University of Zagreb
Faculty of Civil Engineering

University undergraduate and graduate study in Civil Engineering

Study programmes with learning outcomes

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INTRODUCTION

History

The Faculty of Civil Engineering in Zagreb is the oldest and largest institution of higher education in the scientific field of civil engineering in the Republic of Croatia. The Faculty is a part of the University of Zagreb which was established in 1669.

The study of civil engineering in Croatia began with the establishment of Technical Polytechnic in Zagreb which enrolled its first students in 1919. The Civil Engineering Department, at the time one of the four departments of the Technical Polytechnic, had its premises on the first floor of the converted school building at 6, Roosevelt Square. The Technical Polytechnic grew into the Technical Faculty within the University of Zagreb in 1926. In 1940 the Technical Faculty moved to the new building at 26, Fra Andrije Kačića Miošića where the instruction of civil engineering is still conducted today.

In 1956 the Technical Faculty split into the Faculty of Architecture, Civil Engineering and Geodesy, Faculty of Electrical Engineering, Faculty of Mechanical Engineering and Naval Architecture, and the Faculty of Chemistry, Food Technology and Mining.
In 1962 the Faculty of Architecture, Civil Engineering and Geodesy separated into three faculties. The Faculty of Civil Engineering thus became an independent institution of higher education within the University of Zagreb. In 1977 the Faculty integrated with the Civil Engineering Institute of Croatia and operated as the Faculty of Civil Engineering within the newly established Civil Engineering Institute. In the same year two civil engineering colleges merged with the Faculty which started offering vocational studies. When the Civil Engineering Institute was dissolved on July 1, 1991, the Faculty of Civil Engineering of the University of Zagreb once again became an independent institution of higher education. It should be noted that in recent decades, after a series of organisational changes taking into account the latest developments in science, the Technical Faculty has evolved into the present-day technical faculties within the University of Zagreb (Faculty of Architecture, Faculty of Electrical Engineering and Computing, Faculty of Chemical Engineering and Technology, Faculty of Transport and Traffic Sciences, Faculty of Mechanical Engineering and Naval Architecture, Faculty of Geodesy, Faculty of Geotechnical Engineering in Varaždin, Faculty of Civil Engineering, Faculty of Graphic Arts, Faculty of Metallurgy, Faculty of Mining, Geology and Petroleum Engineering, and Faculty of Textile Technology) which make up the Technical Field Council of the University of Zagreb.
After polytechnics were established upon the separation of professional studies from the University in the academic year 1997/1998, the Department of Construction of the Technical Polytechnic of Zagreb was functioning under the Faculty of Civil Engineering. The Department of Construction of the Technical Polytechnic of Zagreb was entirely separated from the Faculty of Civil Engineering on July 8, 2003.

Since the very start of the civil engineering studies until today, the study programmes have several times been innovated and adapted to the real needs of the economy, changing their nominal duration from four to five years. Every new development of study programmes has enriched the contents of individual courses, and introduced new courses brought about by the latest scientific achievements and professional knowledge, as well as the practice of the leading European universities.

The first students of civil engineering graduated from the Faculty in 1923. To date, the Faculty has awarded engineer's degrees to about 7700 students, bachelor's degree in engineering (currently the undergraduate study) to approximately 2500, and master's degree in engineering to about 2200 students. They have all become highly esteemed engineers, appreciated in Croatia and abroad, many of whom have attained international reputation either by significant construction work or by contribution to science.

The Faculty first offered postgraduate scientific studies in civil engineering in the academic year 1963/1964. To this day 560 master's degrees in science and 323 doctoral degrees in science have been awarded, and 57 persons have competed university specialist study programmes. The first doctoral dissertation was defended in 1922.

The year 1919 is considered the founding year of the Faculty. The Day of The Faculty is celebrated on February 21.

The Faculty today

The Faculty's seat is in Zagreb, at 26 Fra Andrije Kačića-Miošića. The Faculty also has premises at 16 Savska cesta (Hydraulics Laboratory) and, during the pandemic and moving out of the buildings in Kačićeva Street due to their complete renovation, in the building at the address 129 Sv. Duh.

Since the academic year 2024/2025, the Faculty consists of thirteen constitutional units: eight departments run by heads, one independent chair and one branch, the Administrative Department run by the Secretary of the Faculty, the Library, and the Department for Quality Assurance and Improvement. For the purpose of efficiency in scientific and teaching work, the departments are divided into chairs which are run by heads. At present, the Faculty consists of the following departments and chairs:

Department of Geotechnics
- Chair for Soil and Rock Mechanics
- Chair for Geotechnical Engineering

Department of Hydroscience and Engineering
- Chair for Fundamental Hydraulic Engineering
- Chair for Water Management Hydraulic Engineering
- Chair for Sanitary and Environmental Engineering

Department of Structural Engineering
- Chair for Concrete and Masonry Structures
- Chair for Timber Structures
- Chair for Metal Structures
- Chair for Bridges

Department of Mathematics
- Chair for Geometry and Physics
- Chair for Mathematical Subjects

Department of Materials
- Chair for Materials Research
- Chair for Materials Technology

Department of Organization, Technology, and Management
- Chair for Management
- Chair for Construction Organization
- Chair for Construction Technology

Department of Transportation Engineering
- Chair for Roads
- Chair for Railways

Department of Engineering Mechanics
- Chair for Mechanics of Materials and Testing Structures
- Chair for Statics, Dynamics and Stability of Structures

Independent Chair for Buildings

Croatian Centre for Earthquake Engineering

Administrative units are as follows: Accounting Office, Department for Legal and General Affairs and Procurement, Student Affairs Office, Office for International Relations and Cooperation, Dean's

Office, IT Support, Department for Quality Assurance and Improvement, and two Centres (Career Centre and Centre for Projects, Innovations and Technology Transfer).

The Faculty has 214 employees: 80 employees in scientific and teaching positions (assistant professors, associate professors, full professors), 6 employees in teaching positions (lecturers, senior lecturers), 51 junior and senior research and teaching assistants, 2 expert associates, 1 expert advisor, 11 project associates, and 63 non-teaching staff. Additionally, the Faculty hires 9 adjunct instructors who participate in instruction at the undergraduate and graduate level.

In order to maintain a high standard of instruction, the Faculty occasionally hires visiting lectures, top scientists and professionals in their fields.

There are approximately 1500 students at the Faculty. The Student Council of the Faculty of Civil Engineering operates within the Faculty.

The Faculty has ten fully equipped laboratories for scientific, teaching and professional work (Geotechnical Laboratory, Hydraulics Laboratory, Laboratory for river and sediment dynamics, Water Research Laboratory, Structural Testing Laboratory, Materials Laboratory, Laboratory for Advanced Material Testing, Transportation Engineering Laboratory, Laboratory for Vibrations and Environmental Noise, and Laboratory for organisation, technology and construction management). A local computer network was set up, and the equipment in lecture rooms and classrooms offers multimedia teaching. Eleven computer rooms (four for undergraduate and seven for graduate students) are equipped with more than 200 state of the art computers. The Faculty is connected to the Internet through the Croatian Academic and Research Network – CARNET.

The holdings of the Faculty Library consist of the following collections: Collection of books and journals of the Faculty of Architecture, Civil Engineering and Geodesy (about 26,372 volumes of books and 2,211 volumes of journals), Collection of old and rare books - created before 1850 (225 volumes), Varia collection, Collection of specialist, doctoral and master's theses (1,273 volumes), Reference collection, Collection of syllabi, and Collection of standards. In addition to printed materials, the Library also has digital collections in the DABAR Repository of the Faculty of Civil Engineering, and on the ViZbi.UNIZG portal of virtual collections of the University in Zagreb.

The Faculty of Civil Engineering of the University of Zagreb acquires journals from the ASCE (American Society of Civil Engineers) database necessary for the scientific work of the Faculty's scientific and teaching staff and students - 11 journals. Access to the database is possible from any computer within the Faculty's computer network. The Faculty is provided with access to electronic databases with a national license. During 2025, the Library migrated from the 'Aleph' integrated library system to the new 'Alma' library system.

About instruction at the Faculty

In the late 1990s a reform of higher education, known as Bologna Process, began in Europe. Croatia soon joined the reform. The purpose of the reform is to create an attractive, efficient and market-tailored higher education system. With the technological and economic domination of the USA the central European system of higher education has been abandoned. According to the new, Bologna

system, university studies are divided into undergraduate and graduate levels, usually lasting three and two years (postgraduate doctoral or specialist studies follow a graduate degree). While the central European higher education system traditionally offered students freedom to organise their own time in fulfilling their duties, the Bologna system defines the timetable and the deadlines much more strictly. However, it should be emphasized that some procedures have been conducted at the Faculty since the 1970s: from continuous monitoring and evaluation of student activities including lecture attendance, student participation in lectures, and independent task solving during exercises, preparation of program assignments and seminar papers to periodical knowledge testing in midterm exams during the semester, so students could be exempt from a part of the final exams.

The undergraduate programme was introduced by the Faculty of Civil Engineering in the academic year 2005/2006, and in 2008/2009 the first generation of bachelors in engineering enrolled in the graduate program. (The accreditations for undergraduate and graduate programs were issued by the Minister of Science, Education and Sport on June 2, 2005, pursuant to Article 51, paragraph 2 of the *Act on Scientific Activity and Higher Education*, and at the proposal of the National Council for Higher Education. Following the re-accreditation procedure conducted by the Agency for Science and Higher Education, the accreditations were renewed in November 2012). According to the Act on Scientific Activity and Higher Education (Official Gazette, No. 119/2022), at the beginning of 2023, the name of undergraduate university studies changed to university undergraduate studies, and graduate university studies to university graduate studies.

When compiling the study programs of the then undergraduate and graduate studies, the curricula of undergraduate and graduate university studies in civil engineering from several of the best universities of the European Union were used (Delft University of Technology, the Netherlands; ETH Zurich, Switzerland; Technical University of Hannover and University of Stuttgart, Germany; University of Trieste and Polytechnic University of Milan, Italy; Imperial College London and University of Glasgow, Great Britain), as well as the guidelines for the development of curricula of two large European projects related to defining the goals of higher education in construction (SOCRATES and ERASMUS Thematic Networks: EUCEET – European Civil Engineering Education and Training and E4 – Enhancing Engineering Education in Europe), and the guidelines by the German Accreditation Association for Study Programmes in Civil Engineering (ASBau – Akkreditirungsverbund für Studinengänge des Bauwesens: Akkreditirung und Qualitätssicherung zeitgemässer Studiengänge des Bauingenieurwesens an deutschen Hochschulen. ASBau e.V., Berlin, 2003).

The university undergraduate programme lasts three years. Upon its completion students earn 180 ECTS credits and the academic title of bachelor (baccalaureus) in civil engineering for men, and baccalaurea in civil engineering for women (abbreviation: univ. bacc. ing. aedif.). It is an integrated program, without specialisations, and comprises the fundamental (natural sciences, mathematics, and fundamental technical courses), and the main part (professional courses that cover all civil engineering branches and a number of non-engineering courses related to civil engineering) with field work and a final exam. It offers students a scientific and professional basis for continuing education at graduate level, and for the ones who decide to find employment, it gives professional knowledge necessary for managing small scale construction projects, designing small scale structures with regard to static loads and participation in planning, designing, construction and supervising major construction works, and maintenance of complex buildings.

Knowledge required for performing highly specialized activities in various branches of civil engineering (planning, designing, construction, supervision and maintaining complex structures, work and systems) and foundations for developmental and scientific research is acquired in one of

the eight specialisations at graduate university programme level: Geotechnics (G), Hydraulic Engineering (HE), Structures (S), Materials (M), Construction Management (CM), Transportation Engineering (TE), Theory and Modelling of Structures (TMS) and Sustainable Construction and Earthquake Engineering (SCEE). The graduate programme lasts two years, 120 ECTS credits are earned and the academic title of master of civil engineering is awarded (abbrev. mag. ing. aedif.). Together with courses in mathematics, humanities and social studies, students attend fundamental scientific and professional courses which they specialise in. Besides compulsory courses, depending on their interests, students enrol in elective ones which can expand their professional knowledge (and not only in their chosen field), as well as their knowledge in mathematics, physics, and foreign languages (for civil engineering).

After the instruction had been conducted at least once for all years of undergraduate and graduate programs, the analysis of identified problems, deficiencies and necessary changes was carried out. In regular meetings of the Faculty Council in April and May of 2011, the proposals of amendments to undergraduate and graduate curricula were accepted. As of the academic year 2012/2013, the instruction in the first year of study, and as of 2013/2014 the instruction in the second year of study has been conducted according to the changed and amended graduate curriculum, while the "new" curriculum for the undergraduate programme was introduced in the academic year 2013/2014. New amendments to all courses of the university graduate study programme Civil Engineering were accepted at the regular session of the Faculty Council in March 2021. According to these minor amendments (up to 20%), teaching at the graduate study has been held from the academic year 2021/2022. At the 258th session of the Faculty Council held in February 2026, amendments to the graduate study programme were approved, introducing a new module titled Sustainable Construction and Earthquake Engineering. These changes did not affect the learning outcomes of the graduate study program.

One of the goals of the reform, according to the guidelines of Bologna Declaration, is the harmonisation of studies in different European countries and achieving comparability of academic degrees while respecting the differences between them. It should diminish administrative barriers, facilitate employment abroad, and enrolment into other universities in the entire European area. An important step in this direction are the international accreditations with the European-Accredited Engineering Program (EUR-ACE) label, which was awarded to the undergraduate and graduate programmes at the Faculty of Civil Engineering by the German Accreditation Agency for Study Programmes in Engineering, Informatics, Natural Sciences and Mathematics ASIIN e.V. (Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik e.V.), in March of 2012. After the re-accreditation procedure that was carried out in 2018, ASIIN's accreditation was extended until September 2024. In the following re-accreditation cycle conducted at the Faculty during 2025, the ASIIN accreditation was extended until October 2026.

University undergraduate study programme Civil Engineering

GENERAL

Duration of study

Three years with 180 ECTS credits.

Enrolment requirements

All four-year secondary school programs and passed state graduation exam.

Study system

Organized and conducted in semesters as a full-time study.

Criteria and transfer requirements of ECTS credits

Students earn ECTS credits according to the Faculty regulations of study curriculum regardless of the value of credits the course has in the main study program.

Conditions under which students who have interrupted their studies or lost the right to study in one study programme can continue their studies

Students who have interrupted their studies can continue if they comply with the programme they are enrolling in.

Students who have lost the right to study at another study programme are allowed to continue if they conform the ECTS credits they have earned to the Faculty's study programme.

Academic title awarded upon graduation

Bachelor (baccalaureus) in civil engineering (for men) / bachelor (baccalaurea) in civil engineering (for women) – abbreviation univ. bacc. ing. aedif.

Certification

Upon completion of the university undergraduate study, the student is issued a diploma (in print and digital form, in Croatian and English), certifying the completion of the studies and acquiring the academic title.

The students are also issued a diploma supplement (in print and digital form, in Croatian and English), certifying the exams passed, grades achieved, and ECTS credits earned.

Graduate studies that students could pursue after completion of this study

- university graduate study of civil engineering at the Faculty or a similar study at other universities in Croatia and abroad,
- professional graduate study in civil engineering at institutions offering such studies,
- with major or minor additional study obligations, a university graduate study or professional graduate studies in other technical professions in Croatia or abroad.

THE PROGRAMME'S LEARNING OUTCOMES

A person who has completed the programme can:

(KNOWLEDGE AND UNDERSTANDING)

- recognize and describe engineering issues,
- recognize the interaction between design, construction, marketing, clients' demands, and removal of structures,
- understand the impact of civil engineering on society and the environment,

(APPLICATION OF KNOWLEDGE AND UNDERSTANDING)

- apply acquired knowledge of mathematics, science and technology in civil engineering,
- prepare and carry out experiments, and analyse and interpret their results,
- use common computer tools to execute calculations and simulations,
- design structures at the basic level,
- static load dimensioning for smaller structures,

(DRAWING CONCLUSIONS, MAKING JUDGEMENTS AND DECISIONS)

- critically evaluate arguments, assumptions, concepts and data when making decisions and solve engineering problems creatively,

(COMMUNICATION, PRESENTATIONS AND TEAMWORK)

- participate in planning, design, execution, supervision, and maintenance of large-scale construction work,
- supervise small-scale construction works,
- exchange information, ideas, problems and solutions with experts and lay persons,
- participate in expert groups and adapt to the requirements of the working environment,
- use common computer tools for creating documents, presentations and websites,

(STUDY SKILLS AND ETHICS)

- apply the acquired knowledge and skills in further professional and academic education,
- adapt to changes in technology and work methods in the process of lifelong learning,
- demonstrate a moral and ethical attitude in solving engineering issues.

PROGRAMME STRUCTURE

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Introduction to Civil Engineering History of Building	30	0	0	3
2	Mathematics 1		60	0	60	9
3	Descriptive Geometry		30	0	45	6
4	Basics of Engineering Informatics		15	0	30	3
5	Mathematical Programmes for Engineers		15	0	15	2
6	Geodesy		30	0	30	4
7	Physical Education and Health Culture 1		0	0	30	-
7	Elective Course	Sociology of Work and Professional Ethics Sociology of Work and Professional Ethics Outline of Civil Engineering Legislation Business Economics English in Civil Engineering 1 German in Civil Engineering 1	30	0	0	3
	Total		**210**	**0**	**210**	**30**

1st year, 2nd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Mathematics 2	60	0	45	8
2	Physics	60	0	15	6
3	Mechanics 1	30	0	30	5
4	Building Construction	45	0	45	7
5	Materials Science	30	0	15	4
6	Physical Education and Health Culture 2	0	0	30	-
	Total	**225**	**0**	**180**	**30**

2nd year, 3rd semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Probability and Statistics		30	0	30	4
2	Strength of Materials 1		45	0	45	7
3	Fluid Mechanics		45	0	30	6
4	Mechanics 2		30	0	30	5
5	Elective Course	Construction Materials Basics of Concrete Technology	30	0	30	5
6	Hydrology		30	0	15	3
7	Physical Education and Health Culture 3		0	0	30	-
	Total		**210**	**0**	**210**	**30**

2nd year, 4th semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Applied Geology Environmental Protection	30	0	0	3
2	Strength of Materials 2		45	0	30	5.5
3	Structural Analysis 1		60	0	45	7.5
4	Introduction to Structural Engineering		30	0	0	2
5	Soil Mechanics		45	0	30	5
6	Elective Course	Water Supply and Sewerage 1 Water Protection	30	0	15	4
7	Law in Construction		30	0	0	3
8	Physical Education and Health Culture 4		0	0	30	-
	Total		**270**	**0**	**150**	**30**

3rd year, 5th semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Concrete and Masonry Structures 1		60	0	45	6.5
2	Rock Mechanics		45	0	30	6
3	Roads		45	0	30	6
4	Elective Course	Construction Technologies	30	0	0	3
		Infrastructure construction technologies				
5	Elective Course	Structural Analysis 2	30	0	30	4.5
		Numerical Modelling of Structures		4	26	
6	Railways		30	0	15	3
	Total		**240**	**0** **4**	**150** **146**	**29**

3rd year, 6th semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Construction Management		45	0	45	6.5
2	Metal Structures		30	0	15	4
3	Bridges		30	0	15	4
4	Elective Course	Timber Structures	30	0	15	4
		Lightweight Structures				
5	Hydraulic Structures		45	0	0	3.5
6	On-Site Education		0	0	45	3
7	Final Assignment					6
	Total		**180**	**0**	**135**	**31**

COURSE CONTENT WITH LEARNING OUTCOMES

1st year, 1st semester

Mandatory courses

MATHEMATICS 1

Credits (ECTS): 9

Hours (total per semester):

- Lectures: 60
- Exercises (auditory): 60

Course objectives:

- Acquisition of theoretical knowledge in differential and integral calculus,
- Acquisition of basic knowledge in linear algebra to be applied by students in future.

Entry competences (prior knowledge, descriptive):

- Secondary school mathematics, basic knowledge of vectors, sequences and functions.

Learning outcomes:

- Knowledge of basic facts and theorems on vectors and analytical geometry in space,
- Acquiring basic knowledge of matrix calculus, with emphasis on linear systems of equations and eigenvalues,
- Knowledge about the basic facts on sequences and series,
- Understanding the basics of differential calculus and its applications,
- Understanding the basics of integral calculus and its applications.

Course content (by course schedule):

- Lectures:
  1. Vectors [6]
  2. Analytic geometry in space [4]
  3. Matrices, linear systems of equations, eigenvalues [10]
  4. Sequences and series [4]
  5. Real functions of real variable, introduction [8]
  6. Differential calculus, continuity, limes, derivation, applications [10]
  7. Integral calculus with applications [16]
- Exercises (auditory):
  1. Vectors [4]
  2. Analytic geometry in space [6]
  3. Matrices [10]
  4. Sequences and series [4]
  5. Functions, introduction [10]
  6. Differential calculus [10]
  7. Integral calculus [16]

Student Evaluation - Continuous assessment:

- First midterm exam – problems

- Second midterm exam – problems
- First midterm exam – theory
- Second midterm exam – theory
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Theory
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Došlić, T., Sandrić, N.: Lecture notes for internal use available at: http://www.grad.unizg.hr/_download/repository/T._____Doslic%2C_N._Sandric%3B_Matematika_1.pdf

Additional reading:

1. Kurepa, S.: *Matematička analiza I*, Zagreb: Tehnička knjiga, 1989.
2. Kurepa, S.: *Uvod u linearnu algebru*, Zagreb: Školska knjiga, 1978.
3. Pauše, Ž.: *Matematički priručnik*, Zagreb: Školska knjiga, 2003.
4. Došlić, T., Sandrić, N.: *Matematika I*, lecture notes for internal use.

DESCRIPTIVE GEOMETRY

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 45 (auditory: 15, construction and design: 30)

Course objectives:

- Expansion of theoretical knowledge on geometric objects and their relations,
- Development of spatial perception,
- Development of the ability to constructively solve spatial problems using planar representations and interpretation of the spatial situation based on the planar representation.

Entry competences (prior knowledge, descriptive):

- Secondary school mathematics.

Learning outcomes:

- Acquired principles of orthogonal and oblique parallel projection,
- Acquired principles of 3D modelling in CAD software,
- Ability to solve spatial and planar problems,
- Ability to apply geometric knowledge to civil engineering.

Course content (by course schedule):

- Lectures:
  1. Plane curves and transformations [4]
  2. Monge's method [12]
  3. Axonometric projection [2]

4. CAD software [2]
5. Cross-sections of surfaces [2]
6. Intersection of surfaces [2]
7. Elevated projection [6]

- Exercises (auditory):
  1. Plane curves and transformations [2]
  2. Monge's method [6]
  3. Axonometric projection [1]
  4. CAD software [1]
  5. Cross-sections of surfaces [1]
  6. Intersection of surfaces [1]
  7. Elevated projection [3]
- Exercises (construction – drawing room or computer room):
  1. Plane curves and transformations [4]
  2. Monge's method [14]
  3. Axonometric image of objects [2]
  4. Cross-sections of surfaces [2]
  5. Intersection of surfaces [2]
  6. Elevated projection [6]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation, submission, and defence of 6 program assignments within the prescribed deadline
- Homework and 2 short tests
- First midterm exam
- Second midterm exam
- Oral exam – grade confirmation

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation, submission and defence of 6 program assignments within the prescribed deadline
- Homework and 2 short tests
- Written exam
- Oral exam

Required reading:

1. I. Babić, S. Gorjanc, A. Sliepčević, V. Szirovicza: *Nacrtna geometrija – zadaci*, HDGG, Zagreb, 2007.
2. S. Gorjanc: *Predavanja iz Deskriptivne geometrije*, (online lecture notes) http://www.grad.hr/sgorjanc/Links/deskriptiva/plan.html
3. V. Szirovicza, E. Jurkin: *Deskriptivna geometrija*, CD-ROM, HDGG i GF, Zagreb, 2005.

Additional reading:

1. I. Babić, K. Horvat-Baldasar: *Nacrtna geometrija*, Sand, Zagreb, 1997.

2. V. Niče: *Deskriptivna geometrija*, Školska knjiga, Zagreb, 1997.

BASICS OF ENGINEERING INFORMATICS

Hours (total per semester):

- Lectures: 15
- Exercises (auditory): 15

Course objectives:

- Achieve basic IT literacy,
- Provide basic IT knowledge and skills necessary to carry out teaching duties that include computer work in other courses.

Learning outcomes:

- Mastering the basic use of operational systems, e-mail and the Internet,
- Mastering 2D technical drawing techniques in the CAD tool,
- Mastering basic functionalities of office tools,
- Become familiar with the role of information and communication technologies in construction, and the directions of development.

Course content (by course schedule):

- Lectures:
  1. Introduction [1]
  2. Engineering informatics – What is it? [5]
  3. Modelling methods and product model [1]
  4. Building Information Model (BIM) [3]
  5. The Internet [1]
  6. Internet security [2]
- Exercises (auditory):
  1. Introductory exercises for CAD [1]
  2. CAD tool [6]
  3. Revit [7]
  4. CAD/Revit [1]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Testing AutoCAD knowledge and skills
- Preparation of a Revit model during exercises - part #1
- Preparation of a Revit model during exercises - part #2
- Preparation of a Revit model during exercises - part #3
- Preparation of a Revit model during exercises - part #4
- Preparation of a cost estimate from the Revit model

Student Evaluation - Examination without Continuous Assessment:

- Testing AutoCAD knowledge and skills

- The first test is held for students who possess the required AutoCAD knowledge and skills, and they are exempt from the AutoCAD practicum if they pass. If not, they attend exercises according to the schedule, after which the second test takes place. At the end of the semester, a third test takes place for students who did not meet the requirements.

Required reading:

1. R. Kučinac, I. Borovec: *Osnove računala i Windows XP*, Miš, 2002.
2. Z. Vičić, *Internet ukratko*, Miš, 2002.
3. E. Finkelstein: *AutoCAD 2002 biblija*, Miš, 2002.

Additional reading:

1. Gladfelter, D.: AutoCAD 2011 i AutoCAD LT 2011, Kompjutor biblioteka, 2011.
2. Autodesk Revit 2020: Fundamentals for Architecture; https://www.ascented.com/courseware/product/revit-2020-fundamentals-for-architecture

MATHEMATICAL PROGRAMMES FOR ENGINEERS

Credits (ECTS): 2

Hours (total per semester):

- Lectures: 15
- Exercises (design in a computer room): 15

Course objectives:

- Training in the application of computer software in solving mathematical tasks,
- Developing the ability of logical reasoning,
- Acquiring basic knowledge in computer programming.

Entry competences (prior knowledge, descriptive):

- Secondary school mathematics.

Learning outcomes:

- The student will be able to solve mathematical problems using a computer,
- The student understands what programming is and is able to write a simple program,
- The student will be able to apply the acquired knowledge and skills in courses of higher years.

Course content (by course schedule):

- Lectures:
  1. Introduction to mathematical programs [1]
  2. Visualisation of functions and data using computer software [2]
  3. Numerical and symbolic calculus using computer software [3]
  4. Basics of computer programming [4]
     - 4.1. Data types, variables, constants, commands
     - 4.2. Looping and branching
     - 4.3. Functions
     - 4.4. Complex types (strings, lists, dictionaries). Derived types
  5. Visual programming and parametric modelling [5]
- Exercises (in the computer room):

1. Arithmetic operations, elementary functions, polynomials, defining functions, graphs of functions [1]
2. 2D and 3D graphics [2]
3. Vectors and matrices [1]
4. Equations, systems of equations, inequalities [1]
5. Limits, derivatives, integrals [1]
6. Data types, variables, commands, loops, branches [3]
7. Visual programming and parametric modelling [4]

- Midterm exams:
  1. Cover numerical and symbolic calculation and visualization,
  2. Cover the basics of programming.

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. K. Fresl: *Course materials MPZI_ **, http://sage.grad.hr
2. *Sage PREP Tutorials,* http://sagemath.org/doc/prep/index.html.
3. M. O'Sullivan, R. Rosenbaum, D. Monarres: *Sage Tutorial*, http://www-rohan.sdsu.edu/~mosulliv/Courses/sdsu-sage-tutorial/index.html.

Additional reading:

1. *SymPy Tutorial*, http://docs.sympy.org/0.7.2/tutorial.html.
2. G. van Rossum: *The Python Tutorial*, http://docs.python.org/2/tutorial/.

GEODESY

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 10, design: 10, fieldwork: 10)

Course objectives:

- Applying the acquired knowledge in project implementation – cooperation of construction and surveying experts,
- Train students for teamwork.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic properties of trigonometric functions,
- Knowledge of the basics of calculus (derivations and integrals),

- Knowledge of the basics of computer work: text processing, spreadsheets, basic graphic programs.

Learning outcomes:

- Ability to analyse and use surveying maps: maps and plans of different scales,
- Understanding the role of the surveying works in construction in various design phases,
- Application of the acquired knowledge in preparation of project documentation and implementation of specific project tasks,
- Analysing and recognising the importance of surveying works in various design tasks and the need to involve geodetic experts,
- Ability to obtain geodetic documentation necessary for the design and transfer of the project into field,
- Performing simpler geodetic tasks in the field.

Course content (by course schedule):

- Lectures:
  1. The shape and size of the Earth and its mapping on maps and plans [2]
  2. Surveying instruments. Basic geodetic measurements: length, angles and altitude differences [2]
  3. The basic theory of errors and adjustment calculus [2]
  4. Coordinate systems in geodesy. National coordinate system [2]
  5. Basic geodetic works. Positional geodetic networks [2]
  6. Altitude geodetic maps. Methods of height determination [2]
  7. Cartography. Scales of geodetic plans and maps. Cartometry [2]
  8. Calculating areas and volumes based on measured values and data obtained from surveying maps: from plans and maps of various scales [2]
  9. Land surveying methods: classic, photogrammetric, satellite [2]
  10. Spatial databases. Geoinformation systems – GIS [2]
  11. Cadastral contents and land registry [2]
  12. Surveying in design and construction [2]
  13. Surveying in various construction branches [2]
  14. Determination of displacements and deformations of objects using different geodetic methods [2]
  15. Contemporary geodetic methods in construction [2]
- Exercises (auditory):
  1. Coordinate calculus. Calculating direction angles, horizontal angles, lengths, areas and volumes from the coordinates of points. First and second geodetic task [2]
  2. Determining altitude differences by geometric and trigonometric precise levelling. Determining the height of objects based on measured sizes. Terrain slope. Profile grade and cross-sections of roads [2]
  3. Surveying methods of capturing details. Practical examples [2]
  4. The theory of errors and adjustment calculus. Examples of direct and indirect measurements [2]
  5. Spatial databases. Examples of GIS based on geodetic data [2]
- Exercises (fieldwork):
  1. Measuring horizontal and vertical angles and oblique lengths (theodolite, measuring station) in triangle [5]

2. Determining altitude differences by geometric and trigonometric precise levelling. Determining the heights of objects based on measured values [5]

- Exercises (design):
  1. Calculating angles and lengths in a triangle using trigonometric functions. Calculating areas by analytic and trigonometry method. Calculating altitude differences and altitude of points by geometric and trigonometric precise levelling [5]
  2. Cartometry: reading the coordinates of 4 points from a map, scale 1: 5000. Numerical calculations of directional angles, horizontal angles, lengths, areas and volumes from coordinates of points on a map. Creating a profile grade and transverse profiles for a section of a traffic route marked on a map, based on the lengths and heights from the map. Calculating the terrain inclination for route sections [5]

Student Evaluation - Continuous assessment:

- Preparation and submission of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and submission of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Barković, Đ., Zrinjski, M.: *Terenska mjerenja*, lecture notes of the Faculty of Geodesy of the University of Zagreb, Zagreb, 2015.
2. Bilajbegović, A., Hofmann-Wellenhof, B., Lichtenegger, H.: *Osnovni geodetski radovi, suvremene metode,* GPS; Tehnička knjiga, Zagreb, 1991.
3. Kapović, Z.: *Geodezija u niskogradnji*, Geodetski fakultet Sveučilišta u Zagrebu, Zagreb, 2010.
4. Pribičević, B., Medak, D.: *Geodezija u građevinarstvu*, V.B.Z. d.o.o., Zagreb, 2003.

Additional reading:

1. Benčić, D., Solarić, N.: *Mjerni instrumenti i sustavi u geodeziji i geoinformatici*, Školska knjiga, Zagreb, 2008.
2. Frančula, N.: *Kartografske projekcije*, lecture notes, Faculty of Geodesy of the University of Zagreb, Zagreb, 2000.
3. Janković, M.: *Inženjerska geodezija II*, Tehnička knjiga, Zagreb, 1982.
4. Macarol, S.: *Praktična geodezija*, Tehnička knjiga, Zagreb, 1985.

PHYSICAL EDUCATION AND HEALTH CULTURE 1

Credits (ECTS): -

Hours (total per semester):

- Lectures: 0
- Exercises: 30

Course objectives:

- …

Entry competences (prior knowledge, descriptive):

- …

Learning outcomes:

- ….

Course content (by course schedule):

- Lectures:
  1. Basketball
  2. Volleyball
  3. Futsal
  4. Handball
  5. Table tennis
  6. Badminton
  7. Archery
  8. Skating
  9. Walking tours

Students' obligations:

- During the semester, students must attend 30 hours of exercises on the selected program or on several selected programs.
- A partial exemption can be obtained based on a health exemption certificate from the Institute for Public Health or a sports exemption through a certificate from sports clubs or the Olympic Committee.

End of semester grading:

- There is no final exam.

Elective courses

INTRODUCTION TO CIVIL ENGINEERING

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- To introduce and interest students in their future profession – civil engineering,
- Enabling students to start their orientation in some field of civil engineering already at the beginning of their studies, that is, a specialization in the later years of their studies.

Learning outcomes:

- The students will gain thorough knowledge about an extensive and ubiquitous profession – civil engineering,
- The students will learn to distinguish between the different areas of civil engineering,
- The students will learn what an element is, what a form is, how to recognize and connect them, give them meaning and importance in the proportions they deserve,
- The students will be able to assess specific achievements and evaluate them in the context of the worldwide achievements in the field of civil engineering.

Course content (by course schedule):

- Lectures:
  1. Introduction: basic terms and basic requirements [2]
  2. Historical overview [2]
  3. Civil engineering profession [1]
  4. Structures in nature [1]
  5. Structural elements of construction works [2]
  6. Construction materials [1]
  7. Construction methods [1]
  8. Structures [2]
  9. 1st midterm exam [2]
  10. Transport infrastructure [2]
  11. Hydrotechnical and geotechnical structures [2]
  12. How a building is built [2]
  13. Sustainable development and digitalization in construction [1]
  14. Management of structures [1]
  15. Regulations and standards [1]
  16. Ethics in civil engineering [1]
  17. Special achievements in construction [1]
  18. Croatian achievements in civil engineering [1]
  19. 2nd midterm exam [2]
  20. Retest [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures, i.e., 9 recorded attendances (a seminar paper can make up for 2 absences from lectures)

- First midterm exam
- Second midterm exam
- Lecture attendance exceeding 75%, i.e., 10, 11, 12, or 13 recorded attendances

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures, i.e., 9 recorded attendances (a seminar paper can make up for 2 absences from lectures)
- Written exam
- Lecture attendance exceeding 75%, i.e., 10, 11, 12, or 13 recorded attendances

Required reading:

1. J. Radić: *Uvod u graditeljstvo,* HAZU, Zagreb, 2016.
2. Lecture materials published on the Merlin platform.

HISTORY OF BUILDING

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Familiarizing students with the development of construction, especially from the point of view of the development of construction solutions and materials

Learning outcomes:

After successfully completing the course, students will be able to

- Follow professional literature and apply acquired knowledge in further training,
- Use acquired knowledge in engineering analyses and work methodology,
- Differentiate between assumptions, arguments and solutions in engineering work,
- Shape and creatively apply the acquired knowledge in practice,
- Present professional topics.

Course content (by course schedule):

- Lectures:
  1. Introduction – the art and history of construction [2]
  2. Construction as primary process, structural elements, historical conditionality of shaping [2]
  3. Construction in Mesopotamia and Egypt [2]
  4. Construction in the Aegean area and Greece [2]
  5. Construction in Ancient Rome [2]
  6. Construction in late Antiquity and early Christianity [2]
  7. Construction in the Middle Ages: Pre-Romanesque, Romanesque, and Gothic style [2]
  8. The modern era I – Humanism and Renaissance [2]
  9. The modern era I – Baroque and Classicism [2]
  10. The modern era II – Foundations of a new Architecture [2]
  11. The present, trends, and tendencies [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm
- Second midterm

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam

Required reading:

1. Bašić S., Sladoljev M., Vezilić N.: Lecture notes for internal use and print copies of lectures.

Additional reading:

1. Muller W., Vogel G.: *Atlas arhitekture 1 & 2*, Golden marketing, Zagreb, 1999.
2. Jason, H. W.: *Povijest umjetnosti*, Stanek d.o.o., 2004.
3. Addis, B.: *Building: 3000 Years of design engineering and construction*, Phaidon, 2007.

SOCIOLOGY OF WORK AND PROFESSIONAL ETHICS

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- The main objective of the course is to train future civil engineers to solve interpersonal problems at the workplace. The course Sociology of Work provides therefore an insight into the basic knowledge of psychology and sociology applied to work. The entire material is adapted to the specifics of the civil engineering profession. While other courses at the Faculty of Civil Engineering primarily deal with construction technology, this course aims at training civil engineers to successfully manage people, to adequately form work groups, and to be able to form positive interpersonal relationships at the workplace, which ultimately enables a significant increase in work productivity. In addition, the course provides basic knowledge of professional ethics. Through discussions with students, the connections between business efficiency and compliance with the principles of business ethics will be analysed.

Entry competences (prior knowledge, descriptive):

- Secondary school knowledge from social sciences courses

Learning outcomes:

- Knowledge of current trends in work;
- Knowledge of proper methods of employee selection;
- Knowledge of methods of motivating employees;
- Knowledge of the basic principles of professional ethics of civil engineers.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]

2. Basic concepts from the sociology of work [2]
3. History of work [2]
4. Classical organization theories [2]
5. Experiments by Elton May [2]
6. Selection of employees [2]
7. Work motivation, rewarding and sanctioning employees [2]
8. Work career [2]
9. Specific features of work in construction [2]
10. Professionalism [2]
11. Professional and business ethics [2]
12. Ethics of studying, scientific ethics [2]
13. Ethics of civil engineers, final lecture [2]

Student Evaluation - Continuous assessment:

- Attendance at a minimum of 11 lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Attendance at a minimum of 11 lectures
- Written exam

Required reading:

1. Antić, Miljenko: *Sociologija rada i profesionalna etika,* Electronic coursebook, 2016.

Additional reading:

1. Haladin, Stjepan: *Tehnologija i organizacija: uvod u sociologiju rada i organizacije*. Zagreb: Društvo za organizaciju građenja Republike Hrvatske, 1993.
2. Jennings, Marianne M. 2006. Business Ethics: Case Studies and Selected Readings. Eagan, USA: Thomson West.
3. Haladin, Stjepan i Miljenko Antić. 2004. Društvene znanosti u obrazovanju građevinskih inženjera, Građevinar 56 (11), Zagreb, str. 690-692.
4. Vecchio, Robert P. 2003. Organizational behavior: core concepts. Mason, Ohio: Thomson/South-Western.
5. Dienhart, John W. 2000. Business, Institutions and Ethics: A Text with Cases and Readings. Oxford University Press.
6. Dessler, Gary. 2005. Human Resource Management. Upper Saddle River, USA: Pearson Education.
7. Kendall, Dina. 2002. Sociology in Our Times: The Essentials. Belmont, USA: Wadsworth.
8. Miller, D.C. i V.H. Form. 1966. Industrijska sociologija. Zagreb: Panorama.
9. Taylor, Frederick Winslow. 1967. Naučno upravljanje. Beograd: Rad.
10. Šporer, Željka. 1990. Sociologija profesije: ogled o društvenoj uvjetovanosti profesionalizacije. Zagreb: Sociološko društvo Hrvatske.
11. Parkinson, C. Northcote i M.K. Rustomji. 1984. Biblija za menadžere. Zagreb: Privredni vjesnik.

SOCIOLOGY OF WORK AND PROFESSIONAL ETHICS

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- The main objective of the course is to train future civil engineers to solve interpersonal problems at the workplace. The course Sociology of Work provides therefore an insight into the basic knowledge of psychology and sociology applied to work. The entire material is adapted to the specifics of the civil engineering profession. While other courses at the Faculty of Civil Engineering primarily deal with construction technology, this course aims at training civil engineers to successfully manage people, to adequately form work groups, and to be able to form positive interpersonal relationships at the workplace, which ultimately enables a significant increase in work productivity. In addition, the course provides basic knowledge of professional ethics. Through discussions with students, the connections between business efficiency and compliance with the principles of business ethics will be analysed.

Entry competences (prior knowledge, descriptive):

- Secondary school knowledge from social sciences courses

Learning outcomes:

- Knowledge of current trends in work;
- Knowledge of proper methods of employee selection;
- Knowledge of methods of motivating employees;
- Knowledge of the basic principles of professional ethics of civil engineers.

Course content (by course schedule):

- Lectures:
  1. Introduction
  2. Definition of basic terms
  3. History of work
  4. Classical theories about the organization of work
  5. Elton Mayos experiment
  6. Selection of workers
  7. Work motivation
  8. Rewarding and punishing of workers
  9. Working career
  10. Professionalism
  11. Professional and business ethics
  12. Ethics of studying and scientific ethics
  13. Business ethic and profit
  14. Ethics of civil engineers, final lecture

Student Evaluation - Continuous assessment:

- Attendance at no less than 11 lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Attendance at no less than 11 lectures
- Written exam

Required reading:

1. Antić, Miljenko: *Sociology of work and professional ethics,* Electronic coursebook, 2016.

Additional reading:

1. Jennings, Marianne M.: *Business Ethics: Case Studies and Selected Readings*, Eagan, USA: Thomson West, 2006.
2. Vecchio, Robert P.: *Organizational behavior: core concepts*, Mason, Ohio: Thomson/South-Western, 2003.
3. Dienhart, John W.: *Business, Institutions and Ethics: A Text with Cases and Readings*, Oxford University Press, 2000.
4. Dessler, Gary: *Human Resource Management, Upper Saddle River*, USA: Pearson Education, 2005.
5. Kendall, Dina: *Sociology in Our Times: The Essentials*, Belmont, USA: Wadsworth, 2022.

OUTLINE OF CIVIL ENGINEERING LEGISLATION

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Introducing the basics of the public (planning and construction) and private law (property law and law of obligations).

Learning outcomes:

- Knowledge of and understanding the basics of the legal system,
- Knowledge of and understanding the basics of property law,
- Knowledge of and understanding the basics of the law of obligations,
- Knowledge of and understanding the basics of spatial planning,
- Knowledge of and understanding the basics of construction.

Course contents:

- Lectures:
    1. Introductory lecture [2]
    2. Basic questions related to the structure of law [4]
    3. Status issues – natural and legal persons [2]
    4. Legal affairs [2]
    5. Property law – possession [2]
    6. Property law – right of ownership [2]
    7. Property law – property rights and land registers [2]
    8. Property rights on other people's possession [2]
    9. Obligation law – general [2]
    10. Obligation law – agreements [2]

11. Cadastre, spatial planning, construction [4]
12. Basic chapters of labour law [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- Completed quizzes on Merlin
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Completed quizzes on Merlin
- Written exam
- Oral exam

Required reading:

1. Rajčić, D., Nikšić, S.: *Uvod u građevinsko prava*, university coursebook, HSN Zagreb 2008.
2. Act on Construction (Official Gazette No. 153/13).
3. Physical Planning Act (Official Gazette No. 153/13)

Additional reading:

1. Relevant regulations

BUSINESS ECONOMICS

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquiring theoretical knowledge about the history and development of economic science,
- Getting to know the concept of a company, its business operations, business results, and the environment in which the company operates.

Learning outcomes:

- Description of the development of economics as a scientific discipline and list the most important economic theorists throughout history,
- Definition of the types of companies, the limitations and principles of business operations, and the business itself through the process of reproduction and business assets,
- Differentiation between business costs, prices and calculations,
- Interpretation of indicators of business results,
- Analysis of the business environment of the company and the factors that affect the company's business operations.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Concepts and history of economics [2]

3. Basics of reproduction process[2]
4. Business assets [2]
5. Costs [2]
6. Prices and calculations [2]
7. Business results [2]
8. Company – concept and types [2]
9. Business environment of the company [2]
10. Factors influencing the company's operations [2]
11. Factors affecting the business of construction companies [2]

Student Evaluation - Continuous assessment:

- Preparation of a seminar paper within the prescribed deadline
- 75% attendance at lectures
- Midterm exams
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a seminar paper within the prescribed deadline
- 75% attendance at lectures
- Written exam
- Oral exam

Required reading:

1. Mariza Katavić: *Osnove ekonomike za graditelje*, Hrvatska sveučilišna naklada, Zagreb, 2009.
2. Lecture notes (materials available on Merlin).

ENGLISH IN CIVIL ENGINEERING 1

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Systematization of basic grammatical structures. Acquiring the terminology of construction materials, history of civil engineering and civil engineering in general. Mastering the technique of translating specialized texts. Delivering short presentations. Expanding the lexicon with elements of conversation. Mastering the correct structuring of sentences and the correct application of grammatical categories.

Entry competences (prior knowledge, descriptive):

- Upper-intermediate (B1).

Learning outcomes:

- Mastering language competences that include civil engineering terminology; independent comprehension of professional literature;
- Reinforcement of basic grammatical categories in professional language – use of the passive voice, past tenses, modal verbs;

- Gaining fluency in structuring sentences and developing skills of delivering individual presentation and writing technical texts.

Course content (by course schedule):

- Lectures:
  1. Civil Engineering as a Profession [2]
  2. What is Cool about Being an Engineer [2]
  3. Go Where the Action Is [2]
  4. Environmental Engineering [2]
  5. Principal Construction Materials [2]
  6. The Birth of Modern Structures [2]
  7. Up in the Air [2]
  8. Bridges [2]
  9. Construction of Bridges [2]
  10. Skyscrapers [2]
  11. Steel Structures [2]
  12. Revision of tenses [2]
  13. Revision of vocabulary [2]
  14. Domes [2]
  15. Aswan High Dam [2]

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 75% attendance at lectures
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 75% attendance at lectures
- Written exam
- Oral exam

Required reading:

1. A. Kralj Štih: *English in Civil Engineering*, Hrvatska sveučilišna naklada, 2004.

Additional reading:

1. D. Bonamy: *Technical English 3*, Pearson Longman, 2011.
2. Building Big Program http://www.pbs.org/wgbh/buildingbig/bridge/ http://www.brantacan.co.uk/bridgedefs.htm

GERMAN IN CIVIL ENGINEERING 1

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Systematization of basic grammatical structures. Acquiring the terminology of construction materials and civil engineering in general. Mastering the technique of translating specialized texts. Delivering short presentations. Expanding the technical language lexicon with elements of conversation.

Learning outcomes:

- Acquisition of language competences that include basic specialized terminology in the field of civil engineering and building construction, development of modern construction science, organization of civil engineering studies, structure development and history of skyscrapers, development of construction materials, and bridges;
- Independent reading of specialized literature;
- Reinforcement of basic grammatical categories in professional language – use of the passive voice, past tenses, modal verbs;
- Gaining fluency in pronunciation, structuring sentences, and developing skills of delivering individual presentation and writing technical texts.

Course content (by course schedule):

- Lectures:
  1. Was ist Bauingenieurwesen? [2]
  2. Wie wird man Bauingenieur(in)? [2]
  3. Bauingenieure haben ein weites Feld... [2]
  4. Gebiete der Bautätigkeit [2]
  5. Geschichte der Baustoffe [2]
  6. Wie haben Erfindungen das Aussehen von Bauten verändert? [2]
  7. Die wichtigsten Baustoffe [2]
  8. Die Entwicklung der ersten Wolkenkratzer [2]
  9. Das Stahlgestell [2]
  10. Die Brücken I [2]
  11. Die Brücken –II [2]
  12. Ein Mann der Perfektion – G. Eiffel [2]
  13. Konstruktiver Ingenieurbau [2]

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 75% attendance at lectures
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 75% attendance at lectures
- Written exam
- Oral exam

Required reading:

1. A. Kralj Štih: *Deutsch in Bauingenieurwesen*, Hrvatska sveučilišna naklada, 2005.

Additional reading:

1. G. Rocco: Übungsgrammatik für Anfänger: Lehr- und Übungsbuch. Niveau A2.

1st year, 2nd semester

Mandatory courses

MATHEMATICS 2

Credits (ECTS): 8

Hours (total per semester):

- Lectures: 60
- Exercises (auditory): 45

Course objectives:

- Application of theoretical knowledge on differential and integral calculus for the functions of several variables,
- Acquiring basic competences in differential equations,
- Acquiring basic competences in contour and surface integrals.

Entry competences (prior knowledge, descriptive):

- Basic knowledge of differential and integral calculus, analytic geometry in space.

Prerequisite:

- Enrolment requirements: teacher's signature for the course: Mathematics 1
- Requirements for taking the exam: course exam passed: Mathematics 1

Learning outcomes:

- Knowing basic theorems about differential equations, recognizing types of equations, and understanding methods of solving,
- Recognizing the problems whose solution leads to ordinary differential equations,
- Knowledge of basic facts and theorems about function of several variables,
- Knowledge of basic facts and theorems about multiple integrals,
- Knowledge of basic facts and application of contour and surface integrals.

Course content (by course schedule):

- Lectures:
  1. Ordinary differential equations, an introduction [2]
  2. The method of separation of variables [2]
  3. First-order linear differential equation [2]
  4. Second-order linear differential equation [4]
  5. Functions of several variables, introduction [2]
  6. Continuity and limit of functions of several variables [2]
  7. Differential of functions of several variables, higher order derivatives [4]
  8. Taylor's theorem [2]
  9. Extremal value of functions of several variables [4]
  10. Multiple integrals, double integrals [4]
  11. Triple integrals [2]
  12. Integration by substitution [4]
  13. Application of multiple integrals in mechanics [4]
  14. Fields, scalar and vector fields, gradient [2]
  15. Divergence and rotation, special fields [4]
  16. Curves and line integrals, line integral of the first kind [4]

17. Line integral of the second kind [4]
18. Surface integrals, surfaces, surface integrals of the first kind [2]
19. Surface integrals of the second kind [2]
20. Divergence theorem, Stokes' theorem [2]

- Exercises (auditory):
  1. Ordinary differential equations [7]
  2. Functions of several variables [11]
  3. Multiple integrals, applications [12]
  4. Fields [3]
  5. Line integrals [6]
  6. Surface integrals [6]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam – problems
- First midterm exam – theory
- Second midterm exam – problems
- Second midterm exam – theory

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Lecture notes for internal use available at: http://www.grad.unizg.hr/_download/repository/MAT2.pdf

Additional reading:

1. I. Brnetic, V. Županovic: *Višestruki integrali*, Element, Zagreb, 2004.
2. N. Elezović: *Diferencijalne jednadžbe*, Element, Zagreb, 2004.
3. P. Javor: *Matematička analiza 2*, Element, Zagreb, 2004.
4. L. Korkut, M. Krnić, M. Pašić: *Vektorska analiza*, Element, Zagreb, 2007.
5. S. Kurepa, Matematička analiza I., Tehnička knjiga, Zagreb 1975.
6. Ž. Pauše: *Matematički priručnik 2*, Školska knjiga, Zagreb 2004.

PHYSICS

Adjuncts: Teachers from the Faculty of Science, according to the annual agreement between the Faculty of Civil Engineering and the Faculty of Science.

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 60

- Exercises: 15 (auditory: 1; laboratory, in the laboratory of the Department of Physics at the Faculty of Science (14)

Course objectives:

- Lectures**:** *acquiring* knowledge in solving special examples and tasks, setting up physics experiments for verifying solutions of the problems; *developing* skills in reducing real life phenomena to physical models, skills in finding equations for physical models, skills in recognising a common physics basics for different real-life phenomena.
- Exercises**:** *developing* skills in preparation for laboratory work and skills for conducting laboratory experiments in a laboratory, data measuring and processing as a team, *gaining* knowledge about the physical basis of phenomena, and about measuring and processing measures.

Entry competences (prior knowledge, descriptive):

- Competence in applying vector, differential, integral and matrix calculus.

Prerequisite:

- Enrolment requirements: teacher's signature for the course: Mathematics 1
- Requirements for taking the exam: course exam passed: Mathematics 1

Learning outcomes:

- Competence in solving special examples and tasks, in setting physics experiments that verify the solutions of problems,
- Skills in recognising a common physical basics for different real-life phenomena,
- Skills in reducing real life phenomena to physical models, in finding equations for physical models,
- Skills in preparation for laboratory work, skill in laboratory teamwork, data measuring and processing, knowledge about the physical basis of phenomena, measuring and processing measures.

Course content (by course schedule):

- Lectures:
  1. Physical quantities and units. Particle kinematics: linear motion, motion in two and three dimensions, circular motion. [4]
  2. Particle dynamics: Newton's laws. Quantity of motion. Dynamics of circular motion and centripetal force. Friction. [4]
  3. Work, kinetic energy and potential energy. Energy conservation law. Collisions. [4]
  4. Material point balance. Moment of force. Rotation of a rigid body. [4]
  5. Dynamics of rotational motion. Balance and elasticity. [4]
  6. Fluid mechanics: pressure, buoyancy, surface tension, capillarity. Bernoulli's equation. Viscosity. [4]
  7. Gravity. Periodic motions: harmonic oscillator. [4]
  8. Mechanical waves. Sound. [4]
  9. Heat and temperature. Gas laws. Heat capacity, phase diagrams. Heat transfer. [4]
  10. Thermodynamics: first and second law of thermodynamics. Circular processes. Entropy. [4]
  11. Electric charge and electric field. Gauss's law. [4]
  12. Electric potential. Capacitors and dielectrics. [4]
  13. Electricity. Electric circuits. [4]
  14. Magnetism. [4]

15. Modern physics. Photoelectric effect. Photons. Quantum mechanics. Atomic structure. [4]

- Laboratory exercises and auditory exercises: follow the lecture program.

Student Evaluation - Continuous assessment:
- Preparation of a report for the completed exercises within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:
- Preparation of a report for the completed exercises within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Exam

Required reading:
1. Kulišić, P.: *Mehanika i toplina,* Školska knjiga, Zagreb, 1991.
2. Henč-Bartolić, V.; Kulišić, P.: *Valovi i optika,* Školska knjiga, Zagreb, 1989.
3. Young, H. D.; Freedman, R. A.: University Physics, Addison-Wesley, San Francisco, 2012.
4. Pavičić, M.: *Zbirka riješenih zadataka iz fizike,* (2. izdanje), Sveučilište u Zagrebu, Zagreb, 1984.
5. Babić, E.; Krsnik, R.; Očko, M.: *Zbirka riješenih zadataka iz fizike,* Školska knjiga, Zagreb, 1988.

MECHANICS 1

Credits (ECTS): 5

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (auditory: 26; design: 4)

Course objectives:
- Teach students the methods of solving problems that arise in engineering calculations of statics as part of technical mechanics;
- Acquisition of theoretical knowledge about the behaviour of the structure under load and about the methods of force transmission;
- Acquisition of practical knowledge on calculation procedures of statically determinate structures.

Entry competences (prior knowledge, descriptive):
- Knowledge of linear algebra, trigonometry, differential and integral calculus (including ordinary differential equations),
- Knowledge of descriptive geometry and secondary school physics.

Learning outcomes:

- Acquire knowledge on the basic axioms and theorems of the statics of rigid bodies, explain the concept of force and moment, be able to determine the components of force in a plane and space, the resultant of a system of forces, the moment of a force about a point and about an axis and the moment of a couple,
- Learn how to reduce a system of forces to selected points,
- Set up equations of equilibrium in a plane and space and determine unknown forces and reactions, get to know graphical analyses of systems of forces in a plane,
- Understand the concept of friction on a surface and determine frictional forces,
- Get to know the determination of the centre of gravity of volumes, surfaces, lines, and complex bodies,
- Explain and apply analytical and graphical procedures for calculating the reactions of statically determinate planar and spatial structures,
- Learn how to determine the distribution of internal forces in simple trusses, beams, three-jointed and Gerber girders, learn about the analysis of forces in cables,
- Explain the concept of virtual work.

Course content (by course schedule):

- Lectures:
  1. Basic concepts and principles. Vector operations. Statics of a particle: forces in plane and space [2]
  2. Rigid bodies: moment of force about a point and about an axis, moment of a couple [2]
  3. Force reduction. The resulting action of the system of forces. Resultant and equilibrium of the system of forces. Equilibrium equations [2]
  4. Statics of bodies in a plane [2]
  5. Connected systems in a plane. Supports in plane. Classification of connected systems [2]
  6. Spatial connected systems. Calculation of reactions. [2]
  7. Forces in parallels. Distributed forces. Centre of gravity. [2]
  8. Beam statics (1). Axis. Internal forces (pinned element, beam). [2]
  9. Beam statics (2). Differential equilibrium equation. A simply supported beam. Diagrams of internal forces. [2]
  10. Beam statics (3). A polygonal girder in a plane. [2]
  11. Beam statics (4). A polygonal girder in space. [2]
  12. Statically determinate simple trusses in plane and space. [2]
  13. Mechanical work and virtual displacements. [2]
  14. Equilibrium of mechanisms. Friction. [2]

- Exercises (auditory):
  1. Introduction. Statics of a particle: Forces in a plane, resultants, equilibrium. Forces in space.
  2. Determining the moment of force about a point and about an axis.
  3. The resulting action. Body equilibrium.
  4. Examples of body equilibrium for joint forces in a plane. Analytical and graphical procedures.
  5. Determination of reactions of planar systems by analytical and graphical procedures.
  6. Determination of reactions in spatial systems. Centres of gravity.
  7. Internal forces in beams. Diagrams of internal forces. (1)

8. Design exercises: Internal forces in beams. Diagrams of internal forces. (2)
9. 1st midterm exam
10. Differential equations between internal forces and loads. Internal force function flow analysis.
11. Polygonal girders.
12. Simple trusses.
13. 2nd midterm exam
14. Trapezoidal beam load - reactions and internal forces. Beams in space (1)
15. Design exercises: Beams in space (2)

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Werner, H.: *Mehanika 1 - Statika*, HSGI, Zagreb, 2007.
2. Nikolić, Ž.: *Mehanika 1*, Sveučilište u Splitu, Fakultet građevinarstva, arhitekture i geodezije, 2022.
3. Matejiček, F.; Semenski, D.; Vnučec, Z.: *Uvod u statiku sa zbirkom zadataka*, Golden marketing, Tehnička knjiga, Zagreb, 2005.

Additional reading:

1. Beer, F. P.; Johnston, E. R.: *Vector Mechanics for Engineers – Statics*, McGraw-Hill, 1988.
2. Kiričenko, A.: *Tehnička mehanika - Statika*, IGH, Zagreb, 1990.
3. Muftić, O.: *Mehanika 1 - Statika*, Tehnička knjiga, Zagreb 1991.
4. Bazjanac, D.: *Tehnička mehanika - Statika*, Tehnička knjiga, Zagreb, 1963.

BUILDING CONSTRUCTION

Credits (ECTS): 7

Hours (total per semester):

- Lectures: 45
- Exercises: 45 (construction)

Course objectives:

- To acquaint students with the structure of buildings, the way in which the whole is composed of its elements, and the issues in the functioning of primary and secondary structures in a building.

Learning outcomes:

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

- Analyse the structure of high-rise buildings,
- Describe the way a building is composed of its elements,
- Assess the issues of functioning of the primary structure (bearing structure) and secondary structure (infill structure) in the building,
- Present professional topics related to the structure of high-rise buildings,
- Use acquired knowledge in engineering analyses and work methodology.

Course content (by course schedule):

- Lectures:
  1. Introduction. Foundation. Hydro-insulation [3]
  2. Basic elements and construction typologies of high-rise buildings... [3]
  3. Stone masonry [3]
  4. Concrete slabs [3]
  5. Dividing slabs [3]
  6. Wall finishes [3]
  7. Ceiling construction [6]
  8. Flooring [3]
  9. Roofs [3]
  10. Roofing [3]
  11. Staircases [3]
- Exercises:
  - 1-5 Site plan 1:500. Preliminary design, ground plan 1:200. Main design, ground plan 1:100.
  - 6-10 Ground plan 1:50.
  - 11-15 Cross-section, staircase and roof 1:50.

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures, 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures, 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Bašić, S.; Sladoljev M.; Vezilić Strmo, N.: Lecture notes for internal use and print copies of lectures

Additional reading:

1. Peulić, Đ.: *Konstruktivni elementi zgrada I. i II.*, Tehnička knjiga, Zagreb, 1980.
2. Peulić, Đ.: *Konstruktivni elementi zgrada*, Croatia knjiga, Zagreb, 2002.
3. Neufert, P.: *Elementi arhitektonskog projektiranja*, Golden marketing, Zagreb, 2002.

MATERIALS SCIENCE

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises (auditory and laboratory): 10 + 5

Course objectives:

- Acquiring knowledge about the internal structure of materials and its connection with the properties of the materials,
- Acquiring knowledge about the behaviour of materials under mechanical and permanent loads.

Entry competences (prior knowledge, descriptive):

- Basic knowledge of physics and chemistry.

Learning outcomes:

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

- Interpret the influence of internal structure on material properties,
- Explain surface properties and capillary phenomena,
- Explain the chemical aspects of the construction material,
- Compare thermal properties of different materials,
- Describe the behaviour of the material under mechanical loads,
- Calculate the basic physical and mechanical properties of the material based on test results,
- Process the results of material testing with simple statistical methods.

Course content (by course schedule):

- Lectures:
  1. Introduction to construction materials [2]
  2. Physical properties of the material - mass, volume, density, porosity [2]
  3. Properties of engineering materials and their application [2]
  4. Surface properties: surface tension, adsorption, capillary phenomena. Other important physical properties [2]
  5. Bonds between atoms. Microstructure development [2]
  6. Thermal, acoustic, and optical properties of materials [2]
  7. Chemical properties of construction materials [2]
  8. Mechanical properties of materials [4]
  9. Material testing. Statistical analysis [2]
  10. Fracture mechanics [2]
  11. Rheology of fluids and liquids [2]
  12. Material fatigue [2]
  13. Material durability [2]
  14. Technical regulations and legislation [2]
- Exercises:
  1. Physical parameters of materials [3]
  2. Permeability properties [3]
  3. Thermal properties of materials [3]
  4. Mechanical properties of materials [4]
  5. Statistical analysis of test results [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- 2 program assignments submitted within the prescribed deadline and positively evaluated
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- 2 program assignments submitted within the prescribed deadline and positively evaluated
- Written exam

Required reading:

1. Bjegović, D.; Balabanić, G.; Mikulić, D.: *Građevinski materijali – zbirka riješenih zadataka*, Građevinski fakultet Sveučilišta u Zagrebu, 2007.
2. Young, J. F.; Mindess, S.; Gray, R. J.; Bentur, A.: *The Science and Technology of Civil Engineering Materials*, Prentice Hall, 1998.
3. Ukrainczyk, V.: *Poznavanje gradiva*, Alcor, Zagreb, 2001.
4. Beslać, J.: *Materijali u arhitekturi i građevinarstvu*, Školska knjiga Zagreb, 1989.
5. Banjad Pečur, I; Štirmer, N.: Lecture notes for internal use for the course Materials Science, course repository, http://moodle. srce.hr; http://www.grad.unizg.hr/predmet/pozmat
6. Lukman, T.; Kalšan, D.; Plavljanić, Đ.; Milovanović, B.; Carević, I.; Ćurković, K.; Grgurić, S.; Ivanović, M., Hrvatska udruga proizvođača toplinsko-fasadnih sustava: Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Zajednički dio, Banjad Pečur, I. (ed.), Sveučilište u Zagrebu Građevinski fakultet, 2016.
7. Kalšan, D.; Milovanović, B: Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere, Monter suhe gradnje, Banjad Pečur, I. (ed.), Sveučilište u Zagrebu Građevinski fakultet, 2016.

Additional reading:

1. Ashby, M.; Jones, D. R. H.: *Engineering Materials 1*, Butterworth Heinemann, 2005.
2. Illston, J. M.; Domone, P. L. J.: *Construction Materials – Their Nature and their Behaviour*, Third Edition.

PHYSICAL EDUCATION AND HEALTH CULTURE 2

Credits (ECTS): -

Hours (total per semester):

- Lectures: 0
- Exercises: 30

Course objectives:

- …

Entry competences (prior knowledge, descriptive):

- …

Learning outcomes:

- ….

Course content (by course schedule):

- Lectures:
  1. Fitness
  2. Pilates
  3. Zumba
  4. Football
  5. Basketball
  6. Volleyball
  7. Handball
  8. Badminton
  9. Table tennis
  10. Athletics
  11. Archery
  12. Skating
  13. Walking tours

Students' obligations:

- During the semester, students must attend 30 hours of exercises on the selected program or on several selected programs.
- A partial exemption can be obtained based on a health exemption certificate from the Institute for Public Health or a sports exemption through a certificate from sports clubs or the Olympic Committee.

End of semester grading:

- There is no final exam.

2nd year, 3rd semester

Mandatory courses

PROBABILITY AND STATISTICS

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises (auditory: 24, computer: 6)

Course objectives:

- Acquiring basic theoretical knowledge about descriptive and inferential statistics and theory of probability,
- Acquiring basic statistical culture.

Entry competences (prior knowledge, descriptive):

- Secondary school mathematics.

Learning outcomes:

- Ability to understand and interpret descriptive statistical data,
- Ability to present descriptive-statistical data,
- Understanding the concept of random variable,
- Knowing the basic features and areas of applicability of the most common probability distributions,
- Understanding the relationship of statistical quantities in a population and sample,
- Knowledge and ability to apply elementary methods and techniques of inferential statistics – interval estimations, tests.

Course content (by course schedule):

- Lectures:
  - The concept of an event. Definitions of probability.
  - Conditional probability. Independent events.
  - Discrete random variables. Likelihood function. Probability distribution function.
  - Expectation, variance and standard deviation of a discrete random variable.
  - Examples of discrete random variables.
  - Continuous random variables. Probability density function and distribution function of a continuous random variable.
  - Expectation, variance and standard deviation of a continuous random variable
  - Uniform, normal, exponential random variable.
  - Function of random variables, random vector and correlation.
  - Descriptive statistics. Organization, presentation, and interpretation of data
  - Descriptive statistics. Measures of central tendency and dispersion.
  - Population and sample. Confidence intervals. Interval estimate of the expectation of a normal distribution
  - The concept of statistical test. Normal distribution hypotheses tests.
  - Probability hypothesis tests. Linear regression

- Exercises (auditory):

1. Combinatorics.
2. The concept of an event. Definitions of probability.
3. Conditional probability. Independent events.
4. Discrete random variables. Likelihood function. Probability distribution function.
5. Expectation, variance and standard deviation of a discrete random variable.
6. Examples of discrete random variables.
7. Continuous random variables. Probability density function and distribution function of a continuous random variable.
8. Expectation, variance and standard deviation of a continuous random variable.
9. Uniform, normal, exponential random variable.
10. Function of random variables, random vector and correlation.
11. Descriptive statistics. Organization, presentation, and interpretation of data.
12. Descriptive statistics. Measures of central tendency and dispersion.

- Exercises (computer)

1. Population and sample. Confidence intervals. Interval estimate of the expectation of a normal distribution.
2. The concept of statistical test. Normal distribution hypotheses tests.
3. Probability hypothesis tests. Linear regression.

Student Evaluation - Continuous assessment:

- Submission of homework
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exams – theory and problems
- Computer-based exam

Student Evaluation - Examination without Continuous Assessment:

- Submission of homework
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Adžaga, N., Martinčić Špoljarić, A. i Sandrić, N. Vjerojatnost i statistika. https://www.grad.unizg.hr/_download/repository/VIS.pdf
2. Pauše, Ž. Vjerojatnost, Školska knjiga, Zagreb, 1988.
3. Pauše, Ž. Uvod u matematičku statistiku, Školska knjiga, Zagreb, 1993.
4. Sarapa, N. Teorija vjerojatnosti, Školska knjiga, Zagreb, 1992.
5. Ilijašević, M. i Pauše, Ž. Riješeni primjeri zadaci iz vjerojatnosti i statistike, Zagreb, 1990.

STRENGTH OF MATERIALS 1

Credits (ECTS): 7

Hours (total per semester):

- Lectures: 45
- Exercises: 45 (auditory: 36, laboratory: 4, design: 5)

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of deformable bodies under the action of external loads,
- Acquisition of theoretical knowledge about the mechanical properties of materials, and the calculation of stresses and deformations of structural elements and the entire structure,
- Acquisition of practical knowledge about procedures for calculating the strength and stiffness of structural elements.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra,
- Knowledge of rigid body statics,
- understanding the concepts of internal forces.

Prerequisite:

- Enrolment requirements: teacher's signature for the courses Mathematics 2 and Mechanics 1,
- Requirements for taking the exam: Mathematics 2 and Mechanics 1 course exams passed.

Learning outcomes:

Students will be able to:

- Applying differential equations of balance and transformation equations to the analysis of stresses and strains,
- Using physical equations and Hooke's law to determine the characteristics of deformable rigid bodies,
- Calculating the stresses of straight rods with torsion,
- Distinguishing pure straight bending, forced bending and skew bending and calculate the strength of the load-bearing element during bending,
- Identifying and calculating the stresses in bending compound and composite girders,
- Defining and calculating the stresses in the fastener elements loaded in shear,
- Using differential equations of the elastic line of a girder when calculating the deflection and angle of rotation of the girder,
- Calculating stress and deformation of thin-walled vessels.

