	Preparing and presenting a seminar paper on a selected topic.
Assessment	Based on the quality of the seminar paper, its presentation and the discussion on the topic of the paper.
Required literature	- Kosmatka S.H., Kerkhoff B., Panarese W.C., MacLeod N.F., McGrath R.J.: Design and Control of Concrete Mixtures, Cement Association of Canada, Seventh Edition, 2002. - Neville, A. M., Properties of Concrete, Prentice Hall, 1995. - Ukrainczyk, V., Beton: struktura, svojstva, tehnologija, Građevinski fakultet Zagreb, 1994.

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF BASIC TECHNICAL SCIENCES (2.15) AND THE SCIENTIFIC BRANCH OF FLUID MECHANICS (2.15.04)

Course: Modelling of Hydrodynamic and Transport Processes in Marine Environment	**Status:** elective	**Code:** I-MF01
Lecturer: asst. prof. Igor Ružić		

Course delivery	Lectures	Office hours	Seminars	Assignments	Practical w.	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4		2.0	2.0	1.0	
A total of ECTS credits: 6.0							

Course objectives	Develop understanding of hydrodynamics in coastal aquatic environments. Develop understanding of mathematical formulations and numerical modelling of flow and transport processes in homogeneous and stratified natural aquatic bodies.
Learning outcomes	- Analyze the basics of physical oceanography. - Describe the mathematical formulation of flow and modelling of an incompressible viscous fluid with a free water face. - Analyze and describe the mathematical formulation of wave generation and deformation. - Analyze the results and describe the application of the numerical model of simulation of coastal sea hydrodynamics.
Topics	- Basics of physical oceanography. Geostrophic flows and wind-driven flows. - Mathematical formulation of incompressible viscous free surface flow. - Numerical modelling of incompressible viscous free surface flow (3-D, 2-D hydrostatic models). - Turbulent flows, turbulent transport equations. - Impact of stratification on turbulent quantities. - Numerical modelling of turbulent stratified flows. Application in coastal hydrodynamics applications. - Mathematical and numerical models of advection, diffusion and dispersion (2D and 3D). - Transport and mixing processes in shallow and semi-deep coastal basins in the presence of baroclinic effects. - Bathymetry and boundary impacts on mixing and homogenization of stratified water column.
Student obligations	Attending lectures and office hours with the lecturer, solving a concrete assignment by using the existing 2-D and 3-D free surface flow and advection/dispersion models.
Exam	Oral exam after successful completion of the assignment.
Assessment	Lectures 40%, assignment 40 %, exam 20 %
Required literature	- Bowden, K.F., Physical Oceanography of Coastal Waters, John Wiley, 1983. - Fischer, H.B et al., Mixing in Inland and Coastal Waters, Academic Press, 1979. - Casulli, V., Numerical Methods for Free Surface Hydrodynamics, Stanford University Lecture Notes, 1993. - Rasmussen, E.B., Vested, H.J., Justesen, P, Ekebjaerg, L.C, System 3 – A Three-Dimensional Hydrodynamic Model, DHI, 1990.
Recommended literature	- Pedersen, F.B., Lecture Notes on Coastal and Estuarine Studies, Environmental Hydraulics: Stratified Flows, Springer-Verlag, 1986. - Okubo, A., Diffusion and Ecological Problems: Mathematical Models, Springer-Verlag, 1980. - Tennekes, H., Lumley, J.L, First Course in Turbulence, MIT Press, 1972.

Course: Numerical Hydrodynamics					**Status:** elective		**Code:** I-MF02
Lecturer: assoc. prof. Vanja Travaš							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	1.4		4.0			
A total of ECTS credits: 6.0							
Course objectives	Give a brief and concise insight into numerical modelling of three-dimensional turbulent fluid flows. Train the students for the implementation of independent research activities in the field of numerical hydrodynamics.						
Learning outcomes	- Implement explicit and implicit CBS algorithm for calculation of spatial fluid flow. - Define the areas of application of different turbulent models.						
Topics	- Computer mechanics. - Elliptic, parabolic and hyperbolic partial differential equations. - Equations of classical hydrodynamics. - Turbulence. - DNS approach to turbulence modelling. - LES approach to turbulence modelling. - RANS approach to turbulence modelling. - Fundamentals of the finite element method. - CBS algorithm. - Explicit and implicit time integration. - Computer implementation of explicit and implicit CBS algorithm. - Visualization and interpretation of results.						
Student obligations	Creating a program task.						
Exam	Presentation of the program task and discussion.						
Assessment	Based on the program task.						
Required literature	- P. Wesseling: Principles of Computational Fluid Dynamics. Springer, 2001. - R.W. Lewis, P. Nithiarasu, K. Seetharamu: Fundamentals of the finite element method for heat and fluid flow. John Wiley & Sons, 2004. - S.B. Pope: Turbulent Flows. Cambridge University Press, 2011.						
Recommended literature	- O. C. Zienkiewicz , R. L. Taylor, P. Nithiarasu: The Finite Element Method for Fluid Dynamics, Sixth Edition (Volume 3), Elsevier Butterworth-Heinemann, 2009.						

Course: Smoothed Particle Hydrodynamics Method for Fluid Dynamics Simulation				**Status:** elective		**Code:** I-MF03	
Lecturer: asst. prof. Elvis Žic							
Course delivery	Lectures	Office hours	Seminars	Laboratory	Exercises	Research	Exam
Number of teaching hours	15						
Allocation of ECTS credits	0.4	0.6	2.0	1.0		1.0	1.0
A total of ECTS credits: 6.0							

Course objectives	Educating doctoral students to understand the Smoothed Particle Hydrodynamics method and its application in the field of hydraulic engineering and geotechnics. Introducing the students to, and working with available software packages for numerical solutions of hydraulic and geotechnical problems in practice.
Learning outcomes	- Apply tools, methods and software solutions within the domain of Computer Fluid Dynamics. - Apply Navier-Stokes equations. - Realize complex problems in hydraulic engineering by applying the Method of Smooth Particle Dynamics. - Understand Lagrange fluid dynamics. - Implement methods in finding solutions for complex hydrotechnical phenomena and processes in nature. - Clearly apply the method of hydrodynamics of smooth particles in hydrotechnics and geotechnics through the development of 2D and 3D numerical programs and consequently make 2D and 3D numerical simulations. - Get acquainted with the currently leading programs SPHysicsgen and SPHysics for the purpose of visualization of solutions derived from 2D and 3D numerical programs.
Topics	- Introduction to Computational fluid dynamics (tools, methods and software solutions). - Classical Fluid Dynamics (the Navier-Stokes equations, Eulerian fluids). - Smoothed Particle Hydrodynamics method - SPH (theoretical background, the governing equations, features and characteristics, density reinitialization, Kernel function, Riemann solver formulation etc.). - Lagrangian Fluid Dynamics (internal and external forces, collision handling, numerical time integration – type of schemes etc.). - Implementation of methods (time and spatial partial distribution, computational efficiency, boundary conditions, physical parameters, fluid properties, rendering, the Lagrangian Fluid Method). - Application of Smoothed Particle Hydrodynamics method in hydrotehnics and geotehnics (several examples in practice, representation of 2D and 3D numerical simulation with Smoothed Particle Hydrodynamics method). - SPHysicsgen i SPHysics software for visualisation.
Student obligations	Attending lectures and office hours. Preparing a seminar paper (or a scientific paper in A, B or C scientific base), which must be presented to the teacher and orally to explain the results of the seminar or scientific paper.
Exam	After preparing a seminar paper (or scientific paper), doctoral student presents their work to the teacher and explain the results of the seminar (scientific paper) orally. Publication of one scientific paper in the A, B or C scientific base after selecting one of the course topics (with a brief oral presentation to the teacher) is also recognized as a passing grade.
Assessment	Prepared seminar paper (or scientific paper) 80%, presentation of a seminar paper (scientific paper) 10%, defense of a seminar paper (scientific paper) 10%.
Required literature	- Liu, G.R.; Liu, M.B., 2003. Smoothed Particle Hydrodynamics - a Meshfree Particle Method. World Scientific Publishing Co. Pte. Ltd., Singapore, 473 pp. - Liu, G.R., 2002. Mesh Free Methods: Moving Beyond the Finite Element Method. CRC Press, Boca Raton. - Li, S.; Liu, W.K., 2002. Meshfree and Particle Methods and Their Applications. Applied Mechanics Review, 55(1), pp. 1-34. - Belytschko, T.; Krongauz, Y.; Organ, D.; Fleming, M.; Krysl, P., 1996. Meshless Methods: an Overview and Recent Developments. Computer Methods in Applied Mechanics and Engineering, 139, pp. 3-47.