Course content (by course schedule):

- Lectures:
  1. General assumptions and basic elements of the calculation. External and internal forces. Basic rod load cases. A general approach to problem solving in the science of strength of materials. Stress analysis. The concept of stress. Stress tensor. Differential equilibrium equation. Transformations of stress tensors components [3]
  2. Main normal and shear stresses. Mohr's circle of stress. Cauchy stress tensor. Stress ellipsoid. Octahedral stresses. Spherical tensor and stress tensor deviator. Connection between internal forces and stress components [3]
  3. Analysis of deformations. The concept of displacement and deformation. Deformation components. Strain tensor. Deformations in a given direction. The directions and sizes of main deformations. Volume deformation. Plane state of deformation. Conditions

of continuity of deformations. Deformable characteristics of rigid bodies – physical equations [3]

4. Experimental data on the relationship between stress and deformation. Hooke's law, material elastic constant. Law of superposition. Saint-Venant's Principle. Hooke's law for: spatial state of stress, plane state of stress, and plane state of strain. Effect of temperature [3]
5. Allowable stress, coefficient of safety, and recent interpretations of structural safety. A general approach to problem solving in the science of strength of materials. Axial load of a rod – stretching and pressure [3]
6. The effect of own weight. A rod with equal tensile and compressive strength. Composed rod. Plan of displacement. Statically indeterminate rod systems. Thermal stresses. Initial stresses. Stress concentration. Potential energy of deformations of an axially loaded rod [3]
7. Axial impact load of the rod. Cable rope extension. Stress and deformation of thin-walled vessels. Shearing. Pure shear potential energy. Calculation of elements loaded in shear [3]
8. Torsion. Torsion of straight rods of a circular cross-section. Potential energy of deformations during torsion. Statically indeterminate problems in torsion. Torsion of non-round cross-section rods. Prandtl's membrane analogy [3]
9. Torsion of thin-walled rods with an open section. Torsion of thin-walled rods of a closed section. Coil springs. Geometrical characteristics of straight sections of a rod – moments of inertia [3]
10. Change of moments of inertia during translation and rotation of the coordinate system. Main moments of inertia. Mohr's circle of inertia. Radius of inertia. Ellipse of inertia. Moments of inertia of simple sections. Moments of resistance of plane sections [3]
11. Bending of straight rods. Pure bending. Calculation of strength and selection of a section in pure bending. Potential energy of deformations during pure bending. General case of bending (bending with forces). Shear stresses in symmetric thin-walled rods [3]
12. Transverse normal stresses in bending a rod by transverse loading. Principal stresses and principal stress trajectories. Calculation of strength when bending by forces. Bending of rods of a variable section. Potential energy of deformations during bending by forces [3]
13. Calculation of composed girders (wooden and metal). Bending a stick made of different materials. Skew bending. Deformations of a straight rod during bending. Differential equations of the elastic line of a girder of the second and fourth order [3]
14. Analytical method of determining the elastic line of girders of constant and variable section. Graphoanalytical method of determining the deformation of the girder. Graphical determination of the elastic line of the girder [3]
15. Determining the deflection using the finite difference method. Deflection due to transverse force. Effect of temperature change on deflection. Calculation of bending stiffness [3]

- Exercises (auditory):
  1. Stress and deformation analysis [6]
  2. Extension and pressure. Rod systems [3]
  3. Stress and deformation of thin-walled vessels. Rings [3]

4. Shear [3]
5. Torsion [3]
6. Geometric characteristics of cross-sections [3]
7. Bending. Skew bending [6]
8. Deflection line of the girder [6]
9. Composite girders [3]

- Exercises (laboratory):
  1. Testing a normal rod, determining the diagram σ - ε. Determination of elasticity constants. Saint-Venant's Principle [3]
  2. The influence of sudden changes in cross-sections on the behaviour of elastic and elastoplastic materials. Torsion of a rod of circular cross-section. Principle of superposition [3]
- Midterm exams:
  1. Stress and deformation analysis. Extension and pressure. Rod systems. Shear
  2. Torsion. Bending. Stresses and deformations during bending

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at auditory exercises
- 100% attendance at laboratory exercises
- 100% attendance at design exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at auditory exercises
- 100% attendance at laboratory exercises
- 100% attendance at design exercises
- Written exam
- Oral exam

Required reading:

1. V. Šimić: *Otpornost materijala I*, Školska knjiga, Zagreb, 2002.

Additional reading:

1. I. Alfirević: *Nauka o čvrstoći I*, Tehnička knjiga, Zagreb, 1989.
2. D. Bazjanac: *Nauka o čvrstoći,* Tehnička knjiga, Zagreb, 1973.
3. J. Brnić, G. Turkalj: *Nauka o čvrstoći I,* Tehnički fakultet Sveučilišta u Rijeci, Rijeka, 2004.
4. Case, J, Chilver, A.: Strength of Materials and Structures, Edvard Arnold, 1985.

FLUID MECHANICS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 45

- Exercises (auditory and laboratory): 30 (26 + 4)

Course objectives:

- Acquisition of theoretical and practical knowledge in hydrostatics and kinematics of fluids, potential flow, dynamics of ideal and real fluids, hydrodynamics of flow and overflow, flow in open channels, groundwater flow, and modelling of hydrodynamic processes.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra,
- Knowledge and understanding of the mechanics of a material point (speed, acceleration, Newton's laws, change in momentum, energy, force, work, power),
- Knowledge and understanding of the physical properties of substances (phases of substances, density, specific volume and quantity of substances),
- Understanding the transfer of forces through substances, stress and pressure,
- Knowledge of rheology, speed of propagation of compressible phenomena, speed of sound, thermal expansion of solids and liquids, changes in state of matter, latent heat, heat capacity, heat conduction, surface tension and capillarity, adsorption and absorption,
- Knowledge of laws of thermodynamics.

Prerequisite:

- Enrolment requirements: teacher's signature for the course: Mathematics 2 and Physics,
- Requirements for taking the exam: Mathematics 2 and Physics course exams passed.

Learning outcomes:

- Explain basic concepts about liquids (fields of physical quantities, physical properties of liquids, rheological diagram, forces on liquids),
- Explain and apply calculation procedures in fluid statics (equilibrium equations, pressure forces on surfaces, buoyancy, stability and swimming of bodies),
- Explain the terms and apply calculation procedures in fluid kinematics (movement of fluid particles, flow line, trajectory, stationarity, uniformity, conservatism, total velocity, pressure and discharge
- Explain the terms and apply procedures and calculations in fluid dynamics (momentum conservation equation, general law of real fluid flow (Saint-Venant and Navier-Stokes equation), kinetic energy conservation equation, Bernoulli's equation for ideal and real fluid, laminar flow, turbulent flow, boundary layer, flow resistance, calculation of local and linear energy losses, geodetic, pressure and energy line, measurement of velocity, pressure and liquid flow),
- Apply the aforementioned knowledge to practical hydrotechnical problems (pressurized systems, pump, turbine, discharge, overflow, open watercourses, potential flow, groundwater flow, forces on a body in a fluid flow, dynamically stable and unstable forms, modelling of hydrodynamic processes).

Course content (by course schedule):

- Lectures:
  1. Introduction: basic concepts about liquids, fields of physical quantities, physical properties of liquids, rheological diagram, forces on liquids [3]
  2. Fluid statics: equilibrium equation (Euler) and its solution, relative rest [3]
  3. Fluid statics: pressure force on surfaces, buoyancy, swimming and stability of bodies in liquid [3]
  4. Kinematics of fluids: movement of fluid particles, flow line, trajectory, stationarity, uniformity, conservatism, total velocity derivative [3]

5. The law of conservation of the field of physical quantities: the law of conservation of mass (equation of continuity) [3]
6. Fluid dynamics: momentum conservation equation, general law of real fluid flow (Saint-Venant and Navier-Stokes equation) [3]
7. Kinetic energy conservation equation, Bernoulli's equation for ideal and real fluid, laminar flow, turbulent flow, boundary layer [3]
8. Flow resistances, calculation of local and line energy losses, G, T, E lines, measurement of speed, pressure and discharge [3]
9. Application to hydrotechnical problems: systems under pressure, pump, turbine [3]
10. Discharge: small opening, large opening, constitution, overflow: sharp-edged and practical profile overflows [3]
11. Open watercourses: diagram of specific energy, flow regimes, uniform flow [3]
12. Open watercourses: non-uniform flow, narrowing and elevation of the bed, hydraulic jump, deposit [3]
13. Potential flow: potential flow equations, boundary conditions, source, sink, dipole [3]
14. Groundwater flow: seepage and Darcy's law, hydrodynamic 3D theory, flows, hydraulic 2D theory, Dupuit's assumptions, water intakes [3]
15. Forces on a body in a fluid flow, dynamically stable and unstable forms, modelling of hydrodynamic processes [3]

- Exercises:
  1. Introductory exercises (auditory) [2]
  2. Hydrostatics (auditory) [2]
  3. Hydrostatics (auditory) [2]
  4. Relative rest, swimming and body stability (auditory and laboratory) [2]
  5. Law of conservation of mass, potential and eddy flow, uniform and non-uniform flow, stationary and unsteady flow (auditory) [2]
  6. Law of conservation of momentum, examples of systems in dynamic equilibrium (auditory) [2]
  7. The law of conservation of kinetic energy, Bernoulli's equation for an ideal fluid, energy and piezometer lines (auditory) [2]
  8. Bernoulli's equation for a real fluid, general solution, determination of local and line losses, measurement of flow and velocities, types of flow, energy and piezometer lines (auditory) [2]
  9. Bernoulli's equation for a real fluid, systems with pipelines under pressure, use of pumps and turbines (auditory and laboratory) [2]
  10. Outflow, sharp-edged spillways, practical profile spillways, specific energy of watercourses, critical depth, determination of flow regime, critical drop (auditory) [2]
  11. Open watercourses, Chezy's equation and application in analytical and graphoanalytical solving of flow problems in open watercourses (auditory) [2]
  12. Non-uniform flow, hydraulic jump and its division, waterfall, narrowing or widening of the watercourse, as well as the rise and fall of the bottom of the channel and the influence on the shape of the water surface (auditory and laboratory) [2]
  13. Potential flow, seepage, hydromechanical 3D and hydraulic 2D theory, use of Dupuit's assumption in engineering problem solving (auditory) [2]
  14. Groundwater flow, galleries, wells with a free water surface and wells under pressure, wells in individual work and in a group, calculations of lowering the level of groundwater in an aquifer under pressure and with a free water surface, the influence

of the proximity of watercourses and vertical impermeable boundaries (auditory and laboratory) [2]

15. Body resistance, modelling on physical models (Froude and Reynolds similarity), dimensional analysis (auditory) [2]
16. Dimensional analysis (auditory) [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Jović: *Osnove hidromehanike*, Element, Zagreb (available in the Library of the Faculty of Civil Engineering),
2. Fancev: *Mehanika fluida*, Tehnička enciklop., sv. 8 (available in the Library of the Faculty of Civil Engineering and at the Chair for Fundamental Research in Hydroscience at the address Savska 16)
3. Agroskin: *Hidraulika*, Tehnička knjiga (available in the Library of the Faculty of Civil Engineering)
4. Virag, *Mehanika fluida: odabrana poglavlja, primjeri i zadaci*, FSB (available in the Library of the Faculty of Civil Engineering)
5. Online: (http://www.grad.unizg.hr/predmet/mehtek)
    a. Lecture notes
    b. Lectures by weeks
    c. Solved example tasks
    d. Previous exams with a key

MECHANICS 2

Credits (ECTS): 5

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 26; construction: 4)

Course objectives:

- Acquire knowledge of the basic theory of motion of particles, bodies and simpler models of mechanical systems, as well as extend knowledge and its applicability in other courses,

- Acquire knowledge and develop an analytical approach to the formulation and solution of problems involving motion and dynamic actions and their effects on connections and internal forces.

Entry competences (prior knowledge, descriptive):

- Good knowledge of trigonometry and the basics of vector calculus,
- Knowledge of the methods of differential and integral calculus, and understanding of the meaning of derivative and integral,
- Knowledge of the statics of particles, bodies and mechanical systems, with an understanding of the transmission of forces in connections.

Prerequisite:

- Enrolment requirements: teacher's signature for the courses Mathematics 2 and Mechanics 1,
- Requirements for taking the exam: Mathematics 2 and Mechanics 1 course exams passed.

Learning outcomes:

- Learn to apply knowledge using mathematics and information technology in solving the problems of motion of particles, bodies, and simpler mechanical systems,
- Explain the kinematic constraints arising from specific connections,
- Explain and apply analytical procedures to determine velocities and accelerations, depending on how the particle motion is defined,
- Explain and apply both analytical and graphical methods for determining velocities and accelerations, depending on how the body motion is defined.,
- Explain and apply graphic procedures to determine the velocity field and displacement field of mechanisms,
- Explain the formulation of the motion problem and apply it to the solution in the motion of a particle, body and systems under the action of external forces,
- Identify and explain the motion of particles, bodies and systems depending on the constraints caused by different connections,
- Explain the problem of small oscillations and apply it to simpler problems in civil engineering that may occur under specific loading conditions.

Course content (by course schedule):

- Lectures:
  1. Introduction to the course, kinematics of a material point, basic concepts (position, velocity, acceleration), rectilinear motion.
  2. Curvilinear plane motion of a material point, choice of coordinate system (rectangular, natural, polar), law of motion. Examples of curvilinear motion: projectile motion, transition curves and loops. Relative motion of a material point.
  3. Dynamics of a material point, Newton's axioms, differential equation of motion, force acting as a function of time, velocity and displacement.
  4. The concept of work and kinetic energy. Equation of work and kinetic energy. Gravitational and elastic potential energy, energy laws and their application to the motion of a material point.
  5. The law of conservation of momentum and angular momentum, impulse of force, collision of a material point with a surface, and the definition of the coefficient of restitution.

6. Central collision of material points. Dynamics of the system of material points in relative motion. Movement of multiple material points connected by kinematic constraints (constrained motion).
7. Rigid body kinematics. Kinematic constraints and types of body motion (translation and rotation of the body around a fixed axis, general planar motion). Choice of reference point. Instantaneous centre of velocity and centre of acceleration in body motion. Basic theorem of rigid body kinematics.
8. Dynamics of rigid bodies, centre of mass and moment of inertia, Steiner's theorem, equations of body motion (Newton's axiom for translation and rotation of bodies).
9. The principle of work and energy in body motion. Kinetic and potential energy in rigid body motion.
10. Momentum and angular momentum, law of impulse and angular momentum for rigid bodies. Collision of a body and particle.
11. Kinematics of rigid body systems - mechanisms. Definition of relative instantaneous centre of velocities between bodies and Kennedy's theorem. Infinitesimal displacement diagram and application of the principle of virtual work, overturning of rigid blocks.
12. Dynamics of rigid body systems. Examples of applying the principles of rigid body dynamics in structural dynamics.
13. Demolition and removal of buildings. Analysis of the building motion during demolition and determination of internal forces influencing collapse.

- Exercises (auditory):
  1. Geometrical interpretation of differential-integral relations for position, velocity and acceleration in rectilinear motion.
  2. Examples of curvilinear motion of a material point, motion described using global and local coordinate systems, motion of a material point in the polar coordinate system.
  3. Definition and solution of the differential equation of motion of a particle.
  4. Application of work-energy principle of a particle motion in horizontal and vertical planes. Application of energy laws in the horizontal and vertical plane.
  5. Problem solving using the impulse-momentum principle and angular momentum. Collision of a material point with the obstacle.
  6. Description of the planar motion of a rigid body. Determining the velocities and accelerations of body points and the angular velocity and angular acceleration of the body.
  7. Dynamics of rigid bodies. Examples of determining the centre of mass and moment of inertia. Steiner's theorem. Definition and solution of differential equations of motion of a rigid body.
  8. Application of the work-energy principles and energy laws in the motion of a rigid body.
  9. Problem-solving using the laws of impulse and angular momentum in rigid body motion. Collision of a body and a material point.
  10. Examples of vibration of a body with one degree of freedom assuming infinitesimal displacements. Determination of the initial conditions for the vibration.
  11. Determining the displacement plan of mechanisms and applying the virtual work theorem.
  12. Determination of the activation factor of the overturning mechanism applied to the out-of-plane failure of walls.

13. Determination of internal forces during body motion.

- Exercises (construction):
  1. Problem-solving of kinematics and dynamics of particles and particle systems.
  2. Problem solving of kinematics and dynamics of rigid bodies.

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Lectures, solved problems and examples of practice assignments are available on the course page http://www.grad.unizg.hr/predmet/meh2_b

Additional reading:

1. Gross, D., Hauger, W., Schroder, J., Wall, W.A., Govindjee, S.; Engineering Mechanics - Dynamics, Springer, Berlin-Heidelberg, 2011.
2. Meriam, J.L., Kraige, L.G.; Engineering Mechanics - Dynamics, 6.th edition, John Wiley & Sons, Inc, 2008.
3. Beer, F.P., Johnston, E.R.; Vector Mechanics for Engineers – Dynamics, McGraw-Hill, 1998.

A. Kiričenko, Tehnička mehanika II. dio, Kinematika, pbi d.o.o. Zagreb, 1997.

4. S. Jecić , Kinematika krutih tijela, Udžbenici Sveučilišta u Zagrebu, Fakultet strojarstva i brodogradnje, 2002.

HYDROLOGY

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30
- Exercises (auditory): 15

Course objectives:

- Acquisition of theoretical and practical knowledge in the field of hydrology, which includes water and water movement in nature, processes in the atmosphere, hydrometry, processing of hydrometric data, application of probability and statistics in hydrology, and parametric methods for determining runoff processes in the basin.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic statistical principles and methods, both empirical and theoretical,
- Knowledge and understanding of the physical properties of substances (phases of substances, density, specific volume and quantity of substances).

Prerequisite:

- Enrolment requirements: teacher's signature for the course Physics.

Learning outcomes:

- Explain basic concepts related to water, the water cycle and nature, atmosphere, and processes and measurements in the atmosphere,
- Explain and apply calculation procedures in the application of probability and statistics in hydrology (empirical and compromise probability, application of theoretical probability density distributions in hydrology, formation of statistical sets of hydrological data, tests of homogeneity and adjustments, errors of statistical parameters),
- Explain terms and apply procedures for basic analysis of meteorological data, hydrological analysis and elaboration of hydrological data,
- Perceive, observe and define the problem of water in civil engineering,
- Detect problems in the description of the process of runoff in the basin and its breakdown into components, the methodology of determining the runoff, and the extreme conditions of occurrence of runoff in the basin.

Course content (by course schedule):

- Lectures:
  1. Introduction to hydrology: basic concepts in hydrology, properties of water, hydrologic cycle, hydrosphere, branches of geophysics, disciplines in hydrology.
  2. Hydrometeorology: atmosphere, parameters, measuring instruments, solar radiation, air pressure, temperature, air humidity, wind, evaporation, precipitation, precipitation measurement, hydrometeorological parameters in Croatia, climate of Croatia.
  3. Precipitation data processing: precipitation parameters, amount and intensity of precipitation, cumulative precipitation, hyetogram, ombrographic record, processing of precipitation data, IDF curves, RDF curves, design storm, data homogeneity, double mass curve, distribution of precipitation in space.
  4. Runoff process in the basin: basin, watershed, river network, morphological characteristics of the basin, runoff, runoff process, direct and base runoff, hydrograph, direct runoff and effective precipitation, runoff coefficient, concentration time, influences on runoff.
  5. Continuity equation and water balance: integral continuity equation, differential form of the continuity equation, continuous functions in the discrete time domain, water balance equation, runoff process, basin as a spatial unit, hydrological year, water balance components.
  6. Other processes in the basin: evaporation, interception, water retention in valleys, snowmelt, infiltration, percolation, filtration, capillary rise, soil water content, Horton model, Philip's model, importance of hydrology, integral management of water resources, practical application of hydrology, tasks of hydrology, damage from natural disasters.
  7. Hydrometry: hydrometric works, hydrological measurements, discharge measurement, groundwater level measurement, basics of statistics in hydrology, processing of hydrometric measurements, hydrograph, frequency and duration curve, stage-discharge curve.

8. Modelling in hydrology: hydrological system, hydrological modelling, methods of hydrological calculations, rainfall-runoff models, models of effective precipitation.
9. Hydrograph models of direct runoff: isochron method, rational method, Ven Te Chow method, estimation of concentration time.
10. Unit hydrograph method: unit hydrograph, unit hydrograph of complex rainfall
11. Composite hydrograph of direct runoff: composite hydrograph using the rational method, composite hydrograph using the unit hydrograph method.
12. Examples: Application of the rational method on a practical example.
13. Basics of oceanology: sea and ocean dynamics, tidal oscillations, tidal force, currents in the Adriatic, measurement of sea currents, examples from practice.

- Exercises (auditory):
  1. Hydrologic cycle.
  2. Meteorology.
  3. Precipitation amounts at a point.
  4. Average precipitation in the basin.
  5. Evaporation, infiltration.
  6. Water balance.
  7. Hydrometry.
  8. Effective precipitation.
  9. Direct runoff.
  10. Rational method.
  11. Complex hydrograph of direct runoff.

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. Lectures in the form of PPT presentations.
2. Žugaj, R.: Hidrologija, udžbenik, Sveučilište u Zagrebu, Rudarsko-geološko-naftni fakultet, Zagreb, 2000.
3. Vuković, Ž.: Osnove hidrotehnike - Knjiga I, Poglavlje 2: Hidrologija, str. 19-133, udžbenik Sveučilišta u Zagrebu, Zagreb 1996.
4. Hrelja, H.: Inženjerska hidrologija, Univerzitet u Sarajevu - Građevinski fakultet; Sarajevo, 2007.
5. Srebrenović, D.: Primijenjena hidrologija, Tehnička knjiga, Zagreb, 1986.
6. Chow, V.T.: Handbook of Applied Hydrology, McGrow-Hill book Company, New York, 1964.
7. Viessman, W.Jr., Lewis, L.G.: Introduction to Hydrology, Harper-Collins-College-Publishers, New York, 1996.

PHYSICAL EDUCATION AND HEALTH CULTURE 3

Credits (ECTS): -

Hours (total per semester):

- Lectures: 0
- Exercises: 30

Course objectives:

- …

Entry competences (prior knowledge, descriptive):

- …

Learning outcomes:

- ….

Course content (by course schedule):

- Lectures:
  1. Basketball
  2. Volleyball
  3. Futsal
  4. Handball
  5. Table tennis
  6. Badminton
  7. Archery
  8. Skating
  9. Walking tours

Students' obligations:

- For students, classes are conducted in the form of exercises from a selected program, and for sports teams in the form of sports training with different goals of the training process,
- During the semester, students must attend 30 hours of exercises on the selected program or on several selected programs.
- A partial exemption can be obtained based on a health exemption certificate from the Institute for Public Health or a sports exemption through a certificate from sports clubs or the Olympic Committee.

End of semester grading:

- There is no final exam.

Elective courses

CONSTRUCTION MATERIALS

Credits (ECTS): 5

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 18, laboratory: 12)

Course objectives:

- Acquiring theoretical knowledge about production technology, properties and use of building materials,
- Acquiring practical knowledge about laboratory tests of the basic properties of construction materials,
- Acquiring knowledge about designing the composition of concrete,
- Acquiring knowledge about quality control of construction materials.

Entry competences (prior knowledge, descriptive):

- Knowledge of physical, mechanical and thermal properties of materials,
- Knowledge of the chemical aspects of the construction materials,
- Knowledge of the basics of statistics.

Prerequisite:

- Enrolment requirements: Mathematics 1 course exam passed
- Requirements for taking the exam: Physics and Materials Science course exams passed.

Learning outcomes:

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

- Describe the production technology of various construction materials,
- Explain the methods of testing the relevant properties of construction materials,
- Explain the mechanisms of environmental action on construction materials,
- Design the concrete composition,
- Compare the properties of different construction materials,
- Examine the basic physical properties of construction materials,
- Apply the test results of construction materials.

Course content (by course schedule):

- Lectures:
  1. Introduction; Information about materials [2]
  2. Stone [2]
  3. Aggregate [2]
  4. Ceramic materials [2]
  5. Mineral binders [2]
  6. Mortars. Plasters [2]
  7. Concrete 1 [2]
  8. Concrete 2; Concrete additives [2]
  9. Hydrocarbon binders [2]
  10. Metals [2]
  11. Wood [2]

12. Polymer materials [2]
13. Glass [2]
14. Adhesives. Paints and varnishes. Insulation [2]
15. Quality control, assurance, and management [2]

- Exercises (auditory):
  1. Stone [2]
  2. Aggregate. Ceramics. [2]
  3. Binders. Mortar. Injection mixtures. [4]
  4. Fresh concrete [2]
  5. Hardened concrete [4]
  6. Mechanical properties of building materials [4]
- Exercises (laboratory):
  1. Stone [2]
  2. Aggregate [2]
  3. Ceramics [2]
  4. Cement: Mortar [2]
  5. Concrete [2]
  6. Mechanical properties of building materials [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- 2 program assignments submitted within the prescribed deadline and positively evaluated
- First midterm exam
- Second midterm exam
- Positively evaluated work in laboratory exercises
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- 2 program assignments submitted within the prescribed deadline and positively evaluated
- Positively evaluated work in laboratory exercises
- Written exam
- Oral exam

Required reading:

1. Banjad Pečur, I.; Štirmer, N.: Lecture notes for internal use for the course Construction Materials, http://www.grad.unizg.hr/predmet/gra_b
2. Bjegović, D.; Štirmer, N.: *Teorija i tehnologija betona*, udžbenik Sveučilišta u Zagrebu, Tiskara Zelina, 2015.
3. Ukrainczyk, V.: *Poznavanje gradiva*, Alcor, Zagreb, 2001.
4. Ukrainczyk, V. *Beton: struktura, svojstva, tehnologija*, Građevinski fakultet Sveučilišta u Zagrebu, 1994.
5. Bjegović, D., Balabanić G., Milulić, D. *Građevinski materijali – zbirka riješenih zadataka*, Građevinski fakultet, Zagreb, 2007.
6. Netinger, I.; Vračević, M.; Bačkalić, Z.: *Opeka - od sirovine do gotovog proizvoda*, Sveučilište Josipa Jurja Strossmayera u Osijeku, Građevinski fakultet u Osijeku, Grafika, 2014.

7. Crnković, B.; Šarić, Lj.:*Građenje prirodnim kamenom*, Institut građevinarstva Hrvatske, Zagreb, 2012.
8. Domone, P.; Illston, J. (eds): *Construction Materials: Their Nature and Behaviour*, Fourth Edition, Spon Press, 2010.

BASICS OF CONCRETE TECHNOLOGY

Credits (ECTS): 5

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 16, laboratory: 10, construction: 4)

Course objectives:

- Basic knowledge about concrete as a construction material,
- Insight into the technology of concrete production, concreting and curing,
- Insight into the individual ingredients in concrete and their proportions,
- Insight into the complexity of concrete and its ingredients,
- Overview of different types of concrete and properties.

Prerequisite:

- Enrolment requirements: Mathematics 1 course exam passed
- Requirements for taking the exam: Physics and Materials Science course exams passed.

Learning outcomes:

- Basic knowledge about the properties of concrete in its fresh and hardened state,
- Knowledge about the properties of concrete components (cement, aggregate, additives) and linking the influence of the properties of the components on the properties of concrete,
- Knowledge about the application of certain concrete technology depending on the type of construction,
- Ability to independently design the composition of concrete,
- Basic knowledge of concrete degradation processes and the ability to recognize individual concrete damage,
- Understanding how to prove the quality of concrete in the concrete plant and on the construction site using laboratory and field testing methods,
- Basic knowledge about the mutual interaction of concrete types, the method of production, transportation, laying and curing,
- Knowledge of special types and special technologies of concrete.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Cement [2]
  3. Aggregate. Water and additives [2]
  4. Fresh concrete and design of concrete composition [2]
  5. Strength of concrete [2]
  6. Deformations of concrete [2]
  7. Durability of concrete [2]
  8. Production and design of concrete composition [2]
  9. Concrete laying and curing. Concrete laying in extreme climatic conditions [2]

10. Special concretes [4]
11. Special technologies of concrete [2]
12. Quality control of concrete and its components [2]
13. Examples from practical application [4]

- Auditory exercises:
  1. Physical parameters of construction materials [2]
  2. Cement [2]
  3. Aggregate [2]
  4. Fresh concrete and concrete mix design [4]
  5. Hardened concrete [4]
  6. Deformations [2]
- Laboratory exercises:
  1. Physical parameters of construction materials. Cement [2]
  2. Aggregate [2]
  3. Fresh concrete and concrete mix design [2]
  4. Hardened concrete [2]
  5. Deformations [2]
- Construction exercises:
  1. Submission of program assignments [4]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- First and second midterm exam
- A minimum grade in laboratory exercises of 3.5
- A minimum grade of 4 for the program assignment
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- Positive grade for the project assignment
- Positive grade in laboratory exercises
- Written exam
- Oral exam

Required reading:

1. Bjegović, D.; Balabanić, G.; Mikulić, D.: *Građevinski materijali – riješeni zadaci*, Građevinski fakultet Sveučilišta u Zagrebu, 2007.
2. Bjegović, D., Štirmer, N.: Teorija i tehnologija betona, Sveučilišta u Zagrebu, Građevinski fakultet, Zagreb, 2015.

Additional reading:

1. Ukrainczyk, V.: Beton: struktura, svojstva, tehnologija, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 1994.

2. Krstulović, P.: Svojstva i tehnologija betona, Građevinski fakultet Sveučilišta: Instutut građevinarstva Hrvatske, Poslovni centar Split, Split, 2000.
3. Đureković, A.: Cement, cementni kompozit i dodaci za beton, Školska knjiga, Zagreb, 1996.
4. Mehta P.K.: Concrete, Structure, Properties and materials, New Jersey: Prentice Hall, Inc., Englewood Cliffs,1986.
5. Neville, A.M.: Properties of concrete, fourth edition. Essex: Longman Group Limited,1995.

2nd year, 4th semester

Mandatory courses

STRENGTH OF MATERIALS 2

Credits (ECTS): 5.5

Hours (total per semester):
- Lectures: 45
- Exercises: 30 (auditory: 24, laboratory: 2, design: 4)

Course objectives:
- Acquisition of theoretical knowledge about the strength of materials in the field of structural mechanics,
- Acquisition of practical knowledge required to understand and solve minor engineering problems related to design and verification of the strength of elements of engineering structures.

Entry competences (prior knowledge, descriptive):
- Knowledge of differential and integral calculus,
- Knowledge of mechanics (statics and kinematics), analysis of stresses and strains and calculation of stresses and strains of straight rods from individual internal forces (longitudinal and transverse, torsion moment and bending moment).

Prerequisite:
- Enrolment requirements: teacher's signature for the course Strength of Materials 1
- Requirements for taking the exam: Strength of Materials 1 course exam passed.

Learning outcomes:
- Recognize static indeterminacy and solve simple statically indeterminate systems,
- Solve simple cases of girders on an elastic base,
- Apply basic strength theories in the design of structural elements loaded with a multiaxial stress state,
- Analyse the stresses of complexly loaded rods, determine the core of the cross-section and apply it to biaxial bending and eccentric loading,
- Determine and understand the importance of the shear centre in thin-walled cross-sections,
- Calculate the stresses and deformations of curved rods and notice the difference compared to straight rods,
- Explain and apply the principle of the minimum potential energy of deformations,
- Explain the problem of loss of stability (buckling) of straight rods and design the rods subjected to buckling,
- Calculate simpler statically determinate and statically indeterminate structures according to the theory of plasticity.

Course content (by course schedule):
- Lectures:

1. Statically indeterminate girders. Solving simpler statically indeterminate girders. Continuous girders. [3]
2. Girder on an elastic base. Differential equation of an elastic line of a girder on an elastic base. An infinitely and semi-infinitely long girder on an elastic base. Finite length girder on an elastic base. Girder on evenly spaced elastic bearings. [3]
3. Strength theories. Theory of maximum normal stresses. Theory of maximum normal deformations. Theory of maximum shear stresses. Theory of potential energy of deformations. The theory of potential energy of shape change. [3]
4. Mohr's theory of strength. Comparison and application of strength theories. [3]
5. Bending by forces of an asymmetrical rod. Shear centre. [3]
6. Compound loading of straight rods. Joint action of longitudinal force and bending moment, longitudinal force and oblique bending. Eccentric loading of short rods. Core of a cross-section. [3]
7. Application of cross-sectional core to oblique bending and eccentric compression. Stress in the section when the tensile zone is not considered. Axial loading and bending of composite beam. Checking the strength in transverse bending of a straight rod. Complex loading of rods – bending and torsion. [3]
8. Potential energy. Work of external forces and potential energy of deformation. Potential energy of deformation expressed as the work of internal forces. Reciprocal work theorem. Theorem of reciprocal displacements. Castigliano's theorems. [3]
9. Crotti-Engesser theorem. Unit load method. Application of Castigliano's theorems to the solution of statically indeterminate problems. Theorem on the minimum potential energy of deformations. Determination of displacements in statically indeterminate systems. Total potential energy of the system. Theorem on the stationarity of the potential energy of the system. [3]
10. Theory of curved rods. Stresses and deformations due to longitudinal and transverse forces. Clean bending of a curved rod. Rods of large and small curvature. Determination of the radius of curvature of the neutral layer. General case of bending of a curved rod. Rational forms of the cross-section of a curved rod in pure bending. [3]
11. Buckling, loss of elastic stability. Types of equilibrium and critical load. Static and energetic method for determining the critical force during bending of a rod. Buckling of the rod in the elastic region. Euler's critical force for basic cases of rod attachment. [3]
12. Critical buckling stress. Buckling of the rod in the plastic region. Empirical expressions for the critical stress. Dimensioning of rods loaded in buckling. Buckling of rods with initial curvature. Eccentric loading of slender rods. Effect of axial loading on rod bending. [3]
13. Structural design according to the theory of plasticity. Prandtl's model of an ideal elastoplastic material. Conditions of plasticity. Rod torsion in the plastic region. The influence of residual stress relief during torsion. Statically indeterminate systems in torsion. [3]
14. Plastic bending of a straight rod. Influence of unloading - residual stress during bending. Deformation of the girder in elastoplastic bending. Bending and axial loading. Statically indeterminate structures. Static and kinematic theorems. Design of structures according to the theory of plasticity, i.e. according to the theory of limit states. [3]
15. Recapitulation of topics covered during the semester. Preparation for the exam. [3]

- Exercises (auditory):

1. Simpler statically indeterminate systems [2]
2. Continuous girder and girder on an elastic base [2]
3. Eccentric loading of short rods. Core of a cross-section. [2]
4. Application of a cross-section core to oblique bending and eccentric compression [2]
5. Shear centre [2]
6. Strength theories [3]
7. Potential energy of deformations. [3]
8. Curved rods [2]
9. Buckling [2]
10. Calculation of statically indeterminate systems according to the theory of plasticity [2]

- Exercises (laboratory):
  1. Experimental determination of stress in a beam subjected to bending. Experimental verification of the displacement reciprocity theorem and the behaviour of thin-walled flat rods (shear centre). Experimental determination of the critical load during buckling of a straight rod. [2]
- Exercises (design):
  1. Solving problems from the areas related to the 1st midterm exam (statically indeterminate systems, cross-section core, shear centre and strength theories). [2]
  2. Solving problems related to the 2nd midterm exam (potential energy, buckling and theory of plasticity). [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Šimić, V.: *Otpornost materijala II*, Školska knjiga, Zagreb, 2002.
2. Šimić, V.: *Otpornost materijala I*, Školska knjiga, Zagreb, 2002.

Additional reading:

1. Goodno, B. J.; Gere, J. M.: *Mechanics of Materials*, 9th ed., Cengage Learning, 2018.
2. Hibbeler, R. C.: „Mechanics of Materials“, 9th ed., Prentice Hall, 2014.
3. Alfirević, I.: *Nauka o čvrstoći II*, Golden marketing, Zagreb, 1999.
4. Timošenko, S.: *Otpornost materijala I i II*, Građevinska knjiga, Beograd, 1965.
5. Brnić, J.; Turkalj, G.: *Nauka o čvrstoći II*, Zigo, Rijeka, 2006.

STRUCTURAL ANALYSIS 1

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 60
- Exercises: 45 (auditory: 39, computer: 3, design: 3)

Course objectives:

- Acquiring theoretical knowledge about the behaviour of constructions under load and other actions and about ways of transferring forces,
- Acquisition of practical knowledge about linear calculation procedures of statically determinate and statically indeterminate rod structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra,
- Knowledge of the statics of a material point, system of points, rigid body and connected systems,
- Understanding of the concepts of stress and deformation and internal forces.

Prerequisite:

- Enrolment requirements: Mechanics 1 course exam passed

Learning outcomes:

- Recognize the geometric invariability and static determinacy or indeterminacy of the rod construction,
- Explain the conditions of equilibrium in plane and space and apply them in the calculation of external and internal forces,
- Explain and apply analytical and graphical procedures for calculating statically determinate planar and spatial structures,
- Explain the concept of virtual work and compare it with equilibrium conditions and kinematic conditions,
- Explain variational theorems and compare them with equilibrium conditions and kinematic conditions,
- Explain and apply analytical calculation procedures of statically indeterminate structures,
- Explain and apply analytical and graphical procedures for determining displacements and deflection lines,
- Apply influence functions to calculate the influence of moving loads.

Course content (by course schedule):

- Lectures:
  1. The scope, objectives and methods of Structural Analysis. Construction and its model. Rigid structures. Geometric invariability, static determinacy and static indeterminacy. Basic assumptions and principles. Differential and integral equations of equilibrium. Statically determinate girders with one disc: graphical and analytical calculation procedures. [4]
  2. Gerber girders: analytical calculation procedure. [2]
     Gerber girders: application of the principle of superposition. [2]
  3. Trusses: geometric invariability and statical determinacy; node methods – graphical and analytical procedures. [2]

Trusses: methods of sections – graphic and analytical procedures [2]

3. Three-hinged and related girders (girders with braces, strengthened, supported and suspended girders): graphic calculation procedures. [2]
   Three-hinged and related girders: graphic and analytical calculation procedures. [2]
4. Three-jointed and related girders: analytical calculation procedures. [2]
   Three-jointed and related girders: application of the principle of superposition. [2]
5. Elastic systems: displacements and deflection lines. Euler-Bernoulli and Timoshenko theory for beam bending. [2]
   Work. Theorem of virtual displacements. [2]
6. Theorem of virtual forces. Unit force method. [2]
   Statically indeterminate constructions: characteristics; solution methods. [2]
7. Force method: basic idea. [2]
   Force method: principal system; equations of continuity. [2]
8. Force method: solving systems of equations. [2]
   Force method: forced displacements; reduction clause. [2]
9. Force method: influence of heat; deformation control. [2]
   Displacement methods, general and engineering. [2]
10. General displacement method: matrix formulation; algorithm. [2]
    General displacement method: static and kinematic condensation. [2]
11. General displacement method: forced displacements; symmetry and antisymmetry. [2]
    Introduction to the finite element method. [2]
12. Drawing of bending lines (Mohr's analogy). [2]
    Influence functions and influence lines: definitions, application. [2]
13. Spatial statically determinate systems: geometric invariability, static determinacy; graphical and analytical calculation procedures. [2]
    Spatial statically determinate systems: Schwedler "dome", Föppl's "shell". [2]
14. Spatial static indeterminate systems: trusses (general displacement method). [2]
    Spatial static indeterminate systems: beam systems (general displacement method). [2]

- Exercises (auditory):
  1. Statically determinate single disk systems. [3]
  2. Gerber girders: analytical calculation procedure [3]
  3. Gerber girders: graphical calculation procedure. Trusses. [3]
  4. Three-jointed and related girders: graphic calculation procedure. [3]
  5. Three-jointed and related girders: analytical calculation procedure. [3]
  6. Three-jointed and related girders: application of the principle of superposition. [3]
  7. Determining displacements and angles of rotation [3]
  8. Force method [9]
- Exercises (computer):
  1. Application of computers in structural calculation [3]
- Exercises (design):
  1. Creating and submitting program assignments. [3]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures

- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. V. Simović: *Građevna statika 1*, Građevinski institut, Zagreb, 1988.
2. M. Anđelić: *Građevna statika 2*, Građevinski fakultet, Zagreb, 2005.
3. M. Anđelić: *Statika neodređenih štapnih konstrukcija*, DHGK, Zagreb, 1993.
4. K. Fresl: *GS – Bilješke i skice s predavanja*, http://master.grad.hr/nastava/gs (web page for the courses Structural Analysis 1 and Structural Analysis 2)
5. P. Gidak, E. Šamec: Statički neodređeni sistemi, (http://master.grad.hr/nastava/gs/gs2/e_sns.pdf)

Additional reading:

1. M. Sekulić: *Teorija linijskih nosača*, Građevinska knjiga, Beograd, 2005.
2. L. P. Felton, R. B. Nelson: *Matrix Structural Analysis*, Wiley, New York, 1997.

INTRODUCTION TO STRUCTURAL ENGINEERING

Credits (ECTS): 2

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of theoretical knowledge about the global stabilization of objects made of different materials,
- Acquisition of knowledge in the field of the basics of structural reliability,
- Acquisition of the ability for a synergistic approach to designing with architects,
- Acquisition of theoretical knowledge about the determination of basic actions on structure and their effects.

Entry competences (prior knowledge, descriptive):

- Knowledge of the statics of a rigid body and connected systems,
- Understanding and the ability to apply equilibrium conditions in plane and space,
- The ability to spatially perceive the construction,
- Knowledge of the basics of building construction elements.

Prerequisite:

- Enrolment requirements: Mathematics 1 and Building Construction course exams passed

Learning outcomes:

- The ability to create dispositional solutions of simpler structures built from different materials of concrete, steel and timber,
- Recognition of key factors related to the reliability of structures,
- The ability to determine the effects on structures and their design situations for different limit states,
- The ability to use European standards for actions.

Course content (by course schedule):

- Lectures:
  1. Structural engineering. Design concept in structural engineering according to EUROCODE European standards. Basic procedures when designing a structure: planning, determination of the preliminary shape of the building. [2]
  2. Basic procedures in the design of structures: determination of action. [2]
  3. Basic procedures in the design of structures: preliminary selection of load-bearing elements and systems with regard to the transfer of action, selection of boundary conditions and stabilization systems. [2]
  4. Basic procedures in the design of structures: preliminary selection of load-bearing elements and systems with regard to the transfer of action, selection of boundary conditions and stabilization systems. [2]
  5. Basic procedures in the design of constructions: calculation, evaluation and final design. Construction performance and maintenance. [2]
  6. Common solutions for the disposition of buildings made of different building materials. [6]
  7. Fundamentals of engineering reliability [6]
  8. Reliability concept incorporated in European standards Eurocode [2]
  9. Ways of determining action [2]
  10. Design situations for different limit states and action effects [4]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam

Required reading:

1. Eurocode 0: *Basis of structural design* (EN 1990:2002+A1:2005+A1:2005/AC:2010)
2. Eurocode 1*: Actions on structures -- Part 1-1: General actions -- Densities, self-weight and imposed loads for buildings* (EN 1991-1-1:2002+AC:2009)
3. Eurocode 1*: Actions on structures -- Part 1-2: General actions -- Actions on structures exposed to fire* (EN 1991-1-2:2002+AC:2009)
4. Eurocode 1: *Actions on structures -- Part 1-3: General actions -- Snow loads* (EN 1991-1-3:2003/A1:2015)
5. Eurocode 1*: Actions on structures -- Part 1-4: General actions -- Wind actions* (EN 1991-1-4:2005+AC:2010+A1:2010)

6. Eurocode 1: Actions on structures -- Part 1-5: General actions -- Thermal actions -- National Annex
7. Eurocode 1*: Actions on structures -- Part 1-6: General actions -- Actions during execution* (EN 1991-1-6:2005+AC:2008)
8. Eurocode 1: *Actions on structures -- Part 1-7: General actions -- Accidental actions*
9. Androić, B.; Dujmović, D.; Džeba, I.: *Metalne konstrukcije 1*; IGH, Zagreb, 1994.
10. Bjelanović, A.; Rajčić, V.: *Drvene konstrukcije prema europskim normama*; Hrvatska sveučilišna naklada, Zagreb, 2005. (2nd ed. 2007.)
11. Milčić, V; Peroš, B.: *Uvod u teoriju sigurnosti nosivih konstrukcija*, Građevinski fakultet Sveučilišta u Splitu, Split, 2003.
12. Kind-Barkauskas, F.; Kauhsen, B.; Polonyi, S; Brandt, J.: *Beton Atlas*; Institut fur internationale Architektur-Dokumentation GmbH, Munchen, 2013.
13. Schulitz, H.C.; Sobek, W.; Habermann, K.J.: *Stahlbau Atlas*; Institut fur internationale Architektur-Dokumentation GmbH, Munchen, 1999.
14. Herzog, T.; Nattere, J.; Schweitezer, R.; Volz, M.; Winter, W.: *Holzbau Atlas*; Institut fur internationale Architektur-Dokumentation GmbH, Munchen, 2003.
15. Course materials are available on the website of the Faculty of Civil Engineering, University of Zagreb.

SOIL MECHANICS

Credits (ECTS): 5

Hours (total per semester):

- Lectures: 45
- Exercises (auditory): 30

Course objectives:

- Acquiring theoretical knowledge about soil behaviour in various conditions,
- Application of theoretical knowledge in solving simpler geotechnical problems.

Entry competences (prior knowledge, descriptive):

- Knowledge of partial differential equations, infinite series and trigonometry,
- Understanding water pressure,
- Understanding and the ability to apply balance conditions in plane,
- Understanding the concepts of stress and deformation and Mohr's circle of stress.

Learning outcomes:

- Define all soil parameters, the principle of effective stresses, potentials for water flow through the soil and shear strength in drained and undrained conditions,
- Explain the granulometric diagram, consistency limits and basic field and laboratory tests for soil,
- Apply all the basic principles of soil mechanics,
- Sketch relevant diagrams from soil mechanics,
- Calculate the limit states of load capacity and serviceability according to Eurocode 7.

Course content (by course schedule):

- Lectures:
  1. Introduction to soil mechanics [3]

2. Basic soil properties and phase relations [3]
3. Granulometric composition of the soil; consistency limits of fine-grained soil [3]
4. Capillarity, soil classification, soil compaction [3]
5. Flow of water through the soil [3]
6. Initial stresses in the soil [3]
7. Additional stresses in the soil [3]
8. Land settlement and consolidation [3]
9. Shear strength of soil [3]
10. Field investigation works [3]
11. Shallow foundation [3]
12. Retaining structures [3]
13. Slope stability [3]

- Exercises (auditory):
  1. Introduction [2]
  2. Phase relations [2]
  3. Soil classification [2]
  4. Water flow through the soil (permeability coefficient with variable and constant potential drop, geodetic and piezometric height, hydraulic potential, pore pressure, hydraulic gradient) [2]
  5. Flow of water through soil 2D (hydraulic gradient, current network and flow) [2]
  6. Initial stresses in soil (total stresses, effective stresses, pore pressures, horizontally layered soil) [2]
  7. Additional stresses in the soil [2]
  8. Shear strength of soil [2]
  9. Shallow foundation [4]
  10. Deep foundation [2]
  11. Retaining structures [2]
  12. Slope stability [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Course materials are available on the course website.
2. Exercise materials are available on the course website.

Additional reading:

1. Roje-Bonacci, Tanja: *Mehanika tla*, II. dopunjeno i izmijenjeno izdanje, Građevinski fakultet Sveučilišta u Splitu, 280 str.

LAW IN CONSTRUCTION

Credits (ECTS): 3
Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of initial theoretical knowledge:
  - On legal principles (or legal concepts),
  - On administrative law, commercial law, and law of obligations;
- Obtaining theoretical and practical knowledge in the areas of construction regulations:
  - Spatial planning and
  - construction;
- Informing students about:
  - Important existing domestic and foreign professional associations for civil engineers,
  - The basics of positive technical regulation and safety at work for builders.

Entry competences (prior knowledge, descriptive):

- Previously completed courses:
  - Building Construction,
  - Materials Science or Construction Materials and
  - Geodesy;
- It is not a requirement, but it would be desirable if the students had passed one of the following elective courses:
  - Sociology of Work and Professional Ethics,
  - Outline of Civil Engineering Legislation,
  - Business Economics.

Learning outcomes:

- Introducing students to the role and provisions of basic laws and regulations that are necessary for the conception, definition and realization of a construction undertaking or project in light of the rights and obligations of its main participants:
  - What do construction experts mean by the term construction project?
  - Who are the main participants in the implementation of the construction project and what are their professional and legal obligations?
  - How to implement a construction project and with the help of which type of technical documentation and on the basis of which legal regulatory solutions or construction conditions?
  - In what legal way can one acquire the right to use a newly built building?
  - What are the legal options for labour and physical protection of civil engineers as managers, contractors or supervisors?
  - What are the existing technical regulations and which professional associations should one join?

Course content (by course schedule):
Lectures:

1. Legal principles: Legal norm. System, sources and subjects of law. Legal relations and affairs [2]
2. The Physical Planning Act. Spatial planning system: goals, principles and subjects of spatial planning, monitoring the spatial solutions, Spatial Development Strategy of the Republic of Croatia, development of construction land, implementation of spatial plans. [2]
3. Development of spatial planning regulations. Urban land consolidation. Types of spatial plans. Location conditions, location permit, location information. Preliminary design [2]
4. Building Act. The main and implementation technical documentation. Standardized design. Essential and other requirements for construction works. Marking and revision systems of project technical documentation. [2]
5. Regulatory solutions for construction. Procedures that can be performed without obtaining permits. Tender projects documentation. Specific examples of reconstructions (post-war, floods, earthquakes). [2]
6. Necessary documentation for obtaining permit procedures. The role and responsibilities of inspection and administrative supervision. Form, layout and application of necessary construction documentation on construction sites [2]
7. Act on Physical Planning and Building Tasks and Activities. Fundamental stakeholders in the construction project. Design and technical expert supervision tasks. Systems of organization of design activities and expert supervision. Performance of works and engineering services. [2]
8. Professional associations: Croatian Chamber of Architects and Croatian Chamber of Civil Engineers, Judge's Web, Croatian Association of Energy Certifiers, Croatian Association for Project Management. Purpose, organization, acts, documentation, legal requirements and insurance system. Authorizations and certifications [2]
9. The other types of domestic and foreign professional associations, goals and roles. Regulation acts and documents. Action plans and the professional actions.

Technical regulation: Standardization system and quality control of construction products. FIDIC. Protection of civil engineers: Legal sources of labour law and protection at work. Legislation, trade unions [2]

10. Contracts and contracting. Preparation of tenders, offers, offering, contracting and assignment of works and services. Handover procedures and final calculation of works and services [2]
11. Obtaining a decision-permit for the use of the building. Obtaining a decision-permit for the removal of a building [2]
12. Safety at work. The legislative framework of protection at work. Occupational safety coordinators. Work performance plan. [2]
13. Danger zones on the construction site. Danger signs and obligations before, during and after construction, related to occupational safety. Safety at work during rough construction works in construction [2]
14. Special usages in construction. General contracting conditions and standardization of parts of technical documentation [2]
15. International aspect of construction law. [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures

- Completed quizzes on Merlin
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Completed quizzes on Merlin
- Written exam
- Oral exam

Required reading:

1. Radujković, M. et al.: Organizacija građenja, 2015.
2. Nahod, M.-M.: Lectures (e-learning) on Merlin, for the course Law in Construction
3. Web pages: nn.hr/Official part; www.mgipu.hr/Propisi
4. Klee, L. : International Construction Contract Law, Wiley Blackwell, 2015.
5. Kelley, G.S.: Construction Law, John Wiley & Sons, 2013.
6. Vojinović, J.: Posebne uzance o građenju sa objašnjenjima i sudskom praksom, 1977.
7. European Valuation Standards 2012 (EVS 2012), "Blue Book", European Group of Valuer's Associations
8. Radujković, J., Izetbegović, J., Nahod, M. M., Osnove građevinske regulative, GF- Sveučilišta u Zagrebu, Zagreb, 2008.

Additional reading:

1. Bienenfeld, J., Blažević-Perušić, J., Rajčić, D.; Sudarević, N.: *Prikaz Zakona o izmjenama i dopunama Zakona o prostornom uređenju i gradnji i Zakona o postupanju s nezakonito izgrađenim zgradama*, Građevinski fakultet Sveučilišta u Zagrebu, 2011.
2. Loboja, A.; Bačurin, N.; Flam, D.; Pandžić, Z.; Pranjić, I.; Rajčić, D.: *Novi propisi o javnoj nabavi*, Građevinski fakultet Sveučilišta u Zagrebu, 2012.

PHYSICAL EDUCATION AND HEALTH CULTURE 4

Credits (ECTS): -

Hours (total per semester):

- Lectures: 0
- Exercises: 30

Course objectives:

- ...

Entry competences (prior knowledge, descriptive):

- ...

Learning outcomes:

- ....

Course content (by course schedule):

- Lectures:
  1. Fitness
  2. Pilates
  3. Zumba

4. Football
5. Basketball
6. Volleyball
7. Handball
8. Badminton
9. Table tennis
10. Athletics
11. Archery
12. Skating
13. Walking tours

Students' obligations:

- For students, classes are conducted in the form of exercises from a selected program, and for sports teams in the form of sports training with different goals of the training process,
- During the semester, students must attend 30 hours of exercises on the selected program or on several selected programs.
- A partial exemption can be obtained based on a health exemption certificate from the Institute for Public Health or a sports exemption through a certificate from sports clubs or the Olympic Committee.

End of semester grading:

- There is no final exam.

Elective courses

APPLIED GEOLOGY

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of basic knowledge in general geology, mineralogy and petrology,
- Acquisition of basic knowledge in hydrogeology and engineering geology for application in construction.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic chemical elements and compounds.

Learning outcomes:

- The ability to distinguish igneous, metamorphic and sedimentary rocks,
- The ability to recognize beds, wrinkles, faults and overthrust,
- Knowledge of the process of formation of karst and different karst forms, as well as familiarity with the problems that builders encounter when building tunnels in karst,
- The ability to use geological maps – recognizing geological symbols, reading the geological age of rocks, their composition and other important geological phenomena of a terrain,
- Acquisition of knowledge about basic engineering-geological classifications of rock mass.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. On geoscience. General geology, stratigraphic. Constitution of the Earth. Geoid. Mineralogy. Mineral. Crystal [2]
  3. Isotropic and anisotropic minerals. Pyrogenic, pneumatogenic, hydrothermal, hydatogenic. Axis, plane centre of symmetry. Crystal systems. Properties of crystals, crystal bonds. Tetrahedral coordination. Coordination number. Polymorphism. Isomorphy [2]
  4. Properties of minerals. Mineral groups. Oxides and hydroxides. Carbonates. Sulfates. Silicates [2]
  5. Introduction to petrology. Rocks. Phenocrysts, monomineralic. Eruptive rocks. The way eruptive rocks appear. Structure and texture of eruptive rocks. Magma acidity. Bowen sequence of crystallization. Table of eruptive rocks [2]
  6. Sedimentary rocks. Transport of sediments. Mineral composition of sedimentary rocks. Structures and textures of sedimentary rocks. General overview of sedimentary rocks. Metamorphic rocks. Zones of metamorphism. Divisions of metamorphic rocks [2]
  7. Tectonics. Outcrops, camber, bed thickness. Beds, folds, anticlines and synclines. Faults. Overthrusts. Types of cracks [2]
  8. Exodynamics of the Earth. Insolation. Hydrogeology. Water, hydrologic cycle. Porosity, permeability. Laminar and turbulent flow. Types of aquifers. Ghyben–Herzberg law. Ice and snow. Wind, organisms [2]

9. Karst. External karst forms. Internal karst forms [2]
10. Types of speleological objects. Speleothems. Groundwater [2]
11. Landslides. Endodynamics. Orogenesis, epigenesis [2]
12. Volcanoes. Earthquakes. Earthquake scales, seismicity [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam

Required reading:

1. Herak, M.: *Geologija*, 1990.
2. Šestanović, S.: Osnove geologije i petrologije, *2001.*

Additional reading:

1. West, T.: Geology Applied to Engineering, *1994.*
2. Monroe, J.; Wicander, R.: *Physical geology*, 2006.
3. Plummer, C.; McGeary, D.; Carlson, C.: *Physical Geology*, 2010.

ENVIRONMENTAL PROTECTION

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquiring theoretical knowledge about basic ecological terms and processes,
- Knowledge of anthropogenic impacts on the environment, primarily from the field of civil engineering,
- Acquisition of knowledge about environmental protection measures and procedures and legal regulations in the field of environmental protection and water management.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic terms in physics, biology, chemistry and civil engineering.

Learning outcomes:

- Understanding of basic ecological processes,
- Recognize and explain basic ecological principles,
- Explain the basic technological procedures of wastewater treatment,
- Understanding waste management,
- Understanding the concept of "sustainable development".

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Basics of ecology and environmental protection; basic terms [2]
  3. Environmental problems: air pollution (sources and consequences) [2]

4. Environmental problems: water pollution [2]
5. Environmental problems: soil pollution and nature pollution [2]
6. Renewable and non-renewable energy sources and climate change [2]
7. Legislation in the field of environmental protection: Environmental impact assessment - identification and classification of impacts [2]
8. Sustainable development and civil engineering [2]
9. The impact of cities, roads and water engineering facilities [2]
10. 1st midterm exam
11. Waste and waste management [2]
12. Landfills [2]
13. Waste water and the application of the combined approach methodology [2]
14. Environmental protection measures and procedures [2]
15. 2nd midterm exam

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- A minimum score of 55% on both midterm exams (average), with the condition of a minimum score of 30% on each midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- A minimum score of 55% on the exam

Required reading:

1. Environmental Protection, lectures, 2026

Additional reading:

1. G. Tyler Miller Jr.: *Living in the Environment: Principles, Connections, and Solutions*, 15th Edition, Thomson Books, 2007.
2. Peter H. Raven, Linda R. Berg, David M. Hassenzahl: *Environment,* 7th Edition, Wiley, 2010.
3. Environmental Protection Act (OG 80/13, 153/13, 78/15, 12/18, 1118/18)
4. National Environmental Protection Strategy
5. Strategy of Sustainable Development of the Republic of Croatia
6. Waste Management Strategy of the Republic of Croatia
7. Regulation on the environmental impact assessment. (OG 61/14 i 03/17)
8. Water Area Management Plan
9. Combined Approach Methodology (Hrvatske vode, 2018)

WATER SUPPLY AND SEWERAGE 1

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises (auditory): 15

Course objectives:

- Acquisition of theoretical knowledge about all aspects of managing urban water supply and sewerage systems,

- Acquisition of practical knowledge in hydraulic dimensioning of individual parts of water supply and sewerage systems as well as their design.

Entry competences (prior knowledge, descriptive):

- Knowledge of mathematical analysis,
- Understanding the basic regimes of water flow (flow under pressure, flow with a free water surface),
- Knowledge of the basics of fluid mechanics (momentum conservation equation, Bernoulli's equation for a real fluid, calculation of local and linear energy losses, pressure and energy line).

Prerequisite:

- Enrolment requirements: teacher's signature for the course Fluid Mechanics.

Learning outcomes:

- Application of acquired knowledge for conceptual development of water supply and sewerage systems,
- Defining relevant parameters and hydraulic design of the water supply and sewage network,
- Dimensioning of the water reservoir,
- Defining the basic parameters for determining the capacity of pumping stations, calculating pump energy consumption, determining the system curve,
- Settling tank sizing.

Course content (by course schedule):

- Lectures:
  1. Water supply - introduction, types of water supply systems [2]
  2. Water consumption [2]
  3. Springs, water intakes [2]
  4. Water intakes, pumping stations [3]
  5. Water conditioning [2]
  6. Water reservoirs, water supply networks [2]
  7. Water supply networks - design [2]
  8. Drainage - introduction, drainage systems [2]
  9. Relevant amounts of wastewater [2]
  10. Sewage networks [2]
  11. Sewage networks - design [2]
  12. Construction of sewage network [2]
  13. Treatment of wastewater and discharges [4]

- Exercises (auditory):
  1. Determination of relevant quantities of water consumption [1]
  2. Dimensioning of water intake structures [1]
  3. Dimensioning of pumping stations [1]
  4. Dimensioning of facilities for water conditioning [1]
  5. Dimensioning of the water tank [1]
  6. Hydraulic calculation of the water supply network [2]
  7. Determination of relevant amounts of wastewater [1]
  8. Hydraulic calculation of the sewage network [2]
  9. Dimensioning of facilities on the sewage network [1]
  10. Determining the parameters for the sizing of wastewater treatment devices [1]

11. Hydraulic calculation of settling tank [1]

Additional calculation tasks and preparation for the midterm exam [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Two midterm exams during the semester

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Vuković, Ž; Halkijević, I.: *Opskrba vodom i odvodnja 1*, course materials, 2024.
2. Trifunović, N.: *Introduction to Urban Water Distribution*, Taylor & Francis Group, London, UK, 2008.

Additional reading:

1. Brandt, M. J.; Johnson, K. M.; Elphinston, A. J.; Ratnayaka, D. D.: Twort's Water Supply, 7th edition, Elsevier, 2016.
2. Butler, D.; Digman, C. J.; Makropoulos, C.; Davies, J.W.: Urban Drainage, 4th edition, CRC Press, USA, 2018.

WATER PROTECTION

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises (auditory): 15

Course objectives:

- Acquiring theoretical knowledge about the ecological laws of water systems,
- Acquiring theoretical knowledge about the procedures and technologies of water protection against anthropogenic action,
- Acquiring practical knowledge about legal regulation of water management.

Learning outcomes:

- Recognize and explain basic ecological principles,
- Explain and apply the legal regulation of water management,
- Explain the basic technological procedures of wastewater treatment,
- Explain the basic sludge treatment procedures,
- Explain the methods of final discharge of treated wastewater.

Course content (by course schedule):

- Lectures:
  1. Basic ecological principles: abiotic and biotic factors, living community, ecosystem of the living area [3]

2. Changes in water quality: sources of pollution, types of wastewater, self-purification capacity of water systems [1]
3. Water quality models: empirical models, numerical models, QUALL, WASP [2]
4. Disturbances of aquatic ecosystems: eutrophication, impact load [2]
5. Water quality management: political and sociological approach, legal measures, spatial planning, economic and financial measures, scientific and technological measures, institutional measures, water protection plans and programs [2]
6. Wastewater treatment: general principles, mechanical treatment, physical treatment, chemical treatment [2]
7. Wastewater treatment: biological treatment, conventional process with activated sludge [2]
8. Wastewater treatment: biological treatment, extended aeration process, SBR [2]
9. Wastewater treatment: biological treatment, removal of nitrogen and phosphorus [2]
10. Wastewater treatment: sludge treatment [2]
11. Wastewater treatment: alternative treatment processes [4]
12. Natural wastewater treatment processes. [2]
13. Mixing models in seas and lakes (VISUAL PLUMES, CORMIX) [2]
14. Control of non-point sources of pollution: phenomenon, sources, control [2]

- Exercises (auditory):
  1. Analysis of wastewater according to certain parameters, relevant for water quality assessment and sizing of treatment plants [1]
  2. Equations of pollution transfer in watercourses [1]
  3. Mathematical modelling of water quality in watercourses (QUAL, WASP) [3]
  4. General equations of the process of wastewater treatment at WWTPs [1]
  5. Equations of kinetics of biological wastewater treatment [1]
  6. Dimensioning of reactors for biological treatment with activated sludge [1]
  7. Dimensioning of reactors for biological treatment with attached microorganisms
  8. Dimensioning of secondary clarifiers [1]
  9. Dimensioning of facilities for sludge treatment [1]
  10. Dimensioning of alternative wastewater treatment plants [1]
  11. Dimensioning of undersea outlets [1]
  12. Mathematical modelling of pollution transfer in the sea (VISUAL PLUMES, CORMIX) [1]
- Midterm exams:
  1. Includes chapters 1 to 7 of lectures and chapters 1 to 6 of exercises
  2. Includes chapters 8 to 14 of lectures and chapters 7 to 12 of exercises

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises

- Written exam

Required reading:

1. Tedeschi, S: *Zaštita voda,* HDGI, 1997.
2. Lectures: PowerPoint presentations and texts by the course instructor (Faculty web page).
3. A collection of solved problems is available on the web page of the Water Protection course.
4. German Guidelines for the Dimensioning of Activated Sludge Plants (DWA-A 131)

Additional reading:

1. Metcalf, Eddy: *Wastewater Engineering,* McGraw Hill, 2003.

3rd year, 5th semester

Mandatory courses

CONCRETE AND MASONRY STRUCTURES

Credits (ECTS): 6.5

Hours (total per semester):

- Lectures: 60
- Exercises: 45 (auditory: 21, design: 24)

Course objectives:

- Acquiring theoretical knowledge about the basics of design of reinforced concrete and masonry elements and structures
- Acquisition of practical knowledge on the basics of design of reinforced concrete and masonry elements and structures, and creation of formwork and reinforcement layouts for these elements and structures.

Entry competences (prior knowledge, descriptive):

- Theoretical and practical knowledge of Structural Analysis (behaviour of structures under load and determination of internal forces in the structure)
- Theoretical and practical knowledge of the Strength of Materials and Construction Materials
- Knowledge of the basic elements of building structures.

Prerequisite:

- Enrolment requirements: teacher's signature for the courses Strength of Materials 2 and Structural Analysis 1
- Requirements for taking the exam: Mechanics 2 and Strength of Materials 1 course exams passed.

Learning outcomes:

- Students have the basic knowledge and skills needed to design basic load-bearing systems of reinforced concrete and masonry structures and the basic principles of conceptual design
- Students acquire basic knowledge about basic load-bearing elements of reinforced concrete and masonry structures
- Students have the knowledge and skills necessary for analysing the behaviour and designing of the basic load-bearing systems of reinforced concrete and masonry structures according to the ultimate limit states, using modern methods and criteria of European standards
- Students are able to create position layouts, formwork layouts and reinforcement layouts for simpler reinforced concrete structures and elements
- Students have the necessary knowledge to design the simplest masonry one-story buildings in areas without strong seismic influences.

Course content (by course schedule):

- Lectures:
  1. On concrete and masonry structures - meaning and use, history and development, advantages and disadvantages. CONCRETE STRUCTURES Regulations. Physical and

mechanical properties of concrete, strength and types of concrete. Physical and mechanical properties of reinforcing steel, strength and type of reinforcement [4]

2. Durability of reinforced concrete elements, determination of the concrete cover. Basic settings of the design of reinforced concrete structures according to the ultimate limit state. Global and partial safety coefficients. Design spans. Actions on the structure. [4]
3. Design of reinforced concrete structures according to the ultimate limit state, design of rectangular cross-sections and T-sections for bending. Double reinforced cross-section. Balanced cross-sectional failure. One-way slabs, reinforcement rules, minimum and maximum reinforcement. [4]
4. Staircases. Two-way slabs (cross-reinforced slabs). Semi-prefabricated panels. Slab reinforcement [4]
5. Calculation of T-section shaped beams according to EN in the middle of span and on the support. Effective beam width in the middle of span and on the support. Minimum and maximum reinforcement of T-section beams in the middle of span and on the support. Design of reinforced concrete elements under the action of shear forces. Calculation of shear reinforcement of beams according to EN. [4]
6. Bar spacing. Adhesion of concrete and reinforcement, anchoring, and lapping of reinforcement. The role of concrete and reinforcement and their joint participation in bearing capacity. Reinforcement tables [4]
7. An example of calculation of a bearing plate in one direction. [4]
8. FIRST MIDTERM EXAM – Calculation and reinforcement layout of one continuous reinforced concrete slab bearing in one direction.
9. Principles and calculation methods of centrically and eccentrically loaded reinforced concrete structural elements (columns and walls). Calculation of the reinforcement of short columns using the Ehlers method and using interaction diagrams. [4]
10. MASONRY STRUCTURES: History and introduction. Material properties. Mechanical and deformation properties of masonry construction materials. Characteristic strength of masonry. Characteristic and design values. [4]
11. Calculation of masonry according to ULS. Unreinforced masonry. Structural behaviour and stability. [4]
12. Design of masonry on concentrated action and shear. Design example. [4]
13. SECOND MIDTERM EXAM – Design of the bearing capacity of an unreinforced wall for vertical compressive force according to the standard EN 1996-1-1.
14. Confined masonry. Lateral load of walls. Reinforced masonry. Structural behaviour and stability. [4]
15. Reinforced masonry and reinforced masonry ceilings. Masonry-infilled frames. [4]

- Exercises (auditory):
  1. Design of the bearing capacity and stability of the RC building - Introduction and position layout of the building. [3]
  2. Design and reinforcement of the slab pos. 100 [3]
  3. Design and reinforcement of the slab pos. 200 [3]
  4. Design of beams and columns of the frame [3]
  5. Reinforcement of frame beams and columns [3]
  6. Wall analysis [3]
  7. Foundation analysis and reinforcement [3]
- Exercises (design):

1. Submission: Plan of positions [3]
2. Submission: Design of the slabs pos. 100 and 200 [3]
3. Submission: Slab reinforcement plan [6]
4. Submission: Design of beams and columns of the frame [3]
5. Submission: Reinforcement of frame beams and columns [3]
6. Submission: Wall analysis [3]
7. Submission: Foundation analysis and reinforcement [3]
8. Submission of the entire program assignment [3]

Student Evaluation - Continuous assessment:

- Preparation of the program assignment within the assigned deadline
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of the program assignment within the assigned deadline
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Sorić, Z., Kišiček, T.: BETONSKE KONSTRUKCIJE 1, University textbook, Građevinski fakultet, Zagreb, 2014.
2. Sorić, Z.: ZIDANE KONSTRUKCIJE, University textbook, self-published, Zagreb, 2016.
3. Sorić, Z.; Pičulin, S.; Zamolo, M.; Kišiček, T. (Jure Radić i suradnici.): *Osnove proračuna*, Chapter V in the book *Betonske konstrukcije, Priručnik*, Udžbenik Sveučilišta u Zagrebu, Zagreb, 2006., pp. 399-663, i. e. 265 pages of a total of 1000. Editor: Čandrlić, V.
4. Sorić, Z.; Kišiček, T.; Galić J. (Jure Radić i suradnici.): book chapter *Betonske konstrukcije*, R*iješeni primjeri, III. Konstrukcijski elementi*, pp. 139-390, i. e. 251 pages of a total of 960 pages. Udžbenik Sveučilišta u Zagrebu: Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, ANDRIS. 2006. Editor: Čandrlić, V.
5. Tomičić, I.: *Betonske konstrukcije*, Društvo Hrvatskih građevinskih konstruktora, Zagreb, 1996.
6. Tomičić, I.: *Priručnik za proračun armiranobetonskih konstrukcija*, Društvo Hrvatskih građevinskih konstruktora, Zagreb, 1996.
7. Exercise materials are available on the course website.

ROCK MECHANICS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 45
- Exercises (auditory): 30

Course objectives:

- Acquiring theoretical knowledge about the behaviour of rocks and the state of stress in the rock mass caused by the action of forces from its immediate physical environment,
- Application of acquired theoretical knowledge in solving simpler problems in the domain of rock mechanics.

Entry competences (prior knowledge, descriptive):

- Understanding and the ability to apply balance conditions in plane,
- Understanding the concepts of stress, deformation, stress-strain curve, stiffness and strength,
- Knowledge of the theory of Mohr's stress circles.

Learning outcomes:

- Understanding the primary and secondary state of stress, as well as how to determine it,
- Acquired knowledge about laboratory and field tests of rocks, and the method of determining the parameters of intact rock (laboratory tests) and rock mass (field tests),
- Acquired knowledge about the method of classification of rock masses,
- Understanding the concepts of rock mass strength and stiffness, as well as discontinuity strength,
- Ability to solve simpler problems from the field of rock mechanics: foundation on rock, stability of rock slopes, stability of rockslides, interaction of rock mass and tunnel substructure.