	- Blanc, T., 2008. Numerical Simulation of Debris Flows with the 2D - SPH Depth Integrated Model. Master's thesis, Escuela Superior de Ingeniera Informatica (ESII), Universitad Rey Juan Carlos, Madrid, 115 pp.
Recommended literature	- Pastor, M.; Haddad B.; Sorbino G.; Cuomo S., 2008. A Depth Integrated Coupled SPH Model for Flowlike Landslides and Related Phenomena. Int. J. Num. Anal. Meth. Geomech., 33, pp. 143-172 - Morris, J.P., 1996. Analysis of Smoothed Particle Hydrodynamics with Applications. Ph. D. thesis, Monash University. - Pastor, M., 2007. Manual and Instructions for SPH Code (Pastor Code, version from 2007), (Manual del usuario, aplicaciones del programa), unpublished manuscript. - Keefer, D.K.; Johnson, A.M., 1983. Earth Flows: Morphology, Mobilisation and Movement. U.S. Geological Survey Professional Paper 1264: U.S. Geological Survey, Denver, CO. - Žic, E., Arbanas, Ž., Bićanić, N., Ožanić, N., A Model of Mudflow Propagation Downstream from the Grohovo Landslide Near the City of Rijeka (Croatia), Natural Hazards and Earth System Sciences. 15 (2015), 1; pp. 293-313 - Žic, E.; Bićanić, N.; Koziara, T.; Ožanić, N.; Ružić, I., 2012. Application of the Solfec Program for the Numerical Modeling of Suspended Sediment Propagation in Small Torrents. 2nd Project Workshop, Monitoring and Analyses for Disaster Mitigation of Landslides, Debris Flow and Floods, Book of Proceedings. Ožanić, N.; Arbanas, Ž.; Mihalić, S.; Marui, H.; Dragičević, N. (eds.), University of Rijeka, Rijeka, pp. 98-101. - Žic, E.; Bićanić, N.; Koziara, T.; Ožanić, N., 2014. The Numerical Modelling of Suspended Sediment Propagation in Small Torrents with the Application of the Contact Dynamics Method. Technical Gazette, 21(5), pp. 939-952.

<table>
<tr><td colspan="6">Course: Modelling Coupled Systems of Shallow Water Flows</td><td colspan="2">Status: elective</td><td colspan="2">Code: I-MF04</td></tr>
<tr><td colspan="10">Lecturer: asst. prof. Nino Krvavica</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Assignments</td><td colspan="2">Exercises</td><td>Exam</td><td>W. exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>4.0</td><td></td><td colspan="2"></td><td>1.0</td><td></td></tr>
<tr><td colspan="10">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="9">- Introducing the equations for coupled systems of shallow water flows.
- Introducing the numerical methods for solving coupled systems of shallow water flows.</td></tr>
<tr><td>Learning outcomes</td><td colspan="9">- Describe and define a system of equations for coupled systems of shallow water flows.
- Explain and select an appropriate numerical scheme for an integration of coupled systems of shallow water equations.
- Implement and apply a numerical scheme for the integration of coupled systems of shallow water equations.
- Properly define initial and boundary conditions for coupled systems of shallow water flows.
- Independently interpret and verify the results of numerical computations.</td></tr>
<tr><td>Topics</td><td colspan="9">System of shallow water equations (1D and 2D Saint-Venant equations). System of equations for sediment transport (1D and 2D Saint-Venant-Exner equations). System of two-layer shallow water equations (coupled system of 1D and 2D Saint-Venant equations). System of equations for pollution transport (1D and 2D Saint-Venant equations coupled with advection-diffusion equations). Analytical and numerical solutions to eigenvalues of coupled systems of shallow water flows. Numerical methods for solving hyperbolic partial differential equations. Introduction to finite difference methods. Introduction to finite volume methods. First-order numerical methods. Approximative Riemman solvers. Lax-Friedrichs scheme. FORCE/GFORCE scheme. HLL/HLLC scheme. PVM scheme. Roe's Q scheme. Second-order and higher-order methods. Definition of initial and boundary conditions. Constitutive equations for friction and mixing processes. Verification of numerical results.</td></tr>
<tr><td>Student obligations</td><td colspan="9">Coursework, writing a report, presenting and defending the results.</td></tr>
<tr><td>Exam</td><td colspan="9">After writing a report, the student presents and defends the results of the coursework.</td></tr>
<tr><td>Assessment</td><td colspan="9">Coursework (70% written report, 30% presentation of the results).</td></tr>
<tr><td>Required literature</td><td colspan="9">- Szynkiewicz, R., 2010. Numerical Modeling in Open Channel Hydraulics (Vol. 83). Springer Science & Business Media.
- Toro, E.F., 2013. Riemann Solvers and Numerical Methods for Fluid Dynamics: a Practical Introduction. Springer Science & Business Media.
- LeVeque, R.J., 2002. Finite Volume Methods for Hyperbolic Problems (Vol. 31). Cambridge University Press.</td></tr>
<tr><td>Recommended literature</td><td colspan="9">- Vreugdenhil, C.B., 2013. Numerical Methods for Shallow-Water Flow (Vol. 13). Springer Science & Business Media.
- Vázquez-Cendón, M.E., 2015. Solving Hyperbolic Equations with Finite Volume Methods (Vol. 90). Springer.
- Krvavica, N., 2016. One-Dimensional Numerical Model for Layered Shallow Water Flow in Highly Stratified Estuaries. Doktorski rad. Sveučilište u Rijeci, Građevinski fakultet, Rijeka.</td></tr>
</table>

ELECTIVE COURSES IN THE SCIENTIFIC FIELD OF BASIC TECHNICAL SCIENCES (2.15) AND THE SCIENTIFIC BRANCH OF ENGINEERING MECHANICS (2.15.06)

Course: Algorithmic Preservation of Mechanical Properties				**Status:** elective		**Code:** I-TM01	
Lecturer: prof. Gordan Jelenić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Introduce students to selected topics in finite-element and time-stepping design in non-linear solid mechanics, where the emphasis is put on the preservation of some of the fundamental mechanical properties.
Learning outcomes	- Define a nonlinear mechanical problem of a deformable body exposed to static load. - Compare linear theory, 2nd order theory and completely nonlinear theory. - Describe a nonlinear mechanical problem using a component-less tensor notation. - Create an algorithmic procedure for the calculation of a nonlinear mechanical problem with several degrees of freedom.
Topics	- Shear locking in beam elements and how to reduce or avoid it through appropriate interpolation of displacements and rotations. - Strain-invariance in finite elements with rotational degrees of freedom. - Objectivity of the algorithmic solution based on the choice of reference surface, line or point in finite elements with rotational degrees of freedom. - Importance of preservation of orbits of relative equilibria in stability of numerical solutions of equations of motion. - Importance of exact solutions along the orbits of relative equilibria in the accuracy analysis of a numerical solution. - Interaction between translational and rotational relative equilibria in 3D motion. - Non-group numerical damping in mechanical systems with symmetries. - Local and global accuracy of time-stepping schemes. - Importance of numerical preservation of mechanical constants in time-stepping schemes. - Time-stepping schemes for rigid-body dynamics.
Student obligations	Preparation and presentation of a seminar paper.
Exam	Submission and presentation of the seminar paper.
Assessment	Based on the quality of the seminar, its presentation and discussion.
Required literature	- Crisfield, M.A. and Jelenić, G., Objectivity of Strain Measures in Geometrically Exact 3D Beam Theory and Its Finite Element Implementation, Proc. R. Soc. Lond. A 455, 1125-1147 (1999). - Jelenić, G. and Crisfield, M.A., Problems Associated with the Use of Cayley Transform and Tangent Scaling for Conserving Energy and Momenta in the Reissner--Simo Beam Theory, Comm. Num. Meth. Eng. 18, 711-720 (2002). - Bottasso, C.L. and Borri, M., Integrating Finite Rotations, Comp. Meth. Appl. Mech. Eng. 164, 307-331 (1998). - Graham, E. and Jelenić, G., A General Framework for Conservative Single-Step Time-Integration Schemes with Higher-Order Accuracy for a Central-Force System, Comp. Meth. Appl. Mech. Eng. 192, 3585-3618 (2003).