Course content (by course schedule):

- Lectures:
  1. Introduction [3]
  2. Introduction to rock mechanics and rock engineering [3]
  3. State of stress and deformation in rock [3]
  4. Engineering properties of rock mass [3]
  5. Description and strength of discontinuities [3]
  6. Classification of rock mass [6]
  7. Rock mass stiffness [3]
  8. Rock mass strength [3]
  9. Stability of rock slopes [3]
  10. Stability of rockslides [3]
  11. Reinforcement of the rock mass with rod anchors [3]
  12. Tunnel construction [3]
  13. Foundation on rock [3]
- Exercises (auditory):
  1. Introduction to rock mechanics and rock engineering [2]
  2. State of stress and deformation in the rock mass problems [2]
  3. Problems from laboratory investigations (ultrasound, PLT) [2]
  4. Problems from laboratory investigations (uniaxial compressive strength, connection of PLT and uniaxial compressive strength) [2]
  5. Problems from stiffness and strength of rock mass [4]
  6. Tasks from rock mass classifications [2]
  7. Problems from the stability of rock slopes (planar failure) [2]
  8. Problems from the stability of rock slopes (wedge) [2]

9. Problems from the stability of rock slopes (rotational failure) [2]
10. Landslide stability tasks [2]
11. Tasks from rock foundation [2]
12. Tasks from underground buildings [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the assigned deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the assigned deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Kovačević, M.S., Mehanika stijena, 2021.

Additional reading:

1. Goodman, R. E.: *Introduction to Rock Mechanics*, Second Edition, 1989.
2. Hudson, J. A.; Harrison, J. P.: *Engineering Rock Mechanics. An Introduction to the Principles*, 1997.

ROADS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 45
- Exercises (design): 30

Course objectives:

- Acquisition of basic theoretical and practical knowledge about road design and construction.

Entry competences (prior knowledge, descriptive):

- Knowledge of working with computer programs for technical drawing.

Prerequisite:

- Enrolment requirements: teacher's signature for the course Soil Mechanics,

Learning outcomes:

- Understanding the basic principles of traffic flow, safety, level of service and capacity,
- Understanding of the basic vehicle dynamics settings relevant to the determination of horizontal, vertical and cross-section elements of the road,

- The ability to use project documentation in the construction of roads,
- The ability to search scientific articles and collect information and data necessary for the solution of practical problems in everyday engineering practice,
- Basic knowledge required for contractor works of construction of road frame, slope protection and drainage system,
- Basic knowledge required for the construction of pavement structures.

Course content (by course schedule):

- Lectures:
  1. Introduction. Basic terms and road typology [3]
  2. Road vehicles [2]
  3. Vehicle movement [3]
  4. Horizontal alignment [6]
  5. Vertical alignment [3]
  6. Three-dimensional alignment. Traffic [3]
  7. Road cross-section [3]
  8. FIRST MIDTERM EXAM [1]
  9. Driving surface geometry [3]
  10. Drainage. [3]
  11. Materials. Earthworks [3]
  12. Road junctions [3]
  13. Traffic areas. Road equipment [3]
  14. SECOND MIDTERM EXAM [1]
  15. Pavement structures [5]
- Exercises (design):
  1. Situation [12]
  2. Longitudinal profile [6]
  3. Normal cross-section [4]
  4. Characteristic cross-sections [4]
  5. Technical description [2]
  6. Submission of program assignments [2]

Student Evaluation - Continuous assessment:

- Preparation and submission of program assignments within the assigned deadline
- First midterm exam
- Second midterm exam
- Oral exam
- Lecture and exercises attendance

Student Evaluation - Examination without Continuous Assessment:

- Preparation and submission of program assignments within the assigned deadline
- Written exam
- Oral exam
- Lecture and exercises attendance

Required reading:

1. Korlaet Ž., Dragčević V., Projektiranje i građenje cesta, udžbenik Sveučilišta u Zagrebu, 2018., str. 225.

2. Dragčević, V.; Korlaet, Ž.: *Osnove projektiranja cesta*, Udžbenik Sveučilišta u Zagrebu, 2003., str. 93.
3. Other materials: http://merlin.srce.hr (e-course on Merlin)

RAILWAYS

Credits (ECTS): 3

Hours (total per semester):
- Lectures: 30
- Exercises: 15 (auditory: 1, design: 14)

Course objectives:
- Acquisition of basic knowledge about the development and importance of railway transport,
- Acquisition of theoretical knowledge about the types of rail vehicles and railway track structures and about the types of loads acting on the track,
- Acquisition of practical knowledge about basic railway track elements and the methods of railway track condition assessment and maintenance.

Entry competences (prior knowledge, descriptive):
- Knowledge of materials mechanical properties ,
- Understanding the concepts of stress and deformation.

Prerequisite:
- Enrolment requirements: teacher's signature for the course Soil Mechanics,
- Requirements for taking the exam: teacher's signature for the course Strength of Materials 1

Learning outcomes:
- Explain the advantages of the railway in relation to other transport systems,
- Explain the effect of forces on the railway track structure and the basis of superstructure calculation,
- Explain the basics of railway superstructure devices (turnouts, travelling platforms, turntables),
- Explain the basics of the main elements of the railway superstructure (rails, sleepers, ballast, fastening systems),
- Explain the basics of rail welding and continuous welded rail
- Explain the basics of railway track control and maintenance.

Course content (by course schedule):
- Lectures:
  1. Basics of railways: historical development and classification [1]
  2. Loading and construction gauge of railway tracks, axle assemblies [2]
  3. Railway vehicles, railway lines categorization [2]
  4. Route selection, curvature and design elements [2]
  5. Railway stations, station equipment, signals, types of railway [2]
  6. Basics of track layout and alignment [2]
  7. Forces acting on the railway track [2]

8. Track superstructure elements: rails, sleepers [3]
9. Track superstructure elements: fastening systems, railway ballast [2]
10. Permanent way elements: turnouts, turntables, travelling platforms [2]
11. Basic requirements for a track arrangement: straight track and track in curve [2]
12. Rail welding [2]
13. Track quality control [2]
14. Track maintenance [2]
15. Special railways [2]

- Exercises (auditory):
  1. Introductory exercises, program assignments [1]
- Exercises (design):
  1. Traction characteristics of the locomotive [2]
  2. Total towed mass on the relevant slope of the track [2]
  3. Cant of the outer rail in the horizontal curve [3]
  4. Stresses in the rail during lifetime [2]
  5. The thickness of the railway ballast and the cross-section of the railway track structure [2]
  6. Design of railway track positional stability [2]
  7. Review and submission of program assignments. [1]

Student Evaluation - Continuous assessment:

- Preparation of an individual program assignment
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of an individual program assignment
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Prister, G.; Pollak, B.: *Gornji ustroj i specijalne željeznice*, Građevinski institut, Zagreb, 1988.
2. Lakušić, S.: *Željeznice*, lectures for the 3rd year students at the Faculty of Civil Engineering, http://www.grad.unizg.hr/predmet/zel
3. Lakušić, S., Ahac, M., Haladin, I., Grgić., V, Vranešić, K. - *ŽELJEZNICE – Off-prints for completing program assignments for 3rd year students of the Faculty of Civil Engineering* (Merlin).

Additional reading:

1. Esveld, C.: *Modern Railway Track,* Second Edition, MRT Productions, Zaltbommel, 2001.

Elective courses

CONSTRUCTION TECHNOLOGIES

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquiring theoretical knowledge on construction preparation techniques, techniques for securing excavation pits, execution of building construction processes, the production, transportation, and placement of concrete the types and operational methods of basic construction machinery, various types of scaffolding and formwork for structural construction, and the methods for demolishing and dismantling buildings.

Learning outcomes:

- Recognize the technological process and create workflows,
- Select the appropriate type of scaffolding for a specific structure and determine the proper method for its assembly,
- For a specific structure, select the appropriate type of formwork, and understand how to monitor and control its usage,
- For earthworks, select the suitable type of machinery and calculate its required capacity,
- Choose a concrete plant for the concreting process, determine the number of transport units needed, and calculate the time required for concrete placement.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Construction site preparation [2]
  3. Construction pit protection [4]
  4. Earthmoving machines [2]
  5. Reinforcement plant and reinforcement works [2]
  6. Production and transport of concrete [2]
  7. Concrete transport and laying – dimensioning [2]
  8. Formwork of vertical and horizontal structures [2]
  9. Scaffolding in building construction [2]
  10. Internal transport - cranes [2]
  11. Masonry works [2]
  12. Drilling, cutting and demolition of buildings [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam, a minimum score of 60%
- Second midterm exam, a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam, a minimum score of 60%

Required reading:

1. Lectures on the website of the Faculty,
2. Zdravko Linarić: *Leksikon osnovne građevinske mehanizacije.*

Additional reading:

1. Off-prints and lectures.
2. Web page //og.grad.hr
3. Mlinarić, V.: *Tehnologija građenja*, TVZ, Zagreb, 2017.
4. Chudley, R., Greeno, R.; *Advanced construction technology*, Pearson Education Limited, Engleska, 2006.
5. Lončarić R.,: *Organizacija izvedbe graditeljskih projekata*, HDGI, Zagreb, 1995.
6. Zdravko Linarić: *Leksikon osnovne građevinske mehanizacije*, *Učinak građevinskih strojeva*, *Postrojenja za izradu gradiva.*

INFRASTRUCTURE CONSTRUCTION TECHNOLOGIES

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of theoretical knowledge about civil engineering construction works procedures; construction techniques and technologies; construction machinery; familiarization with machines for civil engineering works, planning of civil engineering earthwork technology, concrete production, concrete transport and pouring, scaffolding and formwork for civil engineering objects.

Learning outcomes:

- Recognize the technological process and create a sequence of works,
- For a specific structure, choose the type and type of formwork and know how to control it,
- For earthworks, choose the type of machine and dimension its capacity,
- For the concreting process, choose a concrete plant, determine the number of transport machinery and determine the pouring time,
- For earthworks, coordinate the capacities of the machinery.

Course content (by course schedule):

- Lectures:
  1. Introduction: Content and program of instruction. Literature review. Lesson plan. Instructions for passing the midterm exams, obtaining signatures and taking the exam [2]
  2. Civil engineering technology: Construction works. Construction techniques and technologies. Construction machinery. Characteristics of modern construction machinery [2]
  3. *1st group of lectures: Technique and technology of surface earthworks in soil and rock: Earthworks.* Surface excavation of soil and rock. Dozers. Scrapers [2]

4. Excavators. Excavator devices and tools. Rock scraping. Trenchers (trenchers, drain-layers) [2]
5. Transport of bulk materials. Loaders and vehicles. Installation of loose materials. Graders and rollers [2]
6. Choice of technique and technology of earthworks. The performance of machines and vehicles during earthworks [2]
7. *2nd lecture group: Technique and technology of concrete works in civil engineering (transported concrete)*. Concrete works. Transported concrete. Production of fresh concrete. Concrete factories. [2]
8. Scaffolding and formwork in civil engineering. Formwork. Modern formwork systems. Scaffolding systems. [2]
9. Transport of fresh concrete. Fresh concrete pouring. Tower cranes. Constructing horizontal concrete structures. [2]
10. Scaffolding and formwork systems in bridge construction. Prefab construction of bridges. Truck and excavator cranes. [2]
11. Technique and technology of asphalt works. [2]
12. Asphalting works. Rolled asphalt concrete. Cast asphalt concrete. Asphalt macadams [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam, a minimum score of 60%
- Second midterm exam, a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam, a minimum score of 60%

Required reading:

1. Linarić, Z., Burcar Dunović, I. – *Tehnologija građenja niskogradnja*, course materials
2. Linarić, Z.: *Leksikon strojeva i opreme za proizvonju građevinskih materijala. Učinci za strojeve i vozila pri zemljanim radovima*, biblioteka Mineral, Bussines Media Croatia, Zagreb, 2007.
3. Linarić: *Postrojenja za proizvodnju sipkih i povezanih mineralnih gradiva, dobilane, Tvornice betona, asfalttne baze*, biblioteka Mineral, Busines medic Croatica, Zagreb, 2009.
4. Linarić, Z: *Tehnologija građenja I.* - electronic lecture notes.

STRUCTURAL ANALYSIS 2

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 18, computer: 10, design: 2)

Course objectives:

- Deepening theoretical knowledge about the behaviour of structures under load and other actions,

- Acquisition of practical knowledge about analytical and numerical procedures of linear calculation of rod structures.

Entry competences (prior knowledge, descriptive):

- Understanding and the ability to apply balance conditions in plane and space,
- Knowledge of basic procedures for determining reactions, internal forces and deflection lines of statically determined and statically indeterminate structures,
- Understanding of the concept of virtual work and the theoretical basis of variation procedures.

Prerequisite:

- Enrolment requirements: teacher's signature for the course Structural Analysis 1,
- Requirements for taking the exam: Structural Analysis 1 course exam passed.

Learning outcomes:

- Apply analytical and relaxation procedures for the calculation of statically indeterminate structures,
- Explain the theoretical bases of numerical calculation procedures,
- Apply computer programs in calculations of structures and evaluate their applicability,
- Explain and implement the procedures for defining influence functions and drawing influence lines.

Course content (by course schedule):

- Lectures:
  1. Engineering displacement method: unknowns, fixed systems without hinges [2]
  2. Engineering displacement method: unknowns, movable systems without joints [2]
  3. Engineering displacement method: hinges and static condensation; kinematic condensation [2]
  4. Influence functions and influence lines for statically determined systems [2]
  5. Influence functions and influence lines for statically indeterminate systems [4]
  6. Basic concepts of geometric and material nonlinearity [2]
  7. Prestressed cable structures [6]
  8. Relaxation procedures: Cross procedure for fixed systems [2]
  9. Relaxation procedures: the Werner-Csonka procedure [2]
  10. Relaxation procedures: Cross procedure for movable systems [2]
  11. Specific examples of static systems that can be solved by the engineering displacement method and relaxation procedures [2]

- Exercises (auditory):
  1. Force method and general displacement method [2]
  2. Engineering displacement method [6]
  3. Influence functions [6]
  4. Relaxation procedures [4]
- Exercises (computer):
  1. Application of computer programs in the calculation of rod structures [4]
  2. Application of computers in the design of prestressed cable structures [6]
- Exercises (design):
  1. Completing program assignments [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. V. Simović: *Građevna statika 1*, Građevinski institut, Zagreb, 1988.
2. M. Anđelić: *Građevna statika 2*, Građevinski fakultet, Zagreb, 2005.
3. K. Fresl: *GS – Bilješke i skice s predavanja*, http://master.grad.hr/nastava/gs (web page for the courses Structural Analysis 1 and Structural Analysis 2)
4. P. Gidak, E. Šamec: Statički neodređeni sistemi, (http://master.grad.hr/nastava/gs/gs2/e_sns.pdf)

Additional reading:

1. M. Sekulić: *Teorija linijskih nosača*, Građevinska knjiga, Beograd, 2005.
2. L. P. Felton, R. B. Nelson: *Matrix Structural Analysis*, Wiley, New York, 1997.
3. W. Wunderlich, W. D. Pilkey: *Mechanics of Structures. Variational and Computational Methods*, CRC Press, Boca Raton, 2003.

NUMERICAL MODELLING OF STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (construction: 4, computer: 18, seminars: 8)

Course objectives:

- Deepening theoretical knowledge about the behaviour of structures under load and other actions,
- Acquisition of practical knowledge about analytical and numerical procedures of linear calculation of rod structures,
- Acquisition of knowledge about the discretization of the design model,
- Acquisition of practical knowledge in the interpretation of calculation results obtained by calculation on a computer.

Entry competences (prior knowledge, descriptive):

- Understanding and the ability to apply balance conditions in plane and space,
- Knowledge of basic procedures for determining reactions, internal forces and deflection lines of statically determined and statically indeterminate structures,

- Understanding of the concept of virtual work and the theoretical basis of variation procedures,
- Basic mathematical knowledge in the field of differential equations.

Prerequisite:

- Enrolment requirements: teacher's signature for the course Structural Analysis 1,
- Requirements for taking the exam: Structural Analysis 1 course exam passed.

Learning outcomes:

- Apply analytical and relaxation procedures for the calculation of statically indeterminate structures,
- Explain the theoretical bases of numerical calculation procedures,
- Explain and implement the procedures for defining influence functions and drawing influence lines,
- Explain the construction calculation model for construction calculations with software packages,
- Apply computer programs in construction calculations and evaluate their applicability,
- Interpret the results of calculations with software packages.

Course content (by course schedule):

- Lectures:
  1. General displacement method [2]
  2. Engineering displacement method [2]
  3. Relaxation procedures [2]
  4. Influence functions and influence lines, Statically indeterminate systems [2]
  5. Mathematical model of the construction, Discretization of the model [2]
  6. Strong and weak formulation of the assignment [4]
  7. Ritz method [4]
  8. Finite difference method [4]
  9. Finite element method [2]
  10. Spatial systems. Grillage structures. [2]
  11. Walls with openings. Basic concepts of geometric and material nonlinearity. [2]
- Exercises (computer):
  1. Introduction, modelling of simple linear structural systems [2]
  2. Modelling of 2D frames [4]
  3. Modelling of 2D beams [4]
  4. Modelling of trusses [4]
  5. Modelling of 3D beams [4]
- Exercises (construction):
  1. Modelling of the given example [2]
  2. Introduction to the modelling of shell structures [2]

Student Evaluation - Examination without Continuous Assessment:

- Regular attendance – 75% lectures, 100% exercises
- Seminar paper (prerequisite for taking the oral exam)
- Oral exam

Required reading:

1. M. Anđelić: *Građevna statika 2*, Građevinski fakultet, Zagreb, 2005.
2. J. Sorić: *Metoda konačnih elemenata*, Golden Marketing, Zagreb, 2004.
3. M. Meštrović: *NMK – lecture notes*, http://www.grad.hr/kolegiji/nmk

3rd year, 6th semester

Mandatory courses

CONSTRUCTION MANAGEMENT

Credits (ECTS): 6.5

Hours (total per semester):

- Lectures: 45
- Exercises: 45 (auditory: 14, design: 31)

Course objectives:

- Acquiring theoretical knowledge about planning, preparation, organization and control of the construction process
- Acquiring practical knowledge about tools for construction management

Learning outcomes:

- Recognize the roots and basic definition of organization development in construction (different theories of organization, system, project, etc.),
- Explain the organization and scheduling of work processes,
- Explain the organization and management of the construction site,
- Apply the construction price calculation method
- Develop priced bill of quantitates and bill of costs
- Apply the construction time estimation and scheduling method,
- Explain the health, safety and environmental systems in construction.

Prerequisite:

- Enrolment requirements: teacher's signature for the course Building Technology (Building Construction or Technology of Heavy Construction), Law in Construction course exam passed,
- Requirements for taking the exam: Building Technology (Building Construction or Technology of Heavy Construction) course exam passed.

Course content (by course schedule):

- Lectures:
  1. Introduction
  2. System and project
  3. Construction Management Plan
  4. Organization of work processes
  5. Construction site organization and management
  6. Planning and control of construction works, processes and systems
  7. Calculation of costs and prices and priced bill of quantities
  8. Organizational structures, interested parties and stakeholders in construction
  9. Construction project management
  10. Health, Safety and Environment in Construction
- Exercises (auditory):
  1. Item 1. Input data and Bill of Quantities
  2. Item 1. Material statement

3. Item 2. Construction technology plan
4. Item 3. Organization of Work Processes and Network Planning
5. Item 4. Time and Resource Planning
6. Item 5. Construction site plan
7. Item 6. Calculation of construction cost and price and priced bill of quantities

- Exercises (design):
  1. Item 1. Input data and Bill of Quantities
  2. Item 1. Material statement
  3. Item 2. Construction technology plan
  4. Item 3. Organization of Work Processes and Network Planning
  5. Item 4. Time and Resource Planning
  6. Item 5. Construction site plan
  7. Item 6. Calculation of construction cost and price

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- First midterm exam
- Second midterm exam
- Third midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. Radujković, M; Burcar Dunović, I; Dolaček Alduk, Z,; Nahod, M.M.; Vukomanović, Mladen. *Organizacija građenja*, Zagreb: Građevinski fakultet Sveučilišta u Zagrebu, 2015.¸
2. Vukomanović, M., Kolarić, S., Radujković, M. – *Priručnik organizacije građenja*, 2018.
3. Radujković, Mladen; Car-Pušić, Diana; Ostojić Škomrlj, Nives; Vukomanović, Mladen; Burcar Dunović, Ivana; Delić, Davor; Meštrović, Hrvoje. *Planiranje i kontrola projekata*, Sveučilište u Zagrebu, Građevinski fakultet, 2012.
4. Radujković, Mladen; Burcar, Ivana; Vukomanović, Mladen. *Riješeni primjeri zadataka - Organizacija građenja 1 i Metode planiranja*; Zagreb : Građevinski fakultet Sveučilišta u Zagrebu, 2008.
5. 5. Radujković M., Izetbegović J., Nahod M. M., *Građevinska regulativa*, Građevinski fakultet, 2008.
6. Marušić , J.: *Organizacija građenja*, FS- Zagreb, 1994.
7. Lončarić, R.: *Organizacija izvedbe graditeljskih projekata*, HDGI, Zagreb, 1995.

Additional reading:

1. Izetbegović, J.; Žerjav, V.: *Organizacija građevinske proizvodnje*, university handbook, GF Sveučilišta u Zagrebu, Hrvatska udruga za organizaciju građenja, Zagreb, 2009.

METAL STRUCTURES

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (design: 6, construction: 9)

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of steel and aluminium as building materials and their influence on the resistance of structural members and joints,
- Acquisition of knowledge related to the spatial stabilization of buildings made of steel or aluminium members,
- Acquisition of theoretical and practical knowledge about the dimensioning of simple steel structural members.

Entry competences (prior knowledge, descriptive):

- Knowledge of the statics of a rigid body and connected systems,
- Understanding and the ability to apply balance conditions in plane and space,
- Knowledge and ability to determine reactions and internal forces and deflections on statically determinate structures.

Prerequisite:

- Enrolment requirements: Structural Analysis 1 and Introduction to Structural Engineering course exams passed.

Learning outcomes:

- The ability to connect knowledge about the behaviour of steel as a material and the influence of that behaviour on the resistance of steel structural members,
- The ability to create dispositional solutions for simpler structures such as single storey buildings without crane tracks,
- Recognition of key factors for determining basic action effects on structures,
- The ability to determine the action effects at the level of structural members of statically determinate systems,
- The ability to determine the calculated resistances of simpler steel structural members and joints for the ultimate limit state and the serviceability limit state.

Course content (by course schedule):

- Lectures:
  1. Introduction. Terminology and definition of matter [2]
  2. Properties of steel. Basic concepts and steel production. Chemical composition and influence on mechanical properties [2]
  3. Metallographic properties. Thermal treatments. Residual stresses [2]
  4. Characteristic values and definitions of basic terms (Part 1) [2]
  5. Characteristic values and definitions of basic terms (Part 2). Yield criterion hypotheses. Material fatigue. Types of structural steel [2]
  6. Basics of structural reliability and action effects [2]
  7. Resistance of cross-sections and members – dimensioning (Part 1). [2]
  8. Resistance of cross-sections and members – dimensioning (Part 2). [2]
  9. Resistance of cross-sections and members – dimensioning (part 3). [2]

10. Resistance of cross-sections and members – dimensioning (Part 4). [2]
11. Resistance of cross-sections and members – dimensioning (Part 5). [2]
12. Structural modelling [2]
13. Connections and fasteners [2]
14. Corrosion protection and fire resistance [2]
15. Structures from aluminium alloys; Design assisted by testing; Manufacturing and assembly of steel structures [2]

- Exercises (design):
  1. Standards and regulations. Structural steels. Rolling products [1]
  2. Disposition of the single-storey building with modes of action transmission [2]
  3. Disposition of the single-storey building [1]
  4. Determining of action effects [1]
  5. Dimensioning of elements [1]
- Exercises (construction):
  1. Disposition of the single-storey building [2]
  2. Determining of action effects [3]
  3. Dimensioning of members [3]
  4. Midterm exam and submission of program assignments. [1]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- Exercises attendance 100%
- Program assignment submitted and defended within the prescribed deadline
- First midterm exam
- Second midterm exam
- Practical part of the written exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Exercises attendance 100%
- Program assignment submitted and defended within the prescribed deadline
- Theoretical part of the written exam
- Practical part of the written exam

Required reading:

1. Skejić, D.; Lukačević, I.: Lecture notes for the course Metal Structures - academic year 2023./2024., Faculty of Civil Engineering, University of Zagreb,
2. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 1*, IA Projektiranje, Zagreb, 2009.
3. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 2*, IA Projektiranje, Zagreb, 2007.
4. Skejić, D.; Džeba, I.: *Čelične konstrukcije*, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2016.
5. Off-prints on the web pages of the Faculty of Civil Engineering for the course Metal Structures.

Additional reading:

1. Markulak D.: *Proračun čeličnih konstrukcija prema EN 1993-1-1*, Građevinski fakultet u Osijeku, 2008.
2. Markulak, D: Me(n)talne konstrukcije, Građevinski fakultet u Osijeku, 2018.

BRIDGES

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (design: 7, construction: 8)

Course objectives:

- Acquisition of basic knowledge about all load-bearing bridge systems, design, performance and maintenance procedures and methods,
- Acquisition of basic knowledge about conceptual design, analysis of loads on bridges and dimensioning of load-bearing systems.

Entry competences (prior knowledge, descriptive):

- Acquired theoretical knowledge about the behaviour of constructions under load and other actions and about ways of transferring forces,
- Acquired practical knowledge about linear calculation procedures of statically determinate and statically indeterminate structures.

Prerequisite:

- Enrolment requirements: teacher's signature for the courses Concrete and Masonry Structures 1 and Roads,

Learning outcomes:

- Students have the basic knowledge and skills needed to design load-bearing bridge systems and apply the basic principles of conceptual design;
- Students have the knowledge and skills necessary to analyse the behaviour and dimension of load-bearing systems of bridges according to the limit states of load-bearing capacity and serviceability, while using modern methods and criteria of European standards,
- Students have the knowledge and ability to choose the appropriate bearing system of the bridge depending on the geometric boundary conditions in accordance with modern methods and criteria of European standards,
- Students are able to design load-bearing systems of bridges and design a reinforced concrete bridge up to a span of 20 m in accordance with modern methods and criteria of European standards.

Course content (by course schedule):

- Lectures:
  1. Introduction and general information [2]
  2. Types of bridges. Basic requirements for bridges [2]
  3. Traffic conditions. Actions on bridges [2]
  4. Reliability factors of bridges [1]
  5. Bridge disposition elements [1]
  6. Load-bearing structures in bridges [4]
  7. First midterm exam [2]
  8. Substructure [2]
  9. Bridge equipment [2]
  10. Design elements [2]
  11. Bridge construction [3]
  12. Maintenance of bridges. Bridges in extraordinary circumstances [2]

13. Overview of the history of bridge construction [2]
14. Current possibilities in bridge construction [1]
15. Second midterm exam [2]

- Exercises (design):
  1. Introduction to program, disposition and cross-sections, program assignments [1]
  2. Design of cross-section and longitudinal arrangement [1]
  3. Substructure elements [1]
  4. Bridge equipment and details [1]
  5. Action analysis and transverse distribution, preparation for statical analysis [1]
  6. Statical analysis [1]
  7. Dimensioning and reinforcement drawings [1]
- Exercises (construction):
  1. Disposition – control of drawings [2]
  2. Control of load analysis [1]
  3. Control of statical analysis [2]
  4. Control of dimensioning [1]
  5. Review and evaluation of entire program, oral examination [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Radić, J.: *Uvod u mostarstvo*, Hrvatska sveučilišna naklada, Jadring, Sveučilište u Zagrebu – Građevinski fakultet, Zagreb, 2009.
2. Radić, J.; Mandić, A.; Puž, G.: *Konstruiranje mostova*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, Jadring, Zagreb, 2005.
3. Off-prints from exercises

Additional reading:

1. Radić, J. i suradnici: *Betonske konstrukcije – priručnik*
2. Radić, J. i suradnici: *Betonske konstrukcije – riješeni primjeri*

HYDRAULIC STRUCTURES

Credits (ECTS): 3.5

Hours (total per semester):

- Lectures: 45

Course objectives:

- Acquisition of practical and theoretical knowledge about functional and constructive elements of hydrotechnical structures, and characteristic effects on hydraulic structures.

Entry competences (prior knowledge, descriptive):

- Knowledge and understanding of hydrological processes,
- Knowledge and understanding of the basic fluid mechanics principles,
- Knowledge and understanding of the basic properties of soil and rocks and foundations,
- Knowledge of calculations and construction of concrete structures.

Prerequisite:

- Enrolment requirements: Hydrology and Soil Mechanics course exams passed.

Learning outcomes:

- Recognize problems related to hydraulic structures,
- Participate in the definition and creation of bases necessary for the design of hydrotechnical structures,
- Participate in the team for the design and construction of hydraulic structures,
- Participate in the water management team.

Course content (by course schedule):

- Lectures:
  1. Introduction – purpose, definitions, classifications. Basic design data for HS [3]
  2. Types of calculations, calculation of functionality [3]
  3. Structural design, structural loads [3]
  4. Structural design, structural loads [3]
  5. Flood defence [3]
  6. Design of river training [3]
  7. Canals and canal hydraulic structures [3]
  8. Midterm exam [3]
  9. Pipelines and hydraulic tunnels [3]
  10. Dams [3]
  11. Dams. Storage reservoirs. [3]
  12. Storage reservoirs. Hydropower plants. [3]
  13. River navigation structures – input data [3]
  14. River navigation structures - design [3]
  15. Midterm exam [3]

Student Evaluation - Continuous assessment:

- Midterm exams
- Oral exam
- 75% attendance at lectures

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Oral exam
- 75% attendance at lectures

Required reading:

1. Kuspilić N., Ocvirk E.: *Hidrotehničke građevine*, WEB lecture notes of the Faculty of Civil Engineering of the University in Zagreb, 2017.

Additional reading:

1. Stojić, P: *Hidrotehničke građevine I, II, III*, GF Split, 1997., 1998. i 1999.
2. Stojić, P.: *Hidroenergetika*, Građevinski fakultet, Split, 1995.
3. Nonveiller, E.: *Nasute brane*, Školska knjiga, Zagreb, 1983.
4. *Design of Small Dams*, US Department of the Interior, Bureau of Reclamation, 1977.
5. Đorđević, B: *Korištenje vodnih snaga – objekti hidroelektrana*, Naučna knjiga i GF Beograd, 1989.
6. Savić: *Uvod u hidrotehničke građevine*, Beograd, Građevinski fakultet, 2003.
7. Pršić, M.: *Hidrotehničke građevine*, Naval constructions chapters (website).
8. Tadejević, Z., Pršić, M.: *Pomorska hidraulika I*, lecture notes, 1981.
9. Pršić, M., Tadejević, Z.: *Unutarnji plovni putevi*, lecture notes, 1988.

ON-SITE EDUCATION

Credits (ECTS): 3

Hours (total per semester):

- Exercises: 45 (auditory: 3, construction: 6, field 36)

Course objectives:

- Familiarization with technology, technique, organization and work processes on construction sites.

Learning outcomes:

- Recognition of technique, technology and organization of different buildings, their shape and way of carrying out works

Prerequisite:

- Enrolment requirements: passed course exams from the first four semesters.

Course content (by course schedule):

- Exercises (auditory):
  1. Introduction to the course and obligations [3]
- Exercises (fieldwork):
  2. Concrete production [6]
  3. Excavations and protection of the construction excavation pit [6]
  4. Finishing works and facade constructions [6]
  5. Execution of construction works in building construction [6]
  6. Hydrotechnical structures [6]
  7. Transport infrastructure [6]
- Exercises (construction):
  1. Submission and defence of seminars from fieldwork exercises [6]

Student Evaluation:
- Attendance
- Submitted seminar paper

Elective courses

TIMBER STRUCTURES

Credits (ECTS): 4

Hours (total per semester):
- Lectures: 30
- Exercises: 15 (auditory: 8, construction: 7)

Course objectives:
- Acquisition of theoretical knowledge about timber as a construction material,
- Acquisition of practical knowledge about the procedures for dimensioning load-bearing elements of timber structures,
- Acquisition of practical knowledge about the stabilization of timber structures.

Entry competences (prior knowledge, descriptive):
- Theoretical knowledge about the behaviour of constructions under load and other actions and about ways of transferring forces,
- Understanding of the concepts of stress and deformation and internal forces,
- Practical knowledge about linear calculation procedures of statically determinate and statically indeterminate rod structures.

Prerequisite:
- Enrolment requirements: Structural Analysis 1 and Strength of Materials 1 course exams passed,
- Requirements for taking the exam: Strength of Materials 2 course exam passed.

Learning outcomes:
- Knowledge about the physical and mechanical characteristics of wood,
- Apply appropriate evidence of load-bearing capacity and usability of elements,
- Test the load capacity of simpler static systems,
- Apply knowledge about dimensioning and performance of joints with rod fasteners,
- Solve the stabilization of simpler structures,
- Construct simpler load-bearing systems.

Course content (by course schedule):
- Lectures:
  1. General overview of timber structures: historical development, systems, methodological approach [2]
  2. Timber as a material: properties of solid wood, laminated glued wood and wood-based panel materials; classification of timber [4]
  3. Fire safety, protection and durability of timber structures [2]
  4. Calculation procedures of timber structures**:** valid standards and EUROCODE 5 [6]
  5. Fasteners in timber structures: nails, screws, dowels, wood screws, dowels, glues, patented fasteners, joints with thin sheets. Calculation of the bearing capacity of connectors according to EC5 [6]

6. Classic carpentry timber structures. Principles of calculation of elements, design and calculation of element connection details [2]
7. Lattice girders. Calculation principles, design and calculation of connection details in classic and contemporary versions. Transmission of forces in the calculation of details [2]
8. Laminated girders: basics of dimensioning of typical laminated girders of parallel belts and trapezoidal girders. Design and characteristic details [2]
9. Basics of designing planar frame systems. Principles of calculation, design and detail calculation. Spatial stability [4]

- Exercises (auditory):
  1. Description of the assignment. [1]
  2. Elements of the disposition solution of the structure. Method for solving the disposition. [1]
  3. Action models and method of calculation according to EUROCODE 5 standards. Action analysis. [1]
  4. Structural calculation and dimensioning of the secondary structure according to EUROCODE 5 standards. [1]
  5. The main supporting structure. Determining calculation combinations of actions. Creating a numerical (spatial) model of the main load-bearing structure. Structural calculation of the main load-bearing structure. [1]
  6. Dimensioning of elements of the main load-bearing structure according to EUROCODE 5 standards [1]
  7. Details in timber structures Design and calculation of connection details [2]
- Exercises (construction):
  1. Method for solving the disposition. Disposition solution. [1]
  2. Action analysis according to EUROCODE 1 standards. Structural calculation and dimensioning of the secondary structure according to EUROCODE 5 standards [1]
  3. Creating a numerical (spatial) model of the main load-bearing structure. Structural calculation of the load-bearing structure. [1]
  4. Dimensioning of the elements of the main load-bearing structure. [1]
  5. Details of connections in timber structures. Design and calculation of connection details. [1]
  6. Implementation drawing and connection detail drawings. Technical description. [1]
  7. Review and submission of program assignments [1]

Student Evaluation - Continuous assessment:

- Preparation of program assignments
- Short theory test after lectures
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam – calculation task
- First midterm exam – theory
- Second midterm exam – calculation task
- Second midterm exam – theory
- Exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments
- 75% attendance at lectures
- 100% attendance at exercises
- Theoretical part of the exam
- Practical part of the exam – solving the calculation task

Required reading:

1. Bjelanović, A.; Rajčić, V.: *Drvene konstrukcije prema europskim normama*; Hrvatska sveučilišna naklada, Zagreb, 2005. (2nd ed. 2007.)
2. Žagar, Z.: *Drvene konstrukcije I-II*; Pretei, Zagreb, 2003.
3. Magerle, M: *Svojstva drva*; IGH, Zagreb, 1996.
4. Rajčić, V., Čizmar, D., Stepinac, M.: *Riješeni primjeri iz drvenih konstrukcija*, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 2014.
5. Course materials are available on the official website of the course.

Additional reading:

1. Crocetti, R.; Johansson, M.; Johansson, H.; Kliger, R.; Martensson, A.; Norlin, B.; Pousette, A.; Thelandersson, S.: *Design of timber structures I-III*; Swedish Wood, Stockholm, 2022.
2. Blass, H. J.; Sandhaas, C.: *Ingenieurholzbau - Grundlagen der Memessung*; KIT Scientific Publishing, Karlsruhe, 2016.
3. Colling, F.: *Holzbau - Grundlagen und Bemessun (und Beispiele) nach Eurocode 5*; Springer Vieweg, Wiesbaden, 2021.
4. Herzog, T.; Nattere, J.; Schweitezer, R.; Volz, M.; Winter, W.: *Holzbau Atlas*; Institut fur internationale Architektur-Dokumentation GmbH, Munchen, 2003.
5. CEN: European Standards *HRN EN 1995-1-1:2013+A2:2015+NA:2013* and *HRN EN 1995-1-2:2013+NA:2013*; CEN, Brussels, 2013.

LIGHTWEIGHT STRUCTURES

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (design: 8, construction: 7)

Course objectives:

- Acquisition of theoretical knowledge about timber, glass and aluminium as building materials,
- Acquisition of practical knowledge about the procedures for dimensioning load-bearing elements of timber structures as well as load-bearing elements of aluminium structures and load-bearing glass elements,
- Acquisition of practical knowledge about the stabilization of timber structures.

Entry competences (prior knowledge, descriptive):

- Theoretical knowledge about the behaviour of constructions under load and other actions and about ways of transferring forces,
- Understanding of the concepts of stress and deformation and internal forces,
- Practical knowledge about linear calculation procedures of statically determinate and statically indeterminate rod structures.

Prerequisite:

- Enrolment requirements: Structural Analysis 1 and Strength of Materials 1 course exams passed,
- Requirements for taking the exam: Strength of Materials 2 course exam passed.

Learning outcomes:

- Knowledge about the physical and mechanical properties of timber, load-bearing glass and aluminium,
- Apply appropriate evidence of load-bearing capacity and usability of elements,
- Test the load-bearing capacity of simpler static systems made of timber, and elements made of load-bearing glass and aluminium,
- Apply knowledge about dimensioning and performance of joints with rod fasteners,
- Solve the stabilization of simpler structures.

Course content (by course schedule):

- Lectures:
  1. General overview of timber structures: historical development, systems, methodological approach [2]
  2. Wood as a material: properties of solid timber, laminated glued timber and wood-based panel materials; classification of timber. Fire safety [2]
  3. Calculation procedures of timber structures: valid standards and EUROCODE 5 [5]
  4. Fasteners in timber structures: nails, screws, dowels, timber screws, dowels, glues, patented fasteners, joints with thin sheets. Calculation of the bearing capacity of connectors according to EC5 [4]
  5. Classic carpentry wooden structures. Principles of calculation of elements, design and calculation of element connection details [2]
  6. Lattice girders. Calculation principles, design and calculation of connection details in classic and contemporary versions. Transmission of forces in the calculation of details [3]
  7. Aluminium as a material. Calculation procedures of aluminium constructions: EUROCODE 9 [5]
  8. Load-bearing glass as a material, calculation procedures for load-bearing glass entities [5]
  9. Calculation of aluminium-glass facades [2]
- Exercises (construction):
  1. Description of the assignment. [1]
  2. Elements of the disposition solution of the structure. Method for solving the disposition [1]
  3. Models and method of calculation according to EUROCODE 1 standards. Action analysis. Structural calculation and dimensioning of the secondary structure according to EUROCODE 5 standards. [1]
  4. The main supporting structure. Determining calculation combinations of actions. Creating a numerical (spatial) model of the main load-bearing structure. Structural calculation of the main load-bearing structure. [1]
  5. Dimensioning of elements of the main load-bearing structure according to EUROCODE 5 standards. [1]
  6. Details of connections in wooden structures. Design and calculation of connection details. [1]
  7. Dimensioning of aluminium columns and glass panels. [1]
  8. Dimensioning of glass panels. [1]

- Exercises (design):
  1. Method for solving the disposition. Disposition solution. [1]
  2. Action analysis according to EUROCODE 1 standards. Structural calculation and dimensioning of the secondary structure according to EUROCODE 5 standards. [1]
  3. Creating a numerical (spatial) model of the main load-bearing structure. Structural calculation of the load-bearing structure. [1]
  4. Dimensioning of the elements of the main load-bearing structure. [1]
  5. Details of connections in timber structures. Design and calculation of connection details. [1]
  6. Implementation drawing and connection detail drawings. Technical description. [1]
  7. Review and submission of program assignments. [1]

Student Evaluation - Continuous assessment:

- Preparation of program assignments
- Short theory test after lectures
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam – calculation task
- First midterm exam – theory
- Second midterm exam – calculation task
- Second midterm exam – theory
- Exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments
- 75% attendance at lectures
- 100% attendance at exercises
- Practical part of the exam – calculation task
- Theoretical part of the exam

Required reading:

1. Bjelanović, A.; Rajčić, V.: *Drvene konstrukcije prema europskim normama*, Hrvatska sveučilišna naklada, Zagreb, 2005., (II izdanje 2007.)
2. Žagar, Z.: *Drvene konstrukcije I i II*, Pretei d.o.o, Zagreb, 2002./03.
3. Rajčić, V., Čizmar, D., Stepinac, M.: *Riješeni primjeri iz drvenih konstrukcija*, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 2014.
4. Čizmar, D., Rajčić, V.: *Priručnik iz kolegija Lagane konstrukcije*, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb. 2008.
5. Boko, I.; Skejić, D.; Torić, N.: *Aluminijske konstrukcije*; Udžbenici Sveučilišta u Splitu i Udžbenici Sveučilišta u Zagrebu, Split, 2017.
6. Course materials are available on the course website.

Additional reading:

1. CEN: European Standards *HRN EN 1995-1-1:2013+A2:2015+NA:2013 and HRN EN 1995-1-2:2013+NA:2013;* CEN, Brussels, 2013.
2. CEN: European Standards *HRN EN 1999-1-1:2015+NA:2015* and *HRN EN 1995-1-2:2008+NA:2015*; CEN, Brussels, 2015.

3. O'Regan, C.: *Structural use of glass in buildings (Second Edition)*, The Institution of Structural Engineers, London, 2014.
4. Loughran, P.*: Falling Glass - Problems and Solutions in Contemporary Architecture;* Birkhäuser, Basel, Boston, MA, 2003.

STUDY PROGRAMME ORGANISATION

Organisation of courses and student workload

The syllabus is based on the students' workload of 40 hours per week, which includes teaching, field work, practical exercises and other forms of teaching, as well as the time needed for students' preparation for classes.

Instruction is organized and conducted in semesters in accordance with the provisions of the syllabus.

As a rule, the academic year has 44 working weeks, 30 teaching weeks and 14 weeks for ensuring the time necessary for consultations, preparation of exams and exams, and there are no other obligations of other forms of teaching within that period.

The total weekly workload of a student in classes can amount to a maximum of 26 hours.

The share of practical and/or field teaching is determined by ECTS credits.

A regular student enrols from 25 to 35 ECTS credits per semester.

Particularly successful students may be allowed to enrol into more than 35 ECTS credits to complete their studies more quickly or to have a broader education.

Teaching and extracurricular activities of students in physical and health education are performed outside of the hours, which refers to the student's total weekly obligations. This class is compulsory in the first and second year of undergraduate studies, and in the other years of study it is elective. No ECTS credits are assigned to this course.

List of courses and/or modules that students can choose from other study programmes

In accordance with the study program, students can enrol into individual courses of other university study programmes at the University that are not offered by the Faculty.

List of courses and/or modules that can be taught in a foreign language

Courses specified in the syllabus of a particular academic year can be taught in a foreign language.

Enrolment in the next year of study

Students can enrol only in those courses for which they have acquired prerequisites according to the program and study plan.

Prerequisites for taking exams and attending undergraduate study courses are prescribed by a special decision of the Faculty Council.

Undergraduate students acquire the right to enrol into the higher year of study when they fulfil the study obligations prescribed by the Faculty's general legal act, which determines the rules of studying at the Civil Engineering undergraduate study programme.

Students who do not meet the aforementioned requirements can continue their studies according to the rules prescribed by the Faculty's general legal act, which lays down the rules of studying at the Civil Engineering undergraduate study programme.

Lectures and exercises

Students are obliged to attend the forms of teaching that are specified by the study program and syllabus, and in addition to fulfilling other regulations and achieving appropriate results on knowledge tests, it is a requirement for obtaining the teacher's signature.

Exams and other forms of testing

Students' knowledge can be tested and evaluated during classes (midterm exams, practical assignments, etc.), and the final grade is determined in the exam.

The exam from one course can be taken an unlimited number of times in the academic year. Students who do not pass a course exam are obliged to re-enrol into that course.

The syllabus can determine that some forms of teaching are conducted without assessment, that they are assessed descriptively, or that the final grade can be determined by testing and evaluating during the course, or that students' knowledge assessments in certain forms of teaching are included in the final assessment of the students' knowledge of the course achieved in the exam and/or other tests.

The teacher who teaches the course has the right to test and evaluate the students' knowledge in every form of teaching.

Exam deadlines and methods of conducting the exam

Exam dates are: winter, summer, and autumn. Examination periods last at least 3 weeks. In each exam term, there are at least two exam dates for each course.

When justified, the dean can also set extraordinary exam dates.

The exam can be taken by a student who has fulfilled all the prescribed obligations set out in the syllabus. Students have the right to take course exams for courses they enrolled into and the attendance of which has been confirmed by the teacher in the ISVU system.

Completion of studies

The undergraduate study programme ends with a final exam. Courses from which the final exam cannot be taken are listed in a separate general legal act of the Faculty.

Final Assignment

When enrolling into the final semester, students register the course and mentor for the final exam.

The subject of the final exam is drawn up by the mentor, and the student must receive it no later than 6 weeks after the start of classes in the final semester.

The preparation and defence of the written final thesis earn 6 ECTS credits, and it must be such that the student can produce it in 180 effective hours of work. The final exam is taken before a three-member committee.

University graduate study programme Civil Engineering

GENERAL

Duration of study

Two years with 120 ECTS credits.

Enrolment requirements

Completed university undergraduate study programme in Civil Engineering, and under additional conditions, a completed university undergraduate study programme in related technical sciences or professional studies in civil engineering.

Study system

Organized and conducted in semesters as a full-time study.

Criteria and transfer requirements of ECTS credits

Students earn ECTS credits according to the Faculty regulations of study curriculum regardless of the value of credits the course has in the main study program.

Conditions under which students who have interrupted their studies or lost the right to study in one study program can continue their studies

Students who have interrupted their studies may continue their studies, subject to the condition of matching the program in which they are enrolled.

Students who have lost the right to study in one study programme can continue their studies under the condition that the ECTS credits they have achieved are aligned with the study program of the Faculty.

Academic title awarded upon graduation

University Master of Civil Engineering; abbreviation: univ. mag. ing. aedif.

Certification

Upon completion of the university graduate study programme, the student is issued a diploma (in print and digital form, in Croatian and English), certifying the completion of the studies and acquiring the academic title.

The students are also issued a diploma supplement (in print and digital form, in Croatian and English), certifying the exams passed, grades achieved, and ECTS credits earned.

THE PROGRAMME'S LEARNING OUTCOMES

A person who has completed the program can:

(KNOWLEDGE AND UNDERSTANDING)

- Comprehensively understand the general phenomena and problems of civil engineering, especially those in the branch of civil engineering in which the person specialized,
- Demonstrate a high level of professional knowledge and behaviour in civil engineering,

(APPLICATION OF KNOWLEDGE AND UNDERSTANDING)

- Apply acquired knowledge and skills in the planning, design, construction, supervision and maintenance of complex structures, procedures and systems in the field of specialization from the standpoint of stability, safety, usability, environmental protection and costs,
- Apply acquired skills and necessary knowledge to identify, formulate and analyse problems and find one or more acceptable solutions in the branch of civil engineering in which the person specializes,
- Adopt an analytical approach to work, based on a broader knowledge of science,
- Plan, supervise and carry out professional, development and scientific projects,

(DRAWING CONCLUSIONS, MAKING JUDGEMENTS AND DECISIONS)

- Interpret the social aspects of the construction projects on which the person works and the social context in which the construction takes place,
- Take on a leading role in companies and research organizations and contribute to innovations,
- Develop the branch of civil engineering in which the person specializes, taking into account knowledge from other scientific disciplines,

(COMMUNICATION, PRESENTATIONS AND TEAMWORK)

- Interpret their ideas and projects to colleagues,
- Find solutions to technical and social problems in the working environment,
- Apply the acquired knowledge in a creative way when making decisions in responsible workplaces,
- Work at the international level, taking into account cultural, linguistic, social and economic influences,

(STUDY SKILLS AND ETHICS)

- Constantly stay up to date and engage in professional development;
- Accept responsibility for one's own decisions;

- Accept the demands of other professions and be ready to participate in interdisciplinary activities.

PROGRAMME STRUCTURE

Specialisation in GEOTECHNICS

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Mathematics 3 Stochastic processes	45	0	30	7.5
2	Research Methods		15	0	0	1.5
3	Geotechnical Engineering		30	0	30	6
4	Numerical modelling in geotechnics		30	0	45	7.5
5	Applied Soil Mechanics		45	0	30	7.5
	Total		**165**	**0**	**135**	**30**

1st year, 2nd semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Applied Rock Mechanics		30	0	30	6
2	Foundation Engineering		45	0	30	7.5
3	Embankments and Slopes		30	0	30	6
4	Elective Course	Applied Geology Environmental Protection	30	0	0	3
5	Elective courses (one to be chosen)					
	Total					**Min 27**

Elective courses (2nd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Dynamics of Structures and Earthquake Engineering	45	6	24	7.5
2	Theory of Elasticity and Plasticity	45	0	30	7.5
3	Numerical Mathematics	30	0	30	6
4	Perspective	30	0	30	6
5	Geometry in Civil Engineering	15	0	30	4.5
6	Waves and Oscillations	30	0	30	6
7	Courses of other specialisations or of other study programmes				

2nd year, 3rd semester

Course		Total hours			ECTS
		Lecture	Seminar	Practice	
1	Improvement of Soil and Rock	30	0	30	6
2	Retaining Structures	30	0	30	6
3	Hydrogeology and Engineering Geology	30	0	0	3
4	Geotechnical Laboratory	30	0	45	7.5
5	Elective course (two to be chosen)				Min. 10.5
	Total				**Min. 33**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Underground Structures	30	0	30	6
2	Geotechnics and Environmental Protection	30	0	15	4.5
3	Soil Dynamics	30	0	30	6
4	English in Civil Engineering 2	0	0	45	4.5
5	German in Civil Engineering 2	0	0	45	4.5
6	Courses of other specialisations or of other study programmes				

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Geotechnical Design	30	0	30	6
2	Field investigation and Monitoring	30	0	30	6
3	Final Assignment				18
	Total	**60**	**0**	**60**	**30**

Specialisation in HYDRO ENGINEERING

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Mathematics 3 Stochastic processes	45	0	30	7.5
2	Research Methods		15	0	0	1.5
3	Hydraulics 1		45	0	30	7.5
4	Hydrology 2		30	0	30	6
5	River Training		45	0	30	7.5
	Total		**180**	**0**	**120**	**30**

1st year, 2nd semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Water Supply and Sewerage 1 Water Protection	30	0	15	4
2	Elective Course	Applied Geology Environmental Protection	30	0	0	3
3	Elective Course	Structures Data Analysis for Hydrosciences	30	0	30	6
4	Waterways and Ports		45	0	45	9
5	Drainage and Irrigation 1		45	0	30	8
	Total		**180**	**0**	**120**	**30**

2nd year, 3rd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Water Power Use	30	0	30	6
2	Water Supply and Sewerage 2	30	0	30	6
3	Elective courses (a minimum of 3 courses to be enrolled into)				Min. 18
	Total				**30**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1a	Flood Protection	30	0	30	6
1b	Nature-Based River Restoration	30	0	30	6
2a	Modelling in Hydraulic Engineering	30	0	30	6
2b	Hydraulics 2	30	0	30	6
3a	Water and Wastewater Treatment	30	0	30	6
3b	Alternative wastewater collection and treatment systems	30	0	30	6
	One course from groups 1, 2, and 3 to be enrolled into				

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Hydrosystems	45	0	15	6
2	Elective Course (one course to be enrolled into)				6
3	Final Assignment	0		12	18
	Total				**30**

Elective courses (4th semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Urban Hydrology	30	0	30	6
2	Coastal Structures	30	0	30	6
3	Design and construction of water and wastewater infrastructure	30	0	30	6
4	River Channel Stability	30	0	30	6
5	Water Resources Systems Modelling	30	0	30	6

Specialisation in STRUCTURAL ENGINEERING

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Mathematics 3 Stochastic processes	45	0	30	7.5
2	Research Methods		15	0	0	1.5
3	Prestressed Concrete		30	0	30	6
4	Bridges 2		30	0	30	6
5	Metal Structures 2		30	0	30	6
6	Reliability of Structures		30	0	0	3
	Total		**180**	**0**	**120**	**30**

1st year, 2nd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Concrete and Masonry Structures 2	30	0	30	6
2	Metal Structures 3	30	0	30	6
3	Timber Structures 2	30	0	30	6
4	Durability of Structures 1	30	0	30	6
5	Precast Reinforced Concrete Structures	30	0	30	6
	Total	**150**	**0**	**150**	**30**

2nd year, 3rd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Concrete Structures 3	30	0	30	6
2	Bridges 3	30	0	30	6
3	Dynamics of Structures	30	0	15	4.5
4	Elective courses (to be enrolled into 3)				Min. 13.5
	Total				**30**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Stability of Structures	30	0	15	4.5
2	Durability of Structures 2	30	0	15	4.5
3	Tall Buildings	30	0	15	4.5
4	Structural Testing	30	0	15	4.5
5	English in Civil Engineering 2	0	0	45	4.5
6	German in Civil Engineering 2	0	0	45	4.5

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Special Engineering Structures	30	0	15	4.5
2	Composite Structures	30	0	15	4.5
3	Elective Course				3
4	Final Assignment	0		12	18
	Total				**30**

Elective courses (4th semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Earthquake Engineering	30	0	0	3
2	Numerical Mathematics	30	0	30	6
3	Perspective	30	0	30	6
4	Geometry in Civil Engineering	15	0	30	4.5
5	Waves and Oscillations	30	0	30	6
6	Assessment of Existing Bridges	30	0	30	6
7	Existing Masonry Structures – Assessment and Strengthening	30	0	30	6
8	Aluminium Structures	30	0	30	6
9	Structural Design of Facades	30	0	30	6

Specialisation in CONSTRUCTION MATERIALS

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Mathematics 3 Stochastic processes	45	0	30	7.5
2	Research Methods		15	0	0	1.5
3	Theory and Technology of Concrete		30	16	14	6
4	Building Physics		30	0	30	6
5	Polymers		30	6	9	4.5
6	Mechanics of Material		30	0	15	4.5
	Total		**180**	**22**	**98**	**30**

1st year, 2nd semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Applied Geology Environmental Protection	30	0	0	3
2	Elective Course	Quality Management Theory of Elasticity and Plasticity	45	0	30	7.5
3	Durability of Construction Materials		30	4	26	6
4	Special Concrete and Technologies		45	0	30	7.5
5	Concrete and Masonry Structures 2		30	0	30	6
	Total		**180**	**4**	**116**	**30**

2nd year, 3rd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Precast Systems	30	0	30	6
2	Non-Destructive Testings	30	0	30	6
3	Fire Protection	30	0	30	6
4	Elective courses 1 (1 or 2 to be enrolled into)				6
5	Elective courses 2 (one to be enrolled into)				6
	Total				**30**

Elective courses 1 (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Technology of Repair and Strengthening	30	8	22	6
2	Work and Production Organization	30	0	0	3

Elective courses 2 (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Transportation Facility Concrete	30	14	16	6
2	Hydrotechnical Concrete	30	0	30	6
3	Metal Structures 2	30	0	30	6

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Final Assignment				18
2	Elective courses 1 (one to be enrolled into)				6
3	Elective courses 2 (1 or 2 to be enrolled into)				Min. 6
	Total				**30**

Elective courses 1		Total hours			ECTS
		Lectures	Seminar	Practice	
1	High-performance concrete	30	0	30	6
2	Numerical Modelling in Engineering Materials	30	0	30	6
3	Energy renovation of buildings	15	0	45	6

Elective courses 2		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Design of Experiments	30	0	30	6
2	English in Civil Engineering 2	0	0	45	4.5
3	German in Civil Engineering 2	0	0	45	4.5
4	Numerical Mathematics	30	0	30	6
5	Geometry in Civil Engineering	15	0	30	4.5
6	Perspective	30	0	30	6
7	Applied Metallurgy	30	0	30	6
8	Waves and Oscillations	30	0	30	6
9	Green Building	30	15	15	6

Specialisation in CONSTRUCTION MANAGEMENT

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Mathematics 3 Stochastic processes	45	0	30	7.5
2	Research Methods		15	0	0	1.5
3	Construction Management 2		30	0	30	6
4	Building Maintenance Management		30	0	15	4.5
5	Optimization Methods in Construction		30	0	30	6
6	Study of Work		30	0	15	4.5
	Total		**180**	**0**	**120**	**30**

1st year, 2nd semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Construction Equipment		26	4	30	6
2	Management for Construction Industry		30	11	4	4.5
3	Management of construction projects		60	5	25	9
4	Elective courses (to be enrolled into one)	Environmental Protection	30	0	0	3
		Building information modelling	30	0	30	6
		English in Civil Engineering 2	0	0	45	4.5
		German in Civil Engineering 2	0	0	45	4.5
5	Elective courses (1 or 2 to be chosen)					Min. 10.5
	Total					**30**

Elective courses (2nd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Construction Technologies 1	45	0	30	7.5
2	Supervision and Monitoring of Construction Projects	30	0	0	3
3	Numerical Mathematics	30	0	30	6
4	Perspective	30	0	30	6
5	Geometry in Civil Engineering	15	0	30	4.5
6	Management of Structures	30	0	30	6
7	Waves and Oscillations	30	0	30	6
8	Courses of other specialisations or of other study programmes				

2nd year, 3rd semester

Courses		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Organization and Structure of Construction Companies	30	0	30	6
2	Planning and Scheduling Methods	30	0	30	6
3	Sociology of Organization	30	0	15	4.5
4	Elective courses (to be enrolled into two)				Min. 12
	Total				**28.5**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar.	Practice	
1	Human Resource Management	30	0	30	6
2	Construction Technologies 2	30	0	30	6
3	Investment Appraisals in Construction	30	0	30	6
4	Courses of other specialisations or of other study programmes				

2nd year, 4th semester

Courses		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Business Strategies for Construction Companies	45	0	0	4.5
2	Practical training	0	0	60	6
3	Elective courses (to be enrolled into one)				Min. 3
4	Final Assignment	0		12	18
	Total				**31.5**

Elective courses (4th semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Supervision and Monitoring of Construction Projects	30	0	0	3
2	Management of Structures	30	0	30	6
3	Health & Safety in Construction	30	0	15	4.5
4	Building Renovation and Strengthening Technologies	30	0	30	6
5	Courses of other specialisations or of other study programmes				

Specialisation in TRANSPORTATION ENGINEERING

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective Course	Mathematics 3 Stochastic processes	45	0	30	**7.5**
2	Traffic Noise		30	0	15	4.5
3	Transportation Engineering		30	0	30	6
4	Planning and Design of Roads		30	0	30	6
5	Railway Design and Construction		30	0	30	6
	Total		**165**	**0**	**135**	**30**

1st year, 2nd semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Management for Construction Industry		30	0	0	3
2	Elective Course	Applied Geology Environmental Protection	30	0	0	3
3	Pavement structures		30	0	30	6
4	Permanent Way		45	0	15	6
5	Earthworks		30	0	30	6
6	Road Intersections		30	0	30	6
	Total		**180**	**0**	**105**	**30**

2nd year, 3rd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Research Methods	15	0	0	1.5
2	Transportation Tunnels	30	0	30	6
3	Airports	30	0	15	4.5
4	Road equipment	45	0	0	4.5
5	Transport Systems	45	0	0	4.5
6	Elective courses (to be enrolled into two)				Min. 9
	Total				**30**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Drainage of Transportation Facilities	30	0	15	4.5
2	Asphalt Pavement Maintenance and Preservation	30	0	15	4.5
3	Soil Improvement Methods	30	0	15	4.5
4	English in Civil Engineering 2	0	0	45	4.5
5	German in Civil Engineering 2	0	0	45	4.5
6	Vibrations in Transportation Engineering	30	0	15	4.5
7	Courses of other specialisations or of other study programmes				

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Pavement Management	30	0	0	3
2	Elective courses (to be enrolled into two)				Min. 9
3	Final Assignment				18
	Total				**30**

Elective courses (4th semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Parking Facilities	30	0	15	4.5
2	Design of Urban Streets	30	0	15	4.5
3	Railway track Maintenance	45	0	0	4.5
4	Urban Railways	30	0	15	4.5
5	Numerical Modelling of Railway Track Structures	30	0	15	4.5
6	Numerical Mathematics	30	0	30	6
7	Perspective	30	0	30	6
8	Geometry in Civil Engineering	15	0	30	4.5
9	Waves and Oscillations	30	0	30	6
10	Courses of other specialisations or of other study programmes				

Specialisation in THEORY AND MODELLING OF STRUCTURES

1st year, 1st semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Mathematics 3	45	0	30	7.5
2	Research Methods	15	0	0	1.5
3	Mechanics of Material	30	0	15	4.5
4	Nonlinear Statics of Rod Structures	30	0	15	4.5
5	Experimental Methods 1	30	0	30	6
6	Metal Structures 2	30	0	30	6
	Total	**180**	**0**	**120**	**30**

1st year, 2nd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Theory of Elasticity and Plasticity	45	0	30	7.5
2	Dynamics of Structures and Earthquake Engineering	45	6	24	7.5
3	Finite Element Method	30	0	30	6
4	Theory of Composites	30	0	15	4.5
5	Concrete and Masonry Structures 2	30	0	15	4.5
	Total	**180**	**6**	**114**	**30**

2nd year, 3rd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Space Structures	30	4	26	6
3	Structural Testing	30	0	30	6
4	Stability Theory	30	4	26	6
3	Elective courses (for 1-5: courses of a minimum of 9 ECTS credits to be chosen)				Min. 12
	Total				**30**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Methods of Theory of Elasticity and Plasticity	30	0	15	4.5
2	Polymers	30	6	9	4.5
3	Basics of Fracture Mechanics	30	0	15	4.5
4	Programming Structural Analysis Procedures	30	0	15	4.5
5	Numerical Methods in Structural Analysis	30	0	15	4.5
6	Stochastic Processes or courses of other specialisations or of other study programmes				

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Elective courses (for 1-4: at least one course to be chosen)				Min. 12
2	Final Assignment				18
	Total				**30**

Elective courses (4th semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Selected Topics on Strength of Materials	30	0	15	4.5
2	Stochastic Analysis of Structures	30	0	15	4.5
3	Hanging Fabric and Cable Structures	30	0	30	6
4	Structural Assessment and Seismic Performance of Existing Buildings	30	10	20	6
5	Numerical Mathematics	30	0	30	6
6	Perspective	30	0	30	6
7	Geometry in Civil Engineering	15	0	30	4.5
8	Waves and Oscillations	30	0	30	6
9	English in Civil Engineering 2	0	0	45	4.5
10	German in Civil Engineering 2	0	0	45	4.5
11	Courses of other specialisations or of other study programmes				

Specialisation SUSTAINABLE CONSTRUCTION AND EARTHQUAKE ENGINEERING

1st year, 1st semester

Course			Total hours			ECTS
			Lectures	Seminar	Practice	
1	Elective courses	Mathematics 3. Stochastic processes	45	0	30	7,5
2	Research Methods		15	0	0	1,5
3	Basics of sustainable spatial planning		30	15	0	4,5
4	Dynamics of Structures with an Introduction to Earthquake Engineering		30	0	15	4,5
5	Principles of sustainable construction		30	0	30	6,0
6	Seismic design of concrete and masonry buildings		45	0	15	6,0
	Total		**195**	**15**	**90**	**30**

1st year, 2nd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Green and blue infrastructure	30	0	30	6,0
2	Sustainable Transport Infrastructure in Urban Environments	30	0	30	6,0
3	Geotechnical Monitoring and Early Warning Systems (AI/IoT)	30	0	30	6,0
4	Building Information Modelling - BIM	30	0	30	6,0
5	Assessment of the seismic performance of existing buildings	30	0	30	6,0
	Total	**150**	**6**	**150**	**30**

2nd year, 3rd semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Deep energy renovation of buildings	30	0	15	4,5
3	Structural retrofitting of existing structures	45	0	0	4,5
3	Elective courses (for no. 1-15: select courses with min 21 ECTS-a)				min. 21
	Total				**30**

Elective courses (3rd semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Hazards, Risks, and Resilience of Water and Wastewater Systems	30	0	15	4,5
2	Environmental Engineering and Protection of Water Systems	30	0	15	4,5
3	Seismic Resistance of Hydraulic Engineering Structures	30	0	15	4,5
4	Climate change and structures	30	0	15	4,5
5	Structural robustness	30	0	15	4,5
6	Principles of building renovation	30	15	0	4,5
7	Regulation in sustainable and circular construction	30	0	15	4,5
8	Use of timber and bio-based materials in construction and rehabilitation	30	0	15	4,5
9	Vibration in transportation engineering	30	0	15	4,5
10	Asphalt pavement maintenance and preservation	30	0	15	4,5
11	Heritage Structures	30	0	0	3,0
12	Testing and Assessment of Existing Structures	30	0	15	4,5
13	Soil Dynamics and Geotechnical Earthquake Engineering	30	0	15	4,5
14	Sustainable Geoengineering	30	0	15	4,5
15	Courses of other specialisations or of other study programmes				

2nd year, 4th semester

Course		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Elective courses (for no 1-7: select courses with min 12 ECTS)				min. 12
2	Final Assignment				18
	Total				**30**

Elective courses (4th semester)		Total hours			ECTS
		Lectures	Seminar	Practice	
1	Management of structures	30	0	30	6,0
2	Sustainable Project Management	30	0	15	4,5
3	Technologies for Building Renovation and Sustainable Development	30	0	15	4,5
4	Design of urban streets	30	0	15	4,5
5	Railway track maintenance	45	0	0	4,5
6	Urban Microclimate	30	0	15	4,5
7	Courses of other specialisations or of other study programmes				

COURSE CONTENT WITH LEARNING OUTCOMES

Specialisation in GEOTECHNICS

1st year, 1st semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

GEOTECHNICAL ENGINEERING

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (11 auditory + 19 construction)

Course objectives:

- Familiarization with the basic principles of Eurocode 7 and their application to geotechnical structures,
- Acquiring basic knowledge about the types and roles of basic geotechnical structures and measures (shallow and deep foundations, retaining structures, protection of construction pits, cuttings, earthfill structures) and understanding design situations related to them,
- Acquisition of knowledge on the calculation of simpler geotechnical structures (shallow foundations on soil and rock, piles, retaining structures, stabilization of cuttings and excavations in the rock) from the aspect of serviceability and ultimate limit states.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic physical and mechanical properties of soil and rock mass (stiffness, strength),
- Application of basic concepts of soil mechanics (soil classification, index indicators, principle of effective stresses, soil consolidation, settlement and bearing capacity of shallow foundations, soil pressures on walls, groundwater seepage, slope stability).

Learning outcomes of courses (4-8):

- Recognize design situations related to basic geotechnical structures (shallow and deep foundations, retaining structures, slopes, earthfill structures) in accordance with the principles of Eurocode 7,

- Calculate the bearing capacity of shallow and deep foundations in different types of soil and rock,
- Apply simpler methods for assessing the stability of natural and artificial slopes,
- Determine earth pressures on different types of retaining structures and evaluate their stability,
- Perform simpler seismic calculations for basic geotechnical structures.

Course content (by course schedule):

- Lectures:
  1. Introduction to geotechnical engineering [2]
  2. Principles of Eurocode 7 [2]
  3. Types and bearing capacity of shallow foundations in different types of soil and rock [2]
  4. Settlement of shallow foundations [2]
  5. Calculation methods of stability of natural and artificial slopes [2]
  6. Actions on slopes and stabilization procedures [2]
  7. Types of retaining structures and determination of earth pressures [2]
  8. Actions and stability checks of retaining structures [2]
  9. Application of types and bearing capacity of deep foundations [2]
  10. Action and transmission of forces in pile groups [2]
  11. Types of earthfill structures and basics of soil compaction [2]
  12. Construction of earthfill structures and stability checks [2]
  13. Introduction to soil dynamics and the basics of soil cyclic behaviour [2]
  14. Typical problems of seismic geotechnical engineering [2]
  15. Simplified seismic geotechnical calculation [2]
- Exercises:
  1. INTRODUCTION – revision, syllabus, rules (auditory) [2]
  2. EC7 – revision (design situations, project values, part. coeff.), examples for various constructions. (auditory) [2]
  3. Pad foundation (bearing capacity + settlement) – example of calculation of bearing capacity for skew eccentric load and settlement Kanny, Steinbrenner, M&P, 1 . PROGRAM – assignment (auditory and construction) [2]
  4. 1ST PROGRAM ASSIGNMENT – problem solving (construction) [2]
  5. SLOPE – stability calculation in the program GEO-SLOPE, 2. PROGRAM – assignment (auditory and construction) [2]
  6. 2ND PROGRAM ASSIGNMENT – problem solving (construction) [2]
  7. RETAINING WALL – calculation example for gravity and L wall (pressures according to Rankine), 3RD PROGRAM – assignment (auditory and construction) [2]
  8. 3RD PROGRAM ASSIGNMENT – problem solving (construction) [2]
  9. SHEET PILE STRUCTURE – example of calculation for anchoring in one row, 4TH PROGRAM – assignment (auditory and construction) [2]
  10. 4TH PROGRAM ASSIGNMENT – problem solving (construction) [2]
  11. DEEP FOUNDATION ON PILES - example of calculation of bearing capacity (API and DIN) and settlement of piles (DIN), 5TH PROGRAM – assignment (auditory and construction) [2]
  12. 5TH PROGRAM ASSIGNMENT – problem solving (construction) [2]

13. SEISMIC CALCULATION - simpler examples of seismic calculations on geotechnical structures from previous programs, 6TH PROGRAM – assignment (auditory and construction) [2]
14. 6TH PROGRAM ASSIGNMENT – problem solving (construction) [2]
15. REVIEW OF PROGRAM ASSIGNMENTS (construction) 2]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

- Course materials are available on the course website.
- Exercise materials are available on the course website.

Additional reading:

1. Any domestic or foreign book on geotechnical engineering or foundations.

NUMERICAL MODELLING IN GEOTECHNICS

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 30
- Exercises: 45 (5 auditory + 35 on computers + 5 construction)

Course objectives:

- Acquisition of knowledge required for engineering judgment in modelling in geotechnics,
- Application of acquired knowledge in modelling complex geotechnical problems.

Entry competences (prior knowledge, descriptive):

- Understanding of the basic soil properties and parameters relevant to geotechnic analysis,
- Knowledge of the basics of soil mechanics and geotechnic design,
- Understanding of the basic principles of numerical modelling.

Learning outcomes:

- Recognize the appropriate method of numerical modelling for a particular geotechnical problem,
- Explain the results of numerical modelling,
- Choose relevant soil parameters for numerical modelling,
- Analyse the modelled soil behaviour,
- Plan numerical modelling steps for a specific geotechnical problem.

Course content (by course schedule):

- Lectures:
  1. Introduction: Numerical analysis in geotechnics, the importance of finite element network and boundary conditions

2. Numerical analyses of water seepage in soil 1 – saturated conditions, choice of input parameters, flow net
3. Numerical analyses of water seepage in soil 2 – water flow through anisotropic and inhomogeneous soil
4. Numerical analyses of water seepage in soil 3 – modelling the consolidation process, time-dependent effects, consolidation under geotechnical structures
5. Numerical analyses of water seepage in soil 4 – unsaturated soil, unsaturated permeability coefficient
6. Stress-strain analyses 1 - soil constitutive models, drained and undrained numerical analyses
7. Stress-strain analyses 2 – coupled hydraulic and stress-strain analyses
8. Midterm exam
9. Stress-strain analyses 3- foundation modelling (isolated footing, strip foundation, raft foundation)
10. Stress-strain analyses 4 – modelling of excavations and construction pit stabilisation
11. Stress-strain analyses 5 – modelling of embankments and tunnels
12. Stability analyses 1 – coupled hydraulic and stress-strain analyses
13. Stability analyses 2 – LEM stability analyses 1
14. Stability analyses 3 - LEM stability analyses 2 – parameter analyses
15. Stability analyses 4 – phi-c reduction stability analysis

- Exercises (auditory in the computer room):
  1. Structured and unstructured networks and the influence of boundary conditions, familiarization with computer programs
  2. Modelling of seepage in saturated soil
  3. Flow through anisotropic and inhomogeneous soil
  4. Modelling of the soil consolidation process [2]
  5. Modelling of seepage in unsaturated soil
  6. Interaction of seepage analysis and stress-strain analysis
  7. Analyses of settlement and bearing capacity of isolated footing, foundation strips and foundation slabs
  8. Modelling of the construction pit and stabilization with anchors
  9. Modelling of the construction pit and stabilization with struts
  10. Embankment and tunnel modelling
  11. Interaction of seepage analysis and stability analysis
  12. Selection of models and parameters for modelling stability analyses
  13. Stability analysis – parametric analysis
  14. Comparison of LEM and phi-c reduction stability analyses

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Written exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Course materials: Mario Bačić (lectures – PowerPoint presentations).

Additional reading:

1. *GEO-SLOPE International: SLOPEW/W Version 5 Users Guide*. GEO-SLOPE International Ltd., Calgary, Alberta, Canada, 2001.
2. *GEO-SLOPE International: SIGMA/W Version 5 Users Guide*. GEO-SLOPE International Ltd., Calgary, Alberta, Canada, 2001.
3. *GEO-SLOPE International: SEEP/W Version 5 Users Guide*. GEO-SLOPE International Ltd., Calgary, Alberta, Canada, 2001.
4. Potts, D. M.; Zdravkovic, L.: Finite *Element Analysis in Geotechnical Engineering: Application*. Thomas Telford, London, Velika Britanija, 1999.
5. Hicks, M. A., Brinkgreve, R. B. J., Rohe, A.: Numerical Methods in Geotechnical Engineering, CRC Press, 2014.

APPLIED SOIL MECHANICS

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (12 auditory + 18 construction)

Course objectives:

- Familiarization with the mechanical behaviour of fine-grained and coarse-grained water-saturated soils,
- Familiarization with simple analytical models of soil mechanical behaviour,
- Familiarization with the procedures for determining the parameters of simple analytical models of soil mechanical behaviour from the results of common laboratory and field experiments.

Entry competences (prior knowledge, descriptive):

- Application of the basic concepts of the mechanics of continuous media (stresses, deformations, equilibrium, linear elasticity, elastic and plastic deformations, strength),
- Understanding of the basic concepts and application of the finite element method in the mechanics of continuous media,
- Application of basic concepts of soil mechanics (soil classification, index indicators, principle of effective stresses, stiffness and strength of soil, soil consolidation, common laboratory and field geotechnical experiments, calculation of settlement and bearing capacity of shallow foundations, soil pressures on walls, seepage of groundwater, slope stability).

Learning outcomes:

- Recognize important factors that influence the mechanical behaviour of the soil,
- Interpret and analyse the results of usual geotechnical laboratory and field experiments,
- Analyse, compare and connect the results of geotechnical investigation works,
- Evaluate and select the parameters of simple analytical models of soil behaviour relevant to the considered geotechnical problem,
- Choose a calculation model of the geotechnical soil profile relevant to the considered geotechnical problem,
- Basic handling of computer programs for solving problems of boundary conditions on examples of modelling oedometer and triaxial experiments with a linear-elastic soil model and triaxial experiments with an elasto-plastic soil model.

Course content (by course schedule):

- Lectures:
  1. Introductory lecture
  2. Phase relations in soil
  3. Stresses in the soil
  4. Phase relations in soil – student presentations
  5. Behaviour of the soil in the oedometer experiment
  6. Soil behaviour in direct shear tests
  7. Soil behaviour in drained triaxial experiments
  8. Stresses in soil – student presentations
  9. Soil behaviour in undrained triaxial tests
  10. Soil behaviour during compaction
  11. Soil stiffness at small deformations [2]
  12. Laboratory experiments – student presentations [2]
  13. Final presentations and submission of final program assignments
- Exercises:
  1. Introduction
  2. Phase relations in soil [3]
  3. Stresses in soil [4]
  4. Laboratory experiments [5]
  5. Phase relations in the soil, stresses in the soil, laboratory experiments [2]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Contributions to the final grade:

- Written exam 100%.

Required reading:

- Course materials are available on the course website.
- Exercise materials are available on the course website.

Additional reading:

1. Wood, D. M.: *Soil Behaviour and Critical States Soil Mechanics*. Cambridge University Press, Cambridge, UK, 1990.
2. Davies, R. O.; Salvadurai, A. P. S.: *Plasticity and Geomechanics*. Cambridge University Press, Cambridge, UK, 2002.

Elective courses

MATHEMATICS 3

See Chapter Shared Courses

STOCHASTIC PROCESSES

See Chapter Shared Courses

1st year, 2nd semester

Mandatory courses

APPLIED ROCK MECHANICS

Credits (ECTS): 6.0

Hours (total per semester):
- Lectures: 30
- Exercises (auditory): 30

Course objectives:
- Acquisition of advanced theoretical and applied knowledge about the behaviour of rocks due to the performance of geotechnical interventions,
- Application of acquired knowledge in solving more complex problems in the domain of rock mechanics and rock engineering.

Entry competences (prior knowledge, descriptive):
- Understanding the basic concepts of rock mechanics,
- Understanding primary and secondary stress states in rock engineering,
- Knowledge of rock mass classification methods,
- Knowledge of the basic principles of numerical modelling in geotechnics.

Learning outcomes:
- Apply methods of classification and characterization of rock mass and discontinuities in practical operations in rock mass,
- Explain the principles, mechanisms and difficulties in the design, execution and monitoring of interventions in rock in an engineering-adequate manner (verbally, in writing and graphically),
- Formulate and perform appropriate analyses for the needs of evaluating the stability of slopes, foundations and tunnels in the rock mass,
- Select and apply available engineering methods, tools and technologies for the design and execution of operations in the rock mass.

Course content (by course schedule):
- Lectures:
  1. Introduction to applied rock mechanics and rock engineering.
  2. Secondary state of stress for different interventions in the rock mass.
  3. Physical and mechanical properties of rock mass and discontinuities.
  4. Advanced discontinuity characterization and stereographic projection.
  5. Engineering applications of rock mass classification.
  6. Block theory.
  7. Constitutional models of rock mass.
  8. Rock foundations – failure mechanisms, analytical and numerical models.

9. Foundation on rock – essential aspects of performance.
10. Stability of rock slopes – failure mechanisms, analytical and numerical models.
11. Stability of rock slopes – methods of stabilization.
12. Tunnels in rock – failure mechanisms, analytical and numerical models.
13. Tunnels in rock – construction and rehabilitation methods.
14. Measurements and monitoring in rock engineering.
15. Rheology of rock mass.
16. Rock mechanics and environmental protection.

- Exercises:
  1. Introductory exercises
  2. Analytical methods in rock engineering
  3. Numerical methods based on continuum.
  4. Numerical methods based on discontinuity.
  5. Parameter selection for rock engineering constitutive models.
  6. Analysis and interpretation of stereographic projections.
  7. Stability checks of the overlay and laminated roof layers of underground openings.
  8. Numerical analyses of the stability of rock wedges in tunnels.
  9. Numerical analyses of planar failures of rock slopes.
  10. Numerical analyses of wedge failures of rock slopes.
  11. Numerical analyses of overturning of blocks of rock slopes.
  12. Numerical analyses of rockslides.
  13. Numerical analyses of the stability of foundations on rock mass.
  14. Probabilistic methods in rock engineering analyses [2].

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Kovačević, M.S.: Mehanika stijena, Građevinski fakultet Sveučilišta u Zagrebu, university handbook, 2021.
2. Kovačević, M.S.: Course materials (lectures and tables for exercises - PowerPoint presentations)
3. Rocscience Inc.: Rocscience manuals (RSData, CPillar, Dips, RS2, RocSupport, UnWedge, Swedge, RocPlanar, RocTopple, RocFall), Software manuals, Ontario Canada, 2021.

Supplementary reading:

1. Hudson, J. ; Harrison, J.(1997), Engineering rock mechanics: an introduction to the principles, Oxford: Pergamon.
2. Hudson, J.;Harrison, J.(2000), Engineering rock mechanics: part 2. Illustrative worked examples, Oxford: Pergamon.

FOUNDATION ENGINEERING

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (auditory: 16, on computers: 14)

Course objectives:

- Interpret legal regulations related to the design and construction of foundations,
- Choose the type of foundation considering the type of soil, the possibility of execution and the given loads,
- Design and calculate the foundations of the building to meet the conditions of mechanical resistance and stability,
- Develop a program of investigative works necessary for designing the foundation.

Entry competences (prior knowledge, descriptive):

- Interpret the results of geotechnical investigation works,
- Recognize the type and essential mechanical properties of the foundation soil,
- Identify the general requirements for risk consideration in the norms for the design of building structures,
- Calculate settlement, time course of settlement and bearing capacity of soil under simple shallow foundations.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Applied Soil Mechanics, Geotechnical Engineering.

Learning outcomes:

- Recognize and explain design situations and limit states relevant for proving the mechanical resistance and stability of basic structures,
- Design a program and interpret the results of geotechnical investigation works for the purposes of designing and executing basic structures,
- Calculate settlement, bearing capacity, stability and internal forces in shallow foundations and piles,
- Devise a calculation procedure and prove the mechanical resistance and stability of shallow and deep foundations in case of structure-foundation-soil interaction,
- Draw up and design suitable foundations considering the requirements of the structure that rests on them and the properties of the soil,
- Develop the necessary communication and agreements with the designer of the building structure that will be supported by the provided foundation.

Course content (by course schedule):

- Lectures:
  1. Introduction to foundations, types of foundations, criteria, legal regulations
  2. Shallow foundations (types, limit states, design situations, design, details)
  3. Soil testing and determination of design parameters for shallow foundations
  4. Settlement of shallow foundations
  5. Bearing capacity of shallow foundations, sliding of shallow foundations
  6. Dimensioning of shallow foundations according to Eurocode 7
  7. Structure-foundation-soil interaction
  8. Deep foundations, types, limit states, design situations
  9. Methods of execution of deep foundations, details
  10. Soil testing and determination of design parameters for deep foundations

11. Axial load on piles, negative friction
12. Laterally loaded piles
13. Dimensioning of deep foundations according to Eurocode 7
14. Pilot testing, measurements and observations
15. Complex foundation structures

- Exercises:
  1. Isolated footing settlement [2]
  2. Bearing capacity of the soil beneath isolated footing [2]
  3. Isolated footing group and foundation strip [2]
  4. Soil-structure interaction (frame structure on shallow foundations) [2]
  5. Ground slab [2]
  6. Soil-structure interaction (frame construction on shallow foundations) [2]
  7. Bearing capacity and settlement of an axially loaded pile [2]
  8. Bearing capacity and settlement of a transversely loaded pile [2]
  9. Calculation of the pilot group

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

- Course materials: Mario Bačić (lecture texts and PowerPoint presentations).

Additional reading:

1. Bond, A.; Harris, A.: *Decoding Eurocode 7*. Taylor & Francis, London, 2008.
2. Rees, I. C.; Isenhower, W. M.; Wang, S.-T.: *Analysis and Design of Shallow and Deep Foundations*. John Wiley & Sons, Hew Jersey, USA, 2006.
3. Salgado, R.: *The Engineering of Foundations*. McGraw-Hill, Boston, 2008.
4. Tomlinson, M. J.: *Foundation Design and Construction*. Prentice Hall. London, 2000.

EMBANKMENTS AND SLOPES

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (6 auditory + 20 on computers + 4 construction)

Course objectives:

- Acquisition and application of theoretical knowledge when solving more complex geotechnical problems related to steady-state and transient flow of water through soil and earthfill structures,
- Acquisition of theoretical knowledge about the types of earthfill structures, the choice of materials and the method of installation,
- Acquisition of theoretical knowledge about methods of stabilizing unstable slopes,
- Acquisition of theoretical and practical knowledge about calculations of earthfill structures

- and slopes.

Entry competences (prior knowledge, descriptive):

- Understanding the effective and total stresses and water pressure in still water, and the potential for stationary water flow in the soil
- Knowledge of the basic physical and mechanical characteristics of the soil (strength, stiffness, seepage coefficient),
- Knowledge of the basic principles of numerical modelling.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Applied Soil Mechanics, Geotechnical Engineering.

Learning outcomes:

- Define all terms related to steady-state / transient flow of water through saturated/unsaturated soil and earthfill structures,
- Understand and define the relevant boundary conditions for the problems of water seepage through earthfill structures and slopes,
- Understand the failure mechanisms of earthfill structures and slopes,
- Explain the functions of the internal structure of earthfill structures,
- Choose project situations related to different types of earthfill dams,
- Understand the basic problems related to the construction and stability of earthfill dams,
- Carry out seepage and stability calculations of different types of earthfill dams and slopes in accordance with relevant national and European standards,
- Analyse and prove the stability of earthfill structures and slopes in saturated and unsaturated conditions,
- Select and apply available engineering methods, tools and technologies for stabilizing unstable slopes.

Course content (by course schedule):

- Lectures:
  1. Unstable slopes and their causes.
  2. Shear strength parameters in saturated and unsaturated conditions and the method of their selection; drained and undrained strength parameters.
  3. Geotechnical calculation of slope stability with an overview of analytical and numerical methods (MGR and MKE).
  4. Geotechnical calculations of slope stability for different design situations.
  5. Stabilisation of unstable slopes (anchored and nailed slopes, application of geosynthetics, micropiles).
  6. Types of earthfill structures (hydraulic embankments and dams, road embankments, waste disposal sites).
  7. Selection of soil materials, testing in the field and in the laboratory, methods of installation, properties of compacted material.
  8. Midterm exam.
  9. Selection of dam types, zoned embankments, solution variations, presentation of more significant dams.
  10. Analyses of the stability of earthfill structures in different design situations.

11. Water seepage through earthfill structures, water flow in saturated and unsaturated conditions, water flow through anisotropic and inhomogeneous soil.
12. Consolidation of soil under earthfill structures / Construction of embankments on undrained and drained foundation soil.
13. Application of Eurocode for earthfill structures and slopes [2].
14. Monitoring and observation of earthfill structures and slopes.

- Exercises:
  1. Geotechnical calculations of slope stability (application of the limit equilibrium method)
  2. Geotechnical calculations of slope stability (application of the finite element method, strength reduction method)
  3. Geotechnical calculations of slope stability (choice of input parameters, shear strength in saturated and unsaturated conditions)
  4. Geotechnical calculations of slope stability (design situations – static conditions, seismic conditions)
  5. Stabilization of unstable slopes with anchors
  6. Stabilization of unstable slopes with nails
  7. Stabilization of unstable slopes with geosynthetics.
  8. Analysis of different complex landslide stabilisation problems
  9. Geotechnical calculations of the stability of earthfill structures (design situations – static conditions, seismic conditions, rapid drawdown)
  10. Geotechnical calculations of water seepage through earthfill structures (choice of input parameters, zoning of earthfill structures)
  11. Geotechnical calculations of water seepage through earthfill structures (analysis and interpretation of results; flow, gradients)
  12. Program assignment (earthfill structure), analysis of program requirements, selection of the optimal cross-section of the earthfill structure
  13. Eater seepage through the earthfill structure – isotropicity / anisotropicity and homogenous/inhomogeneous cross-section
  14. Steady-state / transient flow of water through a saturated / unsaturated earthfill structure (coefficient of permeability functions for unsaturated soil; soil-water characteristic curve)
  15. Embankment construction in undrained and drained conditions, soil consolidation analysis under the embankment

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- Midterm exam
- Written exam
- Oral exam
-

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- Written exam

- Oral exam

End of semester grading:
- Written (theory and tasks on the computer) and oral exam (a total of 60 points).

Contributions to the final grade:
- The final grade is obtained from the sum of the points earned during the semester (up to 40 points) and in the written and oral exam (up to 60 points) as follows: sufficient 60-70 points, good 70-80 points, very good 80-90 points, excellent 90-100 points.

Required reading:
1. Bačić, M: Course material (lectures - PPT presentations)
2. Nonveiller, E.: Nasute brane – projektiranje i građenje, Školska knjiga, Zagreb, 1983.
3. Nonveiller, E.: Kliženje i stabilizacija kosina, Školska knjiga, Zagreb, 1987.

Additional reading:
1. GEO-SLOPE International: Users Guides (SIGMA /W, SEEP /W, SLOPE W). GEO-SLOPE International Ltd., Calgary, Alberta, Canada, 2021.
2. US Dept. of Interior, Bureau of Reclamation: Design of small dams, 3rded, 1987.
3. U.S. Army Corps of Engineers (USACE): Slope stability, Engineering and Design report, EM 1110-2-1902, 2003.
4. Fredlund, D. G.; Rahardjo, H.: Soil Mechanics for Unsaturated Soils, John Wiley & Sons, NY.
5. Eurocode Standards Series EN 199i ; i = 0, 1, 2, 3, 4, 7, 8.

Elective courses

APPLIED GEOLOGY

Credits (ECTS): 3

Hours (total per semester):
- Lectures: 30

Course objectives:
- Acquisition of basic knowledge in general geology, mineralogy and petrology,
- Acquisition of basic knowledge in hydrogeology and engineering geology for application in construction,

Entry competences (prior knowledge, descriptive):
- Knowledge of basic chemical elements and compounds.

Learning outcomes:
- The ability to distinguish igneous, metamorphic and sedimentary rocks,
- The ability to recognize beds, wrinkles, faults and overthrust,
- Knowledge of the process of formation of karst and different karst forms, as well as familiarity with the problems that builders encounter when building tunnels in karst,

- The ability to use geological maps – recognizing geological symbols, reading the geological age of rocks, their composition and other important geological phenomena of a terrain,
- Acquisition of knowledge about basic engineering-geological classifications of rock mass.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. On geoscience. General geology, stratigraphic. Constitution of the Earth. Geoid. Mineralogy. Mineral. Crystal [2]
  3. Isotropic and anisotropic minerals. Pyrogenic, pneumatogenic, hydrothermal, hydatogenic. Axis, plane centre of symmetry. Crystal systems. Properties of crystals, crystal bonds. Tetrahedral coordination. Coordination number. Polymorphism. Isomorphy [2]
  4. Properties of minerals. Mineral groups. Oxides and hydroxides. Carbonates. Sulfates. Silicates [2]
  5. Introduction to petrology. Rocks. Phenocrysts, monomineralic. Eruptive rocks. The way eruptive rocks appear. Structure and texture of eruptive rocks. Magma acidity. Bowen sequence of crystallization. Table of eruptive rocks [2]
  6. Sedimentary rocks. Transport of sediments. Mineral composition of sedimentary rocks. Structures and textures of sedimentary rocks. General overview of sedimentary rocks. Metamorphic rocks. Zones of metamorphism. Divisions of metamorphic rocks [2]
  7. Tectonics. Outcrops, camber, bed thickness. Beds, folds, anticlines and synclines. Faults. Overthrusts. Types of cracks [2]

  (Midterm exam)
  8. Exodynamics of the Earth. Insolation. Hydrogeology. Water, hydrologic cycle. Porosity, permeability. Laminar and turbulent flow. Types of aquifers. Ghyben–Herzberg law. Ice and snow. Wind, organisms [2]

  (Retest)
  9. Karst. External karst forms. Internal karst forms [2]
  10. Types of speleological objects. Speleothems. Groundwater [2]
  11. Landslides. Endodynamics. Orogenesis, epigenesis [2]
  12. Volcanoes. Earthquakes. Earthquake scales, seismicity [2]
  13. Geological maps. RMR and Q classification of rocks in construction. Determining the age of rocks [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam

Required reading:

1. Herak, M.: *Geologija*, 1990.
2. Šestanović, S.: Osnove geologije i petrologije, *2001.*

Additional reading:

4. West, T.: Geology Applied to Engineering, *1994.*
5. Monroe, J.; Wicander, R.: *Physical geology*, 2006.
6. Plummer, C.; McGeary, D.; Carlson, C.: *Physical Geology*, 2010.

ENVIRONMENTAL PROTECTION

See Chapter Specialisation in Hydraulic Engineering.

DYNAMICS OF STRUCTURES AND EARTHQUAKE ENGINEERING

See Chapter Specialisation in Theory and Modelling of Structures.

THEORY OF ELASTICITY AND PLASTICITY

See Chapter Specialisation in Theory and Modelling of Structures.

NUMERICAL MATHEMATICS

See Chapter Shared Courses

PERSPECTIVE

See Chapter Shared Courses

GEOMETRY IN CIVIL ENGINEERING

See Chapter Shared Courses

WAVES AND OSCILLATIONS

See Chapter Shared Courses

2nd year, 3rd semester

Mandatory courses

IMPROVEMENT OF SOIL AND ROCK

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 12, construction: 18)

Course objectives:

- Acquisition pf theoretical knowledge of methods of improving the foundation soil and rock,
- Application of theoretical knowledge when choosing the appropriate method of improving the foundation soil and rock depending on the problem under consideration (limitation of settlement, accelerated consolidation, etc.).

Entry competences (prior knowledge, descriptive):

- Knowledge of the concepts of stiffness and strength of soil and rocks,
- Understanding soil consolidation and the principle of pore pressures,
- Knowledge of how to determine the settlement of the structure, as well as the bearing capacity of the foundation soil/rock.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Applied Rock Mechanics,
- Course exam passed: Applied Soil Mechanics, Geotechnical Engineering.

Learning outcomes:

- The ability to recognize the problem and choose the optimal soil improving method depending on the considered problem,
- The ability to determine the degree of soil strengthening and calculate the stiffness of the improved soil if the problem of limiting settlement is considered, and the calculation of the strength parameters of the reinforced soil if the bearing capacity of the foundation soil is considered,
- The ability to determine the speed of consolidation and the time required for total consolidation if the problem of reducing pore pressures and accelerating consolidation is considered,
- The ability to conduct simpler laboratory and field experiments in order to control the quality of soil strengthening works (device for uniaxial pressure, SASW).

Course content (by course schedule):

- Lectures:
  1. Method selection and risk management in soil and rock strengthening [2]
  2. Replacing the soil, moving the soil, reducing the load [2]
  3. Overloading, vacuum preloading, load berms, inundation [2]
  4. Vertical drains [3]
  5. Lowering of the groundwater level [3]
  6. Soil freezing, soil heating, strengthening with vegetation [2]

7. Vibration methods of soil strengthening [3]
8. Gravel columns [3]
9. Strengthening of soil by grouting [3]
10. Jet grouting [2]
11. Soil stabilization with cement and lime [2]
12. Application of geosynthetics in soil strengthening [2]

- Exercises:
  1. Vertical drains (auditory) [2]
  2. Deep vibratory compaction (auditory) [2]
  3. Gravel piles (auditory) [4]
  4. Consolidation grouting (auditory) [2]
  5. Jet grouting (auditory) [4]
  6. Preload (auditory) [2]
  7. Anchoring structures (auditory) [2]

  (Midterm exam)
  8. Soil reinforcement (auditory) [4]
  9. Quality control of soil and rock strengthening (laboratory) [2]
  10. Quality control of soil and rock strengthening (fieldwork) [2]
  11. Measurements and observations of reinforced soil and rocks (fieldwork) [2]

Student Evaluation - Continuous assessment:
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:
1. Course materials: Meho Saša Kovačević (lectures – PowerPoint presentations)

Additional reading:
1. Mitchell, J. M.; Jardine, F. M.: *A Guide to Ground Treatment*. CIRIA publication C573, London, UK, 2002.
2. Bell, F. G.: *Engineering Treatment of Soils*, Spon Press, London, UK, 1993.
3. Moseley, M. P.: *Ground Improvement*, CRC Press, Boca Raton, Florida, USA, 1993.

RETAINING STRUCTURES

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (20 auditory + 4 on computers + 6 construction)

Course objectives:

- Acquisition of theoretical knowledge about types of retaining structures,
- Acquisition of theoretical and practical knowledge about the calculations of supporting structures,
- Acquisition of theoretical and practical knowledge about the design, execution and monitoring of retaining structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic physical and mechanical properties of the soil (strength, stiffness),
- Knowledge of the basics of Mohr's stress circles,
- Understanding the seepage of water in the soil,
- Knowledge of the basic principles of numerical modelling.

Learning outcomes:

- Describe and understand the basic concepts of the behaviour of rigid and flexible retaining structures,
- Understand earth pressures on retaining structures and become familiar with the method of their calculation,
- Determine the relevant actions on the retaining structure, including earth pressures, the structure's own weight, external actions and earthquakes,
- Understand the mechanisms of failure and deformation of retaining structures,
- Select relevant project situations related to retaining structures
- Analyse and prove the mechanical resistance and stability of retaining structures in accordance with relevant national and European standards,
- Select and apply available engineering methods, tools and technologies to ensure the resistance and stability of retaining structures,
- Acquire basic knowledge and skills of calculation and dimensioning of structural elements and assemblies of retaining buildings.

Course content (by course schedule):

- Lectures:
  1. Application and types of retaining structures
  2. Selection of project parameters and relevant design situations
  3. Basics of earth pressure calculation - concepts of earth pressure description, strength parameters
  4. Basics of earth pressure calculations - Rankine states, Coulomb's method and accuracy
  5. Basics of calculation of earth pressures - additional load on the surface of the terrain, action of earthquakes
  6. Retaining walls (gravitational and cantilever)
  7. Calculation methods of retaining walls (gravity and cantilever)
  8. Reinforced earthen structures
  9. Calculation methods of reinforced earthen structures
  10. Buried supporting rocks, anchoring of retaining structures, elements of calculation of geotechnical anchors
  11. Calculations of buried retaining rocks (design and theoretical requirements)
  12. Calculations of buried retaining rocks (calculation procedures)
  13. Application of Eurocode for retaining structures

14. Monitoring and observation of retaining structures

- Exercises:
  1. Examples of calculation of retaining structures - soil pressures (active, passive, at rest, Rankine, Coulomb).
  2. The influence of additional loads on retaining structures (additional load on the surface, seismicity: Mononobe - Okabe expressions).
  3. Analysis of the relevant limit states of retaining structures - overturning, sliding, bearing capacity, settlement.
  4. Calculation of the gravity retaining wall – analytical solutions.
  5. Calculation of cantilever retaining wall – analytical solutions.
  6. Calculation of a retaining wall made of reinforced soil – stress-deformation analysis and stability analysis.
  7. Calculation of buried support structures – analytical solutions.
  8. Calculation of anchored buried retaining structures – stress deformation analysis, seepage analysis, stability analysis.
  9. Calculation of braced buried support structures – stress-deformation analysis and seepage analysis, stability analysis.
  10. Dimensioning of anchors and bracing structures.
  11. Preparation of the program assignment.
  12. Submission of program assignments.

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Librić, L: Course materials (lectures - PPT presentations)
2. Nonveiller, E.: Mehanika tla i temeljenje građevina, II. izdanje. Školska knjiga, Zagreb, 1981.

Additional reading:

1. Dembicki, E.: Tlak, otpor i nosivost tla, Sveučilišna naklada Liber, Zagreb, 1982.
2. Gaba, A. R., Simpson, B.; Powrie, W.; Beadman, D. R: Embedded retaining walls-guidance for economic design, Report CIRIA C580, London, 2003.
3. Clayton, C.R.I., Woods, R.I., Bond, A.J., Milititsky, J.: Earth Pressure and Earth-Retaining Structures, 3rd Edition, CRC Press, 2014.
4. GEO-SLOPE International: Users Guides (SIGMA /W, SEEP /W, SLOPE W). GEO-SLOPE International Ltd., Calgary, Alberta, Canada, 2021.
5. Eurocode Standards Series EN 199i ; i = 0, 1, 2, 3, 4, 7, 8.

HYDROGEOLOGY AND ENGINEERING GEOLOGY

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of knowledge in hydrogeology and engineering geology for application in construction,
- Understanding the groundwater regime in karst, getting to know good and bad examples,
- Acquisition of theoretical knowledge about methods of researching rock properties for the purposes of rock mass classification.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic geological concepts.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Applied Geology.

Learning outcomes:

- Understanding the influence of the groundwater regime on construction interventions in karst,
- Getting to know the methods of determining water protection areas,
- Understanding the influence of geological structures on the bearing capacity of the foundation structure and on the stability of slopes in the rock mass,
- The influence of geological structures on the stability of the underground opening in the rock mass,
- The ability to determine the geological parameters necessary to classify the rock mass.

Course content (by course schedule):

- Lectures:
  1. Introduction. Hydrogeology [2]
  2. The role of hydrogeology in civil engineering [2]
  3. Classification of groundwater [2]
  4. Groundwater regime [2]
  5. Research methods [2]
  6. Water in karst [2]
  7. Karst [2]

  (Midterm exam)
  8. Determination of protection zones, Interpretation of hydrogeological research [2]
  9. Engineering geology and its role in civil engineering [4]
  10. Engineering geology and its role in civil engineering. Landslides [2]
  11. Rock classification for geotechnical engineering [2]
  12. Methods of investigating rock properties for construction purposes [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam

Required reading:

1. Herak, M.: *Geologija*, 1990.
2. Šestanović, S.: Osnove geologije i petrologije, *2001.*
3. West, T.: Geology Applied to Engineering, *1994.*
4. Monroe, J.; Wicander, R.: *Physical geology*, 2006.
5. Plummer, C.; McGeary, D.; Carlson, C.: *Physical Geology*,2006.

Additional reading:

1. Weight, W.; Sonderregger, J.: *Manual of Applied Field Hydrogeology*, 2004.
2. Weight, W.: *Hydrogeology Field Manual*, 2008.
3. Waltham, T.: *Foundations of Engineering Geology*, 2002,
4. Poehls, D. J.; Smith, G. J.: *Encyclopaedic Dictionary of Hydrogeology*, 2009.
5. Fetter, C. W.: *Applied Hydrogeology*, 2000.
6. Rahn, P.: *Engineering geology: An Environmental Approach*, 1996.

GEOTECHNICAL LABORATORY

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 30
- Exercises (laboratory): 45

Course objectives:

- Acquisition of theoretical knowledge about the physical and mechanical properties of soil and rock that can be determined by tests in the laboratory,
- Acquisition of theoretical and practical knowledge about the procedure and methodology of laboratory testing,
- Acquisition of knowledge about the interpretation and presentation of the results of laboratory tests.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic physical and mechanical properties of soil and rock necessary for design,
- Working knowledge in Microsoft Office (Word, Excel).

Enrolment requirements (prerequisite):

- Course exam passed: Applied Soil Mechanics.

Learning outcomes:

- Acquired knowledge and understanding of the essential role of laboratory experimental procedures in geotechnical engineering,
- Qualification for conducting laboratory experiments on coherent and non-coherent soil samples, and on intact rock samples,
- The ability to process and interpret the results of laboratory tests,
- Drawing well profiles and engineering and geological soil profiles,
- The ability to create a final report on laboratory tests.

Course content (by course schedule):

- Lectures:
  1. The role of the laboratory in geotechnical engineering [2]
  2. Soil classification [2]

3. Importance of soil [2]
4. Soil density [2]
5. Density of solid particles [2]
6. Granulometric composition of soil [2]
7. Limits of consistency [2]
8. Oedometer experiments [2]
9. Direct shear tests [2]
10. Fall cone tests - undrained soil strength [2]
11. Uniaxial pressure test [2]
12. Unconsolidated undrained triaxial test [2]
13. Consolidated triaxial test [2]
14. Soil permeability [2]
15. Soil compaction [2]

- Exercises (laboratory):
  1. Introduction [3]
  2. Soil classification according to: USDA, AASHTO, USCS, BSCS, AC, unified soil classification, and ESCS soil classification [3]
  3. Determination of water content according to HRS CEN ISO/TS 1789-1 [3]
  4. Determination of soil density according to HRS CEN ISO/TS 1789-2: dimension measurement method, immersion in water method, fluid displacement method
  5. Determination of particle density according to HRS CEN ISO/TS 1789-3
  6. Determination of particle size distribution according to HRS CEN ISO/TS 1789-4
  7. Determination of liquid limit and plasticity according to HRS CEN ISO/TS 1789-12. Determination of liquid limit according to BS 1377: Part 2: 1990 by Casagrande method.
  8. Conducting oedometer tests according to HRS CEN ISO/TS 1789-5
  9. Conducting direct shear tests according to HRS CEN ISO/TS 1789-10
  10. Determination of undrained soil strength by the fall cone test according to HRS CEN ISO/TS 1789-6
  11. Conducting uniaxial pressure tests according to HRS CEN ISO/TS 1789-7
  12. Conducting an unconsolidated undrained triaxial test according to HRS CEN ISO/TS 1789-8
  13. Conducting consolidated triaxial tests according to HRS CEN ISO/TS 1789-9
  14. Determination of soil permeability according to HRS CEN ISO/TS 1789-11
  15. Determination of laboratory dry density and water content according to HRN EN 13286-2

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures, 100% attendance at exercises
- Written exam

Required reading:

1. Course materials: Danijela Marčić (lectures – PowerPoint presentations)

Additional reading:

1. Head, K. H.: *Manual of Soil Laboratory Testing*, Volume 1, 2 i 3, John Wiley & Sons, West, Sussex, UK, 1998.
2. Bardet, J. P.: *Experimental Soil Mechanics*. Prentice Hall, New Jersey, USA, 1997.

Elective courses

UNDERGROUND STRUCTURES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 12, construction: 18)

Course objectives:

- Acquisition of theoretical knowledge about the state of stress around openings in the rock mass due to the construction of underground structures,
- Acquisition of theoretical knowledge about the interaction of underground systems and rock mass,
- Acquisition of theoretical knowledge about the design and construction technology of underground structures,
- Mastering more complex problems in the field of underground construction.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic physical and mechanical properties of soil and rock mass (stiffness, strength, etc.),
- Knowledge of rock mass classifications,
- Understanding of the basic principles of numerical modelling.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Applied Rock Mechanics.

Learning outcomes:

- The ability to calculate the relevant soil/rock parameters required for numerical modelling based on the results of laboratory and field tests and on the basis of rock mass classifications,
- The ability to choose a system for ensuring the stability of an underground structure depending on the environment in which it is located,
- The ability to perform more complex two-dimensional and three-dimensional stress-deformation analyses when assessing the stability of support units of underground buildings,
- Knowledge of the principles of interactive design in underground construction using observations and measurements during execution.

Course content (by course schedule):

- Lectures:
  1. Basic concepts and development of underground structures [2]
  2. Traditional methods of tunnel excavation [2]
  3. Theory of a self-supporting vault [3]
  4. New Austrian tunnelling method [2]
  5. Norwegian method of tunnelling [2]
  6. Primary partition, secondary partition [3]

7. Waterproofing, ventilation [2]
8. The role of rock mass classification in underground construction [2]
9. Analytical methods in underground construction [3]
10. Numerical methods in underground construction [3]
11. Monitoring of underground buildings [2]
12. Designing of underground structures [4]

- Exercises:
  1. Elements of the primary underground system [8]
  2. Load on the support unit: Theories of self-supporting vault [2]
  3. Load on the support unit: Elastically supported ring [2]
  4. Designing the underground system based on the RMR classification [2]
  5. Designing the underground system based on the Q classification [2]
  6. Characteristic curves of rock mass and support unit [2]
  7. Stress-deformation analyses of underground structures [6]
  8. Long-term deformations of underground structures [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Course materials: Meho Saša Kovačević (lectures – PowerPoint presentations)

Additional reading:

1. Hoek, E.; Brown, E. T: *Underground excavations in rock*, The Institution of Mining and Metallurgy, London, England, 1980.
2. ITA: *Guidelines for the design of tunnels*, ITA Working Group on General Approaches to the Design of Tunnels, Tunnelling and Underground Space Technology, Vol. 3, No. 3., 1988.

GEOTECHNICS AND ENVIRONMENTAL PROTECTION

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (7 auditory + 6 on computers + 2 construction)

Course objectives:

- Acquisition of specific knowledge about geotechnical aspects of environmental protection,
- Acquisition of theoretical and practical knowledge about waste disposal and landfills.
- Acquisition of theoretical and practical knowledge about energy exploitation of geotechnical elements
- Understanding the impact of climate change on soil behaviour and geotechnical structures
- Development of ability to apply geotechnical methods in environmental protection and sustainable development of infrastructure

Entry competences (prior knowledge, descriptive):

- Knowledge of the flow process in the soil (concepts of flow, hydraulic gradients, etc.),
- Knowledge about shear stability analyses in soil materials.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Embankments and Slopes

Learning outcomes:

- Define and revise the essential relationships between people and the environment from the aspect of resource use and pollution,
- Define the concept of waste and modern concepts of its disposal,
- Explain the construction and geotechnical aspects of a modern landfill,
- Recognize and apply important mechanical properties of waste in geotechnical analyses,
- Recognize the processes of pollution transfer through the soil and their numerical description,
- Define the roles of geosynthetics in protecting the underground from leachate pollution and in ensuring slope stability.

Course content (by course schedule):

- Lectures:
  1. Basic principles of environmental protection 1 (environmental science, environment on earth, concept and origin of soil, water and air pollution)
  2. Basic principles of environmental protection 2 (contemporary trends in solving environmental problems, concept of sustainable development, regulations)
  3. The impact of civil engineering on environment, engineering, "green" geotechnical solutions
  4. Waste, properties of waste as construction material, application of industrial by-products in geotechnics (fly ash, slag)
  5. Waste disposal site – components of a waste disposal site, harmful products, closed landfill concept, construction method of a waste disposal site
  6. Geotechnical aspects of the landfill, stability of the slope of the landfill (stability in static and seismic conditions, contact with geosynthetics, influence of eluate)
  7. Monitoring of the state of the waste disposal site and the environment, examples of landfill instability and sliding
  8. Transmission of pollution through soil and water, prevention of pollution and remediation of polluted soil
  9. Necessary properties of natural and artificial materials for sealing and drainage layers, use of geosynthetics
  10. Renewable energy sources, geothermal energy, thermal properties of soil
  11. Energy structures - energy piles, energy tunnels and energy retaining walls
  12. Thermal-mechanical behaviour of energy structures, thermal loads
  13. Designing energy structures, numerical and analytical methods, design standards
  14. Climate changes (intense precipitation, high temperatures)
  15. Impact of climate change on geotechnical buildings
- Exercises:
  1. Examples of landfill stability calculations, landfill body and cover
  2. Stability calculations of waste disposal sites [3]
  3. Calculations of pollution transfer through soil
  4. Calculations of the impact of rehabilitation measures on the transfer of pollution through the soil

5. Analyses of energy structures
6. Analyses of energy piles
7. Analyses of a group of energy piles
8. Numerical modelling of precipitation influence on stability, boundary conditions
9. Presentations of seminar papers and discussion [5]

Student Evaluation - Examination without Continuous Assessment:

- Prepared and defended seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Course materials: Mario Bačić (lectures – PowerPoint presentations).
Additional reading:

1. D. Znidarčić, D. Kovačić, P. Kvasnička, M. Mulabdić: *Geotehnologija pri odlaganju komunalnog otpada*, Hrvatsko društvo građevinskih inženjera, Građevni godišnjak, 1996.
2. Z. Milanović: *Deponij – trajno odlaganje otpada*, ZGO-Zagreb, 1992.
3. Z. Milanović, S. Radović, V. Vučić: *Otpad nije smeće*, Gospodarstvo i okoliš, V. Gorica, 2002.
4. M. L. McKinney, R. M. Schoch: *Environmental Science (Systems and Solutions)*, 3rd ed., Jones and Bartlett Publishers, Boston, 2003.
5. ISSMFE Technical Committee TC 5: *Environmental Geotechnics*, Report, Bochum, 1997.
6. R. M. Koerner, D. E. Daniel: *Final Covers for Solid Waste Landfills and Abandoned Dumps*, ASCE Press & Thomas Telford, 1997.
7. R. M. Koerner: *Designing with Geosynthetics*, 4th edition, Prentice Hall, 1998.
8. R. K. Rowe, R. M. Quigley, J. R. Booker: *Clayey Barrier Systems for Waste Disposal Facilities*, E&FN.
9. Rotta Loria, A., Laloui, L.: *Analysis and Design of Energy Geostructures: Theoretical Essentials and Practical Application*, Academic Press, 2019.

SOIL DYNAMICS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 16, design: 14)

Course objectives:

- Acquisition of theoretical knowledge about phenomena in soil and geotechnical structures during dynamic and seismic excitation,
- Acquisition of theoretical and practical knowledge about geotechnical seismic calculations.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of free and forced oscillations, as well as the dynamics of structures,

- Knowledge of the basics of soil mechanics and the mechanical and physical properties of soil (strength, stiffness).

Enrolment requirements (prerequisite):

- Course exams passed: Geotechnical Engineering, Numerical modelling in geotechnics.

Learning outcomes:

- Explanation of the propagation of seismic waves in half-space,
- Understanding the complex relations of stress and deformation in cyclically loaded soil materials,
- Carrying out calculations of dynamically loaded foundations,
- Determination of the liquefaction potential of water-saturated soil,
- Analysis and proof of stability of slopes, and of earthfill and retaining structures during earthquakes.

Course content (by course schedule):

- Lectures:
  1. Introduction: basics of oscillations (free and forced oscillations of an undamped and damped simple oscillator), instruments for measuring oscillations [4]
  2. Waves in elastic media: longitudinal and transverse waves in a rod, reflection, waves in an infinite medium (longitudinal, transverse, reflection and refraction), waves along the boundary (Rayleigh and Lowe waves), attenuation, dispersion [2]
  3. Properties of cyclically loaded soils: hysteresis, stiffness, damping, strength, cyclic volume deformations and pore pressures, laboratory experiments, field experiments [4]
  4. Foundation oscillations: vertical, lateral, torsional, rocking and bound oscillations of shallow foundations, theory and measurements, foundation oscillations on piles, vibration protection [4]
  5. Soil bearing capacity in dynamic conditions [2]
  6. Geotechnical seismic engineering: effects of earthquakes on soil and structures, examples from practice [2]
  7. Earthquake load: definitions of terms, characteristics of ground motion during an earthquake. Propagation of seismic waves: vertical propagation through a stratified medium, nonlinear soil behaviour, amplification [4]
  8. Earthquake behaviour of walls and slopes: Mononobe-Okabe theory for walls, sliding block method, dimensioning of walls for limited lateral displacements, permanent displacements in slopes and embankments [4]
  9. Liquefaction: liquefaction in the laboratory and in the field, laboratory and field experiments, improvement of liquefiable soil [4]
- Exercises (auditory):
  1. Calculation of dynamically loaded foundations [4]
  2. Determination of soil liquefaction potential [4]
  3. Calculation of the seismic stability of slopes and earthfill structures [4]
  4. Seismic calculations of retaining structures [4]
- Exercises (design):
  1. Calculation of dynamically loaded foundations [4]
  2. Determination of soil liquefaction potential [2]
  3. Calculation of the seismic stability of slopes and embanked buildings [4]
  4. Seismic calculations of retaining structures [4]

Student Evaluation - Continuous assessment:

- In-class activity
- Practical work
- Midterm exam
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Practical work
- Midterm exam
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Das, B. M.: *Principles of Soil Dynamics*. Brooks/Cole, Pacific Growe, CA, 1993.
2. Course materials: lectures – PowerPoint presentations

Additional reading:

1. Kramer, S. L.: *Geotechnical Earthquake Engineering*. Prentice Hall, NJ, 1996.
2. Prakash, S.: *Soil Dynamics*. McGraw-Hill, NY, 1981.

ENGLISH IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45

Course objectives:

- Acquisition of vocabulary in the field of transport facilities and geotechnical engineering, developing functional literacy in writing technical reports,
- Independent communication using technical terms,
- Developing the ability to translate from English into Croatian and vice versa.

Entry competences (prior knowledge, descriptive):

- Upper-intermediate (B1).

Learning outcomes:

- Acquisition of language competences that include use of professional terminology in the field of roads and geotechnical engineering,
- Independent reading of specialized literature,
- Reinforcement of basic grammatical categories in professional language – use of the passive voice, past tenses, modal verbs,

- Gaining fluency in structuring sentences and developing skills of delivering individual presentation and writing technical texts.

Course content (by course schedule):

1. A Career in Transportation Engineering [2]
2. Road Structure [2]
3. Construction of a Road [2]
4. A Career in Geotechnical Engineering [3]
5. Tunnels and Tunnelling Tools [2]
6. How to write a CV? [3]
7. The CV and Job Interview Questions [3]
8. Preparing for the Interview Skills – Techniques, Tips and Advice [3]
9. Single presentations on Transportation Issues [3]
10. Transportation System Issues and Challenges [3]
11. The Light at the End of the Tunnel – Revision of vocabulary [4]
12. What's so Special About Geotechnical Engineering? [3]
13. General Considerations in Foundation Design [2]
14. Special Foundation Problems [2]
15. Deep Foundations [3]
16. Presentations [3]

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. A. Kralj Štih: *English in Transportation and Geotechnical Engineering*, course materials.

Additional reading:

1. D. Bonamy*: Technical English 4*, Pearson Longman, 2011.
2. Webpage Building Big, Brantacan, ASCE.
3. Z. Vulelija: *Ilustrirani rječnik arhitekture i građevinarstva – hrvatsko engleski i englesko hrvatski*, Masmedia, Zagreb, 2010.
4. A. Prager: *Trojezični građevinski rječnik*, Masmedia, Zagreb, 2002.

GERMAN IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45

Course objectives:

- Help the student to independently use professional literature by developing comprehension, conversation and translation skills,
- Mastering all forms of oral communication of technical content, from participation in discussions to independent presentations.

Learning outcomes:

- Comprehension and interpretation of technical texts,
- Confidence and independence in oral expression in the technical field and when explaining professional terms,
- Writing a resume and job application.

Course content (by course schedule):

1. Die Geschichte des Kuppelbaus [3]
2. Wie schreibt man einen Lebenslauf? [3]
3. Bewerbungsschreiben [3]
4. Wie bereitet man sich auf ein Interview vor [3]
5. Die größte Drehbrücke der Welt [3]
6. Bewerbungsschreiben [3]
7. Die Geschichte der Tunnelkonstruktion [3]
8. Kräfte und Gegenkräfte [3]
9. Einige Festigkeitsarten [3]
10. Elastizität und Verformung [3]
11. Der Straßenbau [3]
12. Gebäude im Erdbeben [3]
13. Der Flughafen [3]

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. A. Kralj Štih: *Deutsch für Konstruktionen, Geotechnik, Verkehr und Theorie und Modellierung der Konstruktionen*, Kursunterlagen, 2011.

Additional reading:

1. A. Prager: *Trojezični građevinski rječnik*, Masmedia, Zagreb, 2002.

2nd year, 4th semester

Mandatory courses

GEOTECHNICAL DESIGN

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- exercises: 30 (2 auditory + 28 design)

Course objectives:

- Acquisition of knowledge and skills for integral geotechnical design of geotechnical structures or procedures,
- Integrating previously acquired knowledge and skills when solving more complex geotechnical procedures.

Entry competences (prior knowledge, descriptive):

- Using Software for numerical modelling in geotechnics,
- Knowledge of the basic physical and mechanical properties of soil and rock necessary for design,
- Knowledge of laboratory and field investigations,
- Determination of project situations for simpler geotechnical operations.

Enrolment requirements (prerequisite):

- Teacher's signature for the courses: Retaining Structures, Improvement of Soil and Rock.
- Course exams passed: Embankments and Slopes, Foundation Engineering.

Learning outcomes:

- Defining given geotechnical problems and planning geotechnical investigation works,
- Analysis and interpretation of geotechnical investigation works, and determination of the characteristic geotechnical model of the foundation soil,
- Selection of relevant parameters for the design based on investigative works,
- Choosing the appropriate design solution for a given type of geotechnical problem,
- Analysis and interpretation of the results obtained by numerical modelling,
- Evaluation and verification of the selected technical solution for serviceability and ultimate limit states,
- selection and description of performance technology for the selected design solution,
- Drawing up the entire project with attached drawings, cost list, technical description, budgets and technical conditions for the implementation of the selected design solution.

Course content (by course schedule):

- Lectures:
  1. General principles and specifics of geotechnical and structural design
  2. Presentation of the relevant regulations and general provisions of Eurocode 7 - Geotechnics procedures for designing and proving mechanical resistance and stability)
  3. Eurocode 7 – Geotechnics (limit states, geotechnical data)
  4. Eurocode 7 – Geotechnics (geotechnical structures)
  5. Eurocode 8 – Geotechnics (seismic geotechnical engineering)

6. Quality management and quality assurance in geotechnical design and execution
7. Development of field and laboratory investigative works for typical cases (selection of methods, spacing and depth of investigations, sampling density)
8. Reports of investigation works, geotechnical models of foundation soil, selection of relevant geotechnical parameters [2]
9. Variant technical solutions, choice of materials and characteristics of construction technologies [2]
10. Presentations of more complex geotechnical structures and works from practice [4]

- Exercises:
  1. Introduction, description of the program – geotechnical design of typical geotechnical structures
  2. Work on a geotechnical design – preparation of geotechnical data, geotechnical model of the foundation ground [2],
  3. Work on a geotechnical design –selection of technical solutions [3]
  4. Work on geotechnical design – geotechnical calculations [5]
  5. Work on geotechnical design – graphical part, technical terms of execution and costs [3]
  6. Submission of the program

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a design assignment
- Written exam
- Oral exam

Required reading:

1. Course materials: Mario Bačić (lectures – Powerpoint presentations).
2. Course materials of teachers from other geotechnical courses.

Additional reading:

1. *Eurocode 7: Geotechnical design (*EN 1997-1:2004*)*
2. Nonveiller, E.: *Mehanika tla i temeljenje građevina*, 2nd ed. Školska knjiga, Zagreb, 1981.
3. Tomlinson, M. J.: *Foundation Design and Construction*, Longman Scientific and Technical, Harlow, 1995.
4. Bowles, J. E.: *Foundation Analysis and Design*, McGraw Hill, NY, 1982.
5. Coduto, D. P.: *Foundation Design*, Principles and Practices, Prentice Hall, NJ, 1994.
6. *Geotechnical Engineering Handbook* Vol 1-3, Ed. U. Smoltzyck, Ernst&Sohn Verlag, Berlin, 2002.
7. *Technical engineering and design guides adapted from the US Army Corps of Engineers*, ASCE.
8. *CIRIA – design reports*, London.

FIELD INVESTIGATION AND MONITORING

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (fieldwork: 30)

Course objectives:

- Acquisition of theoretical knowledge of in situ properties of soil and rocks during field testing,
- Understanding the concepts of the purpose of measurement, measurement quantities, measurement equipment and measurement results,
- Acquisition of theoretical knowledge about measuring equipment during field tests,
- Acquisition of practical knowledge about the procedure and methodology of field tests,
- Acquisition of knowledge about the interpretation and presentation of the results of field tests.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic physical and mechanical properties of soil necessary for design,
- Knowledge of the basic physical and mechanical properties of rocks necessary for design,
- Knowledge of the concepts of deformations, displacements, stresses, forces, stiffness, necessary for understanding the principles of observation of geotechnical structures.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Geotechnical Laboratory

Learning outcomes:

- Acquired knowledge and understanding of the essential role of research and experimental procedures in geotechnical engineering – in design (field investigations) and verification of executed structures or works (field measurements and observations),
- The ability to carry out simpler field tests as part of investigative works,
- Training in the use of measuring equipment for observation and monitoring,
- The ability to process and interpret the results of field tests,
- The ability to produce a final report on field tests.

Course content (by course schedule):

- Lectures:
  1. Exploration pits. Trial boreholes [2]
  2. Determining the level of groundwater[2]
  3. Penetration tests: standard penetration test, static penetration test, light penetration probe [2]
  4. Pressuremeter tests: Menard pressuremeter, self-boring pressuremeter, dilatometer[2]
  5. Geophysical investigation: refraction, reflection, cross-hole, down-hole [2]
  6. Geophysical investigation: spectral analysis of surface waves, multi-channel analysis of surface waves [2],
  7. Observational program of geotechnical structures [2]
  8. Measurement and monitoring of soil and rock deformation: geodetic surveying [2]
  9. Vertical and horizontal inclinometer [2]
  10. Sliding deformeter and micrometer, clinometer [2]

11. Crack measurement [2]
12. Measurements and observations of stress in soil and rock by pressure cells [2]
13. Methods of testing the integrity and bearing capacity of piles [2]
14. Interpretations of measurement and observation results [2]
15. Numerical back analyses based on measurement results [2]

- Exercises:
  1. Determining the level of groundwater (fieldwork) [2]
  2. Penetration test: Cone penetration test (fieldwork) [4]
  3. Pressure test: dilatometer (fieldwork) [4]
  4. Spectral analysis of surface waves (fieldwork) [4]
  5. Vertical and horizontal inclinometer (fieldwork) [4]
  6. Sliding deformeter and micrometer, clinometer (fieldwork) [4]
  7. Measurements and observations of stress in soil and rock by pressure cells (fieldwork) [4]
  8. Methods of testing the integrity and bearing capacity of piles (fieldwork) [4]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures, 100% attendance at exercises
- Written exam

Required reading:

1. Course materials: Meho Saša Kovačević (lectures – PowerPoint presentations)

Additional reading:

1. Simons, N.; Menzies, B.; Matthews, M.: *A short course in geotechnical site investigation*. Thomas telford, London, UK, 2002.
2. Dunnicliff, J.: *Geotecnical Instrumentation for Monitoring Field Performance*, John Wiley & Sons, New York, USA, 1993.
3. Nicholson, D.; Tse, C.-M., Penny, C.: *The Observational Method in Ground Engineering*. CIRIA. Report 185, London, UK, 1999.

Specialisation in HYDRO ENGINEERING

1st year, 1st semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

HYDRAULICS 1

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (auditory: 8, laboratory: 10, on computers: 12)

Course objectives:

- Teach students the basics of unsteady flow in open channels, pressurized systems (water supply networks, water hammer , oscillations of water masses) and groundwater,
- Teach students the basic processes of substance transfer through fluids.

Entry competences (prior knowledge, descriptive):

- Good knowledge of fluid mechanics, i. e. characteristics of fluids and stationary flow.

Learning outcomes:

- Understanding the relationship between energy transfer and fluid flow,,
- Mastering the elements of matter and energy transport and transfer within fluid flow,
- Mastering the basic terms related to unsteady flow,
- Mastering the basics of unsteady water flow calculations.

Course content (by course schedule):

- Lectures:
  1. Introduction to hydraulics, energy, dominant forces and similarity. Flow in watercourses [3]
  2. Gradual variable open channel flow [3]
  3. Unsteady flow in a watercourse – flow with sudden changes. [3]
  4. Unsteady flow in a watercourse – flow with sudden changes. Flood wave after a dam failure. [3]
  5. Stationary flow in water networks. Unsteady flow in pressurized systems [3]
  6. Oscillations of water masses in systems with a water chamber and an air vessel [3]
  7. Air vessel. Water hammer problem [3]
  8. Water hammer problem in pipeline network [3]
  9. Groundwater [3]

10. Wells [3]
11. Regional groundwater flow models [3]
12. Mechanisms of substance transport in fluid flow[3]
13. Transfer of substances carried in fluid flow [3]
14. Air flow. Effect of wind on building structures [3]

(Midterm exam)

- Exercises:
  1. Calculation of gradually changing flow in watercourses. [2]
  2. Calculation of flood wave propagation in watercourses [2]
  3. Laboratory exercises [4]
  4. Submission of program assignments [2]
  5. Calculation of stationary flow in a ring water distribution system[2]
  6. Oscillations of water masses in a system with a water chamber [2]
  7. Water hammer in s pressure pipeline [2]
  8. Submission of program assignments [2]
  9. Calculation of groundwater flow [2]
  10. Laboratory exercises [4]
  11. Calculation of substance transfer through groundwater; Resistance force of body shape in fluid flow [2]
  12. Submission of program assignments [2]
  13. Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Gjetvaj, G.: Hidraulika (lecture notes for internal use)
2. Gjetvaj, G. i suradnici: Praktikum iz hidraulike
3. Jović, V.: *Osnove hidromehanike*, Element, Zagreb, 2006.

Additional reading:

1. Chow, V. T.: *Open Channel Hydraulics*, Mc Graw-Hill Kogakusha,1986.
2. Roy, D. N.: *Applied Fluid Mechanics*, Ellis Horwood limited, New York, 1988.

HYDROLOGY 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (2 auditory + 10 design + 18 construction)

Course objectives:

- Acquisition of theoretical and practical knowledge in the field of hydrology, which includes analysis of precipitation data, hydrological processes on land: determination of interception and evapotranspiration, seepage into the soil and surface water flow, groundwater, soil moisture, saturated and unsaturated zone, parametric methods for determining processes runoff in the basin – methods for determining direct runoff, and mathematical modelling in hydrology.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics from hydrology courses, which include: water and water movement in nature, processes in the atmosphere, hydrometry, hydrometric data processing, application of probability and statistics in hydrology,
- Knowledge and understanding of the physical properties of substances (phases of substances, density, specific volume and quantity of substances).

Learning outcomes:

- Explain in more detail terms about: hydrological processes on land and enumerate them, analysis of precipitation data, runoff processes in the basin - methods for determining direct runoff, and mathematical modelling in hydrology,
- Apply the acquired theoretical knowledge of hydrology in the construction industry; in building design, they are able to solve simpler problems and tasks in hydrology,
- Explain terms and apply procedures for basic analysis of meteorological data, hydrological analysis and elaboration of hydrological data,
- Students have the knowledge about the meaning and role of water in the development of society, about the role of hydraulic structures in the management of water resources, about the classification, purpose and definition of hydrological data and analyses when dimensioning hydraulic structures.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Revision [2]
  3. Hydrometry: hydrological measurements and observations, measurements of water level, water depth, flow, groundwater, river sediment, ice observation [2]
  4. 1st midterm exam [2]
  5. Processing of hydrometric data: basic processing, flow curve, sediment transport curve, random variable, frequency and durability curves [2]
  6. Analyses of time series: calculation of flood flows, theoretical distribution functions [2]
  7. Precipitation: precipitation parameters, remote measurements of precipitation, precipitation in Croatia, point data processing, IDF curves, RDF curves, design storm [2]
  8. Morphological characteristics of the watershed: longitudinal fall, stream length, watercourse length, watershed and river network [2]
  9. Modelling and GIS technology: GIS components, spatial analyses, examples of hydrological analyses [2]
  10. Runoff process in the watershed: base runoff, direct runoff, runoff on small watersheds, runoff on large watersheds [2]
  11. Effective precipitation models: index method, NRCS-CN method [2]
  12. Direct runoff models: isochron method, unit hydrograph method, synthetic unit hydrograph [2]

13. Continuity equation: water balance, discrete time domain, hydrological year, water balance on Earth [2]
14. Hydrological forecasts: results of the BRIDGE SMS project, results of the MuraDrava-FFS project [2]
15. 2nd midterm exam

- Exercises:
  1. Analysis of hydrological time series. Frequency curves and durability curves. Flow curve. [4]
  2. Probability of flood flows [6]
  3. Submission and commentary of the 1st program assignment [2]
  4. Basin runoff model [2]
  5. Basic characteristics of the basin [4]
  6. Project precipitation. Effective precipitation model. Surface runoff model. Base runoff model. Model of water wave propagation in a watercourse. [4]
  7. Runoff modelling in HEC-HMS. [6]
  8. Submission and commentary of the 2nd program assignment [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Hrelja H.: *Inženjerska hidrologija*, Univerzitet u Sarajevu – Građevinski fakultet, Sarajevo 2007.,
2. Žugaj, R.: *Hidrologija*, Sveučilište u Zagrebu – Rudarsko-geološko-naftni fakultet, Zagreb 2000.,
3. Srebrenović, D.: Primijenjena hidrologija, Tehnička knjiga, Zagreb, 1986.,
4. Vuković, Ž.: Osnove hidrotehnike – Knjiga I, Poglavlje 2: Hidrologija, str. 19-133, udžbenik Sveučilišta u Zagrebu, Zagreb, 1996.,
5. Srebrenović, D.: Problemi velikih valova, Tehnička knjiga, Zagreb, 1986.,

Additional reading:

1. Viessman W.Jr. & Lewis. L.G.: *Introduction to Hydrology*, Harper-Collins-College-Publishers, New York, 1996.
2. Chow, V. T.: Handbook of Applied Hydrology, McGrow-Hill book Company, New York, 1964.

RIVER TRAINING

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises (design): 30

Course objectives:

- Acquisition of basic knowledge about design, execution, maintenance and management of river systems,
- Introduce students to the basic morphological features of watercourses and the interpretation of their changes.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra,
- Knowledge of the basics of fluid dynamics (equation of conservation of momentum, general law of real fluid flow (Saint-Venant and Navier-Stokes equation), equation of conservation of kinetic energy, Bernoulli equation for real fluid, flow resistance, calculation of local and linear energy losses, geodesic, pressure and energy line, velocity, pressure and flow measurement),
- Knowledge of descriptive geometry, drawing in a plane, intersection of lines, drawing arcs using tangents,
- Computer work: basics of drawing using CAD software.

Learning outcomes:

- Define basic physical river laws and describe them with mathematical tools,
- Understand the dynamics of natural watercourses,
- Apply a one-dimensional numerical model of the flow of open watercourses and interpret the influence of river training structures on the water regime,
- Apply engineering solutions for river flow alterations,
- Position the river training structures in the channel and draw their characteristic sections,
- Compare individual variant solutions of river training structures using cost-benefit analysis
-

Course content (by course schedule):

- Lectures:
  1. Purpose, problems and tasks of river training, the role of river training works in water management. Basic definitions and classifications [3]
  2. Morphology of the riverbed [3]
  3. Hydrological properties of natural watercourses, flow regime, sediment regime, ice regime [3]
  4. Hydraulic calculations of natural and artificial watercourses [6]
  5. Flow calculations in open channels [3]
  6. Calculations of channel stability [3]
  7. Morphodynamic analyses of the watercourse channel [3]
  8. Approaches to the problem of local channel instability [3]
  9. River training structures in the main channel [3]
  10. River training structures outside the main channel [3]

11. Embankments[3]
12. Other river training structures [3]
13. Regulating the flow regime [3]
14. Works on the basin and facilities for regulating the water regime, basic principles of functioning [3]
15. Hydraulic structures on watercourses [3]
16. Regulation of small watercourses with an immobile boundary [3]

- Exercises:
  1. Channel axis layout and bank lines [6]
  2. Selection and placement of river training structures [4]
  3. Hydraulic flow calculations for mean water flow[4]
  4. Hydraulic flow calculations for high water [4]
  5. Selection and layout of river training structures [4]
  6. Design of structures [4]
  7. Hydraulic calculations of flow in a channel for mean and high water for a design state [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Lecture notes for internal use: http://www.grad.hr/nastava/hidrotehnika/gf/regulacije

Additional reading:

1. Chang, H. H.: *Fluvial processes in River Engineering*, Krieger publishing company, 1998.
2. Jansen, P. Ph. et al: *Principes of River Engineering – The non-tidal alluvial river*, Pitman Publishing Limited, London, 1979.

Elective courses

MATHEMATICS 3

See Chapter Shared Courses

STOCHASTIC PROCESSES

See Chapter Shared Courses

1st year, 2nd semester

Mandatory courses

WATERWAYS AND PORTS

Credits (ECTS): 9

Hours (total per semester):

- Lectures: 45
- Exercises: 45 (auditory: 24, construction: 21)

Course objectives:

- Training for the construction and design of standard marine structures in accordance with the Building Act and the Conditions for membership in the Chamber of Civil Engineers,
- Training for continuous professional and scientific education.

Entry competences (prior knowledge, descriptive):

- Knowledge of hydraulics, river engineering, concrete structures and foundations.

Learning outcomes:

- Students have expanded knowledge of fluid mechanics, materials, geotechnics and ability to apply it,
- Students have competencies in the field of wave forecasts and skills in physical modelling of sea waves,
- Students have competencies for development projects in naval and river construction,
- Students have the knowledge for development projects in water management,
- Students have skills in laboratory and mathematical modelling of sea wave processes,
- Students have competencies for defining the quality of naval constructions,
- Students have competences for managing construction sites in naval constructions,
- Students have the knowledge to lead a team of various professions in development projects and in the design of naval structures.

Enrolment requirements (prerequisite):

- Teacher's signature for the courses: Hydraulics 1, Hydrology 2.

Course content (by course schedule):

- Lectures:
  1. SEA MOVEMENTS, SEA WAVES [HS], IDEAL WAVES, Introduction (definition, types, description) [HS], Types and basics of ideal wave theory, small amplitude wave theory [3]
  2. Finite amplitude wave theories (introduction: list of theories, slope, mean), *Blitz test 1: Small amplitude waves* [3]
  3. Wave deformations (shoaling, breaking, friction, refraction, diffraction, reflection, transmission) [3]

4. Statistical and spectral description of waves, forecasts of surface wind waves, generation of wind waves [3]
5. Features of the wind waves, features of swell waves [3]
6. Wind wave forecasts, data needed for wind wave forecasts, local short-term forecasts from wind data, regional short-term wind wave forecasts, local long-term [3]
7. Design waves, sea waves of long periods, wave loading of fixed marine structures [3]
8. Construction in the sea [3]
9. Technology of construction of embankment breakwater, technology of construction of vertical breakwaters, ships [3]
10. Ports [3]
11. Traffic systems, port machinery, port warehouses, ship berth, quays [3]
12. Classification and management of seaports in the Republic of Croatia, port shape, port structures [3]
13. Inner port naval structures, quay, other inner port facilities [3]
14. External coastal structures, types of breakwaters, breakwater routing, embankment type breakwater, wall type breakwater [3]
15. Urban coastal facilities, passenger and ferry ports, marinas [3]

- Exercises (auditory, construction):
  1. PR1 – small amplitude wave parameters in deep water, PR2 – small amplitude wave parameters in transitional area, PR3 - wave energy, seminar 1: theory of small amplitude waves [3]
  2. PR4 – wave refraction, seminar 2: finite amplitude wave theory, *test [HS]* [3]
  3. PR5 – plan of refraction*, test 1: waves of small and finite amplitude* [3]
  4. PR6 – single-sided diffraction, PR7 – double-sided diffraction, seminar 3: plan of refraction [3]
  5. PR8 – quay wall elevations, PR9 – reflection on an inclined slope [3]
  6. PR10 – wave transmission
  7. PR11 – wave hindcast, PR12 – wave forecast [3]
  8. Seminar 3:, wave forecast PR13, test 3: irregular waves of short and long periods, wave loads [3]
  9. Seminar 3:, wave forecast PR13 – seaport design, PR14 – bulk cargo [3]
  10. Seminar 4: Wave loads [3]
  11. PR15 – passengers, PR16 – containers [3]
  12. Seminar 5: quay wall stability calculation, test 4: construction, ships, port land boundaries [3]
  13. Seminar 5: quay wall stability calculation [6]
  14. Seminar 5: quay wall stability calculation, test 5: quay wall stability calculation [3]

Student Evaluation - Continuous assessment:

- Preparation and defence of assignments within the prescribed deadline
- 75% attendance at lectures

- 100% attendance at exercises
- Passing grade on midterm exams
- Passing grade on the oral exam to confirm the result on the midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and defence of assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Passing grade on the written exam
- Passing grade on the oral exam

Required reading:

1. Pršić, M., Carević, D.: Pomorske građevine – I, II i III dio: web lecture notes of the Faculty of Civil Engineering, 2019.

Additional reading:

1. Tadejević, Z.; Pršić, M.: *Pomorska hidraulika I - Idealni valovi i struje*. Zagreb: lecture notes of the Faculty of Civil Engineering, 1981.
2. Pršić, M.; Tadejević, Z.: *Riječni plovni putevi*. Zagreb: lecture notes of the Faculty of Civil Engineering, Zagreb, 1988.
3. *CEM – Coastal Engineering Manual*, US Army Corps of Engineering, Coastal Research Center, 2003-2008., http://140.194.76.129/publications/eng-manuals/
4. *Shore Protection Manual*, CERC – Coastal Engineering Research Center, US Government Printing Office, Washington DC 1977. i 1984.
5. *EAU 2004 – Empfehlungen des Arbeitsausschusses Ufereinfassungen*, Ernst & Sohn, Berlin, 2004.
6. *EAU 2004 – Recommandations of the Comitt for Waterfront Structures Harbours and Waterways*, Ernst & Sohn, Berlin, 2006. and e-version 2009.,
7. Tsinker, G. P.: *Handbook of Port Engineering*, John Willey & Sons, 2004, Hoboken, New Jersey, USA.
8. Tsinker, G. P.: *Handbook of Port and Harbour Engineering*, Chapman & Hall, 1997, New York, USA.
9. Thorsen, C. A.: *Port Designer's Handbook* – Recommandations and Guidelines, Thomas Telford, 2003, London, UK.
10. CUR*, C. A.: *Port Designer's Handbook* – Recommandations and Guidelines, Taylor & Francis, Lieden, NL; *Centre for Civil Engineering Research and Codes – Public Works Rotterdam – Port of Roterdam.
11. Gaytwaite, J. W.: *Design of Marine facilities for Berthing, Mooring, and Repair of Vessels Handbook of Port and Harbour Engineering*, 2nd Edition, ASCE Press, 2004, Reston, Virginia, USA.
12. CIRIA*, CUR**, CETMEF***: *The Rock Manual*, 2nd edition, London, 2007, *Construction Industry Research and Information Association, **Centre for Civil Engineering Research and Codes, ***Institute for Maritime and Inland Waterways, France.
13. Kuhn, R.: *Binnen-verkehtswasserbau*, Ernst & Sohn, Berlin 1985.
14. Partenscky, H. W.: *Binnenverkehtswasserbau – Schleusenanlagen*, Springer Verlag, Berlin, 1986.