Recommended literature	- Jelenić, G. and Crisfield, M.A., Interpolation of Rotational Variables in Nonlinear Dynamics of 3D Beams, Int. J. Num. Meth. Eng. 43, 1193-1222 (1998). - Jelenić, G. and Crisfield, M.A., Geometrically Exact 3D Beam Theory: Implementation of a Strain-Invariant Finite Element for Statics and Dynamics, Comp. Meth. Appl. Mech. Eng. 171, 141-171 (1999). - Graham, E., Jelenić, G. and Crisfield, M.A., A Note on the Equivalence of Some Recent Time-Integration Schemes for N-body Problems, Comm. Num. Meth. Eng. 18, 615-620 (2002). - Munoz, J.J., Jelenić, G. and Crisfield, M.A., Master-Slave Approach for the Modelling of Joints with Dependent Degrees of Freedom in Flexible Mechanisms, Comm. Num. Meth. Eng. 19, 689-702 (2003).

Course: Fixed-Pole Approach for Geometrically Non-Linear Beams			**Status:** elective		**Code:** I-TM02	
Lecturer: prof. Gordan Jelenić						
Course delivery	Lectures	Office hours	Seminars	Programming	Exam	W. exam
Number of teaching hours	15					
Allocation of ECTS credits	0.4	0.5	3.5	0.6	1.0	
A total of ECTS credits: 6.0						

Course objectives	Enable the students to: - Express the governing equations of a beam in the so-called fixed pole description, and relate them to the material and spatial descriptions. - Formulate the given problem (see topics below) in the weak form and derive the finite-element framework. - Implement and test the formulation.
Learning outcomes	- Be able to express the equations of motion of the beam in the so-called fixed-pole description and link them to the material and spatial description. - Formulate the given problem (see below) in weak form and derive the formulation for the finite element method. - Implement and test the formulation.
Topics	- Conservation of energy/momenta in dynamic analysis. - Definition of kinematic joints in multi-body analysis. - Alternative methods for implying boundary conditions. Bear in mind that these are only suggestions and that the list of topics may be further extended depending on student research interests
Student obligations	Preparation of a technical report.
Exam	Discussion about the formulation and presentation of the numerical implementation.
Assessment	- Quality of the technical report 70%. - Ability to discuss and present the underlying theory 20%. - Code functionality 10%.
Required literature	- O. A. Bauchau and L. Trainelli, The Vectorial Parameterization of Rotation, Nonlinear Dynamics, vol. 32, no. 1, pp. 71–92, Apr. 2003. - C. Bottasso and M. Borri, Integrating Finite Rotations, Computer Methods in Applied Mechanics and Engineering, vol. 164, no. 3–4, pp. 307–331, Oct. 1998. - M. Gaćeša; G. Jelenić. Modified Fixed-Pole Approach in Geometrically Exact Spatial Beam Finite Elements. Finite Elements in Analysis and Design. 99 (2015); 39-48. - M. Gaćeša Fixed-Pole Concept in 3D Beam Finite Elements – Relationship to Standard Approaches and Analysis of Different Interpolations, dissertation, University of Rijeka, 2015.

<table>
<tr><td colspan="6">Course: Tensor Mechanics of Elastic Continuum</td><td>Status: elective</td><td>Code: I-TM03</td></tr>
<tr><td colspan="8">Lecturer: prof. Gordan Jelenić</td></tr>
<tr><td>Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Assignments</td><td>Exercises</td><td>Exam</td><td>W. exam</td></tr>
<tr><td>Number of teaching hours</td><td>15</td><td></td><td>10</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>3.0</td><td></td><td></td><td>2.0</td><td></td></tr>
<tr><td colspan="8">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="7">- Get acquainted with the tensor description of equations of deformable continua independent of the choice of co-ordinates.
- Understand material and spatial strain and stress tensors as well as constitutive tensors in non-linear mechanics
- Be able to formulate a variational mechanical problem including kinematic, equilibrium and constitutive equations.
- Acquire additional knowledge needed to follow the Course Finite Element Method.
- Prepare for more independent scientific research work in the field of nonlinear continuum mechanics.</td></tr>
<tr><td>Learning outcomes</td><td colspan="7">- Describe a nonlinear mechanical problem using a componentless tensor notation.
- Create an algorithmic procedure for the calculation of a nonlinear mechanical problem with several degrees of freedom.</td></tr>
<tr><td>Topics</td><td colspan="7">- Vector spaces. Tensor algebra. Eigenvalues and eigenvectors of second order tensors. Tensor fields. Differential operators.
- Description of deformation. Deformation gradient. Polar deformation gradient decomposition. Material and spatial strain tensors.
- Equations of motion and Cauchy's theorem. Variation form of equations of motion. Cauchy's, Kirchhoff's and Piola – Kirchhoff's stress tensors. Other stress and conjugation tensors.
- Noll's axioms, simple materials. Material symmetry, isotropy and anisotropy. Green's elasticity (hyperelasticity). Saint Venant – Kirchhoff's, Hencky's and Ogden's material model.</td></tr>
<tr><td>Student obligations</td><td colspan="7">Fulfil course objectives through a seminar paper.</td></tr>
<tr><td>Exam</td><td colspan="7">Discussion on the topic of formulation and presentation of numerical implementation.</td></tr>
<tr><td>Assessment</td><td colspan="7">- Quality of the seminar paper 70%.
- Quality of presentation and discussion 30%.</td></tr>
<tr><td>Required literature</td><td colspan="7">- R.W. Ogden, Non-linear Elastic Deformations, Dover, New York, 1997. ISBN 0-486-69648-0.
- M.A. Crisfield, Non-linear Finite Element Analysis of Solids and Structures, Volumes 1 & 2, Wiley, Chichester, 1991, 1997, ISBN 0-471-97059-X, 0-471-95649-X.
- A. Ibrahimbegović, Nonlinear Solid Mechanics, Springer, 2009, ISBN 978-90-481-2331-5.</td></tr>
<tr><td>Recommended literature</td><td colspan="7">- J.C. Simo, T.J.R. Hughes, Computational Inelasticity, Springer, New York, 1998. 0-387-97520-9.
- T. Belytschko, W.K. Liu, B. Moran, Nonlinear Finite Elements for Continua and Structures, Wiley, Chichester, 2000, ISBN 0-471-98773-5, 0-471-98774-3.
- M.E. Gurtin, E. Fried, L. Anand, The Mechanics and Thermodynamics of Continua, Cambridge University Press, 2010, ISBN 978-0-521-40598-0.
- M. Saje, S. Srpčič, Osnove nelinearne mehanike trdnih teles, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo, Ljubljana, 1993. ISBN 86-80223-23-9.
- I. Alfirević, Uvod u tenzore i mehaniku kontinuuma, Golden marketing, Zagreb, 2003.</td></tr>
</table>