15. *Technical standards and Commentaries for Port and Harbour Facilities in Japan*, The Overseas Coastal Area Development Institute of Japan, 2002.

DRAINAGE AND IRRIGATION 1

Credits (ECTS): 8

Hours (total per semester):

- Lectures: 45
- Exercises (design): 30

Course objectives:

- Getting to know the laws of the plant-soil-water relationship and the basics of designing, planning and managing hydromelioration systems,
- Development of analytical skills in the field of plant-soil-water relations, planning, designing and management of melioration systems, especially in designing systems for surface and underground drainage.

Entry competences (prior knowledge, descriptive):

- Basics of hydraulics and hydrology,
- Working knowledge of basic computer programs for spreadsheets, text creation and technical drawing.

Enrolment requirements (prerequisite):

- Teacher's signature for the courses: Hydraulics 1, Hydrology 2.

Learning outcomes:

- Acquisition of knowledge in hydrology, hydraulics, meliorative pedology, climatology, topography, engineering informatics, designing hydromelioration systems for drainage,
- Perform an analysis of the hydrological, pedological, topographical and climatological characteristics of the catchment areas – agricultural areas,
- Define the criteria and measures for choosing the optimal hydromelioration system of the agricultural area,
- Understand the basic parameters of the plant-soil-water relationship related to underground and surface drainage,
- Create a preliminary design of the hydromelioration system of surface and underground drainage,
- Use computer programs in hydrotechnical melioration projects

Course content (by course schedule):

- Lectures:
  1. The importance of hydrotechnical melioration in agriculture, EU common agricultural policy, buildings for basic melioration drainage in accordance with the Water Act, Water Management Plan [3]
  2. Data for creating plans and projects of hydromelioration facilities and systems. Dimensioning criteria [3]
  3. Conceptual solution of surface drainage – determination of channel layout in the drainage network, channel spacing of the 4th order, higher order channel routing [3]
  4. Calculation of runoff from agricultural land – determination of relevant precipitation, concentration time and drainage module [3]
  5. Dimensioning of the channel network – hydraulic calculation of flow in channels and optimization of channel geometry using DrainCAN and HEC-RAS software [3]

6. Structures on the canal network: floodgate, pipe culvert, plate culvert, culvert, siphon, plug, hydraulic drop structure, threshold, pumping station, crossings and bridges. General technical conditions and examples [3]
7. Hydraulic drop structures and floodgates: approach to dimensioning; channel connections; hydraulic jump; waterfalls; energy dissipators, examples of built structures [3]
8. Pumping stations: basic terms and definitions, selection of the optimal pump, dimensioning of the pumping basin, examples of constructed pumping stations. [3]
9. Maintenance and management of drainage systems [3]
10. Soil pedology, water constants, excess subsurface water, calculation of groundwater flow [3]
11. Stationary calculation of underground drainage, drainage through channels, pipe drainage, drainage wells, vertical, horizontal and radial inflow into drains, determination of drain spacing; Hooghoudt's approach; Ernst's approach [3]
12. Non-stationary calculation of underground drainage [3]
13. Drainage slope and interception drainage: calculation approach; solution examples [3]
14. Drainage and soil salinization: the influence of irrigation on drainage; salt balance in the root zone; salt washing; salinization due to capillary rise of water in the soil [3]
15. Drainage and irrigation as part of agricultural land management [3]

- Exercises (auditory and construction):
  1. Conceptual solution of the surface drainage system [4]
  2. Rainfall - calculation [4]
  3. Hydraulic calculation of flow [6]
  4. Calculation of hydraulic drop structures [4]
  5. Plans - profile grades and cross-sections [4]
  6. Calculation of the underground drainage system [4]
  7. Dimensioning of the pumping station [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of the program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Kos, Z.: *Hidrotehničke melioracije tla – odvodnjavanje*; Školska knjiga, Zagreb, 1989.
2. Group of authors, *Selected chapters* :
   - Knjiga 2, *Podloge za hidrotehničke melioracije*, 1984. (Tomić, F.)
   - Knjiga 3, *Osnovna mreža površinskog odvodnjavanja*, 1985. – projektiranje (Kos, Z.)
   - Knjiga 4, *Detaljna mreža podzemnog odvodnjavanja*, 1987. – projektiranje (Kos, Z.)
   - Knjiga 5, *Građenje sustava površinske i podzemne odvodnje*, 1989. (Marušić, J.)
   - Knjiga 6, *Održavanje sustava površinske i podzemne odvodnje*, 1991. (Marušić, J.); Društvo za odvodnjavanje i navodnjavanje Hrvatske, Zagreb.

Additional reading:

1. Group of authors, *Priručnik za hidrotehničke melioracije*, III. kolo;

- Knjiga 1, *Suvremeni pristup i metode planiranja i upravljanja hidromelioracijskim sustavima*, Rijeka 2003 (Ožanić, N.)
- Knjiga 2, *Elementi planiranja i upravljanja sustava za navodnjavanje*, Rijeka 2005. (Ožanić, N.), Građevinski fakultet Rijeka i HHD i HDON.

2. Group of authors, Selected chapters: *Priručnik za hidrotehničke melioracije – navodnjavanje*, II. kolo;
    - Knjiga 3, *Metode natapanja*, 1994. (Kos, Z.);
    - Knjiga 4, *Sustavi, građevine i oprema za natapanje*, 1995. (Kos, Z.);
    - Knjiga 5, *Planiranje, projektiranje i organizacija natapnih s ustava*, 1996. (Kos, Z.); Građevinski fakultet Rijeka i Hrvatsko društvo za odvodnju i navodnjavanje (HDON), Zagreb.

Elective courses

WATER SUPPLY AND SEWERAGE 1

Credits (ECTS): 4

Hours (total per semester):
- Lectures: 30
- Exercises (design): 15

Course objectives:
- Acquisition of theoretical knowledge about all aspects of managing urban water supply and sewerage systems,
- Acquisition of practical knowledge in hydraulic dimensioning of individual parts of water supply and sewerage systems as well as their design.

Entry competences (prior knowledge, descriptive):
- Knowledge of mathematical analysis,
- Understanding the basic regimes of water flow (flow under pressure, flow with a free water surface),
- Knowledge of the basics of fluid mechanics (momentum conservation equation, Bernoulli's equation for a real fluid, calculation of local and linear energy losses, pressure and energy line).

Enrolment requirements (prerequisite):
- Teacher's signature for the courses: Hydraulics 1, Hydrology 2.

Learning outcomes:
- Application of acquired knowledge for conceptual development of water supply and sewerage systems,
- Defining relevant parameters and hydraulic design of the water supply and sewage network,
- Dimensioning of the water reservoir,
- Defining the basic parameters for determining the capacity of pumping stations, calculating pump energy consumption, determining the system curve,
- Settling tank sizing.

Course content (by course schedule):
- Lectures:

1. Water supply - introduction, types of water supply systems [2]
2. Water consumption [2]
3. Springs, water intakes [2]
4. Water intakes, pumping stations [3]
5. Water conditioning [3]
6. Water reservoirs, water supply networks [2]
7. Water supply networks - design [2]
8. 1st midterm exam
9. Drainage - introduction, drainage systems [2]
10. Relevant amounts of wastewater [2]
11. Sewage networks [2]
12. Sewage networks - design [2]
13. Construction of sewage network [3]
14. Treatment of wastewater and discharges [3]
15. 2nd midterm exam

- Exercises (auditory):
  1. Determination of relevant quantities of water consumption [1]
  2. Dimensioning of water intake structures [1]
  3. Dimensioning of pumping stations [1]
  4. Dimensioning of facilities for water conditioning [1]
  5. Dimensioning of the water tank [1]
  6. Hydraulic calculation of the water supply network [2]
  7. Determination of relevant amounts of wastewater [1]
  8. Hydraulic calculation of the sewage network [2]
  9. Dimensioning of facilities on the sewage network [1]
  10. Determining the parameters for the sizing of wastewater treatment devices [1]
  11. Hydraulic calculation of settling tank [1]
  12. Additional calculation tasks and preparation for the midterm exam [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Two midterm exams during the semester

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Ž. Vuković, Halkijević, I.: Opskrba vodom i odvodnja 1, course materials, 2024

Additional reading:

1. Trifunović, N.: *Introduction to Urban Water Distribution*, Taylor & Francis Group, London, UK, 2008.

2. Brandt, M. J.; Johnson, K. M.; Elphinston, A. J.; Ratnayaka, D. D.: *Twort's Water Supply*, 7th edition, Elsevier, 2016.
3. Butler, D.; Digman, C. J.; Makropoulos, C.; Davies, J.W.: *Urban Drainage*, 4th edition, CRC Press, USA, 2018.

WATER PROTECTION

Credits (ECTS): 4

Hours (total per semester):

- Lectures: 30
- Exercises (design): 15

Course objectives:

- Acquiring theoretical knowledge about the ecological laws of water systems,
- Acquiring theoretical knowledge about the procedures and technologies of water protection against anthropogenic action,
- Acquiring practical knowledge about legal regulation of water management.

Learning outcomes:

- Recognize and explain basic ecological principles,
- Explain and apply the legal regulation of water management,
- Explain the basic technological procedures of wastewater treatment,
- Explain the basic sludge treatment procedures,
- Explain the methods of final discharge of treated wastewater.

Course content (by course schedule):

- Lectures:

1. Basic ecological principles: abiotic and biotic factors, living community, ecosystem of the living area [3]
2. Changes in water quality: sources of pollution, types of wastewater, self-purification capacity of water systems
3. Water quality models: empirical models, numerical models, QUALL, WASP [2]
4. Disturbances of aquatic ecosystems: eutrophication, impact load [2]
5. Water quality management: political and sociological approach, legal measures, spatial planning, economic and financial measures, scientific and technological measures, institutional measures, water protection plans and programs [2]
6. Wastewater treatment: general principles, mechanical treatment, physical chemical treatment [2]
7. Wastewater treatment: biological treatment, conventional process with activated sludge [2]
8. Wastewater treatment: biological treatment, extended aeration process, SBR [2]
9. Wastewater treatment: biological treatment, removal of nitrogen and phosphorus [2]
10. Wastewater treatment: sludge treatment [2]
11. Wastewater treatment: alternative treatment processes [4]
12. Wastewater treatment: alternative processes [2]
13. Natural wastewater treatment processes [2]
14. Mixing models in seas and lakes (VISUAL PLUMES, CORMIX) [2]
15. Control of non-point sources of pollution: phenomenon, sources, control

[2]

- Exercises (auditory):
  1. Analysis of wastewater according to certain parameters, relevant for water quality assessment and sizing of treatment plants [1]
  2. Equations of pollution transfer in watercourses [1]
  3. Mathematical modelling of water quality in watercourses (QUAL, WASP) [4]
  4. General equations of the process of wastewater treatment at WWTPs [1]
  5. Equations of kinetics of biological wastewater treatment [1]
  6. Dimensioning of reactors biological treatment facilities with activated sludge [1]
  7. Dimensioning of reactors biological treatment facilities with attached microorganisms
  8. Dimensioning of secondary clarifiers [1]
  9. Dimensioning of facilities for sludge treatment [1]
  10. Dimensioning of alternative wastewater treatment plants [1]
  11. Dimensioning of undersea outlets [1]
  12. Mathematical modelling of pollution transfer in the sea (VISUAL PLUMES, CORMIX) [1]
- Midterm exams:
  3. Includes chapters 1 to 7 of lectures and chapters 1 to 6 of exercises
  4. Includes chapters 8 to 14 of lectures and chapters 7 to 12 of exercises

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. Tedeschi, S.: *Zaštita voda,* HDGI, 1997.
2. Lectures*: PowerPoint presentations and texts by the course instructor (Faculty web page).*
3. A collection of solved problems is available on the web page of the Water Protection course.

Additional reading:

1. Metcalf & Eddy: *Wastewater Engineering,* McGraw Hill, 2003.
2. German Guidelines for the Dimensioning of Activated Sludge Plants (DWA-A 131)

APPLIED GEOLOGY

See Chapter **Specialisation in Geotechnics.**

ENVIRONMENTAL PROTECTION

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquiring theoretical knowledge about basic ecological terms and processes,
- Knowledge of anthropogenic impacts on the environment, primarily from the field of civil engineering,
- Acquisition of knowledge about environmental protection measures and procedures and legal regulations in the field of environmental protection and water management.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic terms in physics, biology, chemistry and civil engineering.

Learning outcomes:

- Understanding of basic ecological processes,
- Recognize and explain basic ecological principles,
- Explain the basic technological procedures of wastewater treatment,
- Understanding waste management,
- Understanding the concept of "sustainable development".

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Basics of ecology and environmental protection; basic terms [2]
  3. Environmental problems: air pollution (sources and consequences) [2]
  4. Environmental problems: water pollution [2]
  5. Environmental problems: soil pollution and nature pollution [2]
  6. Renewable and non-renewable energy sources and climate change [2]
  7. Legislation in the field of environmental protection: Environmental impact assessment - identification and classification of impacts [2]
  8. Sustainable development and civil engineering [2]
  9. The impact of cities, roads and water engineering facilities [2]
  10. 1st midterm exam
  11. Waste and waste management [2]
  12. Landfills [2]
  13. Waste water and the application of the combined approach methodology [2]
  14. Environmental protection measures and procedures [2]
  15. 2nd midterm exam

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- A minimum score of 55% on both midterm exams (average), with the condition of a minimum score of 30% on each midterm exam
- Extra credit for weekly quizzes and in-class activity

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- A minimum score of 55% on the exam

Required reading:

1. ENVIRONMENTAL PROTECTION, lectures, D. Nakić, 2026

Additional reading:

1. G. Tyler Miller Jr.: Living in the Environment: Principles, Connections, and Solutions, 15th Edition, Thomson Books, 2007.
2. Peter H. Raven, Linda R. Berg, David M. Hassenzahl: Environment, 7th Edition, Wiley, 2010.
3. Environmental Protection Act (OG 80/13, 153/13, 78/15, 12/18, 1118/18)
4. National Environmental Protection Strategy
5. Strategy of Sustainable Development of the Republic of Croatia
6. Waste Management Strategy of the Republic of Croatia
7. Regulation on the environmental impact assessment. (OG 61/14 i 03/17)
8. Water Area Management Plan
9. Combined Approach Methodology (Hrvatske vode, 2018)

STRUCTURES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (design: 18, construction: 12)

Course objectives:

- Acquisition of new theoretical knowledge about structural design,
- Acquisition of practical knowledge about structural design and calculations,
- Acquisition of practical knowledge about the design (proportioning) of structural elements.

Entry competences (prior knowledge, descriptive):

- Knowledge of materials and understanding of material resistance,
- Understanding the basics of geotechnics, hydrotechnics and concrete structures,
- Knowledge of the basics of calculation of different structural systems.

Learning outcomes:

- Understand the basic principles and problems of construction works' design,
- Analyse actions on structures,
- Calculate structural elements and their assemblies in construction works,
- Apply design principles in calculations of structural elements and their assemblies in construction works.

Course content (by course schedule):

- Lectures:
  1. Features of structural systems. Basics of design and calculation. [2]
  2. Lock structures [2]
  3. Drainage system constructions [2]
  4. Actions, combinations of loads, basics of seismic action and design [2]
  5. Concrete structures (ULS, SLS, durability design) [2]

6. Retaining structures [2]
7. Foundation engineering [2]
8. Structures of quays [2]
9. Structures in building construction. Basics of prestressed concrete. [2]
10. Structures in civil engineering works [2]
11. Water towers and tanks [2]
12. Floating structures [2]
13. Pontoon breakwaters [2]
14. Practical examples [4]

- Exercises:
  1. Getting to know the exercise program. Setting and elaboration of the Lock assignment
  2. Review and submission of the Lock assignment
  3. Setting and elaboration of the Shaft assignment
  4. Review and submission of the Shaft assignment
  5. Setting and elaboration of the Retaining wall assignment
  6. Review and submission of the Retaining wall assignment
  7. 1st midterm exam
  8. Setting and elaboration of the Sea wall assignment
  9. Review and submission of the Sea wall assignment
  10. Setting and elaboration of the Diaphragm wall assignment
  11. Review and submission of the Diaphragm wall assignment
  12. Setting and elaboration of the Pile assignment
  13. Review and submission of the Pile assignment
  14. 2nd midterm exam
  15. Retest

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- All program assignments (6) submitted within the prescribed deadline
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- All program assignments (6) submitted within the prescribed deadline
- Written exam

Required reading:

1. Lectures and exercises notes published on Merlin
2. Standards series HRN EN 199i ; i = 0, 1, 2, 7, 8.
3. Sorić, Z., Kišiček T.: *Betonske konstrukcije 1*, Građevinski fakultet, Zagreb, 2014.
4. Radić, J.: *Betonske konstrukcije – riješeni primjeri*, Zagreb, 2006.

DATA ANALYSIS FOR HYDROSCIENCES

Credits (ECTS): 6.0

Hours (total per semester):
- Lectures: 30
- Exercises (design): 30

Course objectives:
- Introduce students with methods and tools for analysing temporal and spatial data in hydrotechnics,,
- Train students for independent creation of research and/or projects using software environments for data management, calculation and graphic display.

Entry competences (prior knowledge, descriptive):
- Advanced use of basic computer tools (MS Excel),
- Knowledge of programming syntax and semantics,
- Knowledge of loops and branching: "for" loop, nested loops, "if" branching

Learning outcomes:
After passing the course, the student will be able to:
- Use the basics of the programming environment for data management, calculation and graphic display (Matlab / Octave, R, QGIS),
- Prepare and process raw time and/or spatial data for use in the calculation of functionality,
- Apply basic statistical analyses and models to the data and evaluate the model results,
- Distinguish basic methods for processing time data in the time and frequency domain,
- Apply a GIS tool for a basic overview of spatial data from hydrotechnics,
- Apply appropriate methods for spatial data analysis for the purpose of processing and use for design,
- Integrate spatial and temporal types of information within one system for the purpose of analysing the basis for hydrotechnical calculations,
- Make decisions based on the analysis of spatial and temporal data within the framework of interdisciplinary design activities.

Course content (by course schedule):
- Lectures:
  1. Data preparation and input using the Matlab / Octave software environment, R. [2]
  2. Application of descriptive statistics methods. [2]
  3. Application of inferential statistics methods. [2]
  4. Regression models. Data-based models. [2]
  5. Model validation. [2]
  6. Introduction to time series analysis. Spectral analysis and filtering. [2]
  7. Trend analysis. [2]
  8. 1st midterm exam
  9. Basics of GIS. Overview of coordinate systems and projections. Spatial data analysis. Storage of geospatial objects: points, polylines, polygons. [2]
  10. Digital relief model. Vector data model. [2]
  11. Layers in GIS. Using publicly available WMS layers in QGIS. [2]

12. Analysis of topographical characteristics. The triangulated irregular network (TIN) model. [2]
13. Analysis of topographical characteristics. Raster model. [2]
14. Application of GIS in hydrotechnics. Projects and research on examples. [2]
15. 2nd midterm exam

- Exercises:
  1. Creating variables and saving data in the Matlab software environment/Octave, R. [2]
  2. Calculation of basic statistical parameters for a set of hydrological data. [2]
  3. Determining the correlation between variables. [2]
  4. Creating a regression model. [2]
  5. Model validation. [2]
  6. Time series analysis and spectrum. [2]
  7. Trend analysis. [2]
  8. Presentation of the 1st part of the project [2]
  9. Project assignment in QGIS. [2]
  10. Entering data into the model [2]
  11. Creating a digital relief model from vector data [2]
  12. Adding data to DTM from WMS layers [2]
  13. Creation of the triangulated irregular network (TIN) model. [2]
  14. Creating a raster model. Data export [2]
  15. Presentation of the 2nd part of the project [2]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Exam (written) – a minimum score of 50%
- All design elements submitted within the prescribed deadline and accurately completed

Required reading:

1. Lectures on the course website. Course materials from the exercises.

Additional reading:

1. Šošić, I. (2004).Primijenjena statistika. Školska knjiga.
2. Husno H. (2000). Vjerovatnoća i statistika u hidrologiji.
3. Tutić, D., Vučetić, N., Lapaine, M. (2002): Uvod u GIS, Sveučilište u Zagrebu Geodetski fakultet
4. Matijević, M., Morić Špánić, A.: Priručnik za rad u QGIS aplikaciji.
5. Chatfield, C. (2004). The analysis of time series: an introduction, CRC press.
6. Venables, W. N., & Smith, D. M. (2004). An Introduction to R: Notes on R, A Programming Environment for Data Analysis and Graphics, v. 2.0. 1. Network Theory, Bristol, UK. - Croatian translation (http://cran.salud.gob.sv/doc/contrib/Kasum+Legovic-UvodUr.pdf).
7. Long, P. J. G. (2005). Introduction to Octave. University of Cambridge.
8. Materials from course:" Applied Time Series Analysis (GEOS 585A)" Meko, D., University of Arizona, USA.
9. Petković, T. (2005). Kratke upute za korištenje MATLAB-a. Zavod za elektroničke sustave i obradbu informacija, Fakultet elektrotehnike i računarstva, Sveučilište u Zagreb.
10. Helsel, D. R., Hirsch, R. M. (1992). Statistical methods in water resources. Amsterdam, Elsevier Science.

11. de Smith, M., Longley, P., Goodchild, M.: Geospatial Analysis - A comprehensive guide, A free web-based GIS resource.
12. Pintar, D., Vranić, M. (2020): Osnove programiranja u R-u (S760). Sveučilište u Zagrebu, Sveučilišni računski centar – Skripta za polaznike tečaja S760.

2nd year, 3rd semester

Mandatory courses

WATER POWER USE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 10, design: 20)

Course objectives:

- Acquisition of practical and theoretical knowledge in the field of water power use and the basics of designing hydropower plants and their elements,
- Acquisition and application of practical knowledge in designing hydraulic structures.

Entry competences (prior knowledge, descriptive):

- Knowledge and understanding of hydrological processes in nature,
- Knowledge of basic hydraulic calculations of elements of hydraulic structures,
- Knowing and distinguishing the application of hydraulic structures,
- Knowledge and understanding of the basic properties of soil and rocks,
- Knowledge of hydraulic calculations of water surfaces.

Enrolment requirements (prerequisite):

- Course exams passed: Hydraulics 1, Hydrology 2.

Learning outcomes:

- Explain basic knowledge about the available energy and water power and the need to use it, explain the basic principles of using water power,
- Distinguish the basic types of hydropower plants and explain the basic principles of their operation,
- Create an energy analysis of water flows,
- Create solutions for the use of water power for the production of electricity and assess its impact on the environment,
- Create a hydraulic calculation for the needs of the hydropower plant construction project

Course content (by course schedule):

- Lectures:
  1. Renewable energy sources. Hydropower [2]
  2. Energy and power [2]
  3. Basics of using water power [2]
  4. Types of hydropower plants [2]
  5. Storage reservoirs [4]
  6. Dams [2]
  7. Hydropower plant construction technology [2]
  8. Input devices [2]
  9. Conductors [2]

10. Non-stationary phenomena [2]
11. Turbines [2]
12. Engine room [2]
13. Fish ladders [2]
14. Hydropower plants and their impacts on the environment [2]

- Exercises:
  1. Annual energy production of a diversion-type electric power station [4]
  2. Annual energy production of a flow hydroelectric power plant [4]
  3. Annual energy production of a flow hydroelectric power plant and a diversion-type electric power station [2]
  4. Placement of the dam in the area [6]
  5. Evacuation of water during construction [6]
  6. Hydraulic calculation [6]
  7. Defence

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures, 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam – obligatory for all students

Required reading:

1. Lectures on the course website.
2. Hidrotehničke građevine, web lecture notes of the undergraduate study.
3.
4. Stojić, P.: *Hidroenergetika*, Split, Građevinski fakultet Sveučilišta u Splitu, 1995.
5. Đorđević, B.: *Korišćenje vodnih snaga*.
6. Đorđević, B.: *Korišćenje vodnih snaga – Objekti hidroelektrana*, Naučna knjiga i GF Beograd, 1989.
7. Žugaj, M.: *Posebne analize u hidrotehnici*, Zagreb, Građevinski institut, 1981.

Additional reading:

1. Mosony, E.: *Water Power Development*, Vol. I-II, Budapest, Akademiai Kiado, 1987.
2. *Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments*, Vol 1-3; New York, American Society of Civil Engineers, 1989.

WATER SUPPLY AND SEVERAGE 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (design): 30

Course objectives:

- Management and maintenance of urban water supply and sewerage systems,

- Acquisition of theoretical knowledge about the procedures and technologies of intake, transport and consumption of drinking water, discharge, transport and discharge of wastewater,
- Acquisition of practical knowledge about the construction and functionality of urban water supply and sewerage structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of water supply and drainage.

Learning outcomes:

- Explain and apply the procedures for assessing input values for the design of public water supply and sewerage systems,
- Apply procedures for dimensioning buildings and devices of public water supply and sewerage,
- Apply water supply and sewerage system maintenance procedures,
- Apply criteria for selecting materials and devices for public water supply and sewerage,
- Explain and apply modern tools for simulating hydrological and hydraulic models of water supply and sewerage systems.

Course content (by course schedule):

- Lectures:
  1. Design documentation of the public water supply and sewerage system [2]
  2. Computer modelling of water supply and sewerage systems [2]
  3. Analysis of water needs and prices of water services [2]
  4. Analysis of water losses in water supply systems [2]
  5. Pump operation regulation [2]
  6. Pumping systems with joint operation of several pumps [2]
  7. Sewage lifting stations, surge tanks, small water supply systems [2]
  8. Sewage pumping stations [2]
  9. Calculation of the pollution load from catchment areas and sanitary protection zones [2]
  10. Storm sewer structures 1 - separators and overflows [2]
  11. Storm sewer structures 2 - retention and siphons [2]
  12. Alternative rainwater sewerage systems [2]
  13. Alternative sanitary sewerage systems [2]
  14. Drains, maintenance of water supply and sewerage systems, trenchless construction methods, reconstruction and rehabilitation of pipelines. [2]
  15. Construction of public water supply and sewerage infrastructure - problems in practice [2]
- Exercises:
  1. Analysis and preparation of design data, defining the concept of technical solutions for water supply and sewerage systems, assigning program assignments [2].
  2. Analysis of the water needs of the program assignment. Practical examples of needs analysis [2].
  3. Computer modelling of water supply systems – defining the geometry of facilities[2].
  4. Definition and calculation of the relevant design calculation quantities of the water supply and sewerage system[2].
  5. Computer modelling of water supply systems – defining hydraulic loads. Practical examples of system analysis according to the IWA methodology [2].

6. Hydraulic calculation and computer dimensioning of water supply system facilities. Analytical functional dimensioning of water supply facilities[2]. .
7. Analysis of drinking water quality and electricity consumption during the operation of pumping stations[2].
8. Computer modelling of the sewerage system – defining the geometry of the objects. Practical examples of analysis of pumping systems[2].
9. Computer modelling of the system sewerage – definition of hydraulic loads
10. Hydraulic calculation and computer dimensioning of sewerage system facilities. Analytical functional dimensioning of drainage facilities[2].
11. Analysis and improvement of the operational characteristics of the water supply and sewerage system within the framework of the program assignment[2].
12. Creation of location plans of water supply and sewerage systems [2].
13. Hydraulic dimensioning of facilities of alternative drainage systems[2].
14. Content of project documentation of different levels and creation of textual parts of the program assignment[2].
15. Corrections and submission of the program assignment[2].

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Two midterm exams during the semester
- Preparation of program assignments during the semester
- Seminar paper with presentation

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments during the semester
- Written exam
- Oral exam
- Seminar paper with presentation

Required reading:

1. Lectures*: PowerPoint presentations and texts by the course instructor (Faculty web page).*

Additional reading:

1. D. Vouk, I. Halkijević: Lectures, exercises, course repository, 2024.
2. Larry W. Mays: Urban Water Supply Handbook
3. D. Ratnayaka, M. J. Brandt, K. M. Johnson, A. J. Elphinston: Twort's Water Supply (7th Edition)
4. J. Thornton, R. Sturm, G. Kunkel: Water Loss Control (2nd Edition)
5. N. Trifunovic: Introduction to Urban Water Distribution
6. D. Butler, J. Davies: Urban Drainage (Third Edition)
7. Water Environment Federation, American Society of Civil Engineers, Environmental and Water Resources Institute (U.S.): Design of Urban Stormwater Controls (2nd Edition)
8. J. Margeta: Kanalizacija naselja: odvodnja i zbrinjavanje otpadnih i oborinskih voda

Elective courses

WATER AND WASTEWATER TREATMENT

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (design): 30

Course objectives:

- Acquisition of theoretical and practical knowledge about municipal wastewater treatment technologies,
- Acquisition of theoretical and practical knowledge about drinking water treatment technologies,
- Acquisition of practical knowledge about relevant origins related to wastewater treatment technologies (legal regulation, ecological, economic, sociological aspects).

Entry competences (prior knowledge, descriptive):

- Prior knowledge about ecological factors of aquatic habitats,
- Prior knowledge of basic legal solutions in water management,
- Prior knowledge of the basics of microbiology of wastewater treatment procedures.

Learning outcomes:

- Explain the basic biochemical processes in wastewater treatment procedures,
- Explain and apply the procedures for dimensioning objects and mechanical equipment at water and wastewater treatment plants,
- Apply municipal wastewater treatment technologies,
- Apply drinking water treatment technologies,
- Apply basic sludge treatment procedures.

Course content (by course schedule):

- Lectures:
  1. The purpose of treatment, legal basis [2]
  2. Hydraulic and pollution load, selection of relevant input quantities for dimensioning [2]
  3. Microbiology of wastewater treatment [2]
  4. Mechanical pretreatment [2]
  5. Biological treatment, suspended microbial cultures [6]
  6. Biological treatment, attached microbial cultures [2]
  7. Alternative treatment technologies [2]
  8. Membrane processes [2]
  9. Constructed wetlands [2]
  10. Treatment of drinking water, underlying assumptions [2]
  11. Sedimentation, filtration [2]
  12. Removal of metals, paint, other chemical compounds [2]
  13. Disposal of sludge from wastewater treatment plants [2]
- Exercises (auditory):
  1. Processing of input data according to DWA worksheets [2]
  2. Dimensioning of each stage of mechanical pretreatment [2]

3. Design of biological reactors [2]
4. Dimensioning of the system with suspended microbial cultures [4]
5. Dimensioning of the system with attached microbial cultures [2]
6. Dimensioning of various modifications of sludge procedures [2]
7. Dimensioning of constructed wetlands [2]
8. Selection and dimensioning of alternative treatment technologies [2]
9. Dimensioning of the MBR system [2]
10. Disposition of elements and unit operations in space [2]
11. Dimensioning of sludge treatment procedures [2]
12. Dimensioning of drinking water treatment procedures [4]
13. Pilot plant design [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Two midterm exams during the semester
- Written exam

Required reading:

1. Lectures*: PowerPoint presentations and texts by the course instructor (Faculty web page).*

Additional reading:

1. Metcalf & Eddy: *Wastewater engineering, Treatment and reuse*, McGraw-Hill, 2003.
2. IWA publishing: Biological wastewater treatment - Principles, Modelling and Design
3. DWA-A 131 worksheet
4. DWA-M 210 worksheet

ALTERNATIVE WASTEWATER COLLECTION AND TREATMENT SYSTEMS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Understanding work principles of alternative wastewater collection and treatment systems
- Differentiation and correct choice of systems depending on local conditions
- Designing and dimensioning of individual systems

- Recognizing the advantages and disadvantages of individual solutions
- Identifying typical design, construction and maintenance errors
- Applying multi-criteria decision making in choosing the optimal solution

Entry competences (prior knowledge, descriptive):

Enrolment requirements (prerequisite):

- Obtained signature for the courses Water Supply and Sewerage 1 and 2

Learning outcomes:

- Explain the basic principles of alternative wastewater collection and treatment systems.
- Explain the basic principles of individual and zoned treatment systems (infiltration fields, sand filters, small devices, activated sludge, SBR, MBBR, MBR, lagoons, trickling filters, constructed wetlands, rotating biological contactors).
- Dimension alternative wastewater collection and treatment systems.
- Identify and avoid typical errors in designing and construction of alternative wastewater collection and treatment systems.
- Apply multi-criteria decision-making methods when choosing the optimal solution.

Course content (by course schedule):

- Lectures:

1. Introduction to alternative systems
2. Basics of designing sewer systems
3. Vacuum sewer system
4. Pressure sewer system
5. Small diameter gravity sewer
6. Comparison of sewer systems
7. Individual treatment systems
8. Small treatment devices (biological processes)
9. Dimensioning of individual systems
10. Zoned treatment systems
11. Biological systems
12. Natural treatment systems
13. Advanced systems (activated sludge, SBR, MBBR, MBR)
14. Construction, maintenance, and practical issues
15. Comparison of sewer systems

- Exercises:

1.

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a design
- Oral exam

Required reading:

1. Internal lecture notes

2. Malus, D., Vouk, D. (2012). Priručnik za učinkovitu primjenu biljnih uređaja za pročišćavanje sanitarnih otpadnih voda, Sveučilište u Zagrebu Građevinski fakultet

Additional reading:

1. Wastewater Engineering – Treatment and Reuse, Metcalf &Eddy, 2003.
2. DWA A-116: 2005 COR 2006, published 2013. SPECIAL SEWERAGE SYSTEMS - PART 1: Vacuum sewerage systems outside buildings
3. DWA A-116: 2005 COR 2006, published 2013. SPECIAL SEWERAGE SYSTEMS - PART 2: Pressure Sewerage Systems Outside Buildings
4. Regulations:
   - Water Act (OG 66/19, 84/21, 47/23)
   - The River Basin Management Plan up to 2027
   - Ordinance on wastewater emission limit values (OG 26/20)
   - Regulation on water quality standard (OG 96/19, 20/23 i 50/23-amended)

FLOOD PROTECTION

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (design): 30

Course objectives:

- Convey knowledge about flood protection issues and the risks of their occurrence,
- Introduce students to the mechanisms of global and local instability of watercourses and mathematical tools for their description,
- Convey knowledge about dimensioning of structures on flood protection systems

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra,
- Knowledge of the basics of fluid dynamics (equation of conservation of momentum, general law of real fluid flow (Saint-Venant and Navier-Stokes equation), equation of conservation of kinetic energy, Bernoulli equation for real fluid, flow resistance, calculation of local and linear energy losses, geodesic, pressure and energy line, speed, pressure and flow measurement),
- Knowledge of descriptive geometry, drawing in 3D space, intersection of lines with a digital elevation model,
- Computer work: basics of drawing using CAD software, advanced operations on raster and vector type data,
- Knowledge of working with the HEC-RAS software.

Learning outcomes:

- Define flood risk maps on the terrain model and estimate the water damage from the flood and the approximate number of the population at risk,
- Define the elements of the flood protection system,
- Dimensioning of structures on the flood protection system and their functional relations,

- Assessment of the erosive effect of the flow on submerged elements of structures over watercourses,
- Distinguish between individual approaches used in empirical assessments of the erosive capacity of flow,
- Assess the extent of flow action due to the construction of structures in different aquatic environments.

Course content (by course schedule):

- Lectures:
  1. Introduction, watercourses as an element of the water management system [2]
  2. Two-dimensional hydrodynamic numerical models for water flow modelling [2]
  3. Types of floods and examples of typical damages [2]
  4. Tasks during the implementation of the EU Directive on flood risk assessment and management [2]
  5. FEH (Flood Estimation Handbook) approach for flood hazard calculation [2]
  6. Creation of flood risk maps in Croatia [2]
  7. Damage assessment and creation of flood risk maps [2]
  8. Passive flood protection approach: Dimensioning of embankments [2]
  9. Calculation of percolation through the embankment and drainage system [2]
  10. Unreliability in the calculation of relevant water levels [2]
  11. Mobile systems for passive flood protection [2]
  12. The active flood protection approach: the impact of retention on the water regime [2]
  13. The active flood protection approach: the impact of reservoirs on the water regime [2]
  14. The active flood protection approach: the influence of flood relief channels on the water regime [2]
  15. The appearance of ice on watercourses [2]
- Exercises (auditory):
  1. Creation of a floodplain terrain model [4]
  2. Flow calculation using a 2D numerical model [2]
  3. Creation of flood hazard maps [4]
  4. Creation of flood risk maps [4]
  5. Calculation of the functionality of the embankment [6]
  6. Dimensioning of retention/accumulation/ flood relief channel and intake structure [6]
  7. Dimensioning of filter drainage at embankments [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper
- Oral exam

Required reading:

1. Chang, H. H: *Fluvial Processes in River Engineering*, Krieger publishing company, 1998.
2. Jansen, P. Ph. et al: *Principes of River Engineering – The non-tidal alluvial river*, Pitman Publishing Limited, London, 1979.
3. Materials on the course website.

Additional reading:

1. *Water Resources Project Planning*, UN Office of Technical Cooperation: Water Resources Series No. 41, NY, 1972.;
2. Hemphil, R.; Bramley, M. E.: *Protection of river and canal banks*, CIRIA and Butterworths, London, UK, 1989.

NATURE-BASED RIVER RESTORATION

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises: 30

Course objectives:
- Acquisition of theoretical knowledge on ecological river revitalisation as a key element of ecosystem restoration. Acquire practical knowledge about riverbed design utilising NbS methods – nature-based solutions.

Entry competences (prior knowledge, descriptive):

Enrolment requirements (prerequisite):
- Teacher's signature for the courses: River Training and Drainage and Irrigation 1

Learning outcomes:
- Define causes of a river's ecological state degradation
- Create a numerical flow model of an existing state prior to the river's revitalisation
- Dimension NbS structures in a river with nature-based solutions
- Describe the advantages and disadvantages of NbS in rivers compared to conventional river regulation methods

Course content (by course schedule):
- Lectures:
  1. River habitat loss, causes of river degradation and the importance of ecological river revitalisation (4 hours)
  2. NbS methods: vegetative riverbed and bank stabilization (4 hours)
  3. Hydraulic flow conditions in the area of flexible vegetation: flood and ecological aspect (4 hours)
  4. Target speeds in the revitalized river: flood and ecological aspect (4 hours)
  5. Comparison of NbS functionality and conventional methods (4 hours)
  6. Monitoring and assessment of river restoration projects (4 hours)
  7. Steps and stakeholders in the implementation of river restoration projects (6 hours)
- Exercises:

Student Evaluation - Continuous assessment:
- 75% attendance at lectures
- 100% attendance at exercises
- Design preparation
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:
- 75% attendance at lectures
- 100% attendance at exercises

- Design preparation
- Oral exam

Required reading:

1. Vita Projekt, (2022): Smjernice za tehničko projektiranje i procjenu socioekonomske izvedivosti mjera zelene infrastrukture u smanjenju rizika od poplava, Hrvatske vode, 705.
2. Schiff, R., MacBroom, J.G. & Armstrong Bonin, J. (2007): Guidelines for Naturalized River Channel Design and Bank Stabilization. NHDES-R-WD-06-37. New Hampshire Department of Environmental Services and the New Hampshire Department of Transportation, 280.
3. Doll, B.A., Grabow, G.L., Hall, K.R., Halley, J., Harman, W.A., Jennings, G.D., Wise, D.E. (2003): Stream Restoration: A Natural Channel Design Handbook, North Carolina Stream Restoration Institute, 128.
4. NRCS 654: (2007) Stream restoration design, U.S. Department of Agriculture, 660.

HYDRAULICS 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 4, laboratory: 12, construction: 14)

Course objectives:

- Teach students how to collect data both from measurements in nature and from measurements in the laboratory,
- They will master the basics of modelling and will make their own model and carry out appropriate measurements and process the results.

Entry competences (prior knowledge, descriptive):

- Good knowledge of fluid mechanics and hydraulics.

Enrolment requirements (prerequisite):

- Course exam passed: Hydraulics 1.

Learning outcomes:

- Learning how to collect measurement data in natural and man-made water systems.
- Learning how to collect measurements in a laboratory setting
- Learning how to model processes in hydrotechnical systems
- Gaining skills about methods of processing databases of collected data,

Course content (by course schedule):

- Lectures:
  1. Measurements in a laboratory :Physical models, fluid flow research methods, a brief history of hydraulic modelling, basics of physical modelling and similarity conditions, examples of physical modelling, advantages and disadvantages of a physical model [2]

2. Laboratory equipment and measurement systems, measurement planning, experiment optimization [2]
3. Measurements in nature: organization and measurement methods [2]
4. Measuring technique: water level measurement, velocity measurement, flow measurement [2]
5. Measuring technique: measurement of pressure and forces, measurement of other parameters (temperature, substance concentration...) [2]
6. Presentation of the concept of making physical [2]
7. Collection and processing of measured data sensors and [2]
8. Collection and processing of measured data, signal processing, multiplexers, analog-to-digital converter [2]
9. Collection and processing of measured data - measurement errors, display of results [2]
10. Presentation of the performed modelling [2]
11. Consultations about the model [4]
12. Analysis of the obtained results - comparison with previously conducted research [2]
13. Exchange of experience gained through modelling [2]
14. Final exam - submission and presentation of modelling results [2]

- Exercises:
  1. Introduction about the creation of the model, selection of the problem to be modelled, description of the available measurement technique [2]
  2. Selection of measurement technique, selection of scale model, concept of scale, experiment plan. [2]
  3. Model making, installation [2]
  4. Conducting measurements [4]
  5. Processing of measurement results [2]
  6. Measurement error analysis (if necessary, repeating failed measurements - making the necessary modifications to the model) [2]
  7. Conducting measurements [4]
  8. Processing of measurement results and proposing model modifications [2]
  9. Conducting measurements [2]
  10. Processing of measurement results [2]
  11. Conducting final measurements [2]
  12. Preparation of the final report [2]
  13. Final - midterm exam - presentation [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Gjetvaj, G.: *Hidraulika 2* (lecture notes for internal use).
2. Kobus, H.: *Hydraulic Modeling*, Verlag Paul Parey, Hamburg, 1980.
3. Novak, P.; Čabelka, J.: *Models in Hydraulic Engineering*, Pitman,1981.

Additional reading:

1. Chow, V. T.: *Open Channel Hydraulics*, Mc Graw-Hill Kogakusha, 1986.
2. Roy, D. N.: *Applied Fluid Mechanics*, Ellis Horwood limited, New York, 1988.
3. Tavaularis, S.: *Measurements in fluid mechanics*, Cambridge University press, 2005.
4. Bos, M. G.: *Discharge measurement structures*, ILRI publication 20, 1989.

MODELLING IN HYDRAULIC ENGINEERING

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (laboratory): 30

Course objectives:

- Acquisition of practical knowledge about physical and numerical modelling of flow in open watercourses and systems under pressure and the transport of substances,
- Gaining insight into the possibilities of applying modern numerical models.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus,
- Knowledge of the general conservation law for field and the dynamics of fluid movement of a material point,
- Understanding the concepts of initial and boundary conditions.

Learning outcomes:

- Understanding the concept of a model,
- Recognizing the advantages and disadvantages of physical and numerical modelling and adopted assumptions and imperfections of each of them,
- Recognizing the appropriate description of boundary and initial conditions,
- Noticing the dimensionality of the problem and the possibility of applying appropriate simplifications,
- Recognition of problems in the numerical discretization of partial differential equations,
- Application of the results of the numerical model in the calculations of pressures and forces on the structure,
- Gaining insight into recent modelling techniques and possibilities of modern free and commercial models,
- Acquiring knowledge about the possibilities of hybrid modelling.

Course content (by course schedule):

- Lectures:
  1. Concept of models and fluid motion modelling. Physical models (laws of similarity, limitations and advantages, types of models). Numerical models (numerical solution

methods, limitations and advantages). Hybrid models. Significance in design, construction and use. [2]

2. Concept of models and fluid motion modelling. Defining the dimensionality of the problem for the implementation of model analyses. Foundations for establishing a physical and/or numerical model. [2]
3. Flow and transport in a continuous aquatic environment. Fluid flow and heat transfer equations. (law of conservation of mass, momentum and energy in three dimensions, equations of state). [2]
4. Flow and transport in a continuous aquatic environment. Navier-Stokes equation for Newtonian fluid (conservative form of fluid flow equations). [2]
5. Flow and transport in a continuous aquatic environment. Differential and integral form of the general transfer equation. Classification by physical characteristics. [2]
6. Turbulence models. Reynolds averaging of the Navier-Stokes equations for incompressible fluids. Calculation of turbulent flows, "RANS mixing length" turbulence model, "RANS k-" turbulence model). [2]
7. Flow and transport in a continuous aquatic environment. Model of three-dimensional flow in an open watercourse. A model of two-dimensional flow in an open watercourse. Heat exchange with atmosphere for 2D and 3D model. [2]
8. Flow and transport in rock with intergranular porosity. Basic laws and process equations (mass conservation law, transport components, generalization of Fick's law, diffusion, dispersion, transport equation). [2]
9. Flow and transport in rock with intergranular porosity. Reactive processes (influence of dying and decomposition, exchange of substances between solid and liquid phases, retardation). [2]
10. Modelling of processes in the ecosystem Population model. Michaelis–Menten kinetics. Ecosystem model with two members (predator – prey), with three members (npz) and with four members (npzd). Link to hydrodynamic model of convective dispersion. [2]
11. Modelling of wave generation. Mechanism of wind wave generation. (theories of wind energy transfer to waves - model implementation). [2]
12. Modelling of wave generation. Non-linear interaction of waves (spectral dissipation in the deep-water area, dissipation due to wave breaking). Non-linear interaction in the shallow water area (dissipation at the bottom). [2]
13. Modelling of pressurized systems. [2]
14. Examples of the application of numerical modelling for the purpose of solving problems in hydraulic engineering. [2]
15. Examples of comparison of numerical and physical modelling results in hydraulic engineering (model-nature correlation). [2]

- Exercises (auditory, construction):
  1. Model of flow in an open watercourse. Establishing a model of stationary and non-uniform flow due to a change in the geometry of the flow bed. [2]
  2. Model of flow in an open watercourse. Case analysis of sudden widening and narrowing of the riverbed (definition of boundary and initial conditions). [2]
  3. Model of flow in an open watercourse. Case analysis of sudden deepening and elevation of the bed (definition of boundary and initial conditions). [2]
  4. Model of flow in an open watercourse Comparison with the calculation based on the theoretical elaboration of the problem. [2]

5. A model of flow in an open watercourse forced by a wind field with variation of wind speeds. [2]
6. Model of flow in an open watercourse. Case analysis of variation of horizontal dimensions. [2]
7. Model of flow in an open watercourse. Case analysis of variation of vertical dimensions. [2]
8. Model of flow in an open watercourse. Case analysis of density variation in the vertical profile. [2]
9. Model of flow through intergranular porosity rock. Establishment of seepage model (2D in vertical plane), definition of boundary and initial conditions. [2]
10. Model of flow through intergranular porosity rock. Analysis of the influence of the change in the width of the barrier profile, the depth of immersion of the dam and the thickness of the aquifer on the velocities and total seepage flows. [2]
11. Model of flow through intergranular porosity rock. Analysis of the influence of isotropy and anisotropy. [2]
12. Model of wave generation. Establishment of the model (generation of design network, definition of boundary and initial conditions). [2]
13. Model of wave generation. Sensitivity analysis of model constants and adoption of model parametrization based on measurement results at the wave recording station. [2]
14. Model of wave generation. Comparison with calculation based on semi-empirical approach. [2]
15. Ecosystem dynamics model. Establishment of a numerical model presented with two members (prey-predator). [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Available on the course website: lecture notes, lectures by weeks, examples of established models.
2. Novak, P.: *Hydraulic modelling - an introduction: principles, methods and applications*, Spoon Press, London, 2010.

2nd year, 4th semester

Mandatory courses

HYDROSYSTEMS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 45
- Exercises: 15 (design)

Course objectives:

- Acquisition of practical and theoretical knowledge in the process of solving complex hydrosystems,
- Acquisition of basic knowledge about water management.

Entry competences (prior knowledge, descriptive):

- Knowledge and understanding of hydrological processes in nature,
- Knowing and distinguishing the application of hydraulic structures,
- Knowledge of the technical characteristics and way of functioning of hydraulic structures.

Learning outcomes:

- Explain basic concepts in the field of water management,
- Know the basic legal regulations,
- Analyse the elements in the technology of solving complex problems, recognize the necessary steps and design the problem-solving procedure,
- Present hydrosystems to a wider audience,
- Compare hydrosystems based on basic financial indicators,
- Participate in teamwork.

Course content (by course schedule):

- Lectures:
  1. Water and water resources. Basic concepts. [3]
  2. Legal regulations [6]
  3. Problem solving technology [6]
  4. Objectives, criteria and measures [3]
  5. Changes in the environment due to the construction of hydrosystems [3]
  6. Assessment of benefits and costs. [6]
  7. Decision making procedures [3]
  8. Management of multifunctional hydrosystems [3]
  9. Integrated water management [9]
  10. Examples of hydrosystems [3]
- Exercises:
  1. Creation of a project assignment according to the selected topic from the content of the lectures

Student Evaluation - Continuous assessment:

- Midterm exams
- Design assignment

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Oral exam

Required reading:

1. *Water Resources Systems Planning and Management. An Introduction to Methods, Models and Applications*, Daniel P. Loucks and Eelco van Beek, Studies and Reports in Hydrology, UNESCO PUBLISHING, 2005.
2. Legal regulations.
3. Vodič za analizu troškova i koristi investicijskih projekata, FOIP biblioteka, 2007.

Additional reading:

1. Linsley, P. K.; Franzini, J. B. et all: *Water-Resources Engineering*, New York, McGraw Hill Book Com. 1991.
2. Đorđević, B.: *Cybernetics in Water Resources Management*, Water Resources Publication, 1993.
3. Thuesen, G. J.; Fabrycky, W. J.: *Engineering Economy*, Prentice-Hall Int. Inc. 1989.
4. James, L. D.; Lee, R. R.: *Economics of Water Resources Planning*, Mc Graw-Hill Inc, 1971.

Elective courses

URBAN HYDROLOGY

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (16 auditory + 14 design)

Course objectives:

- Acquisition of theoretical and practical knowledge about the impact of urbanization on hydrological processes, processing of precipitation data and methods of determining runoff using an empirical approach and mathematical modelling.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics from the courses Hydrology and Hydrology 2, which include: water and water movement in nature, processes in the atmosphere, hydrometry, hydrometric data processing, application of probability and statistics in hydrology, and parametric methods for determining processes,
- Knowledge of the basics from the course Hydrology 2, which include knowledge and understanding of: hydrological processes, analysis of precipitation data, runoff processes in the basin – methods for determining direct runoff, and mathematical modelling in hydrology.

Learning outcomes:

- Define and explain: hydrological processes in urban watersheds, methods for processing precipitation data and methods for calculating runoff in urban basins,
- Create IDF curves and project rain based on precipitation data and the corresponding project hydrogram
- Differentiate and choose the appropriate method of calculating the design rain and runoff hydrograph,
- Apply the acquired theoretical knowledge of urban hydrology in the construction industry; in designing buildings, students are able to solve simpler problems and tasks from urban hydrology.

Course content (by course schedule):

- Lectures:
  1. Hydrological processes in urban basins, hydrologic balance, hydrometeorological network of stations, hydrological information system, impact of urbanization on hydrological processes. [2]
  2. Precipitation, interception, infiltration, retention of water in depressions, surface flow, flow and retention in collecting gutters, gutters and canals. [2]
  3. Hydrological and hydraulic characteristics of urban systems, characteristics of elements of rainwater and mixed sewage systems, open stormwater drainage systems. [2]
  4. Flat and sloping roofs, asphalted surfaces, parks and unasphalted surfaces, gutters and side ditches, catch basins and manholes, water culverts under roads and other structures, sewage network, rain overflows, retention and expansion basins, inlet and outlet structures. [2]
  5. Calculation of runoff from heavy rains, empirical formulas and rational method, time of concentration of runoff and lag time of maximum runoff for rains shorter than the time of concentration. [2]
  6. Effective precipitation and runoff coefficient, precipitation-runoff correlation, snowmelt runoff. [2]
  7. 1st midterm exam
  8. Creation and meaning of IDF curves of rain in urban areas, formation of relevant sets of rain gauge data for creation of IDF curves. [2]
  9. Los Angeles method, Chicago method, SCS Method (Soil Conservation Service Method), other methods. [2]
  10. Determining the relevant rain for designing the sewage system, flooding in urban areas, economic aspects of determining the design rain. [2]
  11. Determination of the design hydrograph based on runoff modelling and the implementation of an economic analysis of the relationship between the costs of the drainage system and damage from urban floods due to heavy rains. [2]
  12. Calculation of runoff from individual buildings, industrial and office buildings, residential blocks and city roads. [2]
  13. Contemporary principles of urban drainage and water quality in urban basins. Mitigation of flood waves and the role of urban retention. [2]
  14. Collection and use of rainwater, discharge into the underground, management of the urban drainage system based on the application of mathematical runoff modelling. [2]
  15. 2nd midterm exam
- Exercises (auditory and construction):

1. Formation of relevant sets of rain gauge data for the calculation of IDF curves (auditory) [2]
2. Formation of relevant sets of rain gauge data for calculation of IDF curves (construction) [2]
3. Calculation of IDF curves [4]
4. Determination and application of the unit and current unit hydrograph method in the urban area [4]
5. Application of HEC-HMS modelling to determine urban runoff. [2]
6. Application of HEC-HMS modelling to determine urban runoff. [2]
7. Application of the unit and current unit hydrograph method and the kinematic wave method in the urban area. [2]
8. Application of the unit and current unit hydrograph method and the kinematic wave method in the urban area. [2]
9. Change in land use due to urbanization. Introducing elements of sustainable urban drainage systems. [2]
10. Change in land use due to urbanization. Introducing elements of sustainable urban drainage systems. [2]
11. Runoff simulations in HEC-HMS. [4]
12. Determination of the design hydrograph. [2]

Student Evaluation - Continuous assessment:

- Preparation and presentation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and presentation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. Hrelja, H.: Inženjerska hidrologija, Univerzitet u Sarajevu - Građevinski fakultet; Sarajevo, 2007.
2. Vuković, Ž.: Osnove hidrotehnike - Knjiga I, Poglavlje 2: Hidrologija, str. 19-133, udžbenik Sveučilišta u Zagrebu, Zagreb 1996.
3. Urbana hidrologija - Okrugli stol, Split 25-26 travnja 2002., zbornik radova, Hrvatsko hidrološko društvo i Hrvatske vode.

Additional reading:

1. Chow, V.T.: Handbook of Applied Hydrology, McGrow-Hill book Company, New York, 1964.
2. Akan A.O., Houghtalen R.J.: Urban Hydrology, Hydraulics, and Stormwater Quality – Engineering Application and Computer Modeling; John Wiley & Sons Ltd. 2003., http://eu.wiley.com
3. Viessman, W.Jr., Lewis, L.G.: Introduction to Hydrology, Harper-Collins-College-Publishers, New York, 1996.

COASTAL STRUCTURES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (auditory): 30

Course objectives:

- Training for the construction and design of special coastal structures in accordance with the Building Act and the Conditions for membership in the Chamber of Civil Engineers,
- Training for specialist professional and scientific education.

Entry competences (prior knowledge, descriptive):

- Knowledge of waterways and ports, hydraulics, concrete structures and foundations.

Learning outcomes:

- Students gain expanded knowledge of coastal, materials, geotechnics and the ability to apply it,
- Students gain advanced competencies in the field of rubble mound breakwaters, marinas, undersea pipelines and elementary competencies in the field of ship locks, and skills in designing their design solutions,
- Students have the competencies to participate in complex development projects in coastal construction,
- Students have the knowledge for development projects in water management,
- Students have the competencies to manage construction sites in the construction of rubble mound breakwaters, marinas and undersea pipelines.

Course content (by course schedule):

- Lectures:
  1. Detailed design of breakwaters, types of rubble mound breakwaters and breakwaters [2]
  2. Rubble mound breakwaters: foundations, types and detailed design, modern single-layer armourstone, loads, lining calculation (Hudson) [4]
  3. Calculation of armourstone (Van den Meer), design of details [4]
  4. Analysis of concrete armours f, examples of constructed breakwaters. [2]
  5. Optimal armourstone design [2]
  6. Undersea pipelines: necessary substrates, types and detailed design, loads [8]
  7. Marinas: functions, design, loads, calculations, constructions, detail design [8]
- Exercises:
  1. Formation of teams. Assignment of seminar papers by teams. Introduction to work through the creation of content and presentation of existing knowledge on the subject of the seminar paper [6]
  2. Presentation of the seminar paper Optimal design of the rubble mound breakwater armourstone [2]
  3. Presentation of the seminar Optimal design of the rubble mound breakwater armourstone
  4. Assignment of the seminar paper Designing submarine pipelines [2]

5. Introduction to work through the creation of content and presentation of existing knowledge on the subject of the seminar paper [2]
6. Submission of the seminar paper Designing submarine pipelines [2]
7. Presentation of the seminar Designing submarine pipelines [2]
8. Assignment of the seminar paper Marina design [2]
9. Introduction to work through the creation of content and presentation of existing knowledge on the subject of the seminar paper [2]
10. Submission of the seminar paper Marina design [2]
11. Presentation of the seminar Marina design [2]
12. Presentation of existing knowledge on beach design [2]
13. An example of designing a beach [2]

Student Evaluation - Examination without Continuous Assessment:

- Preparation and defence of program assignments
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Carević, D., Pršić, M.: Pomorske građevine II, online lecture notes of the Faculty of Civil Engineering, 2017
2. Pršić, M.: *Pomorske građevine*, online lecture notes of the Faculty of Civil Engineering, 2012.
3. Pršić, M.: *Plovni putevi i luke – Ch. I - V (entire), Ch. VI (parts)*, online lecture notes of the Faculty of Civil Engineering, 2012.
4. Pršić, M.: *Hidrotehničke građevine – I. dio-Osnove proračuna i djelovanja, IV. dio-Građevine vodnog prometa*, online lecture notes of the Faculty of Civil Engineering, 2012.

DESIGN AND CONSTRUCTION OF WATER AND WASTWATER INFRASTRUCTURE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Acquisition and application of practical knowledge about administrative procedures in the implementation of project documentation, design and construction of water and wastewater infrastructure, preparation of cost estimates and designs of water and wastewater infrastructure, and application of modern computer software in the field of water infrastructure engineering.

Entry competences (prior knowledge, descriptive):

Learning outcomes:

- Explain and apply the existing regulations in the implementation of project documentation,

- Apply existing knowledge in the preparation of project documentation of different levels of complexity, including cost estimates and designs,
- Apply existing knowledge in the processing of measurement and literature data,
- Apply existing knowledge in modelling the process and construction of water and wastewater infrastructure.

Course content (by course schedule):

- Lectures:
  1. Introduction to the course and legal framework
  2. Administrative procedures and permits
  3. Structure and contents of project documentation
  4. Surveying maps and site plans; Elaboration of the design basis
  5. Defining project conditions: Relevant project conditions: spatial-planning, environmental, functional, and structural
  6. Determining functionality: Setting up the functional concept of the building with the estimated capacity, estimated sections of the structure and the site plan
  7. Appropriate calculations to confirm, or change, the assumed concept, which can be hydraulic, technological, ecological, etc.
  8. Longitudinal and cross-sections of pipelines and channels
  9. Designing water reticulation and structures in water supply systems – detailed development
  10. Designing drainage systems and structures in drainage systems – detailed development
  11. Designing water purification systems - detailed development
  12. Creation of a technical description of the designed solution
  13. Cost estimates and investment estimates
  14. Construction organization and technology, supervision and management of water and wastewater infrastructure construction projects
  15. Presentation of student designs/solutions

Student Evaluation - Continuous assessment:

- Preparation and presentation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and presentation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Internal lecture notes
2. Regulations: Building Act (OG 155/25), Physical Planning Act (OG 155/25),

Water Act (OG 66/19, 84/21, 47/23), Regulation on limit values for wastewater emissions (OG 26/20)

Additional reading:

1. Wastewater Engineering – Collection and pumping of wastewater, Metcalf &Eddy.
2. Wastewater Engineering – Treatment and Reuse, Metcalf &Eddy, 2003.
3. Water Supply and Sewerage, Steel and Mcghee

RIVER CHANNEL STABILITY

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Teach the students to estimate the equilibrium state of a natural river channel
- Familiarize students with different sediment transport mechanisms
- Familiarize students with different methods of measuring sediment

Entry competences (prior knowledge, descriptive):

Learning outcomes:

- Define critical stretches of a river from the aspect of an equilibrium sediment transport
- Establish a reliable numerical model for sediment transport simulation
- Analyse and provide a critical review of the results of the numerical model

Course content (by course schedule):

- Lectures:
    1. Conditions of the incipient sediment motion and methods for estimating boundary conditions of sediment motion (4 hours)
    2. Sediment types, sediment motion processes and bottom forms in sand beds (4 hours)
    3. Detection of the cause of sediment imbalance in the local stretch of the river (4 hours)
    4. Approach to the bedload transport calculation: challenges and methods (4 hours)
    5. Approach to the suspended sediment transport calculation: sediment rating curves (4 hours)
    6. Application of the numerical model of flow and sediment transport for estimating the river's carrying capacity (4 hours)
    7. Analysis and evaluation of the model's results (4 hours)
    8. Methods of sediment transport measurement and guidelines for different sampling approaches (2 hours)

Student Evaluation - Examination without Continuous Assessment:

- Preparation and presentation of the design within the prescribed deadline

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. M.B. Jovanović: Regulacija reka - radovi i građevine, Gradevinski fakultet Beograd,
2. M.B. Jovanović: Regulacija reka – rečna hidraulika i morfologija, Gradevinski fakultet Beograd, 2021.

Additional reading:

1. ASCE Manual 54: SedimentationEngineering - Processes, Measurements,Modeling, and Practice, ASCE Task Committe, 2008, https://doi.org/10.1061/9780784408148
2. R.J. Garde: River Morphology, New Age International, 2006, ISBN 13: 9788122418644
3. B.L. Rhoads: River Dynamics - Geomorphology to Support Management, Cambridge University Press, 2020, https://doi.org/10.1017/9781108164108
4. P.Y. Julien: River Mechanics, Cambridge University Press, 2002
5. N. Chien & Z. Wan: Mechanics of Sediment Trasnport, American Society of Civil Engineers, 1999

WATER RESOURCES SYSTEM MODELLING

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Acquire and apply the methodological framework for solving hydraulic engineering problems by goal-oriented water resources system modelling, including the formulation of the problem, the choice of the model, and result interpretation within the context of decision-making
- Analyse and apply approaches to modelling depending on the spatial and temporal scale of a problem, considering the influence of local, microscale and macroscale problems
- Differentiate and apply different model paradigms (physically based, conceptual, data based and hybrid) within the framework of simulation models and decision models
- Integrate simulation and optimisation approaches for the purpose of supporting decision making in water resources systems

Entry competences (prior knowledge, descriptive):

Learning outcomes:

- Analyse the structure and functioning of water supply systems and identify key input and output variables and states of the system

- Apply methods for estimating input quantities (e.g. precipitation, inflow) by using appropriate models and data
- Develop and apply a simulation model of a water supply system depending on the spatial and temporal scale of the problem
- Differentiate and choose an appropriate model (deterministic/stochastic, aggregated/distributed, physical/data) in relation to the given problem
- Formulate and solve a simple hydrosystem management optimization problem in addition to defining the objective function and constraints
- Integrate simulation and optimisation approaches with the aim of supporting decision making
- Interpret modelling results and evaluate them within the context of an engineering problem and decision making

Course content (by course schedule):

- Lectures:
  1. Introduction to modelling water supply systems
  2. Data and design inputs in hydraulic engineering
  3. Basics of simulation modelling and model classification
  4. Estimation of input system sizes – forecasting
  5. Application of different model paradigms in the estimation of input quantities
  6. Creation of a simulation model
  7. Influence of the spatial and temporal scale in modelling
  8. Model calibration and verification
  9. Optimisation in water supply systems
  10. Basics of decision-making models and classification of models
  11. Decision-making and system output modelling
  12. Application of different model paradigms in decision-making and output modelling
  13. Creation of decision-making models
  14. Simulation-optimisation approach to modelling
  15. Choice of the optimal solution and decision-making

Student Evaluation - Examination without Continuous Assessment:

- Preparation and presentation of the design within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. World Meteorological Organization: Guide to Hydrological Practices, Volume 1 – From Measurement to Hydrological Information, 2008
2. World Meteorological Organization: Guide to Hydrological Practices, Volume 1 – Management of Water Resources and Application of Hydrological Practices, 2009
3. S. Schwindt, B. Negreiros, F. Scolari: Hydroinformatics eBook, Hydro-Informatics.com

Additional reading:

1. D. P. Loucks, E. v. Beek: Water Resources Systems Planning and Management, An Introduction to Methods, Models, and Applications, Springer, 2017

2. O. Bonacci: Oborina: glavna ulazna veličina u hidrološki ciklus, Split, Geing, 1994.
3. V. T. Chow, D. R. Maidment, L. W. Mays: Applied Hydrology, New York, McGraw-Hill, 1988.
4. B. Đorđević: Vodoprivredni sistemi, Naučna knjiga, Beograd, 1990.
5. R. Lenton, M. Muller: Integrated Water Resources Management in Practice, London, Routledge, 2012.

Specialisation in STRUCTURAL ENGINEERING

1st year, 1st semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

PRESTRESSED CONCRETE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (design: 15, construction: 15)

Course objectives:

- Acquisition of theoretical knowledge about prestressing systems and technologies, suitable materials, differences in relation to reinforced concrete, the background of the design approach, the application of prestressed concrete in different types of structures for their exploitation, but also in the construction of special types of structures,
- Acquisition of theoretical and practical knowledge about the realization of prestressing force and its losses, calculation of bending, shear and torsion, checking of cracks, deflections, introduction of prestressing force into the structure, tendons/cables layout, and constructing details.

Entry competences (prior knowledge, descriptive):

- Knowledge of reinforced concrete in terms of materials and design of basic elements.

Learning outcomes:

- Knowledge and skills required for designing prestressed structural elements,
- Knowledge and ability to select steel for prestressing and concrete depending on the conditions of use of prestressed structural elements and conditions of aggressive environmental action in accordance with contemporary methods and criteria of European standards,
- Knowledge and skills necessary for analysing the behaviour and to design prestressed structural elements and load-bearing systems according to the ultimate limit states using contemporary methods and criteria of European standards,
- Knowledge and skills necessary for verification of serviceability limit states with the use of contemporary methods and criteria of European standards,
- The ability to shape and design prestressed structural elements.

Course content (by course schedule):

- Lectures:
  1. Basic principles, historical development, types and systems of prestressing [2]
  2. Prestressing materials, systems and technology and the field of application [2]
  3. Prestressing force, immediate and time losses [2]
  4. Axially prestressed elements. Elements exposed to bending (1) [2]
  5. Elements exposed to bending (2 and 3) [4]
  6. Shear and torsion [2]
  7. Deflections and cracking, Transfer of prestressing [2]
  8. Details and constructive rules for prestressed concrete structures [2]
  9. Cantilever beams. Continuous and partially continuous beams (1) [2]
  10. Continuous and partially continuous beams (2). Composite beams [2]
  11. Prestressed slabs [2]
  12. Elements in compression. Circular prestressing [2]
  13. External prestressing [2]
- Exercises (auditory):
  1. Layout of the structure
  2. Defining appropriate actions/loads, construction phases and usage
  3. Work on structural layout, action analysis and structural calculation
  4. Cable and adhesive prestressing of the main girder
  5. Tendons/cables layout and prestressing force losses
  6. Work on prestressing, tendon layout and losses
  7. Work on prestressing, tendon layout and losses
  8. Dimensioning of the prestressed girder for the ultimate limit state
  9. Work on dimensioning for ULS
  10. Checks of the prestressed girder for the serviceability limit state
  11. Checks of the prestressed girder for the serviceability limit state
  12. Work on checks for SLS
  13. Design and construction of details, creation of a prestressed reinforcement plan for a given girder
  14. Work on the reinforcement plan
  15. Submission of program assignments

Student Evaluation - Continuous assessment:

- Program assignment
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Program assignment
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. A. Mandić, A. Kindij: *Prednapeti beton*, lectures available online, Zagreb, for the current academic year.
2. A.Mandić Ivanković: Prednapeti beton, publication of the latest lectures during 2023/2024.
3. Sorić, Z., Kišiček, T.: BETONSKE KONSTRUKCIJE 1, university handbook, Građevinski fakultet, Zagreb, 2014.
4. Radić, J. i suradnici: *Betonske konstrukcije: priručnik*, Hrvatska sveučilišna naklada: Andris, Zagreb, 2006.
5. Radić, J. i suradnici: *Betonske konstrukcije: riješeni primjeri*, Hrvatska sveučilišna naklada: Andris, Zagreb, 2006.
6. Off-prints from the exercises published online

Additional reading:

1. Rombach, G.: *Spannbetonbau*, Ernst & Sohn, Berlin, 2010.
2. Zilch, K.; Zehetmaier, G.: *Bemessung im konstruktiven Betonbau nach DIN 1045-1 und DIN EN 1992-1-1*, Springer-Verlag, Berlin Heidelberg, 2006.
3. Sengupta, A. K.; Menon, D.: *Prestressed Concrete Structures*, Indian Institute of Technology Madras, 2006.
4. Nawy, E.: *Prestressed Concrete: A Fundamental Approach*, Pearson Education, New Jersey, 2003.
5. Menn, C.: Bruckenbau 1: Grundzüge des Brückenbaus in Stahlbeton und Spannbeton, Zürich, 1979.
6. Libby, J. R.: Modern Prestressed concrete: Design Principles and Construction Methods, Litton Educational Publishing, 1977.
7. Mehmel, A.: Vorgespannter Beton: Grundlagen der Theorie, Berechnung und Konstruktion, Springer-Verlag, Berlin, Heidelberg, 1973.

BRIDGES 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 15, construction: 15)

Course objectives:

- Deepening the theoretical knowledge about more complex bridge systems (reinforced and prestressed concrete, steel and composite bridges),
- Acquisition of practical knowledge about erection and bridge analysis,
- Acquisition of practical knowledge about the dimensioning of structural elements of reinforced concrete, steel and composite bridges.

Entry competences (prior knowledge, descriptive):

- Understanding and ability to apply calculations of concrete and steel structures,
- Knowledge of basic bridge systems,
- Understanding and knowing the structural analysis of different static systems.

Learning outcomes:

- Students are able to conceptually design different bridge systems (reinforced and prestressed concrete, steel and composite bridges),
- Students are able to recognize and analyse different actions on bridges using modern European standards,
- Students are able to perform a complex analysis of reinforced concrete, steel and composite bridges,
- Students are able to analyse and dimension individual structural elements of reinforced concrete, steel and composite bridges using modern methods and criteria of European standards.

Course content (by course schedule):

- Lectures:
  1. Overview of bridge types and selection of a load-bearing bridge system [2]
  2. Concrete plate section bridges [2]
  3. Concrete ribbed section bridges [2]
  4. Concrete box section bridges [2]
  5. Frames and struts [2]
  6. Overpasses, small and integral bridges [2]
  7. First midterm exam [2]
  8. Bridge substructure [2]
  9. Bridges with thin-walled steel girders [4]
  10. Steel orthotropic plates in bridges [2]
  11. Composite bridges [4]
  12. Truss bridges [2]
  13. Second midterm exam [2]
- Exercises (auditory):
  1. Dispositions of bridges, characteristic cross-sectional and longitudinal layout elements [2]
  2. Program assignment – types of crossings, possible types of bridges as crossing options [1]
  3. Disposition of bridge with prefabricated prestressed girders cross-sections [3]
  4. Disposition of bridge with composite cross-sections [3]
  5. Bridge substructure and equipment [2]
  6. Load analysis [4]
- Exercises (construction):
  1. Control of a prestressed concrete bridge disposition [5]
  2. Control of a composite bridge disposition [5]
  3. Control of a concrete bridge load analysis [1]
  4. Control of a composite bridge load analysis [1]
  5. Submission and oral examination of the program assignment [3]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Lecture notes from lectures and exercises, solved examples.
2. Radić, J.: *Masivni mostovi*, Hrvatska sveučilišna naklada, Andris, Zagreb, 2007.
3. Radić, J.: *Uvod u mostarstvo*, Hrvatska sveučilišna naklada, Jadring, Zagreb, 2009.
4. Horvatić, D.; Šavor, Z.: *Metalni mostovi*, Udžbenici Sveučilišta u Zagrebu, HDGK, Zagreb, 1998.
5. Radić, J.; Mandić, A.; Puž, G.: *Konstruiranje mostova*, Hrvatska sveučilišna naklada, Jadring, Zagreb, 2005.

Additional reading:

1. Ryall, M. J.; Parke, G. A. R.; Harding, J. E.: *Manual of bridge engineering*, Thomas Telford, London, 2000.
2. Wiedemann: *Brueckenbau, Stahlbeton und Spannbeton Bruecken*, Werner-Verlag, Duesseldorf, 1982.
3. Mathivat, J.: *The cantilever construction of prestressed concrete bridges*, John Wiley and Sons, New York, 1983.

METAL STRUCTURES 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 30

Course objectives:

- Expanding fundamental knowledge in the field of steel structures design with knowledge of more advanced design methods,
- Understanding and predicting the behaviour of structural members (member under complex loading conditions, uniform built-up compression member, fatigue – design, thin-walled members, plates, welded plate girders),
- Application of expanded knowledge to specific projects of steel structures.

Entry competences (prior knowledge, descriptive):

- Basics of steel structures (undergraduate study).

Learning outcomes:

- Recognize the principles of conceptual design of steel structures,
- Analyse load actions and combinations of load actions for steel structures,
- Define and explain the behaviour of structural members and load-bearing systems until failure,

- Design of steel structural members using contemporary methods and criteria from European standards.

Course content (by course schedule):

- Lectures:
  1. Features of steel structures [2]
  2. Members subjected to bending and axial force [2]
  3. Uniform built-up compression members [2]
  4. Fatigue design [2]
  5. Basic principles of plasticity theory [2]
  6. Structures constructed of thin-walled profiles [2]
  7. Design of plate members [2]
  8. Design of welded plate girders [2]
  9. Basics of the design process [2]
  10. Load actions and concept of the disposition [2]
  11. Load-bearing systems of spatial structures [2]
  12. Load-bearing systems of multi-storey buildings [2]
  13. Economic aspects of steel construction [2]
  14. Details in steel structures [2]
  15. Architecture and steel [2]
- Exercises:
  1. Design of members in tension [2]
  2. Design of members in compression [2]
  3. Design of members under complex loading conditions[4]
  4. Design of uniform built-up compression members [4]
  5. Design of members subjected to fatigue [4]
  6. Examples from the theory of plasticity [2]
  7. Design of thin-walled profile [4]
  8. Design of plate girder [4]
  9. Preliminary design of spatial structures [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Practical part of the written exam
- Theoretical part of the written exam
- Oral exam

Required reading:

1. Skejić, D.: Course notes for Metal structures 2 - ac. year 2023./2024., University of Zagreb, Faculty of Civil Engineering.
2. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 1*, IA Projektiranje, Zagreb, 2009.

3. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 2*, IA Projektiranje, Zagreb, 2008.
4. Androić, B.; Dujmović, D.; Džeba, I.: *Metalne konstrukcije 4*, IA Projektiranje, Zagreb, 2003.
5. Skejić, D.; Džeba, I.: Čelične konstrukcije - Priručnik, Sveučilište u Zagrebu, Građevinski fakultet, Sveučilišni priručnik, Zagreb 2015.

RELIABILITY OF STRUCTURES

Credits (ECTS): 3

Hours (total per semester):
- Lectures: 30

Course objectives:
- Process the basic concepts of the theory of construction reliability,
- Quantify different types of uncertainty related to actions, material properties, geometric data,
- Learn methods of reliability engineering from the aspect of mathematical statistics,
- Calculate the reliability of simpler structural elements based on determining the probability of failure, i.e. the reliability index,
- Probabilistic concept of structural reliability for assessing the level of achieved reliability, which enables the application of new load-bearing systems and new materials on scientifically argued grounds.

Entry competences (prior knowledge, descriptive):
- Knowledge of probability theory and statistics.

Learning outcomes:
- Recognize the framework within which standards for structures were developed, with special reference to EN1990,
- Quantitatively describe loads, in a probabilistic way, for different circumstances,
- Estimate the probability of failure of structural elements using reliability formulated independently of time,
- Apply first-order and second-order reliability methods for the analysis of structural elements,
- Apply simulation methods, including the rough Monte Carlo method and the "Importance sampling" method to assess the reliability of structural elements,
- Identify optimal values of partial factors for action or resistance in order to achieve a predetermined level of reliability.

Course content (by course schedule):
- Lectures:
  1. The meaning of reliability engineering [2]
  2. Definitions and basic concepts [2]
  3. Analysis and evaluation of structural damage [2]
  4. Hazards in construction and residual risks [2]
  5. Recognizing hazards and planning measures to eliminate them [2]
  6. Collection and processing of structure data [2]

7. Stochastic modelling of structural response, action and resistance [2]
8. Basic variables and models [2]
9. Reliability of members [2]
10. The fundamental problem of the limit state function [2]
11. Extended problem of the limit state function [4]
12. Summary of FORM SORM / Exceptional structures [2]
13. Reliability of structures in case of fire [2]
14. Basic principles of reliability in European standards [2]
15. Further development of European standards [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Practical part of the written exam
- Theoretical part of the written exam

Required reading:

1. Skejić, D.; Lukačević, I.: Lecture notes for the course Reliability of Structures - academic year 2022/2023, Faculty of Civil Engineering, University of Zagreb.
2. Androić, B.; Dujmović, D.; Džeba, I.: *Inženjerstvo pouzdanosti 1*, IA Projektiranje, Zagreb, 2003.
3. Androić, B.; Dujmović, D.; Džeba, I.: *Metalne konstrukcije 4*, IA Projektiranje, Zagreb, 2004.
4. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 1*, IA Projektiranje, Zagreb, 2009.

Additional reading:

1. Ditlevsen, O.; Madsen, H. O.: *Structural Reliability Methods*, Wiley, New York, 1996.
2. Miličić, V.; Peroš, B.: *Uvod u teoriju sigurnosti nosivih konstrukcija*, GF Split, Split, 2003.

Elective courses

MATHEMATICS 3

See Chapter Shared Courses

STOCHASTIC PROCESSES

See Chapter Shared Courses

1st year, 2nd semester

Mandatory courses

CONCRETE AND MASONRY STRUCTURES 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (design: 18, construction: 12)

Course objectives:

- Expansion of theoretical knowledge about the design of reinforced concrete and masonry elements and structures
- Expansion of practical knowledge about the design of reinforced concrete and masonry elements and structures, as well as making more complex calculations thereof.

Entry competences (prior knowledge, descriptive):

- Theoretical and practical knowledge of the basics of the design of reinforced concrete and masonry elements and structures.

Learning outcomes:

- Students have the knowledge and skills necessary for designing structural elements of reinforced concrete and masonry structures
- Students have the knowledge and skills necessary to apply the basic principles of conceptual design
- Students know how to analyse the behaviour of structural elements and load-bearing systems of reinforced concrete and masonry structures and design them according to the ultimate and serviceability limit states
- Students have the ability to analyse structural elements of reinforced concrete and masonry structures using modern methods and criteria of European standards.

Course content (by course schedule):

- Lectures:
  1. Structural details of masonry. Masonry [2]
  2. Masonry buildings in seismic areas. [6]
  3. Simple rules for designing masonry buildings. [2]
  4. Reinforcement of walls. [2]
  5. First midterm exam in Masonry structures [2]
  6. Serviceability limit states. Limit states of stress. Limit states of the appearance of cracks. Limit states of crack width. [2]
  7. Serviceability limit states. Deflection limit state. Design example. [2]
  8. 2nd midterm exam in Concrete structures. [2]
  9. Punching shear. [2]
  10. Torsion of reinforced concrete sections. [2]
  11. Beams of variable height. Slab-beam joint. [2]
  12. Slender columns. Biaxial bending. [2]

13. Wall girders. Walls. Foundations. [2]

- Exercises:
  1. Familiarization with the exercise program, the assignment and the method of its creation. Defining the load-bearing structure of the subject building and analysing the impact on the structure and marking the subject positions that need to be calculated (auditory) [2]
  2. Calculation of Fert ceiling and reinforced concrete roof beam [2]
  3. Calculation of the staircase with elaboration of the method of reinforcement [2]
  4. Submission of a part of the program assignment. [2]
  5. Calculation of a reinforced concrete two-way slab of a characteristic floor. Slab modelling using computer software. Elaboration of ceiling reinforcement details and connection with confining elements [2]
  6. Calculation of beams on the ceiling of a characteristic floor [2]
  7. Submission of a part of the program assignment. [2]
  8. Calculation of masonry for vertical load and horizontal load due to wind pressure perpendicular to the wall [4]
  9. Submission of a part of the program assignment [2]
  10. Calculation of RC basement wall [2]
  11. Submission of a part of the program assignment. [2]
  12. Calculation of strip foundations [2]
  13. Submission of program assignments [4]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- Midterm exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Sorić, Z.; Kišiček, T.: *Betonske konstrukcije 2. Projektiranje betonskih konstrukcija prema europskim normama EN*, lecture notes of the Faculty of Civil Engineering, Zagreb, 2012.
2. Sorić, Z.; Kišiček, T.: *Betonske konstrukcije 1. Projektiranje betonskih konstrukcija prema europskim normama EN*, 324 p., Zagreb 2010., 2011.
3. Sorić, Z.: "Zidane konstrukcije", university handbook, self-published, Zagreb, 2016.
4. Technical Regulations for Building Structures (2017).
5. Croatian standards of the HRN EN 1996 series, standards for masonry structures (Eurocode 6).
6. Croatian standards of the HRN EN 1991 series, standards for structural loads (Eurocode 1).

7. Croatian standards of the HRN EN 1992 series, standards for concrete structures (Eurocode 2)

METAL STRUCTURES 3

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises (construction): 30

Course objectives:
- Practical application of the theory of plasticity of steel frame structures,
- Modelling of frame systems for analysis, explanation of the basic concepts of analysis,
- Consideration of different methods of global analysis of frame systems,
- Deepening theoretical knowledge of instability issues and considering their effects in analysis and design,
- Consideration of joints and their modelling with regard to the analysis of frame structures,
- Fundamental aspects of the design of tensegrity structures, tall buildings and steel lattice domes,
- Fundamentals of the design of steel structures in the event of earthquakes.

Entry competences (prior knowledge, descriptive):
- Knowledge of the basic methods of plastic analysis of load-bearing systems,
- Design of structural steel members,

Enrolment requirements (prerequisite):
- Teacher's signature for the course: Metal Structures 2.

Prerequisite for taking the exam:
- Course exam passed: Metal Structures 2.

Learning outcomes:
- Apply plastic and elastic global analyses and appropriate design of structural steel members,
- Recognise the instabilities of structural frame systems,
- Explain the consideration of instability effects in the analysis and design of structural frame systems,
- Apply the basic principles of the design of tensegrity structures and systems of tall buildings and domes.

Course content (by course schedule):
- Lectures:
  1. Introduction and importance of the course / Modelling of frame structures [2]
  2. Classification of frames, frame imperfections and bracing systems [2]
  3. Elastic critical load of frames [2]
  4. Methods of elastic global frame analysis [2]
  5. Methods of plastic global frame analysis [2]
  6. Theory of plasticity in steel frame structures [3]
  7. Analysis and design of frame systems [2]
  8. Analysis and classification of joints [2]
  9. Floor systems [2]
  10. Load-bearing systems of steel structures [2]

11. Special types of steel structures (suspended and tensegrity structures) [2]
12. Load-bearing systems of steel structures - preliminary design (tall buildings, domes) [4]
13. Seismic resistance of steel structures [4]

- Exercises:
  1. Analysis of the design assignment [2]
  2. Preparation of a disposition solution [2]
  3. Analysis of the actions on the structure [2]
  4. Determining the effects of actions [4]
  5. Design of structural members [6]
  6. Design of joints [4]
  7. Preparation of detailing workshop drawings [6]
  8. Preparation of the Quality Assurance Plan [2]
  9. Final submission [2]

Student Evaluation - Examination without Continuous Assessment:

- Preparation and defence of the program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Practical part of the written exam
- Theoretical part of the written exam
- Oral exam

Required reading:

1. Skejić, D.: *Lecture notes for the course Metal Structures 3* - academic year 2023/2024, Građevinski fakultet Sveučilišta u Zagrebu.
2. Dujmović, D.; Androić, B.; Džeba, I.: *Modeliranje konstrukcija prema EC3*, IA Projektiranje, Zagreb 2004.,
3. Džeba, I.; Androić, B.; Dujmović, D.; *Metalne konstrukcije 3*, IA Projektiranje, Zagreb, 1998.,
4. Androić, B.; Dujmović, D.; Džeba, I.: *Metalne konstrukcije 4*, IA Projektiranje, Zagreb, 2003.,
5. Skejić, D.; Džeba, I.: *Čelične konstrukcije - Priručnik*, Sveučilište u Zagrebu, Građevinski fakultet, Sveučilišni priručnik, Zagreb 2015.
6. Davies, J. M.; Brown, B. A.: *Plastic Design*, Blackwell Science, 1996.
7. MacGinley, T. J.: Steel structures - Practical design science, Spon Press - Taylor and Francis Group, London, 2002.
8. Trahair, N. S.; Bradford, M. A., Nethercot, D. A.; Gardner, L.: The Behaviour and Design of Structures to EC 3, Taylor and Francis, London, 2008.

TIMBER STRUCTURES 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30

- Exercises: 30 (14 auditory + 16 construction)

Course objectives:

- Acquisition of theoretical knowledge about wooden laminated and spatial structures made of laminated wood,
- Acquisition of practical knowledge about the procedures for dimensioning load-bearing elements of wooden structures (girders of different geometries, three-jointed systems, wooden houses, wooden roofs, rehabilitation of damaged elements),
- Acquisition of practical knowledge about the stabilization of wooden structures.

Entry competences (prior knowledge, descriptive):

- Theoretical knowledge about the behaviour of constructions under load and other actions and about ways of transferring forces,
- Understanding of the concepts of stress and deformation and internal forces,
- Practical knowledge about linear calculation procedures of statically determinate and statically indeterminate rod structures,
- Understanding the basics of dimensioning wooden structures,
- Understanding of the design and calculation of details in wooden structures.

Learning outcomes:

- Knowledge about the physical and mechanical characteristics of laminated wood,
- Apply appropriate evidence of load-bearing capacity and usability of elements built from laminated wood,
- Check the load capacity of planar and spatial static systems,
- Apply knowledge about dimensioning and performance of joints with rod fasteners,
- Solve the stabilization of wooden structures with complex geometry,
- Construct wooden houses and simple roofs,
- Apply basic knowledge about wooden bridges,
- Apply basic knowledge for joining wood with other materials.

Course content (by course schedule):

- Lectures:
  1. Wood materials - quality control. Panel elements made of wood-based material. New wood-based materials. Composites. [2]
  2. Industrial production of typical laminated constructions. [2]
  3. Laminated glued girders - design and characteristic details of connections. Calculation of typical laminated girders of special geometry. [2]
  4. Laminated glued girders - design and characteristic details of connections. Calculation of typical laminated girders of special geometry. Stresses in curved laminated girders as a result of production. Practical measures to strengthen the stress zone of laminated girders when the bearing capacity is exceeded perpendicular to the grain. [2]
  5. Planar systems of laminated girders: frame and arc. Spatial systems. Characteristic details of connections of laminated structures: design and calculation. [2]
  6. Characteristic details of connections of laminated structures: design and calculation. Protection, restoration and rehabilitation of wooden structures. [2]
  7. Cross laminated timber (CLT) - design basics and industrial production of elements. Calculation of CLT elements and characteristic details of connections. [2]
  8. Classic and modern wooden roofing systems. [2]
  9. Classic and modern wooden roofing systems. Roof renovation and repair. [2]

10. Basics of designing and building wooden buildings. Industrial production of wooden buildings. Analyses of frame and panel building systems. Characteristic details of connections. Construction. [2]
11. Basics of designing and building wooden buildings. Industrial production of wooden buildings. Analyses of frame and panel building systems. Characteristic details of connections. Construction. [2]
12. Flexibility of connections in wooden constructions. Assembled girders. [4]
13. Making a structure composite of wood with wood and wood-based materials. Making a structure composite of wood with other materials. Prestressing in wooden structures: Howe and Cruciano lattice systems. Prestressing. Transversely prestressed systems. [2]
14. Spatial concept and spatial systems of wooden constructions: grille systems, hipari, composites, reticular structures (vaults, spheres). [2]

- Exercises (design):
  1. Description of the assignment. Elements of the disposition solution of the structure. Method for solving the disposition [2]
  2. Models and method of calculation according to EUROCODE 1 standards. Load analysis [2]
  3. Main and secondary load-bearing structure. Determining calculation combinations of actions. Creation of a numerical (spatial) model of the load-bearing structure. Structural calculation of the load-bearing structure. Design and structural calculation of the stabilization system. Spatial stability check. [2]
  4. Dimensioning of load-bearing structure elements. [4]
  5. Basics of designing and building wooden buildings. Review of current issues in the design and construction of modern wooden structures. [2]
  6. Details of connections in laminated wooden constructions. Design and calculation of connection details. [2]
- Exercises (construction):
  1. Method for solving the disposition. Disposition solution. [2]
  2. Action analysis according to EUROCODE 1 standards. [2]
  3. Creation of a numerical (spatial) model of the load-bearing structure. Structural calculation of the load-bearing structure. Design and structural calculation of the stabilization system. Spatial stability check. [2]
  4. Dimensioning of load-bearing structure elements. [2]
  5. Details of connections in laminated wooden constructions. Design and calculation of connection details. Implementation drawing and connection detail drawings. Technical description. [2]
  6. Review and submission of program assignments. [2]
  7. Presentation and defence of design assignments (program assignments) [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments
- Written exam – assignment
- Written exam – theory
- Oral exam
- Seminar paper
- 75% attendance at lectures

- 100% attendance at exercises

Required reading:

1. Bjelanović, A.; Rajčić, V.: *Drvene konstrukcije prema europskim normama*, Hrvatska sveučilišna naklada, Zagreb, 2005., (II izdanje 2007.)
2. Žagar, Z.: *Drvene konstrukcije I-II/III-IV*; Pretei d.o.o, Zagreb, 2003./2001.
3. Žagar, Z.: *Drveni mostovi*; Pretei d.o.o, Zagreb, 2001.
4. Rajčić, V., Čizmar, D., Stepinac, M.: Riješeni primjeri iz drvenih konstrukcija, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 2014.
5. Course materials are available on the official website of the course

Additional reading:

1. Crocetti, R.; Johansson, M.; Johansson, H.; Kliger, R.; Martensson, A.; Norlin, B.; Pousette, A.; Thelandersson, S.: Design of timber structures I-III; Swedish Wood, Stockholm, 2016.
2. Blass, H. J.; Sandhaas, C.: Ingenieurholzbau - Grundlagen der Memessung; KIT Scientific Publishing, Karlsruhe, 2016.
3. Colling, F.: Holzbau - Grundlagen und Bemessun (und Beispiele) nach Eurocode 5; Springer Vieweg, Wiesbaden, 2016.
4. Herzog, T.; Nattere, J.; Schweitezer, R.; Volz, M.; Winter, W.: Holzbau Atlas; Institut fur internationale Architektur-Dokumentation GmbH, Munchen, 2003.
5. CEN: series of European standards *HRN EN 1995-1-1:2013+A2:2015+NA:2013* and *HRN EN 1995-1-2:2013+NA:2013*; CEN, Brussels, 2013.

DURABILITY OF STRUCTURES 1

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- exercises: 30 (design: 14; construction: 16)

Course objectives:

- Acquisition of theoretical knowledge about
  1. Modern durability design,
  2. Deterioration mechanisms of structures from different structures,
  3. The influence of design, construction and maintenance on durability,
  4. Methods of achieving the durability of structures made of different materials,
  5. Risk management,
  6. Reconstruction methodology after major destructions,
  7. Sustainable construction,
- Acquisition of practical knowledge about
  1. Designing the durability of new structures,
  2. Inspections of buildings, categorization of damage, assessment of the condition of the building.

Entry competences (prior knowledge, descriptive):

- Knowledge of structures in terms of knowledge of material properties and design methods.

Learning outcomes:

- Knowledge about the impacts on durability through the design, construction and maintenance of structures,
- Knowledge about the maintenance of existing buildings and building management,
- Skills of proving durability when designing a new structure,
- Knowledge and skills of collecting data on existing structures in order to evaluate them.

Course content (by course schedule):

- Lectures:
  1. Definitions of basic concepts. A modern approach to the durability of buildings. Durability design [2]
  2. Deterioration mechanisms of concrete, masonry, metal and timber structures. Examples of structural damage [2]
  3. Impact of design on durability. Effect of construction on durability [2]
  4. Effect of maintenance on durability. Management of buildings. Other influences on the durability of structures [2]
  5. Condition assessment and structural health monitoring [2]
  6. Durability of structures and limit states [2]
  7. 1st midterm exam
  8. Achieving durability of concrete structures. Achieving durability of masonry structures [2]
  9. Achieving durability of timber structures. Achieving durability of steel structures [2]
  10. Failures, accidents and disasters. Risk management [2]
  11. Temporary and auxiliary buildings. Renovation methodology [2]
  12. Aesthetic, ecological and ethical aspects of sustainability [2]
  13. Sustainable construction [2]
  14. 2nd midterm exam
  15. Retest.
- Exercises:
  1. Inspection and assessment of the building condition [2]
  2. Creating the basic documentation for the inspection of buildings [2]
  3. Inspection of bridges [4]
  4. Inspection of buildings [4]
  5. Types of damages and their graphical representation in the program [6]
  6. Examples of durability verification [2]
  7. Categorisation of damages and the assessment of the structure [6]
  8. Review and submission of program assignments [4]

Student Evaluation - Continuous assessment:

- Program assignment submitted, defended, and positively evaluated within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam – a minimum score of 60%
- Second midterm exam – a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- Program assignment submitted, defended, and positively evaluated within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam – a minimum score of 60%

Required reading:

1. J. Radić: *Trajnost konstrukcija I*, Hrvatska sveučilišna naklada, Jadring, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2010.

Additional reading:

1. J. Radić et al.: *Betonske konstrukcije – Priručnik*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, Andris, Zagreb, 2006.
2. J. Radić et al.: *Betonske konstrukcije – Riješeni primjeri*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2006.
3. J. Radić et al.: *Zidane konstrukcije – Priručnik*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, Andris, Zagreb, 2007.
4. J. Radić et al.: *Betonske konstrukcije – Građenje*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2008.
5. J. Radić et al.: *Betonske konstrukcije – Sanacije*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2008.

PRECAST REINFORCED CONCRETE STRUCTURES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (design: 10, construction: 20)

Course objectives:

- Familiarization with prefabricated concrete elements,
- Acquisition of practical knowledge about the construction and design of precast concrete structures, structural elements and joints and connections,
- Acquisition of practical knowledge about the dimensioning of precast reinforced concrete structures.

Entry competences (prior knowledge, descriptive):

- Understanding and ability to apply design of concrete,
- Knowledge of basic construction systems,
- Understanding and knowledge of the mechanical resistance and stability of various static systems.

Learning outcomes:

- Students have the ability to conceptually design various systems of precast concrete structures (frame and combined structures),
- Students have the ability to perceive and analyse different actions on precast concrete structures by applying European standards,
- Students have the ability to analyse precast concrete structures,
- Students have the ability to analyse and dimension individual structural elements, precast concrete structures using modern methods and criteria of European standards.

Course content (by course schedule):

- Lectures:
  1. Introduction – what are precast concrete structures [2]
  2. Material used in precast concrete structures [2]
  3. Analysis of prefabricated load-bearing concrete frames [2]
  4. Precast concrete floor structures [2]
  5. Precast concrete beams [2]
  6. Precast concrete columns and walls [2]
  7. Horizontal ceiling diaphragms [2]
  8. 1st midterm exam
  9. Precast reinforced concrete beams [2]
  10. Columns [2]
  11. Columns and shear walls [2]
  12. Connections [2]
  13. 2nd midterm exam
  14. Connectors [2]
  15. Foundation and pillar connectors, foundation calculation [2]
- Exercises:
  1. Disposition and preliminary design [6]
  2. Design - secondary girder [4]
  3. Design and reinforcement - main girder [4]
  4. Seismic design [4]
  5. Column design and reinforcement [4]
  6. Foundation design and reinforcement [4]
  7. Submission of program assignments [4]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- Midterm exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Notes from lectures and auditory exercises
2. Sorić, Z., Kišiček, T.: "Betonske konstrukcije 1", Sveučilište u Zagrebu Građevinski fakultet, university handbook, Zagreb, 2014.
3. Sorić, Z., Kišiček, T.: "Betonske konstrukcije 2", Sveučilište u Zagrebu Građevinski fakultet, university handbook, Zagreb, 2018.

Additional reading:

1. Elliott, K. S.: *Precast concrete structures*, Butternwoorth-Heineman, 2002.

2nd year, 3rd semester

Mandatory courses

CONCRETE STRUCTURES 3

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (auditory: 8, design: 22)

Course objectives:
- Expansion of theoretical knowledge about the design of reinforced concrete structures
- Expansion of practical knowledge about the design of reinforced concrete structures, as well as making more complex calculations thereof
- Acquisition of knowledge about the design of reinforced concrete structures in seismic areas.

Entry competences (prior knowledge, descriptive):
- Theoretical and practical knowledge about the design of reinforced concrete elements and structures

Enrolment requirements (prerequisite):
- Teacher's signature for the courses: Precast Reinforced Concrete Structures, Concrete and Masonry Structures 2.

Prerequisite for taking the exam:
- Course exams passed: Precast Reinforced Concrete Structures, Concrete and Masonry Structures 2.

Learning outcomes:
- Students have the knowledge and skills necessary to design structural elements of complex (engineering) reinforced concrete structures and to apply the basic principles of conceptual design,
- Students know how to analyse the behaviour of structural elements and load-bearing systems of complex (engineering) reinforced concrete structures and design them according to the ultimate and serviceability limit states
- Students have the ability to analyse structural elements of complex (engineering) reinforced concrete structures using modern methods and criteria of European standards
- Students have the knowledge and skills to design structural elements of complex (engineering) reinforced concrete structures.

Course content (by course schedule):
- Lectures:
  1. Confinement, ductility, determination of (M-1/r) diagram of a rectangular cross-section, balanced failure [2]
  2. M-1/r diagram – example, partially loaded surfaces of reinforced concrete elements, shear on the joint surface of two concretes that were made at different times, change of partial coefficients for materials [2]

3. Concrete structures in seismic areas - calculation and reinforcement provisions for reinforced concrete beams, columns and walls according to the European standard EN 1998-1 [10]
4. Dimensioning of slender columns [2]
5. Midterm exam [2]
6. Elements in compression with biaxial eccentricity [2]
7. Elements in compression with biaxial eccentricity and slender columns - calculation examples [2]
8. Basics of using non-metallic reinforcement in new concrete structures [2]
9. FRP – as a material for strengthening and reinforcing structures [4]
10. Light-weight concrete structures, unreinforced and weakly reinforced concrete structures. [2]

- Exercises:
  1. Distribution of tasks to students. Defining the load-bearing structure of the building. Making a 3D model of the structure. [2]
  2. Making a 3D model of the structure. [2]
  3. Preparation of a report for a 3D model of the structure. [2]
  4. Defining the load on the structure and calculating of the structure. [4]
  5. Preparation of reports for the loads on the structure [2]
  6. Processing of calculation results [2]
  7. Preparation of reports on calculation results
  8. Preparation of a report on the calculation of the wall and part of the frame [6]
  9. Wall and frame reinforcement layouts [8]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. Sorić, Z.; Kišiček, T.: *Betonske konstrukcije 1. Projektiranje betonskih konstrukcija prema europskim normama EN*, 324 p., Zagreb 2010., 2011.
2. Sorić, Z.; Kišiček, T.: *Betonske konstrukcije 2. Projektiranje betonskih konstrukcija prema europskim normama EN*, lecture notes of the Faculty of Civil Engineering, Zagreb, 2012.
3. Sorić, Z.: ZIDANE KONSTRUKCIJE, university handbook, self-published, Zagreb, 2016.
4. Sorić, Z., Pičulin, S., Zamolo, M., Kišiček, T.,(Jure Radić i suradnici.): Osnove proračuna, V poglavlje u knjizi BETONSKE KONSTRUKCIJE, PRIRUČNIK. university handbook, Zagreb, 2006. g. ISBN 953-169-126-6, Str. 399-663, Urednik: Čandrlić, V.
5. Sorić, Z., Kišiček, T., Galić J.,(Jure Radić i suradnici.): poglavlje u knjizi BETONSKE KONSTRUKCIJE, RIJEŠENI PRIMJERI, III. Konstrukcijski elementi, str. 139-390, Udžbenik Sveučilišta u Zagrebu. 2006. g. Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, ANDRIS. Editor: Čandrlić, V.
6. Tomičić, I.: Betonske konstrukcije, Društvo Hrvatskih građevinskih konstruktora, Zagreb, 1996.
7. Tomičić, I.: Priručnik za proračun armiranobetonskih konstrukcija, Društvo Hrvatskih građevinskih konstruktora, Zagreb, 1996.

8. Exercise materials are available on the course website.

BRIDGES 3

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (design: 15, construction: 15)

Course objectives:

- Deepening of theoretical knowledge about structural design, calculation and construction of more complex bridges (arch, cable-stayed and suspension bridges),
- Acquisition of knowledge about the management and maintenance and repairs of bridges,
- Acquisition of basic theoretical knowledge about the aesthetics of bridges and its application to different load-bearing systems,
- Acquisition of practical knowledge about calculations and modelling of composite and prestressed bridges using computer software,
- Acquisition of practical knowledge on the design of structural elements of composite and prestressed bridges using computer software.

Entry competences (prior knowledge, descriptive):

- Acquired knowledge about the analysis of action and design of structural elements of massive, metal and composite bridges,
- Acquired knowledge and skills in designing prestressed structural elements,
- Acquired basic knowledge about structural degradation processes, maintenance of existing and new structures and structural durability verification.

Enrolment requirements (prerequisite):

- Course exam passed: Bridges 2, Prestressed Concrete.

Prerequisite for taking the exam:

- Course exam passed: Durability of Structures 1, Metal Structures 2.

Learning outcomes:

- Students are familiar with different bridge maintenance methods and elements of the bridge management system,
- Students have practical knowledge about the various causes of damage to individual structural elements of bridges with an elaborate method of repairs and renovation,
- Students have basic knowledge about diagnostics, monitoring, assessment and classification of the condition of bridges and about different methods of calculating the remaining service life of structures,
- Students have the knowledge and skills necessary for the aesthetic design of bridges depending on the load-bearing structure and purpose of the bridge,
- Students have the knowledge and ability to select and design the appropriate load-bearing system of the bridge depending on the geometric and boundary conditions in accordance with European standards and aesthetic criteria,
- Students acquire additional knowledge about the effects of earthquakes on bridges as well as the application of modern materials and structures in bridge construction.

Course content (by course schedule):

- Lectures:
  1. Introduction to the course: Normative framework for arch, cable-stayed and suspension bridges [2]
  2. Arch bridges. [4]
  3. Cable-stayed bridges [4]
  4. Suspension bridges. [2]
  5. Aesthetics of bridges. [2]
  6. 1st midterm exam
  7. Bridge management system. [2]
  8. Assessment and prediction of the condition of bridges. [2]
  9. Maintenance works. BIM for bridges [2]
  10. An integrated approach to bridge design. [2]
  11. World and Croatian achievements in bridge construction. [2]
  12. 2nd midterm exam
  13. Retest
- Exercises:
  1. Introduction to Sofistik, parts of the software, methods of data input, types of elements, parts of the model, definition of materials and cross-sections [2]
  2. Defining model geometry and boundary conditions [2]
  3. Review of the created model [2]
  4. Defining actions, defining permanent loads, defining prestressing systems, modelling construction stages [2]
  5. Defining additional loads – traffic, wind, temperature, earthquake [2]
  6. Review of actions on model [2]
  7. Analysis of calculation results, definition of load combinations for ULS and SLS, design output selection [2]
  8. Review of calculation results [2]
  9. Selection of bearings' layout, dimensioning of bearings and expansion joints [2]
  10. Review of the results of the loaded model [2]
  11. ULS design – arrangement of materials for a steel girder, stability check, calculation of reinforcement of girders, decks and columns [2]
  12. Review of the selection of bearings and expansion joints [2]
  13. SLS design - checking of stresses, decompression and cracks Review of the selection of bearings and expansion joints [2]
  14. Review of the completed model and design [2]
  15. Submission and defence of the program assignment [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures

- 100% attendance at exercises
- Midterm exam
- Written exam

Required reading:

1. Bleiziffer, J., Kušter Marić, M.: Bridges 3 – lectures published on Merlin, Zagreb, publication of the latest lectures during 2023/2024.
2. Vlašić, A., Srbić, M., Kušter Marić, M.: Bridges 3 – lecture notes for exercises published online, Zagreb, publication of the latest off-prints during 2023/2024.
3. Radić, J. et al.: *Betonske konstrukcije – sanacije*, Hrvatska sveučilišna naklada, Zagreb, 2010.
4. Radić, J. et al.: *Betonske konstrukcije – priručnik*, Hrvatska sveučilišna naklada, Zagreb, 2006.
5. Radić, J.: *Masivni mostovi*, Hrvatska sveučilišna naklada, Zagreb, 2007.
6. Radić, J.; Mandić, A.; Puž, G.: *Konstruiranje mostova*, Hrvatska sveučilišna naklada, Zagreb, 2005.

DYNAMICS OF STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 7, on computers: 5, design: 3)

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of structures under dynamic load,
- Acquisition of theoretical and practical knowledge about dynamic analysis procedures,
- Easier interpretation of provisions from seismic regulations.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra,
- Knowledge of static linear calculation procedures of beam structures,
- Knowledge of the basics of kinematics of simple static systems,
- Knowledge of the dynamics of the particle.

Learning outcomes:

- Apply the principles of structural dynamics,
- Carry out analysis of dynamically loaded structures,
- Analyse the results of the dynamic calculation of structures,
- Follow scientific and professional literature in the field of structural dynamics.

Course content (by course schedule):

- Lectures:
  1. Introductory examples [2]
  2. Single degree of freedom system without damping [2]
  3. Single degree of freedom system with damping [2]
  4. Single degree of freedom system: harmonic excitation [2]

5. Single degree of freedom system: Duhamel's integral [2]
6. Concept of response spectrum [2]
7. Response of linear system to earthquake excitation [2]
8. Response of elastoplastic system to earthquake excitation [2]
9. Generalized system with single degree of freedom: Rayleigh quotient [2]
10. System with multiple degrees of freedom: formulation of the problem [2]
11. System with multiple degrees of freedom: static condensation [2]
12. System with multiple degrees of freedom without damping and with damping [2]
13. System with multiple degrees of freedom: harmonic excitation [2]
14. Damping in building structures [2]
15. Response of a linear system with multiple degrees of freedom to earthquake excitation and application of the response spectrum to a system with multiple degrees of freedom [2]

- Exercises:
  1. Defining the degrees of freedom in dynamics (static and dynamic degrees of freedom of the system). [1]
  2. Determination of stiffness and flexibility of static systems. Static condensation. Mass distribution of static systems. [1]
  3. System with single degree of freedom with and without damping: free oscillation (analytical and numerical solution) [2]
  4. System with single degree of freedom: damped and undamped vibration [2]
  5. Response of a linear system with single degree of freedom to earthquake excitation and application of the response spectrum [2]
  6. System with multiple degrees of freedom without damping: problem formulation and modal analysis [2]
  7. System with multiple degrees of freedom: numerical examples [4]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments at design exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments at design exercises
- Written exam
- Oral exam

Required reading:

1. Lazarević, D., Šavor Novak, M., Uroš, M., Dinamika konstrukcija s uvodom u potresno inženjerstvo, lecture notes, Faculty of Civil Engineering, Zagreb, 2018.

Additional reading:

1. Chopra, A.: *Dynamics of Structures, Theory and Application to Earthquake Engineering*, 3rd Edition, Prentice Hall, New Jersey, 2007.

2. Mihanović, A.: *Dinamika konstrukcija*, Građevinski fakultet Sveučilišta u Splitu, Split, 1995.
3. Čaušević, M.: *Dinamika konstrukcija, diskretni sustavi*, Školska knjiga, Zagreb, 2005.

Elective courses

STABILITY OF STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 15

Course objectives:

- Covering of the concepts of stable elastic equilibrium and criteria for elastic stability,
- Explanation of energy and numerical methods for evaluating critical loads,
- Consideration of the effects of geometric and structural imperfections on the assessment of the resistance to buckling of columns, girders, column-girders and buckling of plate construction elements as well as shells.

Entry competences (prior knowledge, descriptive):

- Knowledge of methods of calculating the effects of action (bending moments, internal forces) of load-bearing systems.

Learning outcomes:

- Calculate critical loads exactly or approximately using energy methods of structural elements and simple frame systems,
- Explain the effects of material plasticity and geometric and structural imperfections on the buckling resistance of structural elements,
- Analyse the stability of geometrically perfect and imperfect systems,
- Recognize the differences between linear and non-linear buckling analysis,
- Explain the post-critical behaviour,
- Apply methods of analysis of basic structural elements and systems that are subject to instability.

Course content (by course schedule):

- Lectures:
  1. Concepts of stable and unstable elastic equilibrium [2]
  2. General criteria for elastic stability [2]
  3. Modes of elastic instabilities [2]
  4. General methods for evaluating critical loads [2]
  5. Iterative methods for solving stability problems [2]
  6. The influence of imperfections on the stability of structural elements and systems [2]
  7. Stability of real structural elements [2]
  8. Stability of complex stressed structural elements [2]
  9. Stability of real frame systems [2]
  10. Stability of non-prismatic elements and components [2]
  11. Stability of real plate elements [2]

12. System stability problems when opening plastic joints [2]
13. Stability in the European norm and application of computer software [2]
14. Special problems of structural stability [2]
15. Analysis of the stability of shells and arches [2]

- Exercises:
  1. Numerical example [6]
     Calculation of the critical load and the corresponding buckling mode
     a) Exactly
     b) Raleigh's method
     c) Rayleigh-Ritz method
     d) Galerkin's method
     e) Vianello-Newmark method
  2. Numerical example [7]
     Calculation of the critical load and the corresponding buckling mode of the frame
     a) Exact calculation of the critical load value
        a1) Lateral displacement is prevented
        a2) Lateral displacement is not prevented
     b) Approximate calculation of the value of the critical load with finite elements
        b1) Lateral displacement is prevented
        b2) Lateral displacement is not prevented
  3. Numerical example [2]
     Calculation of the critical stress of a rectangular plate in compression using the Rayleigh-Ritz method

Student Evaluation - Continuous assessment:

- Preparation and defence of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and defence of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. Čaušević, M.: *Statika i stabilnost konstrukcija*, Građevinski fakultet Rijeka, Rijeka, 2004.
2. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 1*, IA Projektiranje, Zagreb, 2009.
3. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 2*, IA Projektiranje, Zagreb, 2008.
4. Dujmović, D.; Androić, B.; Džeba, I.: *Modeliranje konstrukcija prema EC3*, IA Projektiranje, Zagreb, 2003.
5. Lukačević, I.: Lecture notes for the course Stability of Structures, - academic year 2022/2023, Faculty of Civil Engineering, University of Zagreb.

Additional reading:

1. Galambos, T. V.; Surovek, A. E.: *Structural Stability of Steel*, John Wiley and Sons, 2008.
2. Galambos, T. V. (ed.): *Guide to Stability Design Criteria for Metal Structures*, John Wiley and Sons, 1998.
3. Beg, D.; Kuhlmann, U.; Davaine, L.; Braun, B.: *Design of Plated Structures*, Ernst und Sohn, Berlin, 2011.

DURABILITY OF STRUCTURES 2

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (construction)

Course objectives:

- Acquisition of theoretical knowledge about
  1. Contemporary implicit and explicit design of durability,
  2. Achieving the robustness of structures,
  3. Assessment of existing structures,
  4. Numerical modelling of reinforced concrete structures for involving corrosion effects,
  5. effects and modelling of accidental actions on structures such as earthquakes, fire, impacts
  6. Different methods and technologies of repair and strengthening of structures with an emphasis on strengthening with fibre-reinforced polymers and external prestressing;
- Acquisition of practical knowledge about designing the durability of new structures and assessing existing structures, as well as methods of strengthening with fibre-reinforced polymers and external prestressing.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic concepts and principles for achieving the durability of structures,
- Knowledge of implicit durability design for common buildings for a lifetime of 50 years,
- Knowledge of design of reinforced and prestressed concrete structures.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Durability of Structures 1

Prerequisite for taking the exam:

- Course exam passed: Durability of Structures 1

Learning outcomes:

- Knowledge about the maintenance of existing structures and structural management,
- Knowledge of numerical modelling of the effect of corrosion on RC structures,
- The ability to prove durability when designing a new structure in accordance with modern European standards,
- Knowledge and skills of collecting data on existing structures in order to evaluate them,
- The ability to evaluate existing structures in accordance with the modern understanding of the reliability of structures,
- Skills of verification of ultimate and serviceability limit states of existing structures.

Course content (by course schedule):

- Lectures:

1. A contemporary approach to the durability of buildings through design, construction and maintenance [2]
2. Implicit and explicit design for durability, theory and examples [2]
3. Robustness of buildings [2]
4. Assessment of existing structures – Introduction. Collection of data on the structure. Calculation methods for existing structures and procedures for proving reliability [2]
5. Assessment of existing structures – Assessment methods for existing structures, classes and assessment levels [2]
6. Assessment of existing structures – Further knowledge on structural inspection [2]
7. Assessment of existing structures – Examples [4]
8. Computer modelling of reinforced concrete structures – Linear and non-linear analysis. Basic of fracture mechanics. Microplane model [2]
9. Numerical modelling of corrosion effects in reinforced concrete structures [2]
10. General information about the earthquake. Regulations and standards. Assessment of existing structures for seismic action [2]
11. Protective barriers on roads and bridges. Collision with overpass piers [2]
12. General information about fire. Calculation of the building for fire action [2]
13. Repairs and strengthening [2]
14. Strengthening with fibre-reinforced polymers and external prestressing [2]

- Exercises:
  1. Introduction to the subject of the course and conducting exercises through student seminars. [1]
  2. Selection of seminar topics. [1]
  3. Design examples of proving durability when designing a new construction [2]
  4. Design examples of evaluating the existing construction [3]
  5. 1st midterm exam
  6. Seminar presentations [6]
  7. 2nd midterm exam

Student Evaluation - Continuous assessment:

- Seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. J. Radić et al.: *Betonske konstrukcije – Sanacije*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu, Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2008.
2. J. Radić: *Trajnost konstrukcija I*, Hrvatska sveučilišna naklada, Jadring, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2010.

3. Mandić, A.: Durability of Structures 2 - lectures published online, Zagreb, publication of the first lectures in 2010/2011, publication of the latest lectures during 2023/2024.
4. Off-prints for exercises

Additional reading:

1. Rombach, G.: *Spannbetonbau*, Ernst & Sohn, Berlin, 2010.
2. J. Radić et al.: *Betonske konstrukcije – Priručnik*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, Andris, Zagreb, 2006.
3. J. Radić et al.: *Betonske konstrukcije – Riješeni primjeri*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2006.
4. J. Radić et al.: *Zidane konstrukcije – Priručnik*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, Andris, Zagreb, 2007.
5. J. Radić et al.: *Betonske konstrukcije – Građenje*, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu – Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2008.
6. Vollrath, F.; Tathoff, H.: *Handbuch der Brücken – Instandhaltung*, Verlag Bau+Technick GmbH, Düsseldorf 2002.
7. Demetrios E. Tonias, Jim J. Zhao: *Bridge Engineering: Design, Rehabilitation and Maintenance of Modern Highway Bridges*, McGraw-Hill Companies 2007.
8. *Management of bridges/Gestion des ponts*, Highway agency-Service d'Etudes Techniques des Routes et Autoroutes-Transport Research Laboratory-Laboratoire Central des Ponts et Chaussées, Thomas Telford, 2005
9. *Protection of structures against hazards*, Proceedings of the 3rd International Conference organized by CI-Premier Conference Organisation, Venice, Italy, 28-29 September 2006, Ed.: C. Majorana, V. Salamoni, T. S. Lok
10. Rücker, W., Hille, F., Rohrmann, R. : F08a - Guideline for the Assessment of Existing Structures, SAMCO Final Report 2006, Federal Institute of Materials Research and Testing (BAM), Division VII.2 Buildings and Structures, Berlin, Germany
11. Durability and Maintenance of Concrete Structures, Proceedings of the International Symposium organized by CSSE and ASCCT, Dubrovnik, Croatia, Oct 21-23, 2004, Ed.: J. Radić, SECON HDGK, 2004.

TALL BUILDINGS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (design: 7, construction: 8)

Course objectives:

- Acquisition of theoretical knowledge about structural systems of high-rise buildings,
- Acquisition of general knowledge about the architecture and equipment of tall buildings,

- Acquisition of practical knowledge about designing the structure of a building made of steel and/or concrete elements.

Entry competences (prior knowledge, descriptive):

- Knowledge of technical mechanics: statics and dynamics of structures,
- Knowledge of the basics of designing concrete and steel structures.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Concrete and Masonry Structures 2, Metal Structures 3.

Prerequisite for taking the exam:

- Course exam passed: Concrete and Masonry Structures 2, Metal Structures 3.

Learning outcomes:

- Recognize the constructive systems of tall buildings made of concrete and/or steel,
- Recognize the requirements of purpose, location, safety, special architectural features and other conditions that affect the structural design of a tall building,
- Explain the way of transferring horizontal and vertical actions to the load-bearing structure of tall buildings, with an emphasis on the actions of wind and earthquakes,
- Apply previously acquired knowledge of concrete and steel constructions on practical examples of complex structures of high-rise buildings,
- Conceptualize and calculate with approximate methods the constructive system of the building according to the given architectural idea.

Course content (by course schedule):

- Lectures:
  1. Historical overview and examples of exceptional tall buildings [2]
  2. Structural systems and structural behaviour of tall buildings [2]
  3. Design requirements, vertical actions, wind action [2]
  4. Characteristics of seismic and fire design of concrete tall buildings [2]
  5. Characteristics of earthquake and fire design of steel tall buildings [2]
  6. Frame structural systems of tall buildings made of concrete [2]
  7. 1st midterm exam [2]
  8. Frame structural systems of tall buildings made of steel [2]
  9. Shear wall structural systems[2]
  10. Tube structural systems [2]
  11. Special, complex and mixed structural systems [2]
  12. Floor structures [2]
  13. Numerical modelling of concrete structural systems of tall buildings [2]
  14. Numerical modelling of steel and composite structural systems of tall buildings [2]
  15. 2nd midterm exam [2]
- Exercises:
  1. Program assignments, Disposition of tall buildings, Technical description, Preliminary dimensioning of elements, Load analysis Part 1 (permanent, useful, snow, wind, imperfections) [1]
  2. Load analysis Part 2 (earthquake) [2]
  3. Control of disposition and load analysis [2]
  4. Analysis of building stability and horizontal load distribution [2]
  5. Control of building stability and vertical load distribution [1]
  6. Stress check [1]
  7. Control of stress check [1]

8. Dimensioning of structural elements [2]
9. Control of dimensioning of structural elements [2]
10. Submission and oral examination of the program assignment [1]

Student Evaluation - Continuous assessment:
- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:
- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:
1. Vlašić, A.; Puž, G.; Skokandić, D.: Skripta iz kolegija Visoke građevine, Građevinski fakultet Sveučilišta u Zagrebu, 2018.
2. Vlašić, A.; Lukačević, I.: Off-prints from lectures and exercises, 2022-2023.

Additional reading:
1. Stafford Smith, B.; Coull, A.: Tall Building Structures, Analysis and Design, John Wiley & Sons, 1991.
2. Bungale S. Taranath: Reinforced Concrete Design of Tall Buildings, CRC Press Taylor & Francis Group, 2010.
3. Bungale S. Taranath: Structural analysis and design of tall buildings - Steel and composite construction, CRC Press Taylor & Francis Group, 2012.

STRUCTURAL TESTING

Credits (ECTS): 4.5

Hours (total per semester):
- Lectures: 30
- Exercises (laboratory): 15

Course objectives:
- Deepening of theoretical and practical knowledge about the behaviour of structures under real loads,
- Learning about modern measuring equipment and methods in the field of testing building structures.

Entry competences (prior knowledge, descriptive):
- Knowledge of procedures for determining forces in structures,
- Knowledge of stress and deformation calculations due to longitudinal and transverse forces, torsion moment and bending moment,

- Knowledge of basic procedures for analysis and dimensioning of structures (concrete, metal, wood).

Learning outcomes:

- Analysing the behaviour of structural elements and load-bearing systems based on the conducted tests,
- Understanding the behaviour of structures under static and dynamic loading, environmental influences and rheological changes in the material,
- Selection and application of equipment, procedures and methods in structural testing,
- Planning procedures for proving the safety of structures,
- Assessment of the condition of structures and structural elements based on the conducted tests,
- Proving the ability of structures and structural elements to take on the expected loads.

Course content (by course schedule):

- Lectures:
  1. Introduction. The purpose of structural testing. Classification of tests. Scientific and research. Control. Laboratory. Static and dynamic. Short-term and long-term [2]
  2. Mechanical and geometric quantities that are measured during structural testing. Absolute displacement of the point of structure. Change in the spacing of points of structure (deformation). Angle of rotation. Curvature. Relative deformations [2]
  3. Measurement of mechanical and geometric quantities. Elements of accessories. Enlargement. Accuracy. Reliability. Hysteresis. Sensitivity. Measurement area [2]
  4. Measurement of mechanical and geometric quantities. Accessories for measuring: displacements, length changes (tensiometers), angle changes, curvature changes. Calibration of accessories [2]
  5. Tensometry. Classification of tensiometer types: mechanical, optical-mechanical, optical, acoustic, electrical [2]
  6. Electrical resistance strain gauges (ERSG) Types. Method of installation and connection. Sets of measuring instruments. Creation of auxiliary devices for measuring displacement, acceleration, pressure forces, etc. [2]
  7. Analysis of plane state of stress by measuring deformations. Uniaxial state of stress. Biaxial state of stress. Biaxial stress state with known principal stress directions. General biaxial stress state. Rosettes. Triaxial state of deformation and stress [2]
  8. Methods of analysing the state of deformation and stress of structures and their elements. Photoelasticity. Moire method. Process with brittle lacquers [2]
  9. Methods of analysing the state of deformation and stress of structures and their elements. Holographic methods. Geodetic surveying. Modelling [2]
  10. Material verification procedures and characteristics of the tested structure. Core extraction. Ultrasound. Sclerometer. Radiographic imaging [2]
  11. Static testing of structures. Design. Execution [2]
  12. Static testing of structures. Loading mode. Result evaluation. Norms and conditions of construction validity [2]
  13. Dynamic testing. Design. Execution. Loading mode and dimensions to be measured [2]
  14. Dynamic testing. Dynamic parameters of structures. Assessment of measurement results [2]

15. Submission of the seminar paper containing an overview, results and analysis of the conducted laboratory testing [2]

- Exercises (laboratory):
  1. Presentation and description of instruments for static and dynamic tests [1]
  2. Measurement of the same quantity with a portable comparator (determining the accuracy of the instrument). Dose calibration for force measurement (determining the instrument constant). Calibration of the inductive sensor (LVDT) for displacement measurement (determining the instrument constant) [3]
  3. Measurement of deformations and deflections on grids and walls with openings (plexiglass models) [2]
  4. Photoelastic method [2]
  5. Display and description of instruments for static and dynamic tests. [2]
  6. Determination of dynamic parameters (natural frequencies, damping coefficients and modal shapes) on models and structures. [2]
  7. Description and presentation of examples of structural testing in the Laboratory and data processing and analysis. [3]

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. D. Damjanović: *Testing Structures – Lecture notes*, http://www.grad.unizg.hr/predmet/ispkon
2. A. Kiričenko et al.: *Mjerenje deformacija i analiza naprezanja konstrukcija*, DIT-Zagreb, Zagreb, 1982.
3. D. Aničić: *Ispitivanje konstrukcija*, Osijek, 2002.

Additional reading:

1. Alfirević, S. Jecić: *Fotoelasticimetrija*, Liber, Zagreb, 1983.
2. V. Brčić, R. Čukić: *Eksperimentalne metode u projektiranju konstrukcija*, Građ. knjiga, Beograd, 1988.
3. Aničić, D.: Ispitivanje konstrukcija, Osijek 2002.
4. Papoulis, A.: Probability, random variables and stochastic processes, McGraw-Hill, Singapore, 1987.
5. Rohrbach, C.: Handbuch für experimentelle Spanungsanalyse, VDI, Düsseldorf, 1989.
6. Helstrom, C. W.: Probability and stohastic processes for engineers, Macmilan, New York, 1984.

ENGLISH IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45

Course objectives:

- Acquisition of vocabulary with an emphasis on terminology related to structures, creating one's own lexis of specialized terms,
- Writing resumes, job applications, gaining independence in oral presentation, giving presentations.

Entry competences (prior knowledge, descriptive):

- Intermediate and upper-intermediate English.

Learning outcomes:

- Acquisition of language competences that include handling professional terminology from the field of structures,
- Independent reading of specialized literature,
- Reinforcement of basic grammatical categories in professional language – use of the passive voice, past tenses, modal verbs,
- Gaining fluency in structuring sentences and developing skills of delivering individual presentation and writing technical texts.

Course content (by course schedule):

1. Career in Structural Engineering - Varieties in the field of structural engineering [3]
2. Bridge Building - Damages in Arch Building [3]
3. Europe's Longest Viaduct [3]
4. Wembley Stadium [3]
5. Weak Points of the House [3]
6. At the Heart of Dome's Design Process [3]
7. Joint students' presentations [3]
8. Individual students' presentations [3]
9. The Story of the Dome [3]
10. Hyatt Hotel Collapse [3]
11. Terminology practice in Timber Structures I [3]
12. Career Job Hunting – avoiding potential job(interview) disasters – Tips and Advice [3]
13. Creating a CV - How to write a CV? How to write a letter of application/Job Interview Questions [3]
14. Professional Development. Preparing for the Interview Skills –Techniques, Tips and Advice - Recruitment of graduates [3]
15. Preliminary exam [3]

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Alemka Kralj Štih: *English for Structural Engineering and Theory and Modelling of Structures*, course materials, Zagreb, 2014.

Additional reading:

1. Williams: *English for Science and Engineering*, Thomson ELT, USA, 2007.
2. V. Lambert, W. Murray: *Everyday Technical English*, Essex, 2003.

GERMAN IN CIVIL ENGINEERING 2

See Chapter **Specialisation in Geotechnics.**

2nd year, 4th semester

Mandatory courses

SPECIAL ENGINEERING STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (design: 7, construction: 8)

Course objectives:

- Acquisition of theoretical knowledge about the special engineering structures in terms of the use of suitable materials, analysis of actions, design and construction of details, structural design and foundations,
- Acquisition of theoretical and practical knowledge on design, analysis of actions, calculation, detailing and production of workshop and reinforcement drawings of buildings such as a telecommunications tower, mast or water tower.

Entry competences (prior knowledge, descriptive):

- Knowledge of constructions in terms of properties of different materials and calculation of basic elements,
- Knowledge of encompassing different effects on structures.

Learning outcomes:

- Theoretical knowledge of the specifics of engineering structures such as shells, tensile structures, tall buildings, towers, chimneys, masts, wind farms, water towers, telecommunication structures, suspension, movable and floating bridges and submerged tunnels,
- The ability to design special engineering structures,
- Knowledge and skills necessary for analysing effects of wind and earthquake on special structures,
- Knowledge and ability to design special engineering structures in accordance with contemporary methods and criteria of European standards.

Course content (by course schedule):

- Lectures:
  1. Tall buildings – constructive systems, systems for horizontal actions, stiffening systems [2]
  2. Towers, chimneys, masts, wind farms – general, types, function, examples [2]
  3. Concrete towers – foundation, dimensioning [2]
  4. Shells – theory of shells, types, calculation, examples [2]
  5. Tensile structures – form finding, materials [4]
  6. Water towers – function, forms, construction, seismic calculation of liquid tanks [2]
  7. 1st midterm exam
  8. Steel towers, masts, chimneys – design [2]
  9. Telecommunication structures – calculation of masts with stay cables, demolition of masts with stay cables and towers, foundation [2]

10. Movable bridges – types, design examples, construction, maintenance [2]
11. Floating bridges – types, design examples, construction, maintenance [2]
12. Submerged tunnels [2]
13. 2nd midterm exam
14. Retest

- Exercises:
  1. Concrete towers, Details about the assignment for exercises, Giving the assignment [2]
  2. Analysis of actions [1]
  3. Creating a layout drawing [2]
  4. Analysis of actions [2]
  5. Assessment of bending moments according to the 2nd order theory, Dimensioning. Foundation design [3]
  6. Nonlinear analysis using software [4]
  7. Submission of program assignments [1]

Student Evaluation - Continuous assessment:

- All parts of the program assignment submitted within the prescribed deadline and the final submission of the complete program assignment with oral exam within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- All parts of the program assignment submitted within the prescribed deadline and the final submission of the complete program assignment with oral exam within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam – a minimum score of 60%

Required reading:

1. Z. Šavor, A. Mandić: *Special Engineering Structures*, lectures published online, Zagreb, 2011/2012 A. Mandić Ivanković publication of the latest lectures during 2023/2024.
2. Off-prints from the exercises published online

Additional reading:

1. Smith, B. V., *Communication Structures*, Thomas Telford, 2007.
2. Turmbauwerke, *BetonKalender 2006 Teil 1*, Ernst & Sohn, 3-517.
3. Lewis, W. J., *Tension Structures Form and Behaviour*, Thomas Telford, 2003.
4. Huntigton, C. G., *TheTensioned Fabric Roof*, ASCE Press, 2004.
5. Schlaich, J., Bergermann, R., *Leicht weit Light Structures*, Prestel.
6. *Widespan Roof Structures*, compiled by M. Barnes & M. Dickson, Thomas Telford, 2000.
7. Petersen, Ch.: *Abgespannte Maste und Schornsteine Statik und Dynamik*, Bauingenieur-Praxis, Heft 76, W. Ernst & Sohn 1970.

8. Irvine, M., *Cable Structures,* MIT Press, Cambridge, Mass., 1981.
9. *Frei Otto Complete Works, Lightweight Construction Natural Design*, Birkhäuser, Architekturmuseum TU München, 2005.
10. Koglin, T.L.: *Movable Bridge Engineering*, John Wiley & Sons, 2003.
11. *Analysis of the submerged floating tunnel concept*, Forum of European National Highway Research Laboratories (FEHRL), Report No. 1996/2a.
12. Watanabe, E.: *Floating Bridges: Past and Present*, Structural Engineering International (SEI), 2/2003.

COMPOSITE STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 15

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of composite structures made of steel and concrete,
- Acquisition of knowledge about the effects of actions on composite structures,
- Acquisition of theoretical and practical knowledge about the dimensioning of composite structural elements: supports, slabs and columns.

Entry competences (prior knowledge, descriptive):

- Knowledge of the statics of a rigid body and connected systems,
- Knowledge of the behaviour of steel and concrete structures,
- Knowledge of theoretical and practical knowledge related to the dimensioning of steel and concrete structural elements and connectors.

Enrolment requirements (prerequisite):

- Course exam passed: Metal Structures 2.

Learning outcomes:

- The ability to apply knowledge about the behaviour of steel and concrete as materials and the influence of that behaviour on the resistance of connected structural elements,
- Recognition of key factors for determining basic actions on composite structures,
- The ability to determine the effects of actions at the level of structural elements of statically determinate and indeterminate systems,
- The ability to determine the calculated resistances of coupled structural elements of supports, beams, slabs and columns related to the limit state of bearing capacity and the limit state of serviceability.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. General information about composite structures [4]
  3. Important factors for the analysis of composite structures [4]
  4. Shear connectors [2]

5. Composite girders [6]
6. Composite plates [4]
7. Composite columns [4]
8. Serviceability limit state [2]
9. Special types of composite structures [2]

- Exercises (construction):
  1. Composite and non-composite action of steel elements [1]
  2. Determination of creep rate [1]
  3. Resistance of shear connectors [2]
  4. Plastic bending resistance of composite girders [2]
  5. Elastic bending resistance of composite girders [2]
  6. Bending resistance of composite girders with partial longitudinal shear connection [1]
  7. Resistance of composite slabs [1]
  8. Resistance of composite slabs – without anchoring at the ends [1]
  9. Resistance of composite slabs – with anchoring at the ends [1]
  10. Pressure resistance of composite columns [1]
  11. Resistance of composite columns to uniaxial bending with compressive force [1]
  12. Resistance of composite columns to biaxial bending with compressive force [1]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Practical part of the written exam
- Theoretical part of the written exam

Required reading:

1. Androić, Dujmović, Džeba: *Čelične konstrukcije 1*, IA Projektiranje, Zagreb, 2009.
2. Horvatić: *Spregnute konstrukcije čelik-beton*, Masmedia, Zagreb, 2003.
3. Ćurković, I.; Lukačević, I.: Off-prints from lectures and exercises - academic year 2020/2021, Faculty of Civil Engineering, University of Zagreb.
4. Markulak, D: *Me(n)talne konstrukcije*, Građevinski fakultet u Osijeku, 2018.
5. Androić, B.; Dujmović, D.; Lukačević, I.: *Projektiranje spregnutih konstrukcija prema Eurocode 4*, IA projektiranje, 2012.
6. Dujmović, D.; Androić, B.; Lukačević, I.: *Primjeri proračuna spregnutih konstrukcija prema Eurocode 4*, IA projektiranje, 2014.

Additional reading:

1. HRN EN 1994-1-1:2012: Design of composite steel and concrete structures -- Part 1-1: General rules and rules for buildings
2. Johnson: *Composite Structures of Steel and Concrete*, Blackwell Publishing, Oxford, 3rd Edition, 2004.

Elective courses

EARTHQUAKE ENGINEERING

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Learning about seismic activity,
- Acquisition of basic knowledge about seismic design of buildings and bridges,
- Acquisition of practical knowledge about seismic design of concrete, steel, masonry and composite structures,
- Acquisition of basic knowledge about the analysis and design of seismically isolated structures.

Entry competences (prior knowledge, descriptive):

- Understanding and ability to apply design of concrete and steel structures,
- Knowledge of basic construction systems,
- Understanding and knowledge of the static calculation of various static systems.

Learning outcomes:

- The ability to conceptually design various structural systems (concrete, steel, masonry and composite structures),
- The ability to observe and analyse seismic effects on buildings by applying modern European standards,
- The ability to conceptually design structures with passive energy dissipation systems,

Course content (by course schedule):

- Lectures:
  1. Nature of earthquakes and basics of seismology [4]
  2. Structural response, basic terms and ductility [2]
  3. Seismic spectrum [2]
  4. Energy concept of earthquake engineering [2]
  5. Conceptual design [4]
  6. Seismic design according to Eurocode 8 [2]
  7. Midterm exam
  8. Design methods [2]
  9. Special rules for concrete and masonry structures [4]
  10. Special rules for steel, timber and composite structures [2]
  11. Research in earthquake engineering [2]
  12. Midterm exam

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Offprints from lectures
2. HRN EN 1998-1:2011/Ispr.1:2014, Eurocode 8: Design of structures for earthquake resistance -- Part 1: General rules, seismic actions and rules for buildings, European Committee for Standardization, Bruxelles.

NUMERICAL MATHEMATICS

See Chapter Shared Courses

PERSPECTIVE

See Chapter Shared Courses

GEOMETRY IN CIVIL ENGINEERING

See Chapter Shared Courses

WAVES AND OSCILLATIONS

See Chapter Shared Courses

ASSESSMENT OF EXISTING BRIDGES

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Acquisition of theoretical and practical skills for a complete approach to the assessment of existing bridges, from the very collection of data on the structure, through appropriate modelling and determination of critical failure modes to proving safety, serviceability, and reliability.
- Application of the contemporary scientific approach in the practical assessment of existing bridges, taking into account the effects of degradation processes, the effects of relevant loads and changes in demands on bridges throughout the entire expected service life of the structures with the aim of easier decision-making in the ranking of priorities at the level of the road network.

Entry competences (prior knowledge, descriptive):

- Basic knowledge of bridge structures (e.g. in accordance with the Bridges course at the undergraduate programme in civil engineering).
- Basic knowledge about the degradation of structures made of different materials and basic knowledge about structural inspections.

Learning outcomes:

- Choose a proactive approach in collecting data on existing bridges in order to evaluate them,
- Model existing bridges by taking into account the collected structural data,
- Analyse and determine the preliminary failure modes of the bridge structure,
- Assessment of existing bridges in accordance with the contemporary understanding of the reliability of structures,
- Prove the load-bearing capacity and serviceability of existing bridges with successive levels that become more demanding but also more accurate, and gradually approach the actual actions and resistances of the structure,
- Include the effects of degradation processes and changing demands on bridges throughout the entire projected service life of the structures,
- Apply the methodology of assessing the relationship between costs and profits in the bridge maintenance system, which contributes to easier decision-making in the ranking of priorities at the level of the road network.

Course content (by course schedule):

- Lectures:
  1. Bridge assessment approaches: condition assessment and/or safety or reliability assessment.
  2. Evaluating key performance indicators: ranking priorities in bridge repair based on condition assessment
  3. Safety and reliability assessment methodology
  4. Evaluating bridges for traffic load: modelling the impact of traffic load through history and standards
  5. Evaluation of bridges for traffic load: monitoring of traffic weight in motion (WIM, B-WIM)
  6. Seismic assessment of existing bridges: shortcomings and hidden reserves on examples of bridges from Croatia
  7. 1st midterm exam (lectures 1-5)

8. Seismic evaluation of existing bridges: characteristic damage, rapid post-earthquake inspections
9. Seismic evaluation of existing bridges: calculation methods, pushover analysis, ductility capacity, fragility curves
10. Evaluation of collected information: ranking of priorities taking into account economic and social indicators, importance of structure and classes of knowledge
11. Repairs and strengthening of bridges: repairs, strengthening to increase load capacity, external prestressing
12. Repairs and strengthening of bridges: to cover seismic demands
13. Bridge failures, forensic engineering and recommendations for robust structures
14. 2nd midterm exam (lectures 6-12)
15. Retest

- Exercises:

As part of the program assignment, modelling and assessment of the existing bridge for traffic load and/or seismic demand.

1. Design: Data collection and reconstruction of the existing bridge
2. Construction: Creating the layout of the bridge and analysis of the existing bridge (time of construction, design loads, details, materials, exposure, condition,...)
3. Construction: Creating the layout of the bridge and analysis of the existing bridge (time of construction, design loads, details, materials, exposure, condition,...)
4. Design: Traffic load analysis and consideration of a suitable structural model and analysis method
5. Design: Understanding of seismic action and selection of a suitable structural model
6. Construction: Load analysis and creation of a bridge model
7. Construction: Load analysis and creation of a bridge model
8. Proving of load capacity and serviceability; Probabilistic assessment of bridge structure exposed to traffic load
9. Construction: Calculation and assessment of the bridge for traffic load
10. Construction: Calculation and assessment of the bridge for traffic load
11. Design: Pushover analysis of the bridge
12. Design: Global assessment of bridge behaviour in an earthquake
13. Construction: Seismic calculation and assessment of the bridge
14. Construction: Seismic calculation and assessment of the bridge
15. Construction: Submission and defence of the program assignment

Student Evaluation - Continuous assessment:

- All parts of the program assignment submitted within the prescribed deadline and final submission of the complete program assignment with oral examination within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam – a minimum score of 60%
- Second midterm exam – a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- All parts of the program assignment submitted within the prescribed deadline and final submission of the complete program assignment with oral examination within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam – a minimum score of 60%

Required reading:

1. Mandić Ivanković A. et al.: Assessment of existing bridges, Lectures and offprints for exercises
2. Radić J. et al.: Betonske konstrukcije, Sanacije, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu, Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2008. (s naglaskom na poglavlje: Radić, Mandić - Ocjenjivanje postojećih konstrukcija)
3. Mandić Ivanković, A.: Assessment of Bridges Based on Updated Information and Monitoring, Croatian Perspectives, pozvano predavanje, Workshop: Assessment of Existing Structures, Joint Committee on Structural Safety, 28-29 January 2021. https://folk.ntnu.no/jochenk/JCSSWS2101/52Ivankovic.pdf

Additional reading:

1. Radić, J.: Uvod u mostarstvo, Hrvatska sveučilišna naklada, Jadring, Zagreb, 2009.
2. Radić, J.; Mandić, A.; Puž, G.: Konstruiranje mostova, Hrvatska sveučilišna naklada, Jadring, Zagreb, 2005.
3. Radić, J.: Trajnost konstrukcija I, Hrvatska sveučilišna naklada, Jadring, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2010.
4. Radić, J. i suradnici: Betonske konstrukcije – priručnik, Hrvatska sveučilišna naklada, Sveučilište u Zagrebu, Građevinski fakultet, SECON HDGK, Andris, Zagreb, 2007.
5. Strauss, Alfred; Mandić Ivanković, Ana: COST 1406 - Performance Indicators for Roadway Bridges, Technical report of the Working group 1: Performance indicators., Guimaraes, Portugal: COST 1406, 2016 (handbook)
6. Holický, M., 2013. Introduction to probability and statistics for engineers. Springer Science & Business Media
7. Wenzel, H., 2008. Health monitoring of bridges. John Wiley & Sons
8. M. J. N. Priestley, F. Seible, G.M.C. Seismic Design and Retrofit of Bridges. New York: John Wiley & Sons, INC.; 1996.Clough, R.; Penzien, J.: *Dynamics Of Structures*, McGraw-Hill, New York, 1975.