Course: Plasticity Theory in Construction Simulations				**Status:** elective		**Code:** I-TM04	
Lecturer: prof. Gordan Jelenić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Understanding the basic assumptions of the mathematical theory of plasticity and their numerical realization in nonlinear analysis of rod and planar structures. Understanding algorithmic details of calculations for solving nonlinear problems, iterative procedures, and possible convergence problems. Acquiring the ability to conduct practical nonlinear analysis of structures while respecting the nonlinear behaviour of materials. Improved, rational interpretation of the results of practical calculations by the finite element method, their importance and reliability, and their limitations in the simulation of engineering problems. Understanding the algorithmic details of iterative calculations for solving nonlinear problems, and possible phenomena of calculation divergence.
Learning outcomes	- Describe the concept of the flow surface and define different flow criteria in the space of main stresses. - Analyze the selected mechanical problem and compare its response to different flow criteria. - Develop an algorithmic procedure for iterative establishment of equilibrium on the flow surface.
Topics	- Plastic material behaviour, idealization and rheological models. - Basic equations of the theory of plasticity with the assumption of small displacements. - Constitutive equations for solving elasto/ideal plastic problems. - Flow criteria for common engineering materials (Tresca, von Mises, Mohr / Coulomb, Drucker Prager, Hoffman). - Geometric interpretation of plasticity conditions in the space of stress tensor components. - The concept of loading and unloading of materials. - Explicit and implicit methods of integrating constitutive equations, consistent linearization, elastoplastic tangent modulus. - Iterative procedure for satisfying equilibrium conditions and constitutive equations. - Algorithmization of linear and nonlinear hardening of materials, associated and non-associated law of plastic flow. - Finite element method and elastoplastic analysis.
Student obligations	Regular office hours. Preparation and presentation of a seminar paper on a selected topic.
Exam	Preparation and presentation of the seminar paper.
Assessment	Based on the quality of the seminar paper, its presentation and discussion on the paper topic.
Required literature	- R. Hill, Mathematical Theory of Plasticity, Oxford Engineering Science, 1985. - W. F. Chen, Constitutive Equations for Engineering Materials, Elesevier, Amsterdam, 1994. - Owen DRJ, Hinton E, Finite Elements in Plasticity, Pineridge Press, 1980.
Recommended literature	- F. Dunne, N. Petrinic, Introduction to Computational Plasticity, Oxford Engineering Science, 2005. - M. Crisfield, Nonlinear Analysis of Solids and Structures, Vol 2, John Wiley, 1997. - Lubliner, J.: Plasticity Theory, Macmillan, New York, 1990.

Course: Meshless Numerical Methods			**Status:** elective		**Code:** I-TM05	
Lecturer: prof. Vedrana Kozulić						
Course delivery	Lectures	Office hours	Seminars	Research	Exam	W. exam
Number of teaching hours	15		10			
Allocation of ECTS credits	0.6	0.4	3.0	1.0	1.0	
A total of ECTS credits: 6.0						

Course objectives	Introducing numerical procedures for solving various physical problems by meshless methods, and understanding the concept of adaptive technique in the numerical modelling. Enabling students to apply the acquired knowledge in their own scientific and research work and make parts of computational programs using an adaptive technique in the field of their special interest.
Learning outcomes	- Classify types of offline numerical methods. - Model the geometry of a given area by the offline method. - Construct a vector space of basic functions. - Develop a procedure for implementing boundary conditions. - Analyze engineering problems described by ordinary and partial differential equations by the networkless method. - Create parts of a numerical algorithm using collocation technique.
Topics	- Numerical solutions of desired accuracy. - The idea of R-functions. - Numerical modelling using the collocation method with smooth finite functions. - Adaptive technique for modelling of structures under impulse loads (impact, explosion). - Adaptive technique for modelling of wave processes. - Non-linear numerical structural analysis using an adaptive technique.
Student obligations	Preparation of a seminar paper on a selected topic. Publication of obtained results in conferences and journals.
Exam	Preparation of a seminar paper.
Assessment	Research work on the selected topic and presentation of obtained results.
Required literature	- Kozulić V., Numeričko modeliranje metodom fragmenata pomoću Rbf funkcija, Disertacija, Građevinski fakultet, Sveučilište u Splitu, 1999. - Gotovac H., Tečenje i pronos s promjenjivom gustoćom u vodonosnicima, Magistarski rad, Građevinsko-arhitektonski fakultet, Sveučilište u Splitu, 2005.
Recommended literature	- Prenter P. M., Splines and Variational Methods, John Wiley & Sons, Inc., New York, 1989. - Rvačev V. L., Teorija R-funkcij i nekotorija jeje priloženija, Naukova dumka, Kiev, 1982. - Čolak I., Numeričko modeliranje savijanja tankih ploča općeg oblika, Disertacija, Građevinski fakultet, Sveučilište u Mostaru, 2002.

Course: Numerical Methods in Engineering			**Status:** elective		**Code:** I-TM06	
Lecturer: prof. Ivica Kožar						
Course delivery	Lectures	Office hours	Seminars	Programming	Exam	W. exam
Number of teaching hours	15		10			
Allocation of ECTS credits	0.6	0.4	2.0	2.0	1.0	
A total of ECTS credits: 6.0						

Course objectives	Enabling students to understand and apply numerical methods in engineering analysis.
Learning outcomes	- Define and describe the basic methods in solving problems: interpolation, solving equations and numerical integration. - Analyze and compare the stated methods and the corresponding calculation errors. - Define and describe the basic methods of discretization of differential equations. - Describe and make the finite difference method, the finite element method, the finite volume method.
Topics	- Mathematical modelling, approximation errors. - Linear equations (implicit and explicit methods). - Nonlinear equations (secant method, Newton method), solutions of systems of nonlinear equations. - Interpolations and interpolation polynomials (Lagrange, Hermite, Bezier). - Numerical derivations and integration (trapezoidal rule, Simpson equation, Gauss procedure). - Differential equations (elliptic, parabolic, hyperbolic), analogy of variational and differential methods, Dirichlet and Neumann boundary conditions. - Numerical solutions of differential equations using finite difference, finite volumes and finite element methods (examples of Poisson equation using finite differences, uncompressible fluid using finite differences, finite volumes and finite elements). - Partial differential equation (implicit and explicit methods, example of transient heat conduction).
Student obligations	Completion of two assignments made with software by prof. I. Kožar and programs MathCAD and MatLab.
Exam	Two assignments and oral examination.
Assessment	Two assignments make 80% and oral examination 20% of credits. Minimum required credits is 70% (70% - 80% = good, 81% - 90% = very good, > 91% = excellent).
Required literature	- Chapra S.C., Canale R.P. Numerical Methods for Engineers, McGraw-Hill 1990. - Johnson, C. NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS BY THE FINITE ELEMENT METHOD, Cambridge University Press, 1994. - Aganović, I., Veselić, K. JEDNADZBE MATEMATICKE FIZIKE, Školska knjiga - Zagreb, 1985.
Recommended literature	- Sorić J. Metoda konačnih elemenata, Golden marketing – Tehnička knjiga 2004. - MATLAB Partial Differential Equations Toolbox. - Kožar, Ivica; Lozzi-Kožar, Danila, Neki numerički postupci rješavanja istjecanja iz akumulacije, GRAĐEVINAR. 58 (2006), 5; 379-384.

Course: Mechanics of Quasi-Brittle Materials	Status: elective	Code: I-TM07

Lecturer: prof. Joško Ožbolt

Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	

A total of ECTS credits: 6.0

Course objectives	Understand processes in quasi-brittle materials and acquire knowledge for their modelling.
Learning outcomes	- Understand the behaviour of quasi-brittle materials. - Understand the difference between strength theory and fracture mechanics. - Mathematically describe the behaviour of quasi-brittle materials using different theories. - Model cracks (damage) using different approaches. - Understand the influence of the size of the structure on the nominal load capacity (so-called size effect).
Topics	Concrete – a quasi-brittle material. Overview of the behaviour of concrete under three-axial loading conditions. Determination of macroscopic parameters of concrete that are relevant for its fracture behaviour. Why we need to apply fracture mechanics in analysis and design of concrete-like materials. Basics of linear and nonlinear fracture mechanics. Application of fracture mechanics in nonlinear analysis of concrete structures using finite element method. Size effect – influence of the structure size on the nominal strength and ductility of concrete structures. Basic concept for modelling of concrete: (i) theory of plasticity, (ii) damage mechanics, (ii) microplane theory and (iii) smeared crack models. Regularization: (i) local and non-local continuum and (ii) higher order continuum.
Student obligations	One assignment.
Exam	An assignment and oral examination.
Assessment	Assignment makes 80% and oral examination 20% of credits.
Required literature	- Karihaloo, B.L.: Fracture Mechanics & Structural Concrete, Concrete Design & Construction Series, Sidney, 1995. - Bažant, Z.P., Cedolin, L.: Stability of Structures: Elastic, Inelastic, Fracture and Damage Theories, Oxford University Press, NY, 1991. - Belytschko, T., Kam, W. and Moran, B.: Nonlinear Finite Elements for Continua and Structures, Wiley, 2000.
Recommended literature	- Ožbolt, J.: Masstabseffekt und Duktilität von Beton und Stahlbeton Konstruktionen, Habilitationsschrift, Universität Stuttgart, 1995. - Jirasek, M. and Bažant, Z.P.: Inelastic Analysis of Structures, Wiley, 2002. - Zienkiewicz, O.C. and Taylor, R.L.: The Finite Element Method, 5th edition, Butterworth-Heinemann, Oxford, 2000.