EXISTING MASONRY STRUCTURES – ASSESSMENT AND STRENGTHENING

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 14, design: 16)

Course objectives:

- Acquisition of theoretical and practical knowledge about procedures for assessing the condition of existing masonry structures.

- Acquisition of theoretical and practical knowledge on methods of calculating the mechanical resistance and stability of elements or entire existing masonry structures.
- Acquisition of theoretical and practical knowledge about methods and calculation of strengthening of existing masonry structures.
- Acquisition of theoretical and practical knowledge about the application of modern materials in the renovation of masonry structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of structural analysis, resistance of materials, design of masonry structures according to HRN EN 1996 and HRN EN 1998.

Learning outcomes:

- Classify the necessary methods of assessing the condition of existing masonry structures.
- Choose applicable methods in a specific case.
- Plan and apply methods of rehabilitation of masonry structures.
- Recognize the causes of decay and damage to existing masonry structures.
- Assess the condition of the structure and draw conclusions about its restoration or necessary strengthening.
- Analyse all impacts on the existing structure and create an evaluation report on the condition of the masonry structure.
- Apply modern design procedures and materials when strengthening existing masonry structures.
- Apply a probabilistic approach to the assessment of the mechanical resistance and stability of the existing masonry structure.
- Design specific details of the reinforcement of individual masonry structural elements.
- Analyse all impacts on the existing structure and create a project for strengthening of the existing masonry structure.

Course content (by course schedule):

- Lectures:
  1. General information about existing masonry structures [2]
  2. Methods of assessing the condition of existing masonry structures [2]
  3. Special approaches to assessing the condition of existing masonry constructions of cultural heritage [2]
  4. Typical damage to masonry structures during their service life [2]
  5. Behaviour of masonry structures and their damage during seismic actions [2]
  6. Calculation methods of existing masonry structures for seismic actions [2]
  7. A probabilistic approach to assessing the mechanical resistance and stability of the existing masonry structure [2]
  8. Approaches to the global strengthening of the masonry structure [2]
  9. Midterm exam
  10. Calculation of the strengthening of individual elements of masonry structures or the entire structure [2]
  11. Calculation of strengthening using modern materials (FRP, TRM ...) [4]
  12. State of the field and case studies (examples) [2]
  13. The influence of the built environment on the behaviour of individual structures during seismic action [2]

14. Midterm exam

- Exercises:
  1. Familiarization with the exercise program, the assignment and the method of its creation. Defining the masonry structure in question. [2]
  2. Elaboration of the masonry structure in question, preparation of the necessary drawings [2]
  3. Assessment of the conditions of the building – creation of a model in the 3Muri software package [8]
  4. Analysis of calculation results [4]
  5. Selection of the strengthening method of the structure [2]
  6. Calculation of strengthening of structural elements [6]
  7. Creation of implementation reinforcement layouts [4]
  8. Submission of program assignments [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Offprints from lectures and exercises
2. Sorić, Z.: "Zidane konstrukcije", university handbook, self-published, Zagreb, 2016.
3. Technical Regulations for Building Structures (2017)
4. Croatian standards of the HRN EN 1996 series, standards for masonry structures (Eurocode 6)
5. Croatian standards of the HRN EN 1991 series, standards for structural loads (Eurocode 1)
6. Croatian standards of the HRN EN 1998 series, standards for seismic design of structures (Eurocode 1)

ALUMINIUM STRUCTURES

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (construction)

Course objectives:

- To acquire theoretical knowledge of aluminium structures; their design and production.
- To acquire theoretical and practical knowledge about the selection process of aluminium alloys, modern design of structural aluminium members, joints and complex structural systems.

Entry competences (prior knowledge, descriptive):

- Knowledge of structural analysis procedures.
- Knowledge of the basics of the design of steel structures.

Learning outcomes:

- Select the optimum aluminium alloy considering the specific application requirements.
- Determine the optimum structural system considering the specific requirements of application.
- Select and apply the appropriate method of analysis of aluminium structure.
- Design aluminium structural members and their joints according to the rules of Eurocode 9.
- Analyse and preliminary design spatial and innovative aluminium structural systems.
- Evaluate the requirements for durability and execution of aluminium structures.

Course content (according to course schedule):

- Lectures:
  1. Introduction. Field of application. Historical development of aluminium structures. [2]
  2. Production of aluminium and aluminium alloys; of heat treatment, product forms, characteristic properties. [2]
  3. Selection of aluminium alloys for construction. [2]
  4. Introduction to Eurocode 9 and the relationship to other standards. [2]
  5. Analysis of aluminium structures and basis of limit state design. [2]
  6. Fundamentals of the design of aluminium structures: classification of the cross-sections, heat-affected zone and softening of the material. [2]
  7. Calculation of resistance at cross-sectional level: tension, compression, bending, shear, torsion, interaction of effects of actions. [2]
  8. Calculation of resistance at the member level: compression, bending, interaction of bending and longitudinal compression. [2]
  9. Connection technology and design of joints. [2]
  10. Calculation of the resistance of slabs and plate girders. [2]
  11. Structural fire design. [2]
  12. Fatigue design. [2]
  13. Fundamentals of design of spatial aluminium systems and innovative structural solutions. [2]
  14. Durability requirements; corrosion resistance. [2]
  15. Rules for the manufacture and assembly of aluminium structures. [2]
- Exercises:
  1. Design of tension members [4]
  2. Design of compression members [4]
  3. Design of members subjected to bending [4]
  4. Design of complex stressed members [4]
  5. Design of connections [2]

6. Design of joints [4]
7. Design of plate girders [4]
8. Fatigue design [4]

Student Evaluation - Continuous assessment:

- Preparation and defence of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and defence of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Practical part of the written exam
- Theoretical part of the written exam

Required reading:

1. Boko, Ivica; Skejić, Davor; Torić, Neno: ALUMINIJSKE KONSTRUKCIJE, Sveučilište u Splitu, Fakultet građevinarstva, arhitekture i geodezije, Udžbenik Sveučilišta u Splitu i Udžbenik Sveučilišta u Zagrebu, Split, 2017.
2. Skejić, Davor; Džeba, Ivica: ČELIČNE KONSTRUKCIJE, Sveučilište u Zagrebu, Građevinski fakultet, Sveučilišni priručnik, Zagreb 2015.
3. Skejić, Davor; Boko, Ivica; Torić, Neno: ALUMINIJ KAO MATERIJAL ZA SUVREMENE KONSTRUKCIJE, Građevinar 67 (2015)11. 1075-1085.
4. Boko, Ivica; Skejić, Davor; Torić, Neno; Čolić, Antonela: OPTIMALNI IZBOR LEGURE ZA ALUMINIJSKE KONSTRUKCIJE IZLOŽENE POŽARU, Građevinar 72 (2020)3. 225-235.
5. Skejić, Davor, Orehovec, Domagoj, Ćurković, Ivan. MONTAŽNE ALUMINIJSKE HALE, Građevinar 73 (2021)2, 141-151.
6. Skejić, D.: *Lecture notes from the course Aluminum Structures* - academic year 2023/2024, Faculty of Civil Engineering, University of Zagreb

Additional reading:

1. Croatian Standards Institute (HZN): HRN EN 1999-1-1, Eurocode 9: Design of aluminium structures -- Part 1-1: General structural rules (EN 1999-1-1:2007+A1:2009+A2:2013), second edition, Croatian Standards Institute, Zagreb, 2015.
2. *Design of aluminium structures - Introduction to Eurocode 9 with worked examples*, European aluminium, November 2020.
3. Skejić, D.; Dokšanović, T.; Čudina, I.; Mazzolani, F. M.: *The basis for reliability-based mechanical properties of structural aluminium alloys*, Applied Sciences-Basel 11 (2021)10. 4485:1-18.
4. Skejić, D.; Valčić, A.; Čudina, I.: *Optimisation of Aluminium Halls in the Republic of Croatia - Numerical Study*, Technical Gazette 29 (2022)5, 1454-1463.

STRUCTURAL DESIGN OF FACADES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (4 design + 26 construction)

Course objectives:

- Acquisition of theoretical and practical skills in designing modern facades.
- Understanding the scientific approach in designing facade structural systems,
- Acquisition of theoretical and practical knowledge on defining loads and failure scenarios with an emphasis on sufficient robustness of facade systems,
- Acquisition of theoretical and practical knowledge on the design of the details of the connections of facade elements and the design of joints and connectors of the facade to the substructure,
- Acquisition of practical knowledge in the field of facade technology and acquiring knowledge about using specialized software packages for the preparation of blueprints for robotic fabrication (production) of facades.

Entry competences (prior knowledge, descriptive):

- Basic knowledge of aluminium structures and glass structures (e. g. in accordance with the course Lightweight structures in the undergraduate programme in civil engineering).
- Basic knowledge of concrete, metal and wooden structures and joints (e. g. in accordance with the courses Concrete and Masonry Structures 1, Metal Structures 1 and Timber Structures 1 in the undergraduate programme in civil engineering).

Learning outcomes:

- Independently solve structural problems of facade systems
- Apply and analyse mathematical methods in modelling facade systems.
- Apply knowledge about the structural behaviour of materials from which facade elements are made.
- Review and evaluate the production and assembly processes of the facade system, and calculate and prove the load-bearing capacity, stability, usability and safety of the structure for each phase.
- Gather missing information through literature and online research.
- Analyse and discuss project solutions for facade systems with colleagues and experts in the field.
- Apply knowledge to practical problems and critically analyse the obtained results.

Course content (by course schedule):

- Lectures:
  1. Current situation: overview of historical and modern facade systems [2]
  2. Basic specific static systems of facades and their characteristics [2]
  3. Basics of structural planning, application of concepts according to HRN EN: 1990, with an emphasis on designing according to consequence classes while meeting robustness conditions [2]

4. Basics of defining the load on facade systems according to the series HRN EN 1991 [2]
5. Defining the process of building facade systems - planning phase, concept phase, elaboration phase, production phase. Defining the function. Defining the input data for designing the facade construction. [2]
6. Calculation methods (linear and non-linear) and procedures for proving load-bearing capacity, stability, usability and robustness for each of the phases of construction and exploitation of facade systems. [6]
7. Connectors and joints when connecting elements. Conceptual elaboration and dimensioning of welded and bolted joints - application of EUROCODE 3, EUROCODE 5 and EUROCODE 9. [2]
8. Connectors and joints when anchoring the substructure. Conceptual development and dimensioning of anchor plates and anchor areas in concrete and other elements - application of EUROCODE 2, EUROCODE 3, EUROCODE 5 and EUROCODE 9. [2]
9. Numerical modelling of the facade construction - modelling of the system, individual elements and joint details. [4]
10. Drawing implementation projects in specialized software packages connected to machines for making elements. [4]
11. Regulations for designing and testing methods of facade systems in factory conditions. [2]

- Exercises (design):
  1. Description of the assignment. [2]
  2. A visit to the company KFK d.o.o. so the students learn about the entire process of production and testing of facades. [2]
- Exercises (construction):
  1. As part of the design assignment (program), designing the concept of the modern facade, dimensioning the elements of the facade, designing and dimensioning the connection details, and creating the implementation drawings of the facade and its testing program. [22]
  2. Review and submission of program assignments. [2]
  3. Presentation and defence of design assignments (programs) of students. [2]

Student Evaluation - Continuous assessment:

- Preparation of the program assignment
- Preparation of the seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exams
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of the program assignment
- Preparation of the seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Written exam covering the entire course content if the student did not pass midterm exams

- Oral exam

Required reading:

1. Androić, B.; Dujmović, D.; Džeba, I.: *Čelične konstrukcije 1*; IA Projektiranje, Zagreb, 2009.
2. Bjelanović, A.; Rajčić, V.: *Drvene konstrukcije prema europskim normama*; Hrvatska sveučilišna naklada, Zagreb, 2007.
3. Boko, I.; Skejić, D.; Torić, N.: *Aluminijske konstrukcije*, Udžbenici Sveučilišta u Splitu i Udžbenici Sveučilišta u Zagrebu, Split, 2017.
4. Technical regulations for glass structures (Official Gazette of the Republic of Croatia No. 153/13 and 20/17)
5. Čizmar, D., Rajčić, V.: *Priručnik iz kolegija Lagane konstrukcije*; Građevinski fakultet Sveučilišta u Zagrebu, Zagreb. 2008.
6. Herzog, T.; Krippner, R.; Lang, W.: *Facade Construction Manual* (Third Edition), Detail Business Information GmbH, Munchen, 2021.
7. Course materials are available on the official website of the course

Additional reading:

1. CEN: series of European standards *HRN EN 1992:2013+A1:2019+NA:2015*; CEN, Brussels, 2013.
2. CEN: series of European standards *HRN EN 1993:2014+A1:2015+NA:2018*; CEN, Brussels, 2014.
3. CEN: series of European standards *HRN EN 1995:2013+A2:2015+NA:2013*; CEN, Brussels, 2013.
4. CEN: a series of European standards *HRN EN 1999:2015+A1:2012+NA:2013*; CEN, Brussels, 2015.
5. O'Regan, C.: *Structural use of glass in buildings (Second Edition)*; The Institution of Structural Engineers, London, 2014.
6. Loughran, P.*: Falling Glass - Problems and Solutions in Contemporary Architecture;* Birkhäuser, Basel, Boston, MA, 2003.
7. CEN: *CEN TC 250 - TS 19100-1:2020: Design of glass structures - Part 1: In-plane loaded glass components*; CEN, Brussels, 2020.
8. CEN: *CEN TC 250 - TS 19100-2:2020: Design of glass structures - Part 2: Out-of-plane loaded glass components*; CEN, Brussels, 2020.
9. CEN: *CEN TC 250 - TS 19100-3:2020: Design of glass structures - Part 3: Design of in-plane loaded glass components and their mechanical joints*; CEN, Brussels, 2020.
10. Watts, A: *Modern Construction Envelopes* (Fourth Edition); Birkhäuser, 2019.

Specialisation in CONSTRUCTION MATERIALS

1st year, 1st semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

THEORY AND TECHNOLOGY OF CONCRETE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 14 (auditory: 8, laboratory: 6)
- Seminars: 16

Course objectives:

- Understanding the process of hydration and hardening of concrete,
- Understanding the microstructure of concrete and moisture transport within the concrete structure,
- Acquisition of knowledge necessary for the correct selection of the components of the concrete composition, appropriate preparation, laying and compaction in order to ensure the properties of concrete in a fresh and hardened state in use for the intended purpose (performance-based design),
- Acquisition of knowledge about the thermo-hygrometric, mechanical and deformation properties of concrete as a basis for knowledge about the behaviour of the structure,
- Familiarization with the basic properties of special types of concrete,
- Acquisition of knowledge about directions of research in the field of concrete technology in the future.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic properties of components for making concrete,
- Knowledge of concrete composition calculations.

Learning outcomes:

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

- Design the composition of concrete for the required properties in use (proven by tests on the structure),
- Make designed concrete at a concrete plant,
- Create a quality assurance plan for concrete structure performance,

- Demonstrate testing of the properties of concrete in the fresh state and certain properties in the hardened state,
- Evaluate the influence of components and production technology on the properties of concrete in its fresh and hardened state,
- Evaluate the results of concrete properties testing,
- Distinguish types and basic properties of special concrete,
- Know the direction of research in the field of concrete in the future.

Course content (by course schedule):

- Lectures:
  1. Introduction [2]
  2. Components of concrete composition: Cement – classification according to types and production technology, production, hydration, binding, hardening, quality assurance [2]
  3. Components of concrete composition: Aggregate – significance, classifications, types, mineralogy, texture, granulometric structure. Water [2]
  4. Concrete components: Additives to concrete, classifications, significance, types, influence on concrete properties [2]
  5. Fresh concrete – properties and their significance. Concrete composition design [2]
  6. Structure of hardened concrete [2]
  7. Strength and stress states in concrete [2]
  8. Dimensional stability [4]
  9. Durability/Effects – special permanent loads, causes of concrete degradation and consequences [2]
  10. Concrete production. Transport, laying, compaction and curing of concrete [2]
  11. Modelling of concrete properties, the most important computer models, explanation, application [2]
  12. Special concretes – new types and technologies [4]
  13. The future of concrete – achievements and perspectives in properties and application [2]
- Auditory exercises:
  1. Projecting the quality of concrete construction materials – choice of constituent materials – cement [2]
  2. Projecting the quality of concrete construction materials – choice of constituent materials – aggregate [2]
  3. Projecting the quality of concrete construction materials – choice of constituent materials – additions, properties of fresh concrete [2]
  4. Hardened concrete. Control and quality assurance of concrete construction. [2]
- Laboratory exercises:
  1. Creation of project assignment – cement [1]
  2. Creation of project assignment – aggregate [1]
  3. Designing the composition of concrete using computer software [1]
  4. Preparation of the project assignment – design of the composition, production of concrete and testing of its properties in the fresh state [1]
  5. Preparation of the project task – examination of the mechanical properties of concrete and durability properties of concrete [2]
- Seminar [16]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of s seminar paper within the prescribed deadline
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of s seminar paper within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. Bjegović, D.; Štirmer, N.: Teorija i tehnologija betona, udžbenik Sveučilišta u Zagrebu, Tiskara Zelina, 2015.
2. Teorija i tehnologija betona Mjerne metode, Bjegović, D.; Štirmer, N. (ur.), udžbenik Sveučilišta u Zagrebu, Tiskara Zelina, 2022.
3. Bjegović, D., Balabanić, G., Mikulić, D.: Građevinski materijali - zbirka riješenih zadataka, Građevinski fakultet Sveučilišta u Zagrebu, 2007.
4. Mehta, P. K.; Monteiro, P. J. M.: Concrete: Microstructure, Properties, and Materials, McGraw-Hill, fourth edition, 2014.
5. Domone, P.; Illston, J. (eds): Construction Materials: Their Nature and Behaviour, Fourth Edition, Spon Press, 2010

Additional reading:

1. Ashby, M. F.; Jones, D. R.: *Engineering materials 1*, Butterworth Heinemann, 1996.
2. Illston, J. M.; Domone, P. L. J. (ed.): *Construction materials – their nature and behaviour*, E & FN SPON Chapman & Hall, 1994.
3. Maekawa, K.; Chaube, R. P.; Kishi, T.: *Modelling of Concrete Performance*, Hydration, Microstructure and Mass Transport, Spon Press, 2000.
4. Dewar, J.: *Computer modelling of Concrete Mixtures*, Spon Press, 2000.
5. Muravljov, M.: *Osnovi teorije i tehnologije betona*. 3 izdanje. Građevinska knjiga, Beograd, 2005.
6. Grdić, Z.: *Tehnologija betona*, GAF, Niš, 2011.

BUILDING PHYSICS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 16, construction: 8, laboratory: 6)

Course objectives:

1. Acquisition of theoretical knowledge about the combined transfer of heat, moisture and air through building materials and structural elements,

2. Acquisition of practical knowledge about laboratory tests of thermal and acoustic properties of materials,
3. Acquisition of knowledge about the calculation of thermal and acoustic characteristics of the structure.

Entry competences (prior knowledge, descriptive):

4. Knowledge of physical, mechanical and thermal properties of materials,
5. Knowledge of the basics of statistics.

Learning outcomes:

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

- Describe the production technology of various construction materials,
- Explain the methods of testing hygrothermal and acoustic properties of insulating building materials,
- Explain the mechanisms of environmental action on insulating materials,
- Design the hygrothermal and sound protection of buildings,
- Compare the properties of different insulating materials,
- Apply the test results of insulating building materials.

Course content (by course schedule):

- Lectures:
  1. Introduction to construction physics. Definition, importance, history [2]
  2. Heat: Basic terms of the science of heat. Heat transfer – conduction, convection, radiation, solar radiation [2]
  3. Thermal properties of building materials [2]
  4. Thermal insulation of building elements. Temperature curve. Heat accumulation [2]
  5. Moisture transport. Moisture, moist air. Condensation of water vapour on the inner surface of external building elements [2]
  6. Diffusion of water vapour through building elements [2]
  7. Combined transport – heat, air, moisture [2]
  8. Thermal bridges [2]
  9. Thermal stability of external building elements [2]
  10. Acoustics: Physical characteristics of sound. Sound waves in closed space [2]
  11. Building materials for noise protection. Contemporary materials [2]
  12. Transmitting airborne sound from room to room. Transmission of impact sound from room to room [2]
  13. Noise. Noise protection. [2]
  14. Sound insulation and sound insulation calculation methods [2]
  15. Use of insulating materials in practice. [2]
- Exercises:
  1. Examples of problem solving - thermal problems [2]
  2. Using BIM for designing NZEB [2]
  3. Creating a BIM model of the NZEB building [2]
  4. Examples - Mass transport problems [4]
  5. Phases of the project elaboration, giving out program assignments [2]
  6. Numerical calculation of thermal bridges [2]
  7. Thermotechnical systems in buildings [2]
  8. Working with software for Construction Physics [2]
  9. Tour of the IGH laboratory for construction physics [2]
  10. Thermal imaging camera and air permeability testing [2]

11. Moisture [2]
12. Noise [4]
13. Examples - noise in buildings [2]

Student Evaluation - Continuous assessment:

- Program assignment submitted within the prescribed deadline and positively evaluated
- Completed assignments through the e-learning system
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam – a minimum score of 50%
- Second midterm exam – a minimum score of 50%
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Program assignment submitted within the prescribed deadline and positively evaluated
- Completed assignments through the e-learning system
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:
Course materials available on the Moodle e-learning system.

1. ŠIMETIN, Vladimir: Građevinska fizika - GI, Fakultet građevinskih znanosti Sveučilišta u Zagrebu, Zagreb 1983
2. Vadas, Tatjana; Tepavac-Kocijan, Ljiljana; Milovanović, Bojan Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere / Krovopokrivač / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016
3. Ciglar, Ivan; Delladio, Snježana; Milovanović, Bojan Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere / Tesar / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016
4. Kalšan, Darinka; Milovanović, Bojan Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere / Monter suhe gradnje / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016
5. Kalšan, Darinka; Milovanović, Bojan; Hrvatska udruga proizvođača toplinsko-fasadnih sustava Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere / Fasader / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016
6. Lukman, Tatjana; Plavljanić, Đurđa; Milovanović, Bojan Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere / Soboslikar Ličilac / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016
7. Lukman, Tatjana; Kalšan, Darinka; Milovanović, Bojan Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere / Zidar / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016
8. Lukman, Tatjana; Kalšan, Darinka; Plavljanić, Đurđa; Milovanović, Bojan; Carević, Ivana; Ćurković, Katarina; Grgurić, Silvija; Ivanović, Marija; Hrvatska udruga proizvođača toplinsko-

fasadnih sustava Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti – Zajednički dio / Banjad Pečur, Ivana (ur.). Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2016

Additional reading:

1. HENS, Hugo; Building Physics - Heat, Air and Moisture: Fundamentals and Engineering Methods with Examples and Exercises, Wiley-VCH, 20083. Third book
2. HAGENTOFT, Carl-Eric: Introduction to Building Physics - Studentlitteratur AB, 20014.
3. MONOGRAFIJA: Građevinska fizika i materijali - Jugoslovensko društvo za ispitivanje i istraživanje materijala i konstrukcija, Beograd, 2003
4. GALOVIĆ, Antun: Termodinamika I - Fakultet strojarstva i brodogradnje, Zagreb : 2004
5. GALOVIĆ, Antun: Termodinamika II - Fakultet strojarstva i brodogradnje, Zagreb : 2003
6. KULIŠIĆ, Petar: Mehanika i toplina - Školska knjiga Zagreb, 2005
7. STAUFENBIEL, Georg; WESSIG, Josef: Bauphysik und Baustofflehre – eine Einfuhrung in Experimenten - Bauverlag BV GmbH 1989
8. PORGES, George: Applied Acoustics - Peninsula Publishing; 1987
9. BURNS, William: Noise and Man - John Murray Publishers Ltd; 1973
10. BRANDT, Jörg; MORITZ, Helmut: Bauphysik nach Maß - Vbt Verlag Bau U. Technik 2003
11. AMMERER, Walter F.: Wärme- und Kälteschutz im Bauwesen und in der Industrie - Springer, Berlin 2002
12. GASKELl, David: Introduction to the Thermodynamics of Materials, Taylor & Francis, London 1995

POLYMERS

See Chapter Specialisation in Theory and Modelling of Structures.

MECHANICS OF MATERIAL

See Chapter Specialisation in Theory and Modelling of Structures.

Elective courses

MATHEMATICS 3

See Chapter Shared Courses

STOCHASTIC PROCESSES

See Chapter Shared Courses

1st year, 2nd semester

Mandatory courses

DURABILITY OF CONSTRUCTION MATERIALS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 26 (auditory: 12, construction: 10; laboratory: 4)
- Seminar: 4

Course objectives:

- Acquisition of extended theoretical and practical knowledge about the behavior of structures under environmental loads during their service life,
- Training for distinguishing different mechanisms of the deterioration of construction materials and linking the causes and consequences of individual environmental loads with the help of own knowledge and modern scientific trends.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic properties and composition of construction materials,
- Knowledge of the basic mechanisms of transport and exchange of substances within the material,
- Knowledge of the basics of chemical reactions between materials and the environment.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Theory and Technology of Concrete.

Learning outcomes:

- Deepened and expanded knowledge about degradation processes (chemical, physical, mechanical and biological) of construction materials and special permanent loads from the environment,
- Independent creation of a project for the assessment of the condition and maintenance of the structure depending on the type of construction material and the calculation of the service life of the construction materials,
- Recommend to target groups new methods of preventive protection with construction materials depending on the type of construction and environment,
- Ability for cross-professional/interdisciplinary research (civil engineering, chemistry, electrochemistry, wood technology, mechanical engineering, etc.).

Course content (by course schedule):

- Lectures:
    1. Introduction, classification and properties of construction materials, generally about mechanics of the durability of structural materials [2]
    2. Mechanism of metal corrosion [2]
    3. Protection of metals from corrosion [2]
    4. Strategy for designing the durability of materials with metal structures [2]
    5. Mechanism of degradation and protection of stone and polymer [2]
    6. Degradation mechanism and protection of wood [2]
    7. Midterm exam

8. Mechanism of degradation and protection of glass [2]
9. Mechanism of degradation and protection of masonry [2]
10. Mechanics of durability of concrete [4]
11. Protection of concrete and reinforced concrete [2]
12. Strategy for design of durability of materials in RC structures [2]
13. Sustainable construction materials [2]
14. Midterm exam

- Exercises:
  1. Fundamentals of electrochemical corrosion of metals, methods for corrosion testing [2]
  2. Specific forms of corrosion in construction and other engineering branches [2]
  3. Metal protection methods - Example of galvanizing [2]
  4. Examination of the surface protection system of metal structures [2]
  5. Examples of wood damage in construction and other engineering branches [2]
  6. Degradation of materials in soil [2]
  7. Examples of masonry damage in construction [2]
  8. Condition assessment of the concrete [2]
  9. Application of methods for the condition assessment of concrete [2]
  10. Methods of testing reinforcement corrosion in concrete (electrochemical tests, corrosion monitoring) [2]
  11. Examples of reinforced concrete protection (inhibitors, cathodic and anodic protection, stainless steel) [2]
  12. Calculation of service life using computer software [2]
  13. Application of computer software for calculating the service life of structures under specific environmental loads [2]
- Seminars:
  1. Recognition of different mechanisms of degradation based on test results, chemical and microscopic analyses of materials [2]
  2. Final presentations of project assignments with discussion and oral assessment of acquired knowledge [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Positively evaluated seminar papers

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Positively evaluated seminar papers
- Written exam
- Oral exam

Required reading:

1. Bijen, J.: *Durability of Engineering Structures*, CRC Press, Woodhead Publishing Limited, Cambridge, England, 2003.

2. Beushausen, H., Fernandez Luco, L. Performance-based specifications and control of concrete durability, State-of-the-art report RILEM TC 230-PSC, Springer, 2016.

Additional reading:

1. Mays, G.: *Durability of Concrete Structures*, E & FN Soon, London, 1992.
2. Bentur, A.; Diamond, S.; Berke, N. S.: *Steel Corrosion in Concrete*, E & FN Soon, London, 1997.
3. Maekawa, K.; Rajesh, P.; Chaube and Kishi, T.: *Coupled Mass Transport, Hydration and Structure Formation Theory for Durability Design of Concrete Structures*, http://concrete.t.utokyo.ac.jp/en/demos /ducom/brieftheory/ consec1.html.
4. E. Gjorv, Koji Sakai*: Concrete Technology for a Sustainable Development in the 21st Century*, E&FN SPON, London, 2000.
5. Tony C. Liu, Christian Meyer: Recycling Concrete and Other materials for Sustainable Development, ACI International, SP – 219, 2004.
6. Hendriks, Ch. F.; Pieterson, H. S.: *Sustainable Raw materials, Construction and Demolition waste*, RILEM, Report 22, 2000.
7. Jamal M. Khatib: *Sustainability of construction materials*, Woodhead Publishing Limited, 2009.

SPECIAL CONCRETE AND TECHNOLOGIES

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (auditory: 10, laboratory: 16, fieldwork: 4)

Course objectives:

- Understanding of different special concrete technologies,
- Acquisition of knowledge about the selection of constituent components depending on the type of concrete,
- Understanding the dependence between the properties, structure and technology of individual types of concrete,
- Familiarization with the technology of production, transport, laying and curing,
- Acquisition of knowledge about the quality proof method in the concrete plant and on the construction site,
- Acquisition of knowledge about designing compositions for different types of concrete,
- Familiarization with the application of special concrete technologies.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic properties of components for making concrete,
- Knowledge of concrete composition calculations,
- Knowledge of the basics of concrete technology.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Theory and Technology of Concrete.

Learning outcomes:

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

1. Develop an application technology for different types of concrete,

2. Design the composition of concrete for different types of concrete,
3. Make designed concrete at a concrete plant,
4. Create a quality assurance plan for concrete structure performance,
5. Carry out quality control at the construction site,
6. Interpret the results of testing concrete properties.

Course content (by course schedule):

- Lectures:
  1. Introduction to the development directions of concrete technology [3]
  2. Self-compacting concrete [3]
  3. Architectural concrete [3]
  4. Micro-reinforced concrete [3]
  5. Lightweight concretes. Heavyweight concretes [3]
  6. Shotcrete [3]
  7. Concrete with high performance properties. High strength concrete [3]
  8. Hydrotechnical concretes. Massive concrete. Rolled concrete [3]
  9. Concrete pavement structures. Concrete in tunnels [3]
  10. Polymer-modified concretes and mortars. Concrete and mortar for rehabilitation and strengthening [3]
  11. Concrete from recycled aggregate [3]
  12. Mortars. Injection mixtures. [3]
  13. Technology of concreting at high and low temperatures [3]
  14. Special concrete installation technologies [3]
  15. Examples of buildings made with special concrete and technologies [3]
- Auditory exercises:
  1. Achievements in the field of special concrete and technologies [2]
  2. Self-compacting concrete [2]
  3. Micro-reinforced concrete [2]
  4. Thermal calculation of massive concrete [2]
  5. Examples of practical application of special concrete and technologies [2]
- Laboratory exercises:
  1. Self-compacting concrete [2]
  2. Micro-reinforced concrete [2]
  3. Lightweight concrete [2]
  4. Testing the properties of hardened self-compacting concrete [2]
  5. Testing the properties of hardened microreinforced concrete [2]
  6. Testing the properties of hardened lightweight concrete [2]
  7. Ultra-high strength concretes [2]
  8. Testing the properties of ultra-high-strength hardened concrete [2]
- Fieldwork:
  1. Examples of application in practice [4]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- 2 program assignments submitted and positively evaluated within the prescribed deadline
- Oral exam

Required reading:

1. Bjegović, D.; Štirmer, N.: Teorija i tehnologija betona, udžbenik Sveučilišta u Zagrebu, Tiskara Zelina, 2015
2. Ukrainczyk, V.: *Beton: struktura, svojstva, tehnologija*, Građevinski fakultet Sveučilišta u Zagrebu, 1994.
3. Newman, J.; Seng Choo, B.: *Advanced Concrete Technology-Process*, Elsevier Ltd., 2003.
4. 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.
5. Mehta, P. K: *Concrete, Structure, Properties and Materials*, New Yersey: Prentice Hall, Inc., Englewood Cliffs, 1986.
6. Neville, A.M.: *Properties of concrete*, fourth edition. Essex: Longman Group Limited, 1995.

Additional reading:

1. Aitcin, P. C.: *High-Performance Concrete*, E&FN SPON, London, 1998.
2. Nawy, E.: *Fundamentals of high-performance concrete*, Second edition, John Wiley&Sons, Inc., New York, 2001.

CONCRETE AND MASONRY STRUCTURES 2

See Chapter Specialisation in Structural Engineering.

Elective courses

APPLIED GEOLOGY

See Chapter Specialisation in Geotechnics.

ENVIRONMENTAL PROTECTION

See Chapter Specialisation in Hydraulic Engineering.

QUALITY MANAGEMENT

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (auditory: 10, construction: 20)

Course objectives:

- Acquisition of knowledge about the principles of quality management,

- Acquisition of knowledge of the application of statistical methods for the evaluation of the quality of construction products,
- Acquisition of knowledge about the process of assessing the conformity of construction products.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic probability distributions,
- Knowledge of the system for evaluating the conformity of construction products.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Theory and Technology of Concrete.

Learning outcomes:

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

- Create a Laboratory Quality Manual,
- Organize interlaboratory testing,
- Apply statistical methods for evaluating the quality of construction products,
- Make a sampling plan,
- Create a control chart and operational curve,
- Describe management systems.

Course content (by course schedule):

- Lectures:
  1. Introduction to the field of quality and quality management [3]
  2. Accreditation of laboratories and certification of construction products [3]
  3. Basic principles of quality control, quality assurance and total quality management [3]
  4. Statistical tools for data analysis [3]
  5. Quality information systems [3]
  6. Quality management methods and techniques [3]
  7. Factory production control [3]
  8. Quality management in concrete production [3]
  9. Harmonization of the legislation of the Republic of Croatia with the legislation of the EU [3]
  10. European and international quality standards [3]
  11. Quality in construction projects [3]
  12. Environmental Management – Life Cycle Assessment (LCA) [3]
  13. Measurement uncertainty [3]
  14. Quality assurance of test results [3]
  15. Trends in the field of quality management [3]
- Exercises (auditory):
  1. Creation of the Laboratory Quality Control Manual [2]
  2. Material sampling plans for quality control testing [2]
  3. Creating a control plan for building materials [2]
  4. Assessment of measurement uncertainty [4]
- Exercises (construction):
  1. Solving and creating program assignments [20]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Juran, J. M.; Gryna, F. M.: *Planiranje i analiza kvalitete*, treće izdanje, Mate d.o.o., Zagreb, 1999.
2. Skoko, H.: *Upravljanje kvalitetom*, Sinergija, Zagreb, 2000.
3. Štirmer, N.; Gabrijel, I.: Internal lecture notes for the course Quality Management, course repository, http://www.grad.unizg.hr/predmet/uprkva

Additional reading:

1. De Feo, J.; Barnard, W.: *Juran Institute's Six Sigma Breakthrough and Beyond*, Juran Institute, 2003.
2. Feigenbaum, A. V.: *Total quality control*, McGraw-Hill, 1991.
3. Juran, J. M.; De Feo, J.: *Juran's Quality Handbook: The Complete Guide to Performance Excellence*, 6th Edition, McGraw Hill, 2010.
4. Deming, W. E.: *Some Theory of Sampling*, Dover Publications, 2010.
5. Kelly, J. M.: *Total Quality management*, Protecon, Zagreb, 1997.
6. Shewhart, W. A.: Statistical *Method from the Viewpoint of Quality Control*, Dover Publications, 2011.

THEORY OF ELASTICITY AND PLASTICITY

See Chapter Specialisation in Theory and Modelling of Structures.

2nd year, 3rd semester

Mandatory courses

PRECAST SYSTEMS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 20, construction: 6, fieldwork: 4)

Course objectives:

- Acquisition of knowledge about different types of prefabricated elements,
- Understanding the dependence between materials, technology and properties of prefabricated elements,
- Acquisition of knowledge about the design and construction of prefabricated buildings,
- Acquisition of knowledge about joints in prefabricated systems,
- Learning about the basics of production of prefabricated elements.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic properties of concrete,
- Knowledge of the basics of concrete technology.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Special Concrete and Technologies.

Learning outcomes:

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

- Evaluate the applicability of certain types of prefabricated elements,
- Choose a prefabricated element for a specific application,
- Propose the technology of production, transportation and assembly of the prefabricated element,
- Evaluate the test results of prefabricated elements,
- Make a program to prove the quality of the prefabricated element.

Course content (by course schedule):

- Lectures:
  1. Basic principles of production and construction with prefabricated systems [2]
  2. Materials for prefabricated systems [2]
  3. Structural systems in high-rise construction [2]
  4. Precast concrete elements in high-rise construction [2]
  5. Precast concrete ceiling structures [2]
  6. Application of prefabricated systems in bridge construction and roads [2]
  7. Application of prefabricated systems in other areas of construction [4]
  8. Unreinforced precast concrete elements [2]
  9. Composite structures with precast concrete elements [2]
  10. Ecological aspects of prefabricated construction [2]
  11. Storage, transport and assembly of prefabricated systems [2]

12. Factories of prefabricated systems [2]
13. Special technologies and materials for prefabricated systems [2]
14. Robotics, economics and coordination among construction participants [2]

- Auditory exercises:
  1. Joints in skeletal systems of high-rise buildings [2]
  2. Joints in panel systems of high-rise buildings [2]
  3. Joints in prefabricated ceiling structures [2]
  4. Joints in composite constructions [2]
  5. Application of prefabricated systems in bridge construction [2]
  6. Midterm exam
  7. Application of prefabricated systems in naval construction [2]
  8. Examples of construction with prefabricated systems [4]
  9. Midterm exam
- Construction exercises:
  1. Seminars [6]
- Fieldwork:
  1. Visit to the factory for the production of prefabricated concrete elements [4]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Required reading:

1. FIB Commission 6: *Planning and Design Handbook on Precast Building Structures*, 2004.
2. Kim S. Elliot: *Precast Concrete Structures*, Butterworth Heinmann, 2002.
3. Kim S. Elliot: *Multi-storey precast concrete framed structures*, Blackwell Science, 1996.
4. National Precast Concrete Association Australia, Concrete Institute of Australia: *Precast Concrete Handbook*, 2002.
5. FIB bulletin no. 21: *Environmental issues in prefabrication*, state-of-art report, 2003.
6. FIB bulletin no. 19: *Precast concrete in mixed construction*, state-of-art report, 2002.

Additional reading:

1. Precast Concrete Institute: *Design Handbook Precast and Prestressed Concrete*, Fifth Edition, 1999.

NON-DESTRUCTIVE TESTINGS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 16, laboratory: 14)

Course objectives:

- Familiarization with non-destructive testing methods for assessing the condition of materials in construction,
- Understanding the theoretical and practical principles of application of certain non-destructive tests,
- Acquisition of knowledge about planning and implementation of non-destructive tests,
- Acquisition of knowledge about the interpretation of the results of non-destructive tests,
- Acquisition of knowledge about the assessment of the state of the structure based on the obtained test results,
- Familiarization with the application of non-destructive testing in the construction of buildings.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic material properties,
- Basic knowledge about mechanisms of damage to materials and structures.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Special Concrete and Technologies, Durability of Structural Materials.

Learning outcomes:

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

- Interpret the results of various non-destructive tests,
- Organize and carry out non-destructive tests,
- Create a test program during the construction or enhanced maintenance of the facility,
- Propose the application of the test method depending on the condition of the object,
- Give an assessment of the condition of the facility based on the conducted tests.

Course content (by course schedule):

- Lectures:
  1. Introduction to non-destructive testing methods [2]
  2. Staff. Penetrant testing [2]
  3. Visual inspections [2]
  4. Principles of determining the strength of materials in construction [2]
  5. Estimation of the strength of young concrete using the maturity method [2]
  6. Methods of determining permeability properties of concrete [2]
  7. Electrical and magnetic test methods [2]
  8. Ultrasound examination [2]
  9. Methods based on the propagation of acoustic waves through a material [2]
  10. Acoustic emission [2]
  11. Radar testing [2]
  12. Infrared thermography [2]
  13. Radiation methods [2]
  14. Regulations and norms for the implementation of non-destructive testing. [2]
  15. Planning of non-destructive tests [2]
- Auditory exercises:
  1. Visual inspections [2]
  2. Non-destructive determination of strength [2]
  3. Tests of properties related to durability [2]
  4. Midterm exam
  5. Impact methods and ultrasonic methods [2]

6. Examples of non-destructive testing on existing facilities [4]
7. Midterm exam

- Laboratory exercises:
  1. Non-destructive strength determination: sclerometer, lock test, capo test, pull off test [2]
  2. Application of maturity method [2]
  3. Tests of properties related to durability [2]
  4. Tests using the ultrasound transmission method [2]
  5. Impact methods and ultrasonic methods [2]
  6. Acoustic emission [2]
  7. Infrared thermography [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Malhotra, V. M.; Carino, N. J.: *Handbook on Nondestructive Testing of Concrete*, Second Edition, CRC Press, 2004.
2. Raj, B.; Jayakumar, T.; Thavasimuthu, M.: *Practical non-destructive testing*, Alpha science, 2002.

Additional reading:

1. Krstelj, V.: *Ultrazvučna kontrola*, FSB, Zagreb, 2003.

FIRE PROTECTION

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 8, laboratory: 4, construction: 10, on computers: 6, fieldwork: 2)

Course objectives:

- Acquire knowledge of the parameters of fire development in enclosed spaces,
- Acquire knowledge of the principles of testing and classification of materials and construction elements with regard to reaction to fire and fire resistance properties,
- Acquire knowledge of the fire analysis of structural elements made of different materials according to the prescriptive and performance-based design approach,

- Acquire the knowledge of active fire protection measures,
- Acquire knowledge of current regulation in the Republic of Croatia according to which fire protection measures for buildings are designed,
- Define parameters for assessment the condition of fire-damaged structures depending on the materials they are made of.

Entry competences (prior knowledge, descriptive):

- Basic knowledge of materials science, mathematics, thermodynamics and chemistry.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Special Concrete and Technologies,
- Course exam passed: Building Physics.

Learning outcomes:

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

- Quantitatively assess various fire parameters in enclosed spaces (fire load, heat release rate, maximum temperature developed in the fire compartment, etc.),
- Evaluate and classify materials and construction products according to the results of testing the properties of reaction to fire and fire resistance,
- Analyse the main effects of high temperature on the properties (thermal and mechanical) of construction materials (concrete, steel, timber, etc.),
- Analyse the fire resistance of structural elements with regard to the prescriptive performance-based approach,
- Create a fire safety report according to current regulations in the Republic of Croatia,
- Evaluate fire-damaged structures in terms of material (concrete, steel, timber, brick, etc.).

Course content (by course schedule):

- Lectures:
  1. Introduction to the course [2]
  2. Fundamentals of the origin and spread of fires in buildings [2]
  3. Modelling the development of fires [2]
  4. Fire effects on materials and structures – general information [2]
  5. Fire effects on reinforced concrete structural elements and protection measures [2]
  6. Fire effects on steel structural elements and their protection [2]
  7. Fire effects on wooden construction elements and their protection [2]
  8. Condition assessment of fire-damaged structures [2]
  9. Active fire protection measures [4]
  10. Architectural and urban fire protection measures [8]
  11. Regulations in the field of fire protection [2]
- Auditory exercises:
  1. Fundamentals of the origin and spread of fires in buildings [2]
  2. Behaviour of materials in fire – testing and classification of building materials according to fire characteristics [2]
  3. Condition assessment of fire-damaged structures [2]
  4. Case studies [2]
- Laboratory exercises:
  1. Reaction of materials to fire [2]
  2. Effects of fire on structures [2]
- Construction exercises:
  1. Fundamentals of the origin and spread of fires in buildings [2]
  2. Content of fire safety report [8]

- On computers:
  1. Modelling of fire development [2]
  2. The effect of fire on structure elements - calculation of the developed temperatures [4]
- Fieldwork: Passive and active fire protection measures on a specific building [2]

Student Evaluation - Continuous assessment:
- 75% attendance at lectures
- 100% attendance at exercises
- Program assignments prepared and submitted within the prescribed deadline
- 2 midterm exams

Student Evaluation - Examination without Continuous Assessment:
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:
1. Jelčić Rukavina. et al.: *Course repository*, http://www.grad.unizg.hr/predmet/zop.
2. Buchanan, A. H.: *Structural Design for Fire Safety*, John Wiley & Sons Ltd, England, 2002.
3. Purkiss, J. A.: *Fire safety engineering – Design of structures*, Second edition. Oxford: Elsevier Ltd. 2007.
4. *Design of buildings for the fire situation*, Leonardo da Vinci pilot project CZ/02/B/F/PP-134007 (http://eurocodes.jrc.ec.europa.eu/showpublication.php?id=66)
5. Vidaković, M.: *Požar i arhitektonski inženjering*, Fahrenheit, Beograd, 1995.

Additional reading:
1. Lectures at the postgraduate specialist study Fire Engineering.
2. Drysdale, D.: *An Introduction to Fire Dynamics*, Wiley & Sons, 2003. (selected chapters).
3. *An Introduction to Fire Dynamics by Dougal Drysdale*, 2nd Ed., Wiley 1998.
   http://www.civ.ed.ac.uk/research/fire/technicalreports.html
   http://www.civ.ed.ac.uk/research/fire/thesis.html
4. Karlsson, B.; Quintiere, J. G.: *Enclosure Fire Dynamics*, CRC Press, 2000 (selected chapters).
5. HRN EN 1991-1-2, Eurocode 1: Actions on structures -- Part 1-2: General actions -- Actions on structures exposed to fire
6. HRN EN 1992-1-2, Eurocode 2: Design of concrete structures -- Part 1-2: General rules -- Structural fire design
7. HRN EN 1993-1-2, Eurocode 3: Design of steel structures -- Part 1-2: General rules -- Structural fire design
8. HRN EN 1994-1-2, Eurocode 4: Design of composite steel and concrete structures -- Part 1-2: General rules -- Structural fire design
9. HRN EN 1995-1-2, Eurocode 5: Design of timber structures -- Part 1-2: General -- Structural fire design
10. HRN EN 1996-1-2, Eurocode 6: Design of masonry structures -- Part 1-2: General rules -- Structural fire design

11. HRN EN 1999-1-2, Eurocode 9: Design of aluminium structures -- Part 1-2: Structural fire design
12. ACI 216 R-89: *Guide for Determining the Fire Endurance of Concrete Elements*, 1994.
13. ACI 216.1-97/TMS 0216.1-97: *Standard Method for Determining Fire Resistance of Concrete and masonry Construction Assemblies*, 1997.
14. SFPE Handbook od Fire Protection Engineering, 2nd Edition, National Fire Protection Association, 1995.

Elective courses

TECHNOLOGY OF REPAIR AND STRENGTHENING

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 22 (auditory: 14, construction: 8)
- Seminars: 8

Course objectives:

- Integration of knowledge gathered in undergraduate and graduate engineering courses and additional training for the needs of independent analysis of existing buildings and rehabilitation design (repair, renovation and/or strengthening).

Entry competences (prior knowledge, descriptive):

- Explanation of the properties of individual construction materials and their possible mechanisms of degradation,
- Theoretical and practical knowledge about the behaviour of structures under load and other actions,
- Recognition of different mechanisms of material degradation based on the observed consequences on the embedded material.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Special Concrete and Technologies, Durability of Construction Materials,
- Course exam passed: Building Physics.

Learning outcomes:

3. Connect a specific mechanism of concrete degradation with the principle and method of repairing reinforced concrete structures,
4. Distinguish and compare different materials and systems for repairing and strengthening reinforced concrete structures,
5. Prescribe the required properties of materials and systems and methods of quality control during and after the repair and strengthening of reinforced concrete structures,
6. Analyse and compare different methods of structural repair in terms of functionality and durability, as well as environmental and economic profitability during the entire lifetime,

7. Recommend and prescribe the optimal principle and method of repair depending on the cause of premature deterioration of the structure and the results of a multi-criteria comparison of alternatives,
8. Independent creation of a rehabilitation project that includes: condition assessment, proposed repair and strengthening method, repair materials and repair control methods during and after execution.

Course content (by course schedule):

9. Lectures:

1. Introduction [2]
2. Causes of damage and condition assessment of concrete structures [2]
3. Technology of repair of concrete structures [4]
4. Strengthening technologies of concrete structures [2]
5. Interaction of materials, technologies and structure during renovation [2]
6. Protection systems of concrete structures [4]
7. Construction, quality control and maintenance of concrete structures [2]
8. Condition assessment, repair and strengthening of masonry structures [4]
9. Condition assessment, repair and strengthening of metal structures [3]
10. Condition assessment, repair and strengthening of pavement structures [3]

10. Exercises:

Auditory:

1. Examples of failure of concrete structures [2]
2. Legal regulation for rehabilitation of concrete structures [2]
3. Content and equipment of the rehabilitation project [2]
4. Removal, surface preparation and reprofiling of concrete [2]
5. Special rehabilitation methods [2]
6. Strengthening of concrete structures [2]
7. Condition assessment of the metal structures [2]

Construction:

1. Creating a project assignment [8]

Seminars:

1. Selection and condition assessment of the project structure [2]
2. Selected methods of rehabilitation of the project structure [2]
3. Selected and prescribed requirements for materials and systems, quality control during and after execution [2]
4. Work plan and estimate of costs for rehabilitation of the project structure [2]

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper – Students will prepare the seminar paper during the semester, independently and in consultation with the instructor. The paper will encompass the application of the acquired theoretical knowledge on a specific example of a structure.
- Oral exam – to pass the exam, it is necessary to answer a minimum of half of the questions correctly.

Required reading:

1. Raupach, M., Buttner, T. Concrete Repair to EN 1504 Diagnosis, Design, Principles and Practice, CRC Press, Taylor & Francis Group, 2014.

2. Japan Concrete Institute. Practical Guideline for Investigation, Repair and Strengthening of Cracked Concrete Structures, 2013.
3. Radić et al. Betonske konstrukcije - Sanacije, Zagreb: Hrvatska sveučilišna naklada, Sveučilište u Zagrebu - Građevinski fakultet, Secon HDGK, Andris, 2008.
4. HRN EN 1504 Products and systems for the protection and repair of concrete structures.

Additional reading:

1. Balia, A et al. Manuale delle murate storiche, Volume II. Schede operative per gli interventi di restauro strutturale, Tipografia del genio civile, 2011
2. Panasyuk, V.V., Marukha, V.I. Sylovanyuk, V.P. Injection Technologies for the Repair of Damaged Concrete Structures, Springer, DOI 10.1007/978-94-007-7908-2, 2014.
3. Whittle, R. Failures in Concrete structures. Case Studies in Reinforced and Prestressed Concrete, CRC Press, Taylor & Francis Group, 2013.
4. Agocs, Z., Ziotko, J., Vican, J., Brodniansky, J. Assessment and refurbishment of steel structures, Spon Press, Taylor & Francis Group, 2005.

TRANSPORTATION FACILITY CONCRETE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 16 (auditory)
- Seminars: 14

Course objectives:

- Acquisition of theoretical knowledge about production technology, properties and use of concrete on roads,
- Acquisition of practical knowledge about laboratory tests of properties relevant to road concrete,
- Acquiring knowledge about designing the composition of concrete,
- Acquiring knowledge about quality control of construction materials.

Entry competences (prior knowledge, descriptive):

- Knowledge of physical, mechanical and thermal properties of materials,
- Knowledge of the basics of statistics.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Special Concrete and Technologies.

Learning outcomes:

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

- Describe the material technology for individual concrete elements on roads,
- Explain the relevant properties of concrete for these elements,
- Design the concrete composition,
- Compare the properties of different concretes for roads,
- Apply concrete test results for individual elements.

Course content (by course schedule):

- Lectures:

1. Concrete elements on roads and airports [4]
2. Pavements: concrete pavements, asphalt pavements [4]
3. Surface treatment – roughness [2]
4. Micro-reinforced concrete [2]
5. High strength concretes [2]
6. Polymer modified concretes. Shotcrete; grouting [2]
7. Concrete in tunnels [2]
8. Renovation concretes and mortars [2]
9. Concrete production technology for roads [2]
10. Concreting in extreme climatic conditions I [4]
11. Rolled concrete pavement [2]
12. Vacuum concrete [2]

- Exercises (auditory):
  1. Conditions for concrete used on roads [4]
  2. Calculation of temperature flow in concrete [2]
  3. Assessment of the risk of cracks [2]
  4. Concrete composition design and testing program [4]
  5. Presentation of topics and selection of seminar topics, instructions [2]
  6. Errors in concrete pavements [2]
- Seminar:
  1. Creation and presentation of the seminar [14]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the seminar paper

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper
- Oral exam

Required reading:

1. Ukrainczyk, V.: *Beton: struktura, svojstva, tehnologija*, Građevinski fakultet Sveučilišta u Zagrebu, 1994.
2. Ukrainczyk, V.: *Poznavanje gradiva*, Alcor, Zagreb, 2001.
3. Beslać, J.: *Materijali u arhitekturi i građevinarstvu*, Školska knjiga, Zagreb, 1989.
4. Korlaet, Ž.: *Uvod u projektiranje i građenje cesta*, udžbenik, Sveučilište u Zagrebu, 1995.

Additional reading:

1. *ACI Manual of Concrete Practice*, ACI Publication, SAD
2. Derucher, K. N.; Korfiatis, G. P.: *Materials for Civil & Highway Engineers*, second edition, Prentice Hall, 1988.

HYDROTECHNICAL CONCRETE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 20, construction: 10)

Course objectives:

- Acquisition of knowledge about the characteristic properties of mass concrete,
- Acquisition of knowledge about different methods of preventing the appearance of thermal cracks,
- Acquisition of knowledge about the protection of concrete elements in hydrotechnical buildings,
- Acquisition of knowledge about the possibilities of applying special types and technologies of concrete in hydrotechnical buildings.

Entry competences (prior knowledge, descriptive):

- Knowledge of the composition and properties of concrete.

Learning outcomes:

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

- Assess the risk of thermal cracks in mass concrete,
- Choose suitable components for the composition of mass concrete,
- Analyse the influence of components and environmental conditions on temperature changes in concrete,
- Propose the technology of concrete hydrotechnical constructions,
- Evaluate the results of testing concrete in hydrotechnical buildings,
- Analyse and evaluate materials for rehabilitation of hydrotechnical structures.

Course content (by course schedule):

- Lectures:

1. Introduction: characteristics and application of hydrotechnical concrete [2]
2. Heat of hydration: thermal stresses and cracks; volume changes [2]
3. Control of cracks in massive concrete [2]
4. Selection of ingredients for the production of massive hydrotechnical concrete and composition design [2]
5. Transportation, laying and maintenance of concrete: dynamics of concreting [2]
6. Concrete laying in extreme climatic conditions [2]
7. Strength and deformations: risk of cracks [2]
8. Mass concrete cooling systems [2]
9. Special concretes and technologies for the construction of hydrotechnical structures: rolled concrete, prepacked concrete, concreting under water [2]
10. Concretes with improved waterproofing [2]
11. Erosion of concrete in hydraulic structures. Examples of rehabilitation [2]
12. Protection of concrete elements in hydraulic structures [2]
13. Assessment of the condition of hydrotechnical concrete in existing structures [2]
14. Examples of hydrotechnical structures [2]
15. Regulations and standards in the field of application of hydrotechnical concrete [2]

- Exercises (auditory)

1. Cement and heat of hydration; Mixture temperature [4]
2. The process of heat release of hydration [2]

3. Calculation of heat flow in young concrete [4]
4. Temperature distribution and appearance of stress in concrete during construction and risk of cracks [2]
5. Development of strength and stiffness in young concrete; behaviour of young concrete under load [2]
6. Calculation of stress in young concrete [2]
7. Heat loss from solid bodies [2]
8. Calculation of the flow of temperature in massive concrete and assessment of the risk of the appearance of cracks - solving and creating a program [2]

- Exercises (construction):

1. Solving and creating a program assignment [10]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper within the prescribed deadline
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. *Advanced Concrete technology*, Processes, ed. Newman, J.; Seng Choo, B., Elsevier, 2003.
2. ACI 207.1R-05 *Guide to Mass Concrete*.
3. ACI 207.2R-07 *Report on Thermal and Volume Change Effects on Cracking of Mass Concrete.*
4. ACI 207.3R-94 *Practices for Evaluation of Concrete in Existing Massive Structures for Service Conditions.*
5. ACI 207.4R-05 *Cooling and Insulating Systems for Mass Concrete* (Reapproved 2012).
6. ACI 207.5R-11 *Report on Roller-Compacted Mass Concrete.*
7. ACI 210R-93 *Erosion of Concrete in Hydraulic Structures.*
8. Štirmer, N.; Gabrijel, I.: Internal lecture notes from Hydrotechnical Concrete, course repository, http://www.grad.unizg.hr/predmet/hidbet.
9. Bjegović, D.; Štirmer, N.: Teorija i tehnologija betona, udžbenik Sveučilišta u Zagrebu, Tiskara Zelina, 2015.

Additional reading:

1. *Prevention of Thermal Cracking in Concrete in Early Ages*, RILEM Report, Ed. R. Springenschmid, E & FN Spon, 1998.
2. Monteiro, P. J. M.: *Concrete – Microstructure, Properties and Materials*, McGraw-Hill, 2006.

METAL STRUCTURES 2

See Chapter Specialisation in Structural Engineering.

WORK AND PRODUCTION ORGANIZATION

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Provide students with a fundamental understanding of the organization and management of work in production and on construction sites
- The focus of the course is on process management and industrial engineering related to construction
- The production of modular and prefabricated building elements takes parts of the construction process to factories, which is why process management is one of the important topics for the understanding and success of engineers in business
- Students acquire the necessary knowledge and skills for effective analysis, planning, organizing and monitoring of work and production processes at construction sites and factories.

Entry competences (prior knowledge, descriptive):

- Basic understanding of construction processes and construction technology, as well as the ability to think analytically and solve problems
- Students should be familiar with the basic principles of project management and be able to apply mathematical and statistical tools in the analysis and planning of work processes.

Learning outcomes:

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

- Understand the basic principles of work organization and production in construction
- Analyse and plan construction processes using relevant tools and techniques
- Apply the concepts of quality and safety management in work processes on construction sites and in the production of building materials and elements
- Apply basic concepts of industrial engineering
- Identify and solve problems related to the organization and management of work on construction sites and in production facilities
- Apply knowledge of resources, times and costs in planning and monitoring construction activities.

Course content (by course schedule):

- Lectures:
  1. A short refresher and introduction [2]
  2. Work organization: Historical development of work organization; Development of civil engineering; Organization of work; Taylor's principle; Principles of work organization; The future of work studies; fundamental areas of development of labour science. [2]

3. Organization of production: Concept of production; Production goals; Scientific disciplines of production organization; characteristic stages of production development [2]
4. Development of organizational theories: Disadvantages of the classical approach to organization; Neoclassical theory of organization; Contemporary theories of organization; Systematic approach to organization theory [2]
5. Theories of general management: Recent contributions to the development of general management; Development of general management; newer approaches to the development of general management; Criticism of recent general management theories[2]
6. Construction production: Construction as an economic branch; Characteristics and limitations of the development of civil engineering and construction production; Construction production in the "broader sense"; Construction production in the "narrow sense"; Production technological process; Study of work and productivity; Distribution of technological processes; Basic structure of the technological process; Technological process flow indicators; Capacity of production technological system [2]
7. Informatics in construction production: Management of construction production; General development of modern IT technology and IT systems in construction companies [2]
8. Implementation of construction projects: The life cycle of a construction project [2]
9. Human resources and managerial approach to project management [2]
10. Human resources in production: Essential psychological characteristics of builders; Essential psychological methods in the study of people as persons [2]
11. Human resources in production: Physiological influences on man; Sociological influences on man; Influences of the working environment on people in construction [2]
12. Rationalization of construction production: Methodological approach to rationalization of production; Modelling of construction production; Procedures for the rationalization of construction production; Algorithm for rationalization of construction production. [2]
13. Organization of preparation of construction production: Preparation of construction production; Tasks during production preparation; Methodological approach when designing production preparation; Modelling of future production and construction products; Approach to designing the preparation of construction production [2]
14. Simulation of construction production: Definition of the term simulation; Application of the most famous simulation methods (Queueing theory, Monte Carlo method) [2]
15. Design organization (aspects and application in construction): Introduction and philosophy of multidisciplinary design: Methodological approach to design: system thinking, system engineering, system dynamics. Planning, architectural and engineering design: Integration; Phase and parallel model of multidisciplinary design [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam
- Oral exam

Required reading:

1. J .Izetbegović, V.Žerjav, *Organizacija građevinske proizvodnje,* Hrvatska udruga za organizaciju građenja i Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 2009.
2. *J.* Izetbegović, *Proučavanje graditeljske proizvodnje, GF.-Zagreb, 2007.,* http://www.og.grad.hr
3. C.P. Robert and G. Casella*, Introducing Monte Carlo Methods with R,* Springer, 2010.
4. *J.*Marušić, *Organizacija građenja,* university handbook, FS, Zagreb, 1994.
5. D.Taboršak, *Studij rada,* Orgdata, Zagreb,1994.
6. J.K. Yates, *Productivity Improvement for Construction and Engineering: Implementing Programs That Save Money and Time,* ISBN: 978-0784413463, 2014.

2nd year, 4th semester

Elective courses

NUMERICAL MODELLING IN ENGINEERING MATERIALS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 16, construction: 14)

Course objectives:

- Acquisition of knowledge about the application of computer simulations in material engineering using traditional numerical methods (finite differences and finite elements) as well as stochastic methods (cellular automata, neural shells).

Entry competences (prior knowledge, descriptive):

- Knowledge of the physical properties of building materials,
- Knowledge of the basic methods of transport of mass and energy,
- Prior knowledge related to derivation and integration of functions.

Enrolment requirements (prerequisite):

- Course exam passed: Mathematics 3 or Stochastic Processes, Durability of Structural Materials.

Learning outcomes:

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

- Identify the mechanisms of heat and mass transfer necessary for the numerical analysis of transport through concrete,
- Apply finite difference methods and finite element methods for the analysis of temperature changes in young concrete,
- Apply the finite difference method and the finite element method to the problem of chloride transport through concrete,
- Apply the method of finite differences and finite elements to heat transfer problems,
- Carry out a simulation of the hydration of Portland cement.

Course contents:

- Lectures:
  1. Introduction to transport processes [2]
  2. Mechanisms of molecular transport [2]
  3. General principle of balance [2]
  4. Initial and boundary conditions [2]
  5. Finite difference method – rejection errors and Taylor series [2]
  6. Finite differences – elliptic equations [2]
  7. Finite differences – parabolic equations [2]
  8. Finite element method [2]
  9. Application of the finite element method to two-dimensional, time-dependent problems [2]

10. Nonlinear problems [2]
11. Finite element method [2]
12. Application of the finite element method to one-dimensional problems [4]
13. Application of the finite element method to two-dimensional problems [2]
14. Inverse methods [2]
15. Neural shells and fuzzy sets [1]

- Exercises (auditory):
  1. Introduction to MathCad [2]
  2. Solving equations in MathCad [2]
  3. Programming in MathCad [2]
  4. Solving problems using the finite element method [6]
  5. Numerical simulation of cement hydration [4]
- Exercises (construction):
  1. Solving and creating a program assignment [14]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. Balabanić, G.: *Numeričko modeliranje u inženjerstvu materijala*, (selected chapters), lecture notes, 2010.

Additional reading:

1. Chapra, S. C.; Canale, R. P.: *Numerical Methods for Engineers*, McGraw-Hill, Sixth Edition, 2009.
2. Brodkey, R. S.; Hershey, H. C.: *Transport Phenomena – A Unified Approach*, McGraw-Hill, 1988.
3. Rappaz, M.; Bellet, M.; Deville, M.: *Numerical Modeling in Materials Science and Engineering*, Springer, 2002.
4. Raabe, D.: *Computational Materials: The Simulation of Materials Microstructure and Properties*, John Wiley & Sons Inc, 1998
5. Dalbelo Bašić, B.: *Umjetne neuronske mreže – skripta i predavanja za predmet Umjetna inteligencija*, Fakultet elektrotehnike i računarstva, Zavod za elektroniku, mikroelektroniku i inteligentne sustave, Zagreb, svibanj 2008.

HIGH-PERFORMANCE CONCRETE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 20, laboratory: 10)

Course objectives:

- Acquisition of knowledge about the selection of constituent components depending on the properties of concrete,
- Understanding the dependence between properties, structure and technology,
- Familiarization with the technology of production, transport, laying and curing,
- Acquisition of knowledge about the quality proof method in the concrete plant and on the construction site
- Acquisition of knowledge about composition design.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic properties of components for making concrete,
- Knowledge of concrete composition calculations,
- Knowledge of the basics of concrete technology.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Non-Destructive Testings,
- Course exam passed: Special Concrete and Technologies, Durability of Structural Materials,

Learning outcomes:

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

- Design the composition of concrete with high performance properties,
- Make designed concrete in the laboratory and at the concrete plant,
- Implement concrete quality assurance measures at the concrete plant and construction site,
- Carry out tests of concrete in the fresh state and certain properties in the hardened state,
- Evaluate the influence of components and production technology on the properties of concrete in fresh and hardened state,
- Evaluate the results of testing the mechanical and durability properties of concrete,
- Design the technology of production, laying and maintenance of concrete with high performance properties.

Course content (by course schedule):

- Lectures:
  1. Historical development, definitions and classification [2]
  2. Basic principles of obtaining [2]
  3. Rules for the selection of components [2]
  4. Compatibility criteria of components [2]
  5. Composition design methods [2]
  6. Production, transportation and laying technology [2]
  7. Optimization of the curing process [2]
  8. Relationship between structure and properties [2]
  9. Behaviour in the fresh state [2]
  10. Test methods [2]
  11. Mechanical properties [2]
  12. Durability properties [2]
  13. Connection of technology and structural application [2]
  14. Special types of concrete with high performance properties [2]
  15. Structural application [2]
- Auditory exercises:
  1. Introduction to the selection of components and composition design [2]
  2. Selection of components depending on the required properties [2]

3. Basic dependencies in composition design [2]
4. Specific features of technology in different applications [2]
5. Quality control at the concrete plant and construction site [2]
6. Micro-reinforced concrete of high serviceability [2]
7. Application in conditions of an aggressive environment [2]
8. Laboratory and field testing of properties [2]
9. Examples of application in building technology [2]
10. Examples of application in civil engineering [2]

- Laboratory exercises:
  1. Determining the properties of constituent components [2]
  2. Composition design [2]
  3. Methods of testing properties in the fresh state [2]
  4. Examination of durability properties of hardened concrete [2]
  5. Examination of the mechanical properties of hardened concrete [2]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. Nawy, E.: *Fundamentals of high-performance concrete*, Second edition, John Wiley&Sons, Inc., New York, 2001.
2. Aitcin, P. C.: *High-Performance Concrete*, E&FN SPON, London, 1998.
3. ACI SP-189: *High Performance Concrete: Research to Practice*, 1989.

Additional reading:

1. *Proceedings from International Symposium on Utilization of High Strength/High Performance Concrete*, University of Leipzig, 2002.
2. Naaman, A. E.; Reinhardt, H. W.: *High Performance Fiber Reinforced Cement Composites 2 (HPFRCC 2)*, E & FN Spon, 1996.

ENERGY RENOVATION OF BUILDINGS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 15
- Exercises: 45 (auditory: 15, construction: 30)

Course objectives:

- Acquisition of advanced and highly specialized knowledge for evaluating the energy efficiency of existing buildings and selecting suitable methods for sustainable energy renovation of buildings.
- Acquisition of advanced and highly specialized knowledge to raise the level of energy efficiency and thermal comfort of the existing building stock by applying proven and economically justified renovation measures.

- Introducing students to advanced and specialized approaches in the analysis and assessment of energy efficiency of buildings.
- Mastering advanced and specialized methods for proper assessment of the condition of the building envelope, with the aim of restoring all damaged areas before installing systems that affect energy efficiency.
- Familiarity with advanced and highly specialized materials, technical systems and their properties, related to durability, safety and fire protection and energy efficiency.
- Developing group work skills by applying the team learning method.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic material properties.
- Basic knowledge of building physics.
- Basic knowledge about the durability and maintenance of buildings.
- Knowledge of the basic procedures for assessing the condition of buildings.
- Basic knowledge about the origin and spread of fire in buildings.
- Knowledge of basic structural elements and building construction systems.

Learning outcomes:

- Create a program assignment for assessing the condition of existing buildings in terms of the condition of materials and structure, energy efficiency and fire protection.
- Apply advanced and highly specialized knowledge about the properties of building materials, products and systems, with an emphasis on durability, fire behaviour and energy efficiency during renovation.
- Analyse the types of applicable systems and their design methods in energy renovation of buildings.
- Create a project for the energy renovation of existing buildings, taking into account measures to renovate the existing structure and fire protection.
- Show that the applied measures of renovation and thermal comfort of the building are simple, provable and cost-justified.
- Create a maintenance program for applied renovation systems.
- Demonstrate the ability to take responsibility during design and the ability to work in a team.

Course content (by course schedule):

- Lectures
  1. Introduction to energy renovation, Legal framework – recommendations and obligations (1)
  2. Overview of possible strategies for in-depth energy renovation of existing buildings (2)
  3. Technical systems in buildings, lighting, control systems (2)
  4. Environmental impacts, damage and durability of building materials (2)
  5. Deficiencies and needs in the renovation of the existing building stock (2)
  6. Models of sustainable building renovation (2)
  7. Proper selection of materials and technical systems for the energy renovation of the existing building stock (2)
  8. Proper selection of materials and technical systems for energy renovation respecting fire protection requirements (2)

- Auditory exercises
  1. Energy properties and characteristics of the existing building stock (2)
  2. The use of renewable energy sources in the energy renovation of buildings (2)
  3. Energy renovation and rehabilitation of structural elements of buildings under cultural monument protection (2)
  4. Cost optimum of energy renovation of buildings (2)
  5. Energy renovation in several steps (step by step renovation) (2)
  6. Comfort parameters in buildings (2)
  7. Evidence of the quality of installed materials during energy renovation of buildings (1)
  8. Case studies (2)

- Construction exercises
  1. As part of the construction exercises, groups of students will assess the state of the building from the building stock, perform a design [30]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. Hugo Hens. Applied Building Physics: Ambient Conditions, Building Performance and Material Properties. Ernst & Sohn. 2010
2. Hugo Hens. Performance Based Building Design 1: From Below Grade Construction to Cavity Walls. Ernst & Sohn. 2012
3. Hugo Hens. Performance Based Building Design II: From Timber-framed Construction to Partition Walls. Ernst & Sohn. 2013
4. Christopher Gorse, David Highfield. Refurbishment and Upgrading of Buildings, Spon Press, 2009
5. Croskills priručnici - Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere (svesci: Zajednički dio, fasader, zidar, tesar, krovopokrivač, soboslikar-ličilac, monter suhe gradnje), Građevinski fakultet
2. Sveučilišta u Zagrebu, 2017.
6. Wolfgang M Willems; Simone Dinter; Kai Schild. Handbuch Bauphysik Teil 1 - Wärme- und Feuchteschutz, Behaglichkeit, Lüftung. Vieweg
7. Wolfgang M Willems; Simone Dinter; Kai Schild. Handbuch Bauphysik Teil 2 – Schallund Brandschutz, Fachwörterglossar. Vieweg
8. Colwell S., Baker T., Fire Performance of external thermal insulation for walls of multistorey buildings, British research establishment, 3rd Edition. 2013
9. Jelčić Rukavina, M., Carević, M., Banjad Pečur, I.: Zaštita pročelja zgrada od požara - Priručnik za projektiranje i izvođenje, Građevinski fakultet Sveučilišta u Zagrebu, 2017.