Course: Configuration-Dependent Interpolation in Non-Linear Beam Elements			**Status:** elective		**Code:** I-TM08
Lecturer: asst. prof. Edita Papa Dukić					
Course delivery	Lectures	Office hours	Seminars	Programming	Exam
Number of teaching hours	15				
Allocation of ECTS credits	0.4	0.5	3.5	0.6	1.0
A total of ECTS credits: 6.0					

Course objectives	Enable the students to: - Apply the configuration-dependent interpolation to geometrically exact beam theory of Reissner. - Derive the finite element formulation. - Implement and test the formulation.
Learning outcomes	- Apply interpolation to geometrically nonlinear Reissner beams. - Derive the formulation for the finite element method. - Implement and test the formulation.
Topics	- Implementation to 3D problems. - Alternative definition of beta" parameter in higher-order elements. - Apply the interpolation to materially non-linear problems. Bear in mind that these are only suggestions and that the list of topics may be further extended depending on student research interests.
Student obligations	Preparation of a technical report.
Exam	Discussion about the formulation and presentation of the numerical implementation.
Assessment	- Quality of the technical report 70%. - Ability to discuss and present the underlying theory 20%. - Code functionality 10%.
Required literature	- G. Jelenić and M. A. Crisfield. Objectivity of Strain Measures in Geometrically Exact 3D Beam Theory and its Finite Element Implementation. Proceedings of the Royal Society of London series A – Mathematical Physical and Engineering Sciences, 455:1125-1147, 1999. - E. Papa Dukić; G. Jelenić; M. Gaćeša. Configuration-Dependent Interpolation in Higher-Order 2D Beam Finite Elements. Finite Elements in Analysis and Design. 78 (2014); 47-61. - E. Papa Dukić Configuration-Dependent Interpolation in Non-Linear Higher-Order 2D Beam Finite Elements, thesis, University of Rijeka, 2013.

Course: Fracture Mechanics				**Status:** elective		**Code:** I-TM09	
Lecturer: prof. Zoran Ren							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Enabling students to apply FM in structural analysis.
Learning outcomes	- Acquire knowledge of basic concepts of fracture mechanics. - Distinguish between different mathematical models. - Determine material parameters for model implementation. - Compare and justify analysis results.
Topics	- Types of fracture. - Linear elastic fracture mechanics. - Elasto-plastic fracture mechanics. - Fatigue crack growth. - Fracture mechanics of concrete. - Finite element techniques in fracture mechanics.
Student obligations	One assignment.
Exam	An assignment and oral examination.
Assessment	Assignment makes 80% and oral examination 20% of credits.
Required literature	- Linear Elastic Fracture Mechanics for Engineers: Theory and Applications / L. P. Pook. - Southampton; Boston: WIT Press, cop. 2000. - Elementary Engineering Fracture Mechanics / by David Broek. – Dordrecht: M. Nijhoff, 1986. - Fracture Mechanics / H. L. Ewalds, R. J. H. Wanhill. - London: Arnold, 1989. - Fracture Mechanics: Fundamentals and Applications / T. L. Anderson. - 2nd ed. - Boca Raton: CRC Press, cop. 1995.
Recommended literature	- The Practical Use of Fracture Mechanics / by David Broek. - Dordrecht; Boston : London : Kluwer, 1988. - Engineering Fracture Mechanics / S. A. Meguid. - London; New York : Elsevier Applied Science, 1989. - Fracture Mechanics of Rock / ed. by Barry Kean Atkinson. - [Reprinted with corrections 1989]. - London [etc.]: Academic Press, 1989. - Concrete Design Based on Fracture Mechanics / editors Walter Gerstle, Zdenek P. Bažant. - Detroit: American Concrete Institute, 1992. - Mehanika loma: zbrano gradivo / Maks Oblak. - 1. ed. - Maribor: Fakulteta za strojništvo, 1995. - Fracture Mechanics of Concrete: Material Characterization and Testing / ed. by A. Carpinteri, A.R. Ingraffea. - The Hague: Martinus Nijhoff Publishers, 1984. - Numerical Fracture Mechanics / by M. H. Aliabadi and D. P. Rooke. - Dordrecht: Kluwer Academic Publishers; Southampton ; Boston : Computational Mechanics Publications, 1991. - Computational Methods in the Mechanics of Fracture / edited by Satya N. Atluri. – Amsterdam: North-Holland, 1986.

Course: Convergence and Error Estimation in Finite Element Method				**Status:** elective		**Code:** I-TM10	
Lecturer: assoc. prof. Dragan Ribarić							
Course delivery	lectures	Office hours	seminar	design	exercise	exam	w. exam
Number of teaching	15		10				
Allocation of ECTS	0.6	0.4	4.0			1.0	
A total of ECTS credits6.0							

Course objectives	The aim of the course is to gain knowledge about the consistency and speed of convergence of the finite element model, and stability with respect to the complication of the model, or distortion of the network of elements. The student should gain insight into the techniques of checking the consistency of new finite element models, the assessment of the speed of their convergence as well as the stability with respect to the change in the geometry of modelling networks.
Learning outcomes	- Define possible convergence criteria of the finite element method (FEM) when the finite element network is dense. - Define the error on the FEM model. - Distinguish the convergence criteria with respect to the accuracy and robustness of the model and analyze them numerically. - Distinguish the expected accuracy of the FEM model according to the interpolation functions used.
Topics	Definitions of errors in FEM. Patch test as a consistency criterion. Superconvergence and optimal sampling points. Gradient and stress reconstruction. Estimation of error after reconstruction. Suggestions for seminar papers: - Comparison of consistency and convergence rate on the example of a four-page membrane element with Lagrange interpolation and an element enriched with internal degrees of freedom. Error estimation on a model of a Timoshenko beam with rod elements developed on bound interpolation with 2, 3 or 4 nodes. - Error estimation on a model of a Timoshenko beam with rod elements developed on bound interpolation with two nodes, and elements with unbound interpolation of the same order. - Comparison of consistency and rate of convergence on the Timoshenko beam model with rod elements with unbound interpolation of different rows. - Comparison of consistency and convergence rate on a Mindlin model of plates for four-sided plate elements with bound and unbound second-order interpolation. - Comparison of consistency and convergence rate on a Mindlin model of plates for four-sided plate elements with bound and unbound third-order interpolation.
Student obligations	Prepare and present a seminar paper on a selected topic.
Exam	By preparing and presenting a seminar paper.
Assessment	Based on the quality of the seminar paper, its presentation and discussion on the paper topic.
Required literature	- O.C. Zienkiewicz, R.L. Taylor, The Finite Element Method for Solid and Structural Mechanics, Elsevier Butterworth-Heinemann, Oxford, 2005. - O.C. Zienkiewicz, R.L. Taylor, The Finite Element Patch Test Revisited, Comput. Methods Appl. Mech. Engrg 149(1997).
Recommended literature	- G. Jelenić, E. Papa, Exact Solution of 3D Timoshenko Beam Problem Using Linked Interpolation of Arbitrary Order, Archive of Applied Mechanics 18: 171-183, (2011). - J.F. Hiller, K.J. Bathe, Measuring Convergence of Mixed Finite Element Discretizations: an Application to Shell Structures, Comp. and Struct. 81(2003). - P.S. Lee, K.J. Bathe, The Quadratic MITC Plate and MITC Shell Elements in Plate Bending, Advances in Engineering Software, 41(2010). - D. Ribarić, G. Jelenić, Higher-Order Linked Interpolation in Quadrilateral Thick Plate Finite Elements, Finite Elements in Analysis and Design 51: 67-80, 2012. - D. Ribarić, Higher-Order Linked Interpolation in Moderately Thick Plates and Facet Shells Finite Elements, Doctoral Thesis, 2012.

Course: Plates and Shells				**Status:** elective		**Code:** I-TM11	
Lecturer: assoc. prof. Dragan Ribarić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	4.0			1.0	
A total of ECTS credits: 6.0							

Course objectives	Present the theory of shell structures and finite element procedures to solutions of structural shell problems.
Learning outcomes	- Analyze the differential equations of a plate according to Kirchhoff-Love's theory of thin plates and according to Mindlin-Reissner's theory of moderately thick plates. - Analyze the differential equations of thin and moderately thick shells. - Analyze layered plates and shells. - Define finite elements for board modelling and apply in a computer program. - Define finite elements for shell modelling. - Distinguish the most important known finite elements for plates and shells in terms of interpolations and accuracy on typical test numerical models from the literature.
Topics	- Nonlinear shell theory. - Dynamics of shells. - Analytical solutions to some linear plate and shell problems. - Finite element formulation of nonlinear shell theory. - Finite element formulation for dynamic analysis of shells. - Design of metal tanks according to Eurocode. - Design of reinforced concrete shells. - Finite element limit load analysis of reinforced concrete plates. - Design of optimal shell shape. - Finite element analysis of shell problems with Feap. - Finite element analysis of shell problems with Sap2000 Nonlinear. - Finite element analysis of shell problems by using symbolic system AceGen.
Student obligations	Preparation of a seminar paper.
Exam	Presentation of the seminar paper.
Assessment	Based on the seminar paper and the quality of its presentation and discussion.
Required literature	- P.L. Gould, Analysis of Shells and Plates, Springer, 1988. - J.C. Simo, D.D. Fox, On a Stress Resultant Geometrically Exact Shell Model. Comp. Meth. Appl. Mech. Engng., 72, 267-304, 1989 & 73, 53-62, 1989 & 79, 21-70, 1990
Course objectives	- J. N. Reddy, Mechanics of Laminated Composite Plates, Theory and Analysis, CRC Press, 1997. - L. A. Samuelson, S. Eggwertz, Shell Stability Handbook, Elsevier, 1992. - J.N Reddy, Theory and Analysis of Elastic Plates, CRC Press, 1999. - M. Farshad, Design and Analysis of Shell Structures, Kluwer, 1992. - E. Ramm, A. Matzenmiller, Consistent Linearization in Elasto-Plastic Shell Analysis, Eng. Comput., 5, 289-299, 1988. - A. Ibrahimbegović, F. Gruttmann, A Consistent Finite Element Formulation of Nonlinear Membrane Shell Theory with Particular Reference to Elastic Rubberlike Material, Finite Elements in Analysis and Design, 12, 75-86, 1993. - B. Brank, J. Korelc, A. Ibrahimbegović, Dynamics and Time-Stepping Schemes for Elastic Shells Undergoing Finite Rotations, Computers and Structures, 81, 1193-1210, 2003.

Course: Modelling of Layered Beam Structures				Status: elective		Code: I-TM12	
Lecturer: assist. prof. Leo Škec							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	1.4	4.0				
A total of ECTS credits: 6.0							

Course objectives	- Introduce the kinematics of layered beam structures (how conditions at the interconnection between layers influence the number of degrees of freedom). - Understand the limitations of analytical solutions and the necessity for the development of numerical methods (FEM – finite element method) for layered structures in case of material and/or geometrical nonlinearity. - Understand and apply cohesive zone models for numerical modelling of delamination of layered beam structures. - Address advantages and disadvantages of certain algorithms for solving nonlinear problems in examples of delamination of layered beam structures (load control, displacement control, arc-length method) and apply some of the more sophisticated and robust algorithms. - Individually, partially or completely, develop a code in a program package chosen in agreement with the lecturer for a certain problem of layered beam structures. - Know, understand and, if possible, perform basic laboratory tests for delamination of layered structures in modes I and II, as well as in the mixed-mode.
Learning outcomes	- Get acquainted with basic analytical and numerical models for the analysis of layered beam girders. - Understand the basic modes of delamination and the problems we encounter in numerical modelling of delamination of layered beam girders. - Independently develop code or part of code for analysis of layered beam girders in a software package. - Understand and, if possible, perform some of the basic laboratory tests for beam girder delamination in modes I and II and in mixed mode.
Topics	- Analytical models for layered beams with rigid or compliant interconnection between layers. - Using multi-layer beam finite elements with a rigid interconnection between layers as an alternative for discretising the plane structures (theory of large and/or small displacements and rotations). - Delamination of plane layered beam structures: delamination modes (I, II and mixed-mode), interface elements with cohesive zone models (CZM) and damage, numerical procedures for solving delamination problems, delamination in problems with small and/or large displacements and rotations). - Experimental validation of existing numerical models for delamination of beam structures: laboratory tests on specimens for pure modes I and II and/or mixed-mode. - Delamination of systems with large displacements and rotations – numerical modelling and experimental validation of different peeling tests. - Rate-dependent delamination – numerical modelling and experimental validation of the results. - Delamination of plates as an extension of the beam theory – numerical modelling and experimental validation of the results.
Student obligations	Individual development of a numerical model and, if necessary, active involvement in laboratory tests. Office hours as agreed with the lecturer. Production of seminar papers in phases. Submission of seminar papers and the oral exam.
Exam	Production of seminar papers and oral exams with the lecturer in phases.
Assessment	Lecturer's estimation of the student's engagement and the quality of submitted seminar papers.

Required literature	- M. A. Crisfield, Non-Linear Finite Element Analysis of Solids and Structures, Vol. 1, Wiley, Chichester, England, 1996. - Z. Bažant, L. Cedolin, Stability of Structures, Dover, 2003. - T. L. Anderson, Fracture Mechanics: Fundamentals and Applications, Third Edition, CRC Press, Boca Ranton, Florida, USA, 2005. - R. de Borst, Fracture in Quasi-Brittle Materials: a Review of Continuum Damage-Based Approaches, Engineering Fracture Mechanics 69 (2002) 95-112. - G. Alfano, M. A. Criseld, Finite Element Interface Models for the Delamination Analysis of Laminated Composites: Mechanical and Computational Issues, International Journal for Numerical Methods in Engineering 50 (7) (2001) 1701-1736. - G. Alfano, M. A. Crisfield, Solution Strategies for the Delamination Analysis Based on a Combination of Local-Control Arc-Length and Line Searches, 58 (7) (2003), 999-1048. - L. Škec, Non-Linear Static Analysis of Multilayered 2d Beams with Various Contact Conditions between Layers, Ph.D. thesis, University of Rijeka, Faculty of Civil Engineering (2014). - L. Škec, G. Jelenić, N. Lustig, Mixed-Mode Delamination in 2D Layered Beam Nite Elements, International Journal for Numerical Methods in Engineering 104 (2015) 767-788. - L. Škec, G. Jelenić, Geometrically Non-Linear Multi-Layer Beam with Interconnection Allowing for Mixed-Mode Delamination, Engineering Fracture Mechanics. 169 (2017), 1-17. - M. Musto, G. Alfano, A Novel Rate-Dependent Czm Combining Damage and Visco-Elasticity, Composite Structures 118 (2013) 126-133. - M. Musto, G. Alfano, A Fractional Rate-Dependent Cohesive-Zone Mode I, International Journal for Numerical Methods in Engineering 105 (5) (2015), 313-341.

<table>
<tr><td colspan="5">Course: Introduction to Nonlinear Mechanics - One-Dimensional Problems</td><td colspan="2">Status: elective</td><td colspan="2">Code: I-TM13</td></tr>
<tr><td colspan="9">Lecturer: assist. prof. Leo Škec</td></tr>
<tr><td colspan="2">Course delivery</td><td>Lectures</td><td>Office hours</td><td>Seminars</td><td>Assignments</td><td>Exercises</td><td>Exam</td><td>W. exam</td></tr>
<tr><td colspan="2">Number of teaching hours</td><td>15</td><td>0</td><td>10</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Allocation of ECTS credits</td><td>0.6</td><td>0.4</td><td>3.0</td><td></td><td></td><td>2.0</td><td></td></tr>
<tr><td colspan="9">A total of ECTS credits: 6.0</td></tr>
<tr><td>Course objectives</td><td colspan="8">Get familiar with the rigorous approach to mechanics of deformable bodies on the examples of one-dimensional stress state and notice where the simplifications in the theory of second order, linear mechanics and engineering theory of beams come from. Be able to start more independent scientific research work in the field of nonlinear continuum mechanics.</td></tr>
<tr><td>Learning outcomes</td><td colspan="8">- Define a one-dimensional nonlinear mechanical problem of a deformable body exposed to static or dynamic loading.
- Compare linear theory, 2nd order theory and completely nonlinear theory.
- Create an algorithmic procedure for the calculation of a nonlinear mechanical problem with several degrees of freedom.</td></tr>
<tr><td>Topics</td><td colspan="8">- Equations of motion, kinematic and constitutive equations of a mechanical problem.
- Direct and variational approach and method of displacement.
- Newton-Raphson iterative procedure.
- Load control, displacement control, arc-length method.
- Methods of integration of equations of motion.</td></tr>
<tr><td>Student obligations</td><td colspan="8">Preparation and presentation of a seminar paper.</td></tr>
<tr><td>Exam</td><td colspan="8">Discussion on the topic and presentation of the seminar paper.</td></tr>
<tr><td>Assessment</td><td colspan="8">Seminar paper quality 70%.
Presentation and discussion quality 30%.</td></tr>
<tr><td>Required literature</td><td colspan="8">- R. de Borst, M.A. Crisfield, J.J.C. Remmers, C.V. Verhoosel, Non-linear Finite Element Analysis of Solids and Structures, Wiley, Chichester, 2012, ISBN 978-0-470-66644-9.
- T. Belytschko, W.K. Liu, B. Moran, Nonlinear Finite Elements for Continua and Structures, Wiley, Chichester, 2000, ISBN 0-471-98773-5, 0-471-98774-3.</td></tr>
<tr><td>Recommended literature</td><td colspan="8">- J. Lubliner, Plasticity Theory, Macmillan, New York, 1990. ISBN 0-02-946307-6.
- J.C. Simo, T.J.R. Hughes, Computational Inelasticity, Springer, New York, 1998. 0-387-97520-9.</td></tr>
</table>

Course: Experimental Dynamics of Solid and Deformable Systems				**Status:** elective		**Code**: I-TM14
Lecturer: assist. prof. Nina Čeh						
Course delivery	Lectures	Office hours	Seminars	Laboratory	Exam	W. exam
Number of teaching hours	15		10			
Allocation of ECTS credits	0.6	0.4	2.0	2.0	1.0	
A total of ECTS credits: 6.0						

Course objectives	Planning, conducting, measuring and post-processing the results of laboratory experiments of solid and deformable structures or structural elements, which are subject to dynamic excitation.
Learning outcomes	- Analyze a solid or deformable dynamic system and its degrees of freedom. - Define the parameters to be obtained experimentally. - Define the dynamic excitation and design the mechanism used to subject such excitation to the model. - Plan and conduct the measurement of the quantities of interest. Analyze independently the results obtained from the measurements and form the conclusions about the behaviour of the physical model.
Topics	Dynamics of blocky systems. Collisions between bodies. Experimental assessment of energy dissipation in rigid bodies. Dynamics of long-span structures due to non-uniform support excitation. Energy dissipation in deformable bodies. Dynamic response of systems subject to earthquake excitation. Experimental research of systems with emerging discontinuities. Experimental validation of various numerical and analytical models. Non-contact optical methods for measurement of deformation and strain. The suggested topics could be expanded according to student research interests.
Student obligations	Prepare and present a report on the chosen topic.
Exam	Preparation and presentation of the report.
Assessment	Based on quality of the produced report, its presentation and the discussion on the topic.
Required literature	- R. Allemang, Peter Avitabile: Handbook of Experimental Structural Dynamics, Springer-Verlag New York, 2021. - N. Čeh: A Contribution to Dynamic Characterisation of Ordered Blocky Systems, doctoral thesis, Sveučilište u Rijeci, Građevinski fakultet, 2018.
Recommended literature	- GOM Aramis v6.3 and v8.1, manual for using the hardware and software. - Quanser ST-III, laboratory manual

Course: Basics of Peridynamics				**Status:** elective		**Code**: I-TM15	
Lecturer: assist. prof. Teo Mudrić							
Course delivery	Lectures	Office hours	Seminars	Assignments	Exercises	Exam	W. exam
Number of teaching hours	15		10				
Allocation of ECTS credits	0.6	0.4	3.5			1.5	
A total of ECTS credits: 6.0							
Course objectives	Understand the basic characteristics of peridynamics. Describe the basic peridynamic theory of a continuum and present the fundamental equation of motion in peridynamics. Clarify the constitutive modeling of materials and the determination of material parameters based on parameters from classical continuum mechanics. Present the numerical solution of the fundamental equation. Introduce a method for coupling peridynamics grids and finite element method meshes.						
Learning outcomes	- Understand the basics of peridynamics. - Understand the microelastic brittle material prototype in peridynamics. - Describe the advantages of peridynamics to model crack initiation and propagation. - Apply peridynamics to a simple 2D problem.						
Topics	Peridynamic model of a continuum. A constitutive model of the prototype microelastic brittle material and relation between material parameters in peridynamics and classical continuum mechanics for a prototype microelastic brittle material. Numerical solution of the fundamental equation of motion in peridynamics. Coupling of finite element meshes with peridynamics grids. The suggested topics could be expanded according to the student research interests.						
Student obligations	Prepare a report on the chosen topic. Present and discuss the report.						
Exam	Preparation of the report and its presentation to the lecturer.						
Assessment	Report presentation and discussion with the lecturer.						
Required literature	- Madenci, E., Oterkus, E.: Peridynamic Theory and Its Applications, Springer, New York, 2014.						
Recommended literature	- Silling, S.A.; Reformulation of Elasticity Theory for Discontinuities and Long-Range Rorces; J. Mech. Phys. Solids; 2000; 48 (1); 175-209. - Silling, S.A. i Askari, E.; A Meshfree Method Based on the Peridynamic Model of Solid Mechanics; Comput. & Structures; 2005; 83 (17-18); 1526-1535. - Zaccariotto, M., Mudric, T., Tomasi, D., Shojaei, A., Galvanetto, U.; Coupling of FEM Meshes with Peridynamic Grids; Comput. Methods Appl. Mech. Engrg.; 2018; 330; 471-497.						

4. Study delivery requirements

4.1 Facilities

The faculty has facilities in the building at the address Radmila Matejčić 3 in Rijeka where it is located and where the curricular teaching activities will take place. In total, the building has 14 modernly equipped lecture halls (for 32 – 165 students), six classrooms for practical work and three IT cabinets with a total of 70 workstations equipped with a computer and two rooms for individual work of students. Computer programs are updated regularly. The faculty has a new library with a spacious reading room equipped with networked computers.

Within the project "Development of Research Infrastructure on the Campus of the University of Rijeka" (RISK), five Faculty laboratories were equipped with modern laboratory equipment, but also with equipment intended for field testing (in-situ): laboratory of roads and traffic, geotechnics laboratory, structures laboratory, materials testing laboratory and hydraulic engineering laboratory. The RISK project is co-financed by the European Regional Development Fund (ERDF) and the Ministry of Science, Education and Sports of the Republic of Croatia and is run under the code RC.2.2.06-0001.

Laboratory of roads and traffic is equipped with laboratory equipment that allows implementation of basic testing of asphalt mixtures, but also advanced dynamic tests. Particular emphasis in the procurement of equipment was given to equipment that allows determining the condition of existing roads.

Geotechnics laboratory is equipped with equipment for geotechnical testing of soil and rocks. In addition to the standard equipment used in geotechnical laboratories, such as equipment and devices for soil classification, direct shear, consolidation and triple testing of soil, the geotechnical laboratory is equipped with other newly developed and advanced equipment. The laboratory is divided into two parts depending on the type of material on which the tests can be performed: the laboratory for soil mechanics and dynamics and the laboratory for rock mechanics.

Structures laboratory is equipped with equipment for laboratory and field testing of structural elements of structures and constructions. Among the capital equipment of the laboratory, universal pressure-tensile testing machine (UTM) and a rigid steel frame with two actuators should be pointed out. The main purpose of the UTM is a monotonous static test, and, in addition, low-cycle tests up to 0.5 Hz can also be performed. The rigid steel frame with two actuators is equipment for precise static and dynamic testing of prefabricated elements and parts of various civil engineering and other structures.

Materials testing laboratory is equipped with laboratory equipment for destructive and non-destructive testing of physical and mechanical properties of inorganic binders, aggregates, fresh and hardened concrete and other materials. The laboratory has the equipment for testing samples, but also for preparing the samples for testing.

Hydraulic engineering laboratory has the equipment for model testing and field testing. Model tests can be performed in an experimental groove, an experimental pool with a segmental wave generator, a hydrological chamber, a filtration chamber and an air tunnel. For the implementation of field tests, the laboratory has various measuring devices that can be used for investigating the mechanical characteristics of surface water, as well as groundwater.

4.2 Teaching staff

Table 9 lists the teachers teaching at the Study. In order to be appointed as a mentor or commentator, teachers must meet the prescribed criteria for selecting a mentor at the postgraduate university studies of the University of Rijeka. A renowned expert, who is not a member of teaching staff at doctoral studies, may also be appointed and recognized as a mentor to a student, but in that case the Faculty Council also assigns the student one teacher as a co-mentor.

Table 9. List of teachers teaching at doctoral study

No.	Teacher	Scientific branch	Institution	Contact
1	prof. dr. sc. Željko Arbanas	Geotechnics	University of Rijeka, FCE**	zeljko.arbanas@uniri.hr

2	assoc. prof. dr. sc. Adriana Bjelanović	Load-Bearing Structures	University of Rijeka, FCE**	adriana.bjelanovic@gradri.uniri.hr
3	assoc. prof. dr. sc. Mladen Bulić	Load-Bearing Structures	University of Rijeka, FCE**	mladen.bulic@gradri.uniri.hr
4	assoc. prof. dr. sc. Bojan Crnković	Theory of Probability and Statistics	University of Rijeka, Department of Mathematics	bojan.crnkovic@uniri.hr
5	asst. prof. dr. sc. Nina Čeh	Engineering Mechanics	University of Rijeka, FCE**	nina.ceh@gradri.uniri.hr
6	prof. dr. sc. Aleksandra Deluka-Tibljaš	Transportation Engineering	University of Rijeka, FCE**	aleksandra.deluka@gradri.uniri.hr
7	assoc. prof. dr. sc. Sanja Dugonjić Jovančević	Geotechnics	University of Rijeka, FCE**	sanja.dugonjic@gradri.uniri.hr
8	prof. dr. sc. Davor Grandić	Load-Bearing Structures	University of Rijeka, FCE**	davor.grandic@gradri.uniri.hr
9	asst. prof. dr.sc. Bojana Horvat	Hydraulic Engineering	University of Rijeka, FCE**	bojana.horvat@gradri.uniri.hr
10	prof. dr. sc. Suzana Ilić *	Hydraulic Engineering	University of Rijeka, FCE**	s.ilic@lancaster.ac.uk
11	asst. prof. dr. sc. Vedran Jagodnik	Geotechnics	University of Rijeka, FCE**	vedran.jagodnik@gradri.uniri.hr
12	prof. dr. sc. Gordan Jelenić	Engineering Mechanics	University of Rijeka, FCE**	gordan.jelenic@gradri.uniri.hr
13	prof. dr. sc. Barbara Karleuša	Hydraulic Engineering	University of Rijeka, FCE**	barbara.karleusa@gradri.uniri.hr
14	prof. dr. sc. Vedrana Kozulić*	Engineering Mechanics	University of Split, FCE**	vedrana.kozulic@gradst.hr
15	prof. dr. sc. Ivica Kožar	Engineering Mechanics	University of Rijeka, FCE**	ivica.kozar@gradri.uniri.hr
16	asst. prof. dr. sc. Paulina Krolo	Load-Bearing Structures	University of Rijeka, FCE**	paulina.krolo@gradri.uniri.hr
17	asst. prof. dr. sc. Nino Krvavica	Hydraulic Engineering	University of Rijeka, FCE**	nino.krvavica@gradri.uniri.hr
18	asst. prof. dr. sc. Ivan Marović	Project Management	University of Rijeka, FCE**	ivan.marovic@gradri.uniri.hr
19	assoc. prof. dr. sc. Leo Matešić	Geotechnics	University of Rijeka, FCE**	leomat@uniri.hr
20	asst. prof. dr. sc. Silvija Mrakovčić	Materials	University of Rijeka, FCE**	silvija.mrakovcic@gradri.uniri.h
21	asst. prof. dr. sc. Teo Mudrić	Engineering Mechanics	University of Rijeka, FCE**	teo.mudric2@gradri.uniri.hr
22	prof. dr. sc. Nevenka Ožanić	Hydraulic Engineering	University of Rijeka, FCE**	nozanic@uniri.hr
23	prof. dr. sc. Joško Ožbolt	Engineering Mechanics	University of Rijeka, FCE**	josko.ozbolt@gradri.uniri.hr
24	asst. prof. dr. sc. Edita Papa Dukić	Engineering Mechanics	University of Rijeka, FCE**	edita.papa@gradri.uniri.hr
25	prof. dr. sc. Boris Podobnik	Theory of Probability and Statistics	University of Rijeka, FCE**	bpodobnik@gradri.uniri.hr
26	prof. dr. sc. Zoran Ren*	Engineering Mechanics	University of Maribor	zoran.ren@um.si

27	assoc. prof. dr. sc. Dragan Ribarić	Engineering Mechanics	University of Rijeka, FCE**	dragan.ribaric@gradri.uniri.hr
28	asst. prof. dr. sc. Josip Rubinić	Hydraulic Engineering	University of Rijeka, FCE**	jrubinic@gradri.uniri.hr
29	asst. prof. dr. sc. Igor Ružić	Hydraulic Engineering	University of Rijeka, FCE**	iruzic@gradri.uniri.hr
30	asst. prof. dr. sc. Željko Smolčić	Load-Bearing Structures	University of Rijeka, FCE**	zeljko.smolcic@gradri.uniri.hr
31	prof. emeritus Mate Sršen	Transportation Engineering	University of Rijeka, FCE**	mate.srsen@uniri.hr
32	asst. prof. dr. sc. Ivana Sušanj Čule	Hydraulic Engineering	University of Rijeka, FCE**	ivana.susanj2@gradri.uniri.hr
33	asst. prof. dr. sc. Paulo Šćulac	Load-Bearing Structures	University of Rijeka, FCE**	paulo.sculac@gradri.uniri.hr
34	asst. prof. dr. sc. Leo Škec	Engineering Mechanics	University of Rijeka, FCE**	leo.skec@gradri.uniri.hr
35	prof. dr. sc. Ivana Štimac Grandić	Load-Bearing Structures	University of Rijeka, FCE**	istimac@gradri.uniri.hr
36	asst. prof. dr. sc. Sanja Šurdonja	Transportation Engineering	University of Rijeka, FCE**	sanja.surdonja@gradri.uniri.hr
37	asst. prof. dr. sc. Neira Torić Malić	Engineering Mechanics	University of Rijeka, FCE**	ntoric@gradri.uniri.hr
38	assoc. prof. dr. sc. Vanja Travaš	Hydraulic Engineering	University of Rijeka, FCE**	vanja.travas@uniri.hr
39	prof. dr. sc. Goran Turk*	Engineering Mechanics	University of Ljubljana	goran.turk@fgg.uni-lj.si
40	asst. prof. dr. sc. Martina Vivoda Prodan	Geotechnics	University of Rijeka, FCE**	martina.vivoda@gradri.uniri.hr
41	asst. prof. dr. sc. Goran Volf	Hydraulic Engineering	University of Rijeka, FCE**	goran.volf@gradri.uniri.hr
42	prof. emeritus Ivan Vrkljan	Geotechnics	University of Rijeka	ivan.vrkljan@uniri.hr
43	asst. prof. dr. sc. Elvis Žic	Hydraulic Engineering	University of Rijeka, FCE**	elvis.zic@gradri.uniri.hr

* external staff members
** Faculty of Civil Engineering

4.3 Study program funding

The Study is funded from the following sources:

- own funds of the Faculty,
- funds of scientific research projects and appropriate foundations,
- funds of the University or the relevant Ministry,
- cooperation with the economy,
- personal funds of students.

The Study is additionally funded through state scholarships, state and university foundations, international cooperation funds, cooperation agreements with domestic and foreign institutions (exchange of students and researchers) and cooperation agreements between the University, the County and the City.

The Faculty shall cover the costs of teaching equipment and its depreciation, as well as the costs of faculty building maintenance from its own funds. The engagement of the dean, vice-deans and members of the Committee for Doctoral Study is considered as part of their regular work activities and is as such rewarded within the existing personal income. The faculty shall cover the travel and accommodation costs of visiting teachers from the funds obtained for the needs of international cooperation.