DESIGN OF EXPERIMENTS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 12, construction: 14, laboratory: 4)

Course objectives:

- Acquisition of theoretical knowledge about the combined effect on construction (performance, environment, load),
- Acquisition of practical knowledge about laboratory and field tests and their combinations that simulate real conditions,
- Acquisition of knowledge about research planning procedures for professional and scientific purposes.

Entry competences (prior knowledge, descriptive):

- Knowledge of physical, chemical, mechanical and thermal properties of materials,
- Knowledge of the basics of statistics.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Non-Destructive Testings.

Learning outcomes:

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

- Describe actions (loads) on material and building,
- Explain the mechanisms of environmental action on the material,
- Explain the methods of testing the properties of building materials for day-to-day operation,
- Design testing methods for day-to-day operations,
- Compare the results of material measurements,
- Apply the test results of construction materials.

Course content (by course schedule):

- Lectures:
  1. Introduction, purpose, type and importance of testing [2]
  2. Modelling of physical phenomena [4]
  3. Numerical solving and programming of physical models [2]
  4. Planning and design of the experiment [4]
  5. Choice of instruments for the experiment [2]
  6. Statistical design of the experiment [2]
  7. Construction of measuring devices [2]
  8. Electrical measurement of non-electric quantities [2]
  9. Automation of measurements using a computer [2]
  10. Virtual laboratory [2]
  11. An example of an experiment for professional research [2]
  12. Example of an experiment for scientific research [2]
  13. Scientific literature [2]
- Exercises (auditory):
  1. Defining the experiment [4]
  2. Choice of instruments [2]

3. Instrument design for non-standardized testing [2]
4. Examples of non-standardized measurements [2]
5. Virtual laboratory [2]

- Exercises (construction):
  1. Setting the assignment – defining a problem (program) [2]
  2. Modelling of physical-chemical processes [4]
  3. Choice of instruments [2]
  4. Automation of measurements using a computer [2]
  5. Results processing [2]
  6. Analysis of results [2]
- Exercises (laboratory):
  1. Laboratory standardized tests [2]
  2. Laboratory non-standardized tests [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper
- Presentation of the seminar paper

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper
- Oral exam

Required reading:

1. Montgomery, D. C.: *Design and Analysis of Experiments*, International Student Version, 7th Edition, Wiley, 2009.

Additional reading:

1. Hicks, C. R.: *Fundamental Concepts in the Design of Experiments*, Holt, Reinhart and Winston, Inc., 1973.
2. Ashby, M. F.; Joneas, D. R. H.: *Engineering Materials 1*, Butterworth-Heinemann, Oxford - Boston - Johannesburg - Melbourne - NewDelhi - Singapore, 1996.

APPLIED METALLURGY

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (design): 10
- Exercises (construction): 20

Course objectives:

- To expand fundamental engineering knowledge about structural steels in order to facilitate the acquisition of new insights into the reliability of steel structures, their fabrication, and assembly;
- Acquisition of theoretical knowledge about the production methods of structural steels, their properties from the aspect of material selection for a particular structure exposed to specific conditions of use;
- Acquisition of practical knowledge for the selection of the appropriate type and group of steel from the aspect of brittle failure and resistance to lamellar tearing, that is, the specific application of the European standard EN 1993-1-10;
- Acquisition of theoretical background for assessing the durability of existing structures and for ensuring the quality of erection of new structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic production methods and basic properties of steel,
- Basic knowledge steel structures design.

Learning outcomes:

- To explain the modern production processes and shaping of products from alloyed carbon steels;
- To explain the advanced engineering steel properties with an emphasis on toughness and fatigue properties of the material;
- To apply the knowledge and skills necessary for selecting the steel quality when designing structural members of steel structures in different operating conditions according to contemporary methods and criteria of European standards;
- To explain and apply the knowledge about the weldability of structural steels;
- To apply specific skills and knowledge in the design of steel structures to avoid brittle failure;
- To explain basics of advanced fracture mechanics and apply this knowledge in the process of structural durability assessment.

Course content (by course schedule):

- Lectures:
  1. Introduction [1]
  2. Properties of carbon steel alloys [1]
  3. Manufacturing and forming processes [2]
  4. Introduction to engineering properties of steel [2]
  5. Advanced engineering properties of steel - Toughness [2]
  6. Advanced engineering properties of steel - Fatigue properties of material [2]
  7. Types and quality groups of steel [6]
  8. Selection of steel quality group [2]
  9. Selection of steel quality group to avoid brittle fracture - Toughness requirements [2]
  10. Additional design rules to avoid brittle fracture [4]
  11. Weldability of structural steels [2]
  12. Influence of hot-dip galvanizing on toughness [2]
  13. Introduction to aluminium metallurgy and metallography of aluminium alloys [2]
- Exercises (design):
  1. Determination of engineering properties of steel [2]
  2. Determination of mechanical properties of welds by hardness testing [1]
  3. Fracture toughness [2]

4. Selection of a steel quality subgroup with regard to the maximum allowed thickness [2]
5. The selection of a steel quality subgroup considering the member through-thickness properties [1]
6. Additional design rules to avoid brittle fracture [1]
7. Fatigue assessment procedure (remaining service life) of existing steel structures [1]

- Exercises (construction):
  1. Determination of mechanical properties of welds by hardness testing [5]
  2. Selection of a steel quality subgroup with regard to the maximum allowed thickness on the examples of structural bridge members [2]
  3. Selection of a steel quality subgroup with regard to the maximum allowed thickness on examples of structural industrial building members [2]
  4. The selection of a steel quality subgroup considering the member through-thickness properties [1]
  5. Selection of a steel quality subgroup considering the properties through-thickness of the element on the examples of structural connections (joints) in bridges [4]
  6. Additional design rules to avoid brittle fracture [1]
  7. Additional design rules to avoid brittle fracture on examples of structural joints [2]
  8. Fatigue assessment procedure (remaining service life) of existing steel structures [1]
  9. Fatigue assessment procedure (remaining service life) of existing steel structures on the example of a bridge [2]

Student Evaluation - Continuous assessment:

- Preparation and defence of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation and defence of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Practical part of the written exam
- Theoretical part of the written exam

Required reading:

1. Skejić, D.: Lecture notes from the course Applied Metallurgy - academic year 2023/2024, Faculty of Civil Engineering, University of Zagreb
2. Skejić, D.; Androić, B.; Dujmović, D.: Selection of steel based on toughness, Građevinar 64 (2012) 10, str. 805-815.
3. HRN EN 1993-1-10:2011 (EN 1993-1-10:2005 + AC:2005): Eurocode 3: Design of steel structures -- Part 1-10: Material toughness and through-thickness properties, 2011
4. G. Sedlacek et al.: Commentary and worked examples to EN 1993-1-10 'Material toughness and through thickness properties' and other toughness oriented rules in EN 1993, First Edition, September 2008.

5. B. Kühn et al.: Assessment of Existing Steel Structures: Recommendations for Estimation of Remaining Fatigue Life, JRC Scientific and Technical Reports, Joint Report, JRC European Commission, February 2008.
6. Boko, I.; Skejić, D.; Torić, N.: Aluminijske konstrukcije, Sveučilište u Splitu, Fakultet građevinarstva, arhitekture i geodezije, Udžbenik Sveučilišta u Splitu i Udžbenik Sveučilišta u Zagrebu, Split, 2017.
7. M. Gojić: Metalurgija čelika, Metalurški fakultet u Sisku, Sveučilište u Zagrebu, Sisak, 2005.

GREEN BUILDING

Credits (ECTS): 6,0

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (10 auditory, 20 construction)

Course objectives:
- The objective of this course is to enable students for advanced and integrated understanding of sustainable construction, so they are able to independently critically analyse, evaluate and optimize construction materials, structural systems, and technical solutions from the viewpoint of environmental impact, circular economy and durability, with the application of applicable standards and tools for objective sustainability validation including the application of life cycle assessment (LCA) at the product and building level. Students will be able to apply LCA at the product and building level, analyse and optimise the observed cases from an environmental perspective.

Entry competences (prior knowledge, descriptive):
- Knowledge of basic material properties
- Knowledge of basic environmental concepts

Learning outcomes:
- Explain the principles of sustainable and regenerative construction in different life cycle phases
- Understand the legal and legislative framework for sustainable built environment
- Identify environmental impacts in different project phases and different life cycles
- Understand and apply lice cycle assessment method and methods for the objective validation of life cycle assessment
- Apply and critically analyse methods for reducing the environmental impact of construction in different project phases and different life cycles

Course content (by course schedule):
- Lectures:
    1. Introduction to the concepts of linear and circular economy and the role of civil engineering, key aspects of green building: ecological, environmental, sociocultural and technological aspects [2]
    2. Legal and standardisation framework for sustainable use of natural resources in civil engineering [2]

3. Construction waste management strategies, recycling and reuse of a building, its materials, and parts after demolition [2]
4. Building durability management strategy, properties-based design approaches [2]
5. Industrial waste and secondary materials management strategy, use of ecological raw materials and secondary materials [2]
6. Tools for the comparison of the ecological footprint of a construction product, second generation certificates [2]
7. International green building certificates (LEED, BREEAM, DGNB) [2]
8. Green building management, Examples of green building [2]
9. Life cycle assessment calculation for phases A to D (LCA methodology) [2]
10. Life cycle assessment calculation for phases A to D – system boundaries, functional unit [2]
11. Life cycle assessment calculation for phases A to D – analysis and interpretation [2]
12. Life cycle assessment calculation for phases A to D – allocation [2]
13. Environmental impact statements / ecological indicators within the scope of the Construction Products Regulation [4]
14. Application of life cycle thinking (LCT) [2]

- Exercises:
  1. Key features of LCA and LCT [5]
  2. LCA – defining the goal and area of application, data analysis [5]
  3. Environmental impact assessment [5]
  4. Defining system boundaries, functional units and input data [5]
  5. LCA interpretation [5]
  6. Creation of LCA [5]

Student Evaluation - Continuous assessment:

- Preparation of a design within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Oral defence of the design

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a design within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. Kubba, Sam: Handbook of Green Building Design and Construction, LEED, BREEAM, and Green Globes, Second Edition, Elsevier, 2017
2. Kibert, Charles J.: Sustainable construction, Green building design and Delivery, John Wiley & Sons, 2013
3. Jamal Khatib Sustainability of Construction Materials, Woodhead Publishing, 2009

4. Emina K. Petrovic Brenda Vale Maibritt Pedersen Zari Materials for a Healthy, Ecological and Sustainable Built Environment, Woodhead Publishing, 2017 Charles J. Kibert Sustainable Construction: Green Building Design and Delivery, Wiley, 2016.

Additional reading:

1. Guidelines for green concrete structures, fib, 2012.
2. Schokker, A. J.: The sustainable Concrete Guide, U.S. Green Concrete Council, 2010.

NUMERICAL MATHEMATICS

See Chapter Shared Courses

PERSPECTIVE

See Chapter Shared Courses

GEOMETRY IN CIVIL ENGINEERING

See Chapter Shared Courses.

WAVES AND OSCILLATIONS

See Chapter Shared Courses

ENGLISH IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45

Course objectives:

1. Acquisition of skills in writing professional reports, resumes, and summarizing data and information from the technical field,
2. Gaining independence in presenting in a foreign language through work on creating presentations.
3. Entry competences (prior knowledge, descriptive):
4. Intermediate and upper-intermediate English.
5. Learning outcomes:
6. Comprehension of technical texts,
7. Independent writing of reports on technical procedures and their execution,
8. Coherent and structured communication and clear presentation of ideas with correct pronunciation,

9. Use of technical terms for efficient communication.

Course content (by course schedule):

1. Creating a CV - How to write a CV? Writing a letter of application / Job Interview Questions [3]
2. Professional Development. Preparing for the Interview Skills – Techniques, Tips and Advice. Recruitment of graduates [3]
3. Managing a Project [3]
4. Mission to Accomplish. Managing Projects and Complexity [3]
5. Company profile [3]
6. Time, Quality and Cost Issues: comparing Benefits & Weighing. Alternatives [3]
7. How to write an e-mail [3]
8. Leadership Strategy in Construction Process [3]
9. Construction Site Organization [3]
10. Preparing Tender Documentation [3]
11. Managing Projects and Complexity / Setting Goals II [3]
12. Single/Joint presentations [3]
13. Starting a career [3]
14. Risk Management [3]

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. A. Kralj Štih: *English in Hydro Engineering and Constructio*n Materials, course materials, Zagreb, 2010.

Additional reading:

1. Williams, English for Science and Engineering, Thomson ELT, USA, 2007
2. V.Lambert&W.Murray, Everyday Technical English, Essex, 2003

GERMAN IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45

Course objectives:

- The aim of this course is to help the student to independently use professional literature by developing comprehension, conversation and translation skills,

- Mastering all forms of oral communication of technical content, from participation in discussions to independent presentations.

Learning outcomes:

- Comprehension and interpretation of technical texts,
- Confidence and independence in oral expression in the technical field and when explaining professional terms,
- Writing a resume and job application.

Course content (by course schedule):

1. Projektmanagement im Ingenieurbau
2. Deutsch im Berufsalltag - Ein Tag im Leben eines Bauingenieurs
3. Projektmanagement im Ingenieurbau
4. Deutsch im Berufsalltag - Ein Tag im Leben eines Bauingenieurs
5. Bauleitung und Bauwirtschaft
6. Die Geschichte einer Renovation
7. Eine Frau an der Baustelle – Nadia Tschammer
8. Beton-Stahlbeton-Spannbeton
9. Porträts der Bauingenieure
10. Verschiedenste Brückenarten
11. Bauholz
12. Individuelle Präsentierung - Die Teampräsentierung
13. Wie man sich auf ein Interview vorbereitet
14. 10 goldene Fragen der Präsentation

Student Evaluation - Continuous assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Kralj Štih A., Deutsch für Vertiefungsrichtungen im Bauingenieurwesen, Sveučilišna skripta, Zagreb, 2015
2. V. Eismann, Erfolgreich bei Präsentationen, Trainingsmodul, Cornelsen Verlag, 2006.

Additional reading:

1. A. Prager: *Trojezični građevinski rječnik*, Masmedia, Zagreb, 2002.

Specialisation in CONSTRUCTION MANAGEMENT

1st year, 1st semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

CONSTRUCTION MANAGEMENT 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 13, design: 17)

Course objectives:

- Acquisition of theoretical knowledge to optimize planning, preparation, organization and control of the construction process,
- Acquisition of practical knowledge about methodologies for the organization of construction,
- Acquisition of knowledge about the use of advanced computer tools for the integrated management of construction projects.

Entry competences (prior knowledge, descriptive):

- Knowledge of the method of additional and direct calculation in construction,
- Theoretical knowledge from the organization of construction, such as price analysis, network planning, organizational charts, theories of organization, construction regulations, etc.

Learning outcomes:

- Recognize the theory of cost significant items,
- Explain the method of direct calculation in construction,
- Explain the cash flow in construction projects,
- Apply the cost significant items method,
- Explain different organizational structures in building systems.

Course contents:

- Lectures:
  1. Building Information Modelling
  2. Building Information Modelling

3. Application of software in calculation
4. Work breakdown structure (WBS) and organization breakdown structure (OBS)
5. Linking money with construction time
6. Organization of supply and logistics in the construction process
7. Theory of cost significant items
8. Creation of alternative solutions to construction management plan
9. Monitoring and control of construction execution
10. Organizational structures and contracting models in construction
11. Value management in construction and the concept of constructability
12. New trends in construction organization and Seminars

- Exercises (auditory):
  1. 1: Creation of BIM models and proof of measures in BIM software
  2. 2: Creating the WBS of the project
  3. 3: Creation of the cost sheet by additional calculation in the Gala software
  4. 4: Calculating the duration of the activity and creating a plan in the Gala software
  5. 5: Creation of the cost sheet by direct calculation in the Gala software
  6. 6: Selection of cost-relevant items. Analysis of the possibility of creating alternative solutions
  7. 7: Creation of a model for construction monitoring and control
- Exercises (design):
  1. 1: Creation of BIM models and proof of measures in BIM software
  2. 2: Creating the WBS of the project
  3. 3: Creation of the cost sheet by additional calculation in the Gala software
  4. 4: Calculating the duration of the activity and creating a plan in the Gala software
  5. 5: Creation of the cost sheet by direct calculation in the Gala software
  6. 6: Selection of cost-relevant items. Analysis of the possibility of creating alternative solutions
  7. 7: Creation of a model for construction monitoring and control

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a program assignment within the prescribed deadline
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a program assignment within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. Radujković, M. i dr.– Organizacija građenja 2015.
2. Vukomanović, M., Kolarić, S., Radujković, M. – Priručnik organizacije građenja, 2018.

3. Radujković M. – Organizacija građenja, 2008. (online lecture notes)
4. Lončarić R. – Organizacija izvedbe graditeljskih projekata, HDGI, Zagreb, 1995..
5. McGeorge & Palmer. – Construction Management, New Directions, Blackwell Science, Oxford, 2006 itd.
6. Radujković, M. i dr. - Planiranje i kontrola projekata 2013
7. Vukomanović, M. i Radujković, M. - Poslovna izvrsnost u graditeljstvu 2012

BUILDING MAINTENANCE MANAGEMENT

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 3, design: 12)

Course objectives:

- Train the student to create a building maintenance project,
- Train the student to use methods for creating a list of priorities in building maintenance.

Entry competences (prior knowledge, descriptive):

- It is necessary to know the calculation of the bill of quantities and the bill of costs.

Learning outcomes:

- Understanding the parts of the building maintenance project,
- Application of damage identification methods,
- Application of the multi-attribute method for deciding on the priority list of maintenance works,
- Application of the analytic hierarchy process for deciding on the priority list of maintenance works,
- Application of the "Expert Choice" computer software,
- Understanding the position of building maintenance in the context of managing a company's real estate portfolio.

Course content (by course schedule):

- Lectures:
  1. Introduction and general concepts
  2. State of regulations in the field of building maintenance
  3. Regular maintenance, preventive and reactive maintenance, reconstructions, repairs and emergency interventions
  4. Maintenance cost structure
  5. Building maintenance in the context of the entire construction process
  6. Building maintenance management: short-term and long-term maintenance plans
  7. Structure of the building maintenance project
  8. Planning and organization of maintenance works: Information technologies in maintenance; BIM and maintenance
  9. Maintenance and contracting strategies; Analysis of the life cycle cost of the building
  10. The place and role of building maintenance in facilities management
  11. Maintenance of old and legally protected buildings;
  12. Monument annuity and modality of annuity collection
  13. The impact of climate change on building maintenance
  14. Maintenance and renovation of buildings in accordance with energy efficiency

15. Management of the company's real estate portfolio (Corporate Real Estate Management) with an emphasis on the management and maintenance of buildings

- Exercises:
  1. Defining project tasks
  2. Inspection of the selected building and creation of photo documentation of damage to the building
  3. Inspection of the building and completion of standardized forms for the maintenance of the building
  4. Creating a list of damage to the building
  5. Creation of a detailed description of damage to the building with photo documentation
  6. Creation of a proposal to repair damage for the selected building
  7. Creation of a proposal to repair damage for the selected building
  8. Defining criteria for multi-criteria analyses and creating a list of priorities for maintenance plans
  9. Creating a list of maintenance priorities using the analytic hierarchy process with the Superdecisions software
  10. Creating a list of priorities with a multi-attribute approach
  11. Estimate of costs for all planned works on building maintenance/renovation
  12. Creation of a time plan for damage repair
  13. Simulation of building maintenance costs with @Risk - DecisionTools Suite
  14. Program presentations and defences
  15. Program presentations and defences

Student Evaluation - Continuous assessment:
- Timely preparation and submission of program assignments
- 75% attendance at lectures
- 100% attendance at exercises
- 2 midterm exams: a minimum score of 60% of total points must be obtained on each midterm exam

Student Evaluation - Examination without Continuous Assessment:
- Timely preparation and submission of program assignments
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam according to the exam schedule

Additional reading:
1. Mills, E., "Building Maintenance & Preservation", Architectural Press, Oxford, 1996.
2. Flanagan, R., Jewell, C., "Whole Life Appraisal for Construction", Blackwell Science, Oxford, 2005.
3. Sonnemann, G., Margni, M. (Eds.), "Life Cycle Management", Springer Netherlands, Dordrecht, 2015. 4. Preiser, W., Hardy, A.E., Schramm, U. (Eds.), "Building Performance Evaluation (2nd ed.)", Springer, Berlin, 2018.
4. Wood, B., "Building Maintenance", Wiley-Blackwell, Hoboken, New Jersey, 2009.

5. Stanford, H., "Effective Building Maintenance: Protection of Capital Assets", Fairmont Press, Georgia, USA, 2010.

OPTIMIZATION METHODS IN CONSTRUCTION

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (auditory: 15, design 15)

Course objectives:
- Acquisition of knowledge about operational research methods and their application in problems of optimization of organization and of construction technology.

Entry competences (prior knowledge, descriptive):
- Knowledge of the basics of organization and construction technology,
- Understanding the basics of linear algebra and mathematical statistics.

Learning outcomes:
- Demonstrate the ability to solve linear programming problems using the graphical and simplex method,
- Demonstrate the ability to solve dynamic deterministic and probabilistic programming problems,
- Demonstrate the ability to use the methods of decision-making in certainty, decision-making with risk and decision-making in uncertainty,
- Demonstrate the ability to create Monte Carlo simulation models.

Course content (by course schedule):
- Lectures:
  1. Introduction
  2. Linear programming models with two variables, graphical solution, graphical sensitivity analysis
  3. Transition from graphical to algebraic solution, simplex method
  4. Artificial initial solution, special cases in the application of the simplex method
  5. Definition of dual problem, relationship between primal and dual, interpretation of duality
  6. Postoptimal analysis and sensitivity analysis
  7. Transport models
  8. Network models
  9. Deterministic dynamic programming
  10. Deterministic models of inventory
  11. Non-linear programming
  12. Decision-making in certainty, decision-making with risk, decision-making in uncertainty
  13. Probabilistic dynamic programming, probabilistic models of inventory, queuing systems
  14. Monte Carlo simulation, random number generators
  15. Simulation languages

- Exercises:
  1. Graphic solution
  2. Simplex method
  3. Graphical solution and simplex method with the help of a computer
  4. Artificial initial solution, special cases in the application of the simplex method
  5. Definition of dual problem, relationship between primal and dual, interpretation of duality
  6. Postoptimal analysis and sensitivity analysis
  7. Transport models, network models
  8. (1st midterm exam)
  9. Deterministic dynamic programming, deterministic models of inventory
  10. Non-linear programming
  11. Decision-making in certainty, decision-making with risk, decision-making in uncertainty
  12. Probabilistic dynamic programming, probabilistic model of inventory, queuing systems
  13. Monte Carlo simulation, random number generators, simulation languages
  14. (2nd midterm exam)
  15. Retest

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- 2 midterm exams: a minimum score of 60% of total points must be obtained on each midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam – a minimum score of 60% is required

Required reading:

1. Lj.Martić: Matematičke metode za ekonomske analize II, Narodne novine, Zagreb, 1965.
2. W.Jurecka, H.J.Zimmermann: Operation Research in Bauwesen, Springer Verlag, 1972.
3. N.Limić: Linearno i nelinearno programiranje, Informator, Zagreb, 1978.
4. V.Čerić: Simulacijsko modeliranje, Školska knjiga, Zagreb, 1993.
5. V.Žiljak: Simulacija računalom, Školska knjiga, Zagreb, 1982.
6. H.A.Taha: Operations research, Prentice Hall, 2003

STUDY OF WORK

Credits (ECTS): 4.5
Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 10, on the computer: 5)

Course objectives:

- Based on a detailed analysis of the construction productivity, the student will master methods and techniques for studying work, with the support of which they can impact work design and increase efficiency in construction processes, along with acquiring detailed theoretical knowledge such as:
    - Work organization,
    - Theories of organizations,
    - Development of general management,
    - Construction productivity,
    - Application of information technology (IT) in construction,
    - Execution of construction projects
    - Managerial approach to project management,
    - Human resources,
    - Rationalization of construction productivity,
    - Organization of preparation of construction productivity and
    - design organization

Entry competences (prior knowledge, descriptive):

- Knowledge of the main construction technological processes:
    - Earthworks,
    - Carpentry works,
    - Concrete works,
    - Reinforcement works,
    - Reinforced concrete works,
    - Masonry works,
    - Asphalt works and
    - Hydrotechnical works.
- Understanding the application and use of computers.

Learning outcomes:

- Knowledge of the methodological procedure in the preparation of the Elaborate of study of work and process management,
- Mastery of calculating construction norms through the application of work study methods;
- application of simulation methods in the construction industry.,

Course content (by course schedule):

- Lectures:

1. A short refresher and introduction
2. Organization of work and production: Historical development of work organization; Construction development; Organization of work; Four (4) Taylor principles; Principles of work organization; The future of studies of work; Two (2) fundamental areas of development of labour science. Concept of production; Production goals; Scientific disciplines of production organization; Five (5) characteristic stages of production development
3. Work study. Objectives, methods, content and results.
4. Labour force classification, norms and normatives. Vocational and educational degrees. Official classifications of competency levels.

5. Time and material measurement. Development of time and material normatives (standards) in construction.
6. Process determinants of production, storage and installation of materials. Parameters on the basis of which coordination of workers in groups and organization of work processes is carried out.
7. Coordination of workers and machines in early groups. Rules of coordination in work operations and work processes. Regard for quantities and units of work.
8. Practical maxima of the amount of work in time and space. Organizational and technological limitation of work efficiency.
9. Connection of work processes and project activities. Analytics of processes and activities. Static and dynamic process planning.
10. Determination of working groups. Optimal use of resources on activities.
11. Human resources in production and construction works. Productivity of workers and their optimal grouping. Labour productivity factors; Physiological impacts on workers; Sociological influences on persons; Influences of the working environment on construction professionals.
12. Application of material and time standards. Normatives and standards. International differences and applicability. Presentation and explanation of the application of normatives in the construction industry of the Republic of Croatia and the world; Review of the practice of applying standard norms and those specific to individual organizations; Creation and use of norms and normatives in EU practice; Comparison of EU and Croatian best practice; Trends in the study of work and the use of modern technologies.
13. Studying construction work in the context of the economy. Social dialogue, safety and the right to work.
14. Industrialization 4.0 in the context of labour studies. Robotization and the impact of industrialization on production processes.
15. Production simulation. Definition of the term simulation; Application of the best-known simulation methods (Queueing theory, Monte Carlo method, discrete event method)

- Exercises:

1. Introduction and division of students into groups
2. Mathematical basis for the study of work
3. Breakdown of elements of work processes and working hours at the operational and market level.
4. A digital approach to dynamic process modelling.
5. A digital approach to dynamic process modelling.
6. Tasks of work organization in different conditions.
7. Coordination of workers and machines in workgroups.
8. Tasks of the organization of work processes - conditions and variant solutions.
9. Tasks of the organization of work processes - conditions and variant solutions.
10. Students are introduced to the possibilities of using IT software packages for simulations and solving concrete examples.
11. Students are introduced to the possibilities of using IT software packages for simulations and solving concrete examples.
12. Students are introduced to the possibilities of using IT software packages for simulations and solving concrete examples.
13. Students are introduced to the possibilities of using IT software packages for simulations and solving concrete examples.

14. Students are introduced to the possibilities of using IT software packages for simulations and solving concrete examples.
15. Conclusion of the course and final consultations with students; Integration of what has been learned.

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Solution of the project assignment submitted within the prescribed deadline
- Assessment of the anonymous solution of the project assignment submitted
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Solution of the project assignment submitted within the prescribed deadline
- Assessment of the anonymous solution of the project assignment submitted
- Written exam
- Oral exam

Required reading:

1. Nahod, M.-M. – Study of Work, course material, e-learning system Merlin 2021/2022.
2. C.P. Robert and G. Casella, Introducing Monte Carlo Methods with R, Springer, 2010.
3. Thomas H.R., Ellis R.D. - Construction Site Management and Labor Productivity Improvement, ASCE Press, 2017
4. J.Marušić, Organizacija građenja, university handbook, FS, Zagreb, 1994.
5. J.K. Yates, Productivity Improvement for Construction and Engineering: Implementing Programs That Save Money and Time, ISBN: 978-0784413463, 2014.

Elective courses

MATHEMATICS 3

See Chapter Shared Courses

STOCHASTIC PROCESSES

See Chapter Shared Courses

1st year, 2nd semester

Mandatory courses

CONSTRUCTION EQUIPMENT

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 26
- Seminars: 4
- Exercises: 30 (auditory: 12, construction: 18)

Course objectives:

- Acquisition of theoretical knowledge about the planning, use and maintenance of construction equipment, machines and machinery systems,
- Acquisition of practical knowledge on procedures for calculating performance, price, capacity, reliability and usability of construction equipment and machine systems.

Entry competences (prior knowledge, descriptive):

- Knowledge of the method of additional and direct calculation in construction,
- Knowledge of theoretical knowledge from construction technology and organization, such as types of basic construction equipment, calculation of the practical effect of the equipment, price of the working hour of the equipment, price analysis, network planning, technology maps, etc. Knowledge of mathematical methods of probability and statistics.

Learning outcomes:

- Identify facilities for the production of materials,
- Recognize the working systems of construction equipment,
- Apply the equipment selection method,
- Apply the method of planning equipment work,
- Apply the method of calculating the price of the working hour of the equipment,
- Apply the method of calculating the reliability of equipment.

Course content (by course schedule):

- Lectures:
  1. Introduction
  2. The performance of construction equipment
  3. Determining the working time of the equipment
  4. Selection of equipment and planning of machine work
  5. Reliability of equipment systems
  6. Machine work costs
  7. Lifetime and economy of machines
  8. Midterm exam 1
  9. Plants for the production of materials
  10. Operating systems

11. Construction logistics
12. Cranes and internal transport
13. Mobile technologies and analysis of the use of construction machinery and equipment
14. Seminar papers
15. Midterm exam 2

- Exercises:
  1. Introductory instructions for creating the program assignment
  2. The performance of construction equipment
  3. Equipment work planning
  4. Equipment work costs
  5. Reliability of construction equipment
  6. Optimizing the choice of construction equipment
  7. Final review of program assignment
  8. Submission of program assignments

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline
- First midterm exam
- Second midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam

Contributions to the final grade:

- Program assignment 30%, seminar 10% and midterm exam 60% or exam 100%.

Required reading:

1. Linarić Z.: Leksikon strojeva i opreme za proizvodnju građevinskih materijala, Učinci za strojeve i vozila pri zemljanim radovima, biblioteka Mineral, Busines Media Croatia, Zagreb, 2007.
2. Linarić Z.: Postrojenja za proizvodnju sipkih i povezanih mineralnih gradiva, biblioteka Mineral, Busines Media Croatia, Zagreb, 2009.
3. Radujković, M; Burcar Dunović, I; Dolaček Alduk, Z,; Nahod, M.M.; Vukomanović, Mladen. Organizacija građenja, Zagreb : Građevinski fakultet Sveučilišta u Zagrebu, 2015.
4. Slunjski, E.; Strojevi u građevinarstvu, HGDI, Zagreb, 1995.
5. Taboršak, D.; Studij rada, četvrto izdanje, Orgadata, Zagreb, 1994.
6. Trbojević, B., Praščević, Ž.; Građevinske mašine, Građevinska knjiga, Beograd, 1991.
7. Žaja, M.; Ekonomika proizvodnje, Školska knjiga, Zagreb, 1991.
8. Electronic textbooks – www.grad.hr→staff→full professors→Zdravko Linarić→attached documents: Knjiga 1: Leksikon strojeva, Učinak građevinskih strojeva, Troškovi strojnog

rada, Izbor strojeva i planiranje strojnog rada u građenju, Postrojenja za proizvodnju gradiva I. Dio; Drobilane, Tvornice betona, Asfaltna postrojenja, Sustavi građevinskih strojeva.

9. Offprints

MANAGEMENT FOR CONSTRUCTION INDUSTRY

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises 15 (auditory: 4, seminars: 11)

Course objectives:

- Acquiring a theoretical knowledge of management principles, project management, and business decision-making,
- Understanding corporate concepts, construction operations, outcomes, and market concepts.

Entry competences (prior knowledge, descriptive):

- Preferably knowledge of the basics of economics within the Business Economics course (elective course in the first year of undergraduate studies).

Learning outcomes:

- Explain management fundamentals, including development and functions,
- Describe management as a process including planning, organising, motivating, and controlling,
- Explain decision-making styles and processes for businesses,
- Definition of company types, the limitations and principles of business operations, and the business itself through the process of reproduction and business assets,
- Differentiation between business costs, prices and calculations,
- Interpretation of indicators of business results,
- Analyse market types and market exchange participants.

Course content (by course schedule):

- Lectures:
  1. Introduction
  2. 1. Basic principles of management
  3. Managers/technomanagers Management functions
  4. Development of Management Schools of management
  5. 2. Management as a process – planning, organizing
  6. Management as a process – motivation, control
  7. 3. Company – concepts, types
  8. Companies – reproduction process, business assets of the company
  9. 4. Costs, prices and calculations
  10. 5. Business results – financial reports, success indicators
  11. 6. Business decision-making – methods and styles
  12. Business decision-making – communication
  13. 7. Market and market operations
  14. Market and exchange participants

15. Presentation of seminar papers

- Exercises:
  1. Management – Concept/Merlin
  2. How to write a seminar paper?
  3. Who are effective leaders?
  4. How to prepare a successful presentation?
  5. Case study
  6. Presentation of the seminar work – discussion
  7. 1st midterm exam
  8. Case study
  9. Case study
  10. Presentation of the seminar work – discussion
  11. 2nd midterm exam
  12. Case study
  13. Presentation of the seminar work – discussion
  14. Seminar Presentation of the seminar work – discussion
  15. Seminar 3rd midterm exam

Student Evaluation - Continuous assessment:

- Prepared and presented seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Prepared and presented seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Katavić, M.: Osnove ekonomike za graditelje, Hrvatska sveučilišna naknada, Zagreb, 2009.
2. Sikavica, P., Bahtijarević-Šiber, F., Pološki vokić, N.: Temelji menadžmenta, Školska knjiga, Zagreb, 2008.
3. Sherratt, F., Farell, P.: Introduction to Construction Management, Routledge, NY; 2015.
4. Materials available on the e-learning system Merlin

CONSTRUCTION PROJECT MANAGEMENT

Credits (ECTS): 9

Hours (total per semester):

- Lectures: 60

- Exercises: 30 (auditory: 16, design: 14)

Course objectives:

- Acquisition of theoretical knowledge about planning, managing, leading, organizing and controlling construction projects and other aspects of project management,
- Acquisition of practical knowledge of construction project management tools.

Entry competences (prior knowledge, descriptive):

- Knowledge of the method of additional and direct calculation in construction,
- Theoretical knowledge from the organization of construction, such as price analysis, network planning, organizational charts, theories of organization, construction regulations, etc.

Learning outcomes:

- Recognize the foundations of project management (Strategies, Goals, Content, Phases, Lifetime, Participants, Limitations, Success Variables, Project Sustainability),
- Recognize management processes in the front end (Project identification, Project concept and definition, Early Project Design, Project execution preparation),
- Recognize the management processes throughout the implementation phases (Starting execution, Execution, Completion of execution) apply the method of planning machine work,
- Apply various the team life cycle and leadership models,
- Apply various risk management methods,
- Apply various quality management methods

Course contents:

- Lectures:
  1. Basic knowledge of project management (Development of project management, Basic knowledge according to IPMA, ISO 21500 and PMI standards)
  2. Basics of construction project management (Strategies, Goals, Content, Phases, Lifetime, Participants, Constraints, Success Variables, Project Sustainability)
  3. Management in the front-end phases (Identification of the project, Definition of the project, Preparation of the execution of the project)
  4. Management throughout execution phases (Initiation of execution, Execution, Completion of execution)
  5. Construction project manager, Execution management (Required qualifications, Special features of the manager, Job of the manager, Responsibilities of the manager, Project management program)
  6. Teamwork (Definition of a team, Characteristics of an effective team, Team formation – composition and size, Teamwork, Individual team roles, Teamwork problems, Examples of project teams, Leadership, Conflicts)
  7. Risk management in construction projects (Definitions of risks, Essential characteristics of risks, Effects of risks in construction projects, Identification of sources of risk, Analysis of risks, Response to risks)
  8. Change management in Construction (Sources of changes, Deciding on changes, Administration of changes)
  9. Human resource management (Importance and functions, Management techniques, Human resource planning)

10. Quality/cost/time management in construction projects (Elements of quality, Standardization of quality, Quality in the project and business system, Quality as a strategic goal, Total quality management, Management methods and techniques)
11. Management of information and communication in construction projects (Information, Communication, Information technologies, Information system planning, Decision making)
12. Documentation of construction project management (Assignment of works and services, Contract documentation, Domestic and foreign sources of documentation, Performance contracts, Concession agreements, Engineering contracts, Documentation for contractual claims and disputes)
13. Information systems (IS) and information technologies (IT) in the context of construction project management

- Exercises:
  1. Project description (SWOT, purpose, strategic and project goals, short-term and long-term)
  2. Project description (SWOT, purpose, strategic and project goals, short-term and long-term)
  3. Interested parties (Internal, external, strength matrix, interest, attitude, their potential influence, their wishes, needs and goals in the project)
  4. Interested parties (Internal, external, strength matrix, interest, attitude, their potential influence, their wishes, needs and goals in the project)
  5. Project content (scope, WBS, documentation for all project phases, project concept as a unifying document, management team, team functions, team collaboration)
  6. Project content (scope, WBS, documentation for all project phases, project concept as a unifying document, management team, team functions, team collaboration)
  7. Project activity planning (WBS, OBS, human and material resources, prices)
  8. Project activity planning (WBS, OBS, human and material resources, prices)
  9. Risks in the project (identification and register of risks, impact and consequences of risks on the project, risk reduction measures
  10. Risks in the project (identification and register of risks, impact and consequences of risks on the project, risk reduction measures)
  11. Project communication plan, and project monitoring and control (RAM, communication plan with reference to the WBS-OBS structure, control and reporting system, corrective activities, communication forms)
  12. Project communication plan, and project monitoring and control (RAM, communication plan with reference to the WBS-OBS structure, control and reporting system, corrective activities, communication forms)
  13. Closing the project - project close out (lessons learned, transfer of knowledge from the project, saving the database, handover and closing the project)
  14. Presentation of the project plan (the entire course program)
  15. Final defence and submission of the program assignment

Student Evaluation - Continuous assessment:

- First midterm exam
- Second midterm exam
- Third midterm exam

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper within the prescribed deadline

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of a seminar paper within the prescribed deadline

Required reading:

1. Radujković M. , Pienaru A., et al. – PM Toolkit, Hrvatska udruga za upravljanje projektima, Zagreb, 2004.
2. Radujković M. – Upravljanje građevinskim projektima, GF Zagreb 2009., (non-reviewed lecture notes)
3. Skendrović V. – Upravljanje projektima , GF Osijek, Osijek, 2002.
4. International Project Management Association – ICB v.4., , IPMA, Zurich 2015.
5. Project management Institute – A Guide to Project Management Body of Knowledge, 6th Edition, PMI, USA, 2017.,
6. Izetbegović J., Žerjav V., Organizacija građevinske proizvodnje, university handbook, GF Sveučilišta u Zagrebu, Hrvatska udruga za organizaciju građenja, Zagreb, 2009.
7. Vukomanović, M. i Radujković, M – Poslovna izvrsnost u građevinarstvu RH, Sveučilište u Zagrebu, Građevinski fakultet i Hrvatska udruga za organizaciju građenja, 2011.
8. Radujković, M; Burcar Dunović, I; Dolaček Alduk, Z,; Nahod, M.M.; Vukomanović, Mladen. Organizacija građenja, Zagreb : Građevinski fakultet Sveučilišta u Zagrebu, 2015.
9. Radujković, Mladen; Car-Pušić, Diana; Ostojić Škomrlj, Nives; Vukomanović, Mladen; Burcar Dunović, Ivana; Delić, Davor; Meštrović, Hrvoje. Planiranje i kontrola projekata, Sveučilište u Zagrebu, Građevinski fakultet, 2012.
10. Radujković, Mladen; Burcar, Ivana; Vukomanović, Mladen. Riješeni primjeri zadataka - Organizacija građenja 1 i Metode planiranja; Zagreb : Građevinski fakultet Sveučilišta u Zagrebu, 2008.
11. European Commission; Centre of Excellence in Project Management (CoEPM²). PM'2 Project Management Methodology Guide, Open Edition, Brussels, / Luxemburg, 2016.
12. Office of Government Commerce. Managing Successful Projects with PRINCE2, UK, 2009.

Elective courses

ENVIRONMENTAL PROTECTION

See Chapter Specialisation in Hydraulic Engineering.

ENGLISH IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45 (auditory)

Course objectives:

- The classes are focused on the language needs of future construction managers, that is, on mastering important professional terminology from various fields of civil engineering in general, and on acquiring the vocabulary of business language. Language classes also include linguistic preparation of students for the upcoming work experience – simulating an interview through oral exercises, writing a letter to an employer, writing a job application. The aim of the course is to help the student to independently use professional literature and participate in all forms of oral communication of technical content, from participation in discussions to independent and joint presentations.
- Developing comprehension, conversation and translation skills.

Entry competences (prior knowledge, descriptive):

- Intermediate and upper-intermediate English.

Learning outcomes:

- Comprehension and interpretation of technical texts,
- Independent writing of a report on a technical procedure and its execution,
- Confidence and independence in oral expression in the professional field and explaining professional terms,
- Language skills for the design of tender documents,
- Analysing, selecting and organizing ideas and information from different sources.

Course content (by course schedule):

1. Creating a CV - How to write a CV? Writing a letter of application / Job Interview Questions
2. Professional Development Preparing for the Interview Skills – Techniques, Tips and Advice Recruitment of graduates
3. Managing a Project
4. Mission to Accomplish Managing Projects and Complexity
5. Company Profile
6. Time, Quality and Cost Issues: comparing Benefits & Weighing Alternatives
7. How to Write an E-mail?
8. Leadership Strategy in Construction Process
9. Construction Site Organization
10. Preparing Tender Documentation
11. Managing Projects and Complexity / Setting Goals II
12. Single/Joint presentations
13. Starting a Career
14. Risk Management
15. Preliminary exam

Student Evaluation - Continuous assessment:

- Preparation of a presentation

- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. A. Kralj Štih, English for Civil Engineering Specialization Fields (Construction Management), University course materials, Zagreb, 2015
2. Williams, English for Science and Engineering, Thomson ELT, USA, 2007
3. V.Lambert&W.Murray, Everyday Technical English, Essex, 2003

GERMAN IN CIVIL ENGINEERING 2

Credits (ECTS): 4.5

Hours (total per semester):

- Exercises: 45

Course objectives:

- The aim of this course is to help the student to independently use professional literature by developing comprehension, conversation and translation skills,
- Mastering all forms of oral communication of technical content, from participation in discussions to independent presentations.

Learning outcomes:

- Comprehension and interpretation of technical texts,
- Confidence and independence in oral expression in the technical field and when explaining professional terms,
- Writing a resume and job application.

Course content (by course schedule):

1. Projektmanagement im Ingenieurbau
2. Deutsch im Berufsalltag - Ein Tag im Leben eines Bauingenieurs
3. Projektmanagement im Ingenieurbau
4. Deutsch im Berufsalltag - Ein Tag im Leben eines Bauingenieurs
5. Bauleitung und Bauwirtschaft
6. Die Geschichte einer Renovation
7. Eine Frau an der Baustelle – Nadia Tschammer
8. Beton-Stahlbeton-Spannbeton
9. Porträts der Bauingenieure
10. Verschiedenste Brückenarten
11. Bauholz
12. Individuelle Präsentierung - Die Teampräsentierung

13. Wie man sich auf ein Interview vorbereitet
14. 10 goldene Fragen der Präsentation
15. Endprüfung

Student Evaluation - Continuous assessment:
- Preparation of a presentation
- 100% attendance at exercises
- Midterm exams

Student Evaluation - Examination without Continuous Assessment:
- Preparation of a presentation
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:
1. Kralj Štih A., Deutsch für Vertiefungsrichtungen im Bauingenieurwesen, Sveučilišna skripta, Zagreb, 2015
2. V. Eismann, Erfolgreich bei Präsentationen, Trainingsmodul, Cornelsen Verlag, 2006
3. Online sources: www.bau.de

BUILDING INFORMATION MODELLING

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (auditory: 11, design 19)

Course objectives:
- Acquisition of theoretical knowledge about building information modelling (BIM),
- Acquisition of theoretical knowledge about planning, management, organization and control of BIM construction projects,
- Acquisition of practical knowledge of BIM tools and processes for planning, preparation and execution of construction projects,
- Acquisition of practical knowledge about the necessary competencies of persons involved in BIM project management,
- Acquisition of practical knowledge about standards, processes and tools for applying the BIM concept in projects.

Learning outcomes:
- Explain the definition, properties and importance of BIM in construction projects.
- Recognize the necessary competencies of persons involved in the BIM project.
- Create and interpret the BIM execution plan and the employer's information requirements (EIR).
- Create a plan for communication, monitoring and quality control in BIM projects.
- Create a BIM model of the building.

- Create and evaluate a 5D construction execution plan.
- Interpret the relationship between the BIM project execution plan and the project management plan.

Course content (by course schedule):

- Lectures:
  1. Modelling and information management in the BIM environment (nD modelling)
  2. Roles and responsibilities of persons involved in BIM projects
  3. Data standards in BIM projects (ISO 16739, ISO 12006-3, ISO 29481, etc.)
  4. Process standards in BIM projects (family of ISO 19650 standards)
  5. Defining model information: BIM objects and libraries, levels of detail (LOD), classification systems (ISO 12006-2 and ISO 17412)
  6. Employer's information requirements (EIR) and BIM execution plan (BEP) in projects (context in project management, purpose and necessary principles in application)
  7. Delivery of digital information and use of information in different phases of the project (PIM, AIM, COBie, Digital Plan of Work, etc.)
  8. Exchange and security of information use in BIM projects (common data environment, UK Government Soft Landing scheme, etc.)
  9. Conditions for contracting the application of BIM on projects (ownership of BIM models, intellectual rights, insurance and exposure to risks, etc.)
  10. The state of BIM application (global and national standards, certificates, professional organizations that promote and support the application of BIM, legal regulations, etc.)
  11. Maturity levels and organizational resistance and changes in BIM implementation
  12. Values from the application of BIM technology in projects (improvement of construction and maintenance processes, reduction of waste, elimination of errors, improvement of the quality of deliveries, improvement of coordination of participants, etc.)
  13. New trends and the future of management in BIM projects
- Exercises (auditory):
  1. 1: Defining the input data for working in the BIM environment
  2. 2: Quality control of the BIM model (original and IFC file)
  3. 3: Creating a 4D BIM model
  4. 4: Creation of 5D BIM model
  5. 5: Creating a dynamic scheme of the construction site
  6. 6: Creating a BIM execution plan
- Exercises (design):
  1. 1: Defining the input data for working in the BIM environment
  2. 2: Quality control of the BIM model (original and IFC file)
  3. 3: Creating a 4D BIM model
  4. 4: Creation of 5D BIM model
  5. 5: Creating a dynamic scheme of the construction site
  6. 6: Creating a BIM execution plan

Student Evaluation - Continuous assessment:

- First midterm exam
- Second midterm exam
- 75% attendance at lectures

- 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. Sacks, R. i dr.. -BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 3rd Edition, 2018.
2. EU BIM Task Group - Handbook for the introduction of Building Information Modelling by the European Public Sector
3. Jurčević, M. et al. – Opće smjernice za BIM pristup u graditeljstvu, Zagreb, 2017.
4. Andabaka, F. i dr. - Smjernice za BIM pristup u infrastrukturnim projektima, Zagreb, 2021.
5. Orešić, V. – BIM plan izvršenja – BEP, 2017. 90
6. ISO 12006-2:2015 Building construction – Organization of information about construction works – Part 2: Framework for classification
7. ISO 12006-3:2007 Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information
8. ISO 16739-1:2018 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries – Part 1: Data schema
9. ISO 29481-1:2010 Building information modelling – Information delivery manual – Part 1: Methodology and format
10. ISO 29481-2:2012 Building information models - Information delivery manual - Part 2: Interaction framework
11. ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including BIM - Information management using building information modelling - Part 1: Concepts and principles
12. ISO 19650-2:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 2: Delivery phase of the assets
13. ISO 19650-3:2020 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 3: Operational phase of assets
14. ISO 19650-4:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 4: Information exchange
15. ISO 19650-5:2020 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) Information management using building information modelling - Part 5: security-minded approach to information management
16. ISO 15686-4:2014 Building Construction — Service Life Planning — Part 4: Service Life Planning using Building Information Modelling

17. ISO 17412-1:2020 Building Information Modelling - Level of Information Need - Part 1: Concepts and principles
18. CIC Research Group, Department of Architectural Engineering, The Pennsylvania State University - The BIM Project Execution Planning Guide and Templates - Version 2.0, 201

CONSTRUCTION TECHNOLOGIES 1

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (auditory: 10, design: 20)

Course objectives:

- Familiarization with techniques and technologies of earthworks in soil and rock, logistics and technology of disposal of construction waste, equipment for recycling construction waste, techniques and technologies of blasting activities, protection of earthworks and buildings, excavations under the surface, excavations of tunnels, construction of pipelines.

Learning outcomes:

- Identification of the terrain and proper selection of machines for work,
- Specify the machines for the demolition and of the recycling plant,
- Recognize the problems of the works and determine the technology and technique of underground works on pipelines,
- Recognize the problem and dimension and determine the technology and technique of tunnel excavation works,
- Determine the method and size of the blasting activities in the quarry

Course content (by course schedule):

- Lectures:
  1. Technique and technology of earthworks in soil and rock. Technique and technology of construction. Excavation of rock
  2. Technique and technology of earthworks - Excavation of soil and rock Transport of bulk construction materials and construction of earthworks Preparatory works for earthworks
  3. Technique, technology and logistics of dealing with construction waste Environmental protection, construction waste Collection of construction waste Recycling of construction waste
  4. Technique, technology and logistics of dealing with construction waste. Use of recycled materials
  5. Technique and technology of rock blasting (Explosives, igniters and explosive tapes; NONEL-activation system. Theory of blasting, Parameters of blasting. Perimeter (contour) blasting.
  6. Fieldwork – a tour of the construction site with an introduction to and reflection on the technique and technology of earthworks.
  7. 1st midterm exam
  8. Technique and technology of the production of stone rubble Production of bulk building materials for earthfill structures Crushing and crushing plants Screening, calculation of screens

9. Technique and technology of stone rubble production Washing of stone rubble. Mobile crushers and screens Protection of earthworks and structures – buildings Stabilization and consolidation of the foundation soil, Jet grouting Protection of slopes.
10. Protection of earthworks and structures – buildings Protection of slopes Protection of trenches, protection of construction pits, diaphragms
11. Technique and technology of underground excavations (tunnelling) Technique and technology of underground excavations NATM
12. Technique and technology of underground excavations (tunnelling) TBM Technique and technology of pipeline execution (microtunnelling) Selection and planning of technique and technology of earthworks Performance of machines and vehicles during earthworks Costs of earthworks
13. Selection and planning of technique and technology in bridge construction
14. 2nd midterm exam
15. Corrective exam

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Program assignment submitted and defended within the prescribed deadline
- First midterm exam – a minimum score of 60%
- Second midterm exam – a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Program assignment submitted and defended within the prescribed deadline
- Written exam, a minimum score of 60%

Required reading:

1. Božić B.: Miniranje u rudarstvu, graditeljstvu i geotehnici, Udžbenici Sveučilišta u Zagrebu, Geotehnički fakultet u Varaždinu, Varaždin, 1998,
2. Ester Z.: Miniranje I., Eksplozivne tvari, metode i svojstva ispitivanja, Udžbenici Sveučilišta u Zagrebu, RGN fakultet, Zagreb, 2005,
3. Linarić Z.: Leksikon strojeva i opreme za proizvodnju građevinskih materijala, Učinci za strojeve i vozila pri zemljanim radovima, biblioteka Mineral, Busines Media Croatia, Zagreb, 2007,
4. Roje-Bonacci T.: Potporne građevine i građevinske jame, Građevinsko-arhitektonski fakultet u Splitu, Sveučilište u Splitu, IGH d.d. Zagreb, Split 2005;
5. Other content: electronic textbooks available on the Merlin e-learning system: Linarić, Zdravko: Izbor strojeva i planiranje strojnog rada u građenju Linarić, Zdravko: Leksikon osnovne građevinske dokumentacije Linarić, Zdravko: Sustavi građevinskih strojeva Linarić, Zdravko: Troškovi strojnog rada u građenju Linarić, Zdravko: Učinak građevinskih strojeva

SUPERVISION AND MONITORING OF CONSTRUCTION PROJECTS

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition and connection of knowledge in the field of construction regulations, quality management and organization theory in order to monitor and control construction.

Entry competences (prior knowledge, descriptive):

- Basics of construction regulations,
- Basics of construction technology.

Learning outcomes:

- Explain the normative and contractual bases of monitoring and control of the construction process,
- List and describe the duties of expert supervision in the phases of the project,
- Describe the principles of quality, cost and time control in the construction process,
- Explain the activities of technical consulting of investors.

Course content (by course schedule):

- Lectures:
  1. Normative bases of professional supervision over the execution of works, laws and regulations
  2. Contractual basis of professional supervision. Professional supervision and other participants in the project. Structure of the supervisory team and relations within it
  3. The role and duties of professional supervision in the project phases: appointment, introduction of the contractor to the work, verification of technical documentation, geodetic survey
  4. Control of quantities, methods of measurement and calculation
  5. Quality control
  6. Control of the dynamics of work execution
  7. Financial control. Evaluation of extra-cost works
  8. Calculation situations. Completed situation and costing
  9. Technical inspection, handover of the building
  10. Official communication and documentation
  11. Normative bases of technical consulting. Selection of consultants and elements of the technical consultancy contract
  12. The function of a consultant in project phases: preparation and implementation of tenders, contracting of individual phases of project execution
  13. Monitoring project performance in terms of time, quality and costs. Consulting of investors
  14. Contract annexes and supporting documentation
  15. Responsibility of the consultant. Professional associations and norms

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- First midterm exam – a minimum score of 60%
- Second midterm exam - a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Written exam, a minimum score of 60%

Required reading:

1. Course materials from lectures
2. Texts of acts, regulations and other construction and technical regulations

MANAGEMENT OF STRUCTURES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory 10, design 20)

Course objectives:

- Teach students about the concept and importance of building management,
- Train students to apply the acquired knowledge for building management in the phase of designing and using the building.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of management.

Learning outcomes:
After successfully completing this course, the student will be able to:

- Explain the connection between building maintenance and management
- Apply computer software for determining priorities in building management
- Apply building management models under given conditions
- Create a building management strategy for a specific company.

Course content (by course schedule):

- Lectures:
  1. Introduction to building management
  2. Management of buildings in the context of the organization
  3. Development of the concept of building management in the world and in Croatia
  4. International standards for building management
  5. Connection between building maintenance and management
  6. The effect (performance) of buildings
  7. Building management models
  8. Building management models
  9. Application of information technologies
  10. Specifics of building management in construction companies
  11. The relationship between company strategy and construction management strategy
  12. The connection between organizational culture, workplace and management
  13. Safety at the workplace
  14. Sustainable development and management of buildings
  15. New trends and challenges in building management
- Exercises:
  1. Defining project tasks

2. Description of the elements for creating a case study
3. Creation of program content proposals
4. Analysis of existing building management strategies in the world
5. Analysis of existing building management strategies in Croatia
6. Selection of construction company for case study analysis
7. Analysis of the organizational structure of the company
8. Analysis of the company's mission, vision and strategy
9. Analysis of the company's existing properties
10. Analysis of the employee's workplace
11. Creation of a proposal for a building management strategy for a selected construction company
12. Creation of a proposal for a building management strategy for a selected construction company
13. Creating a list of priorities using the analytical hierarchical approach with the Superdecisions software
14. Program presentations and program assignment defences
15. Program presentations and program assignment defences

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures, 100% attendance at exercises
- Written exam

Required reading:

1. Atkin, B., Brooks, A., "Total Facility Management (5.izd.)", Wiley-Blackwell, Hoboken, 2021.
2. HRN EN ISO 41014:2020 Facility management -- Development of facility management strategy.

Additional reading:

1. Levitt, J.D., "Facilities Management: Managing Maintenance for Buildings and Facilities", Momentum Press, New York, 2013.
2. Lowry, D., "The Complete Guide to Facility Management", CreateSpace Independent Publishing Platform, 2017.
3. Roper, K.O., Payant, R.P., "The Facility Management Handbook (4th ed.)", AMACOM, 2014.

NUMERICAL MATHEMATICS

See Chapter Shared Courses

PERSPECTIVE

See Chapter Shared Courses

GEOMETRY IN CIVIL ENGINEERING

See Chapter Shared Courses

WAVES AND OSCILLATIONS

See Chapter Shared Courses

2nd year, 3rd semester

Mandatory courses

ORGANIZATION AND STRUCTURE OF CONSTRUCTION COMPANIES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- exercises (auditory: 15, design: 15)

Course objectives:

- Acquisition of knowledge about the basics of organization theory, and methods and techniques of organization design and their application in business systems in construction.

Entry competences (prior knowledge, descriptive):

- Understanding the basics of construction technology,
- Knowledge of the basics of construction regulations.

Learning outcomes:

- Explain the basic concepts from the theory of organization,
- Explain the organization design process,
- Explain the characteristics of individual functions in the construction business system,
- Demonstrate the process of designing an organization using the example of a construction business system.

Course content (by course schedule):

- Lectures:
  1. Typology of business systems in construction
  2. Basics of organization and theories of organization
  3. Organizational structure, demonstrating the elements of the organizational structure. Elements of the organizational structure of the construction business system: human resources, machines and equipment
  4. Elements of the organizational structure of the construction business system: material, information
  5. Business functions of the construction business system: research and development, human resources management
  6. Business functions of the construction business system: procurement, sales, marketing
  7. Business functions of the construction business system: information management, knowledge management
  8. Business functions of the construction business system: improvement of the organization, quality management
  9. Business functions of a construction company: production function
  10. Business functions of the construction business system: planning
  11. Business functions of the construction business system: finances and accounting,

12. Factors of organization formation. Designing the organizational structure of a construction company.
13. Organizational changes. Re-engineering
14. Legal forms of companies.
15. Forms of cooperation and integration between business systems in construction

- Practice
    1. Organization of classes and selection of seminar topics
    2. Distribution of literature for the seminar and familiarization with the BPM tool
    3. Business systems in construction
    4. Organization theory
    5. Organizational structure
    6. Elements of organizational structure
    7. Business functions of the construction business system
    8. 1st midterm exam
    9. Creation of business process schemes for certain functions of the construction business system
    10. Characteristics of the business process for certain functions of the construction business system
    11. Optimization of business processes for certain functions of the construction business system
    12. Organizational design, organizational changes
    13. Forms of cooperation of business systems
    14. 2nd midterm exam
    15. Retest

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Program assignment submitted and defended within the prescribed deadline
- Seminar paper submitted and defended within the prescribed deadline
- First midterm exam, a minimum score of 60%
- Second midterm exam, a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Program assignment submitted and defended within the prescribed deadline
- Seminar paper submitted and defended within the prescribed deadline
- Written exam, a minimum score of 60%

Required reading:

1. Lj.Martić: Matematičke metode za ekonomske analize II, Narodne novine, Zagreb, 1965.
2. W.Jurecka, H.J.Zimmermann: Operation Research in Bauwesen, Springer Verlag, 1972.
3. N.Limić: Linearno i nelinearno programiranje, Informator, Zagreb, 1978.
4. V.Čerić: Simulacijsko modeliranje, Školska knjiga, Zagreb, 1993.
5. V.Žiljak: Simulacija računalom, Školska knjiga, Zagreb, 1982. 6. H.A.Taha: Operations research, Prentice Hall, 2003.

PLANNING AND SCHEDULING METHODS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 8, on the computer: 22)

Course objectives:

- Acquisition of advanced theoretical knowledge about planning, monitoring and control for construction projects,
- Acquisition of advanced practical knowledge of planning methods and techniques,
- Acquisition of knowledge about the use of computer tools for planning and monitoring construction projects.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic planning methods for construction projects,
- Theoretical knowledge about construction organization, such as network planning, resource planning, organization charts, organization theories, construction regulations, price analysis, etc.

Learning outcomes:

- Explain and apply project planning and control methods,
- Create a detailed basic time plan of activities,
- Create a resource and cost plan,
- Analyse the basic plan of the project,
- Optimize the use of resources and shorten the duration of the project,
- Design a project monitoring and control system,
- Evaluate the progress of the project,
- Identify the essential elements of the multi-project planning system.

Course contents:

- Lectures:

1. Introduction to planning
2. Planning by management levels
3. Basic techniques of network and line planning
4. Resource planning
5. Cost planning
6. Joint time and cost planning
7. Project monitoring and control
8. Company project planning
9. Planning and BIM
10. Planning with uncertainty
11. AI and planning in construction
12. Midterm exam
13. Planning with uncertainty

14. Critical chain method
15. Midterm exam

- Exercises:

1. Creation of the basic plan, MS Project
2. Creation of the basic plan, MS Project
3. Creation of the basic plan, MS Project
4. Resource and cost planning using MS Project
5. Resource and cost planning using MS Project
6. Resource and cost planning using MS Project
7. Project execution monitoring and reporting using MS Project
8. Project execution monitoring and reporting using MS Project
9. Company project planning
10. Company project planning
11. Creating a basic plan using an alternative program
12. Creating a basic plan using an alternative program
13. Planning with uncertainty and the critical chain method with the help of computers
14. Planning with uncertainty and the critical chain method with the help of computers
15. Final review and evaluation

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- All parts of the program assignment submitted within the prescribed deadline
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- All parts of the program assignment submitted within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. Nahod, M.-M. - Planning and Scheduling Methods, course materials, e-learning system Merlin 2021/2022.
2. Mubarak S., Construction Project Scheduling and Control Fourth Edition, Wiley, 2019.
3. Radujković et al. – Planiranje i kontrola projekata, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb 2012.
4. Thomas H.R., Ellis R.D. - Construction Site Management and Labor Productivity Improvement, ASCE Press, 2017 5. Vanhoucke M. - Project Management with Dynamic Scheduling, Springer, 2012.

SOCIOLOGY OF ORGANIZATION

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 14, construction: 1)

Course objectives:

- The main goal of the course is to train future civil engineers to manage construction organizations. This is why the course Sociology of Organization provides insight into basic knowledge in sociology, social psychology and organizational theory. While other courses at the Faculty of Civil Engineering primarily deal with construction technology, this course aims at training civil engineers to successfully manage organizations, to adequately form work groups, and to be able to form positive interpersonal relationships at the workplace, which ultimately enables a significant increase in work productivity.

Entry competences (prior knowledge, descriptive):

- Basic knowledge in the field of social sciences.

Learning outcomes:

- Basic knowledge of social psychology,
- The art of managing an organization (leadership),
- Knowledge and recognition of organizational culture as well as the ability to change it,
- The ability to form an appropriate organizational structure.

Course content (by course schedule):

- Lectures:
  1. Introductory lecture, rules, overview of topics
  2. Social groups
  3. Group behaviour
  4. Organizational culture
  5. Formation and maintenance of organizational culture
  6. Meaning of organizational culture; The influence of national culture on organizational culture
  7. Examples of organizational cultures (1)
  8. Examples of organizational cultures (2)
  9. Specificities of national cultures
  10. Power in the organization
  11. Management of the organization
  12. Business organization in the era of globalization
  13. Development of organizations: creation, growth, decline and collapse of organizations
  14. Change management in the organization
  15. Second midterm exam
- Exercises:
  1. Social organizations in the animal world
  2. Obedience to authority
  3. Social facilitation
  4. Conformity
  5. Contemporary trends in organizational design
  6. Symbols of organizational culture

7. Ben and Jerry's organizational culture
8. Organizational culture of the Faculty of Civil Engineering
9. Role and changing of the organizational culture
10. Questions about business ethics
11. Business ethics in construction
12. Types of power
13. Psychosocial characteristics of leaders
14. Technology and organization
15. Sociology of organization - general discussion

Student Evaluation - Continuous assessment:

- Attendance at a minimum of 11 lectures and seminars
- First midterm exam
- Second midterm exam
- Seminar

Student Evaluation - Examination without Continuous Assessment:

- Attendance at a minimum of 11 lectures and seminars
- Written exam
- Seminar

Required reading:

1. Sikavica, Pere. 2011. Organizacija. Zagreb: Školska knjiga.
2. Janićijević, Nebojša. 2013. Organizacijska kultura i menadžment. Beograd: Čugura print.
3. Handel, Michael J. (ur.). 2003. The Sociology of Organizations, London: Sage Publications.
4. Aronson, Elliot, Timothy D. Wilson, Robin M. Akert. 2005. Socijalna psihologija. Zagreb: Mate
5. Zvonarević, Milan. 1989. Socijalna psihologija. Zagreb: Školska knjiga.
6. Jones, Gareth R. 2004. Organizational Theory, Design and Change. Upper Saddle River, USA: Pearson Education.
7. Antić, Miljenko, Antita Cerić i Maja Lazić, 2010. „Organizational culture of the department of construction management and economics, Faculty of Civil Engineering, University of Zagreb", Organization, Technology & Management in Construction, Vol. 2:1, str.136-144.
8. Buchanan, David i Andrzej Huczynski.1997. Organizational Behavior: An Introductory Text.
9. Harloww: Pearson Education.
10. Haladin, Stjepan. 1993. Tehnologija i organizacija: uvod u sociologiju rada i organizacije. Zagreb: Društvo za organizaciju građenja Republike Hrvatske.
11. Vecchio, Robert P. 2003. Organizational behavior: core concepts. Mason, Ohio: Thomson/South-Western.
12. Kendall, Dina. 2002. Sociology in Our Times: The Essentials. Belmont, USA: Wadsworth.
13. Miller, D.C. i V.H. Form. 1966. Industrijska sociologija. Zagreb: Panorama

Elective courses

HUMAN RESOURCE MANAGEMENT

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 8, design: 22)

Course objectives:

- Understanding the concept and importance of human resource management in companies,
- The ability to apply acquired knowledge for the development of human resource management strategies in companies.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of management.

Learning outcomes:

- Application of methods for planning the needs and structure of employees,
- Application of selection methods for selecting employees,
- Strategic planning of employee development,
- Understanding the importance of communication between project participants,
- Understanding multicultural teams,
- Application of motivational techniques.

Course content (by course schedule):

- Lectures:
  1. Introduction to human resources management
  2. Development of human resources management
  3. The meaning, content and functions of human resources
  4. The importance of human resource management for the success of the company
  5. Characteristics of human resource management in construction companies
  6. The relationship between company strategy and human resources strategy
  7. Techniques and strategies of human resource management in construction companies
  8. The role of communication between project participants
  9. Communication risks and the role of trust in construction projects
  10. Human resource planning in construction companies; Forecasting needs
  11. Selection of job candidates
  12. Team building; International projects and multicultural teams
  13. Motivation and reward of employees
  14. Safety and health protection of employees; professional ethics
  15. New trends and challenges in human resource management in construction
- Exercises:
  1. Defining project tasks
  2. Description of the elements for creating a case study
  3. Creation of program content proposals
  4. Analysis of existing human resource management strategies in construction companies in the world
  5. Selection of a construction company for the case study

6. Analysis of the organizational structure of the company
7. Creation of a proposal for a human resource management strategy for a selected construction company
8. Creation of a proposal for a human resource management strategy for a selected construction company
9. Application of candidate selection methods and techniques
10. Application of candidate selection methods and techniques
11. Creation of proposals for motivating and rewarding employees
12. Writing a resume
13. Situational interviews
14. Program presentations and defences
15. Program presentations and defences

Student Evaluation - Continuous assessment:

- Timely preparation and submission of project assignments
- 75% attendance at lectures
- 100% attendance at exercises
- 2 midterm exams: A minimum score of 60% of the total points is required on each midterm exam

Student Evaluation - Examination without Continuous Assessment:

- Timely preparation and submission of project assignments
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam according to the exam schedule

Required reading:

1. Bahtijarević-Šiber, F., "Strateški menadžment ljudskih potencijala - suvremeni trendovi i izazovi", Školska knjiga, Zagreb, 2014.
2. Cerić, A., Trust in Construction Projects, Taylor&Frances, Routledge, Oxon, 2016.
3. Dainty, A., Loosemore, M., Lingard, H., "Human Resource Management in Construction Projects", Spon Press, London, 2003.

Additional reading:

1. Dessler, G., "Upravljanje ljudskim potencijalima (12. izd.)", Mate, Zagreb, 2015.
2. Briscoe, D.R. , Schuler, R.S., " International Human Resource Management", 2nd ed. Routledge, London. 2004.
3. Marchington, M., Wilkinson, A., "Human Resource Management at Work", CIPD, Devon, 2008.

CONSTRUCTION TECHNOLOGIES 2

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30

- Exercises: 30 (auditory: 10, construction: 14, fieldwork: 6)

Course objectives:

- In-depth introduction to the techniques and technologies for constructing scaffolds for various purposes, formwork techniques and technologies for different types of structures, specialized formwork and materials, production, transportation, and assembly of prefabricated elements for halls and bridges, and the sizing of assembly tools.

Entry competences (prior knowledge, descriptive):

- Material covered in the course Building Technology and Technology of Heavy Construction of the undergraduate programme and Construction Technologies 1.

Learning outcomes:

- Identify the building in the project and select as well as dimension the appropriate type of scaffolding,
- Identify the building in the project and select as well as dimension the appropriate type of formwork,
- Plan and organize the production of prefabricated structural elements,
- Organize and dimension the transportation of prefabricated elements,
- Determine the appropriate lifting equipment and dimension it for assembling the prefabricated structure.

Course content (by course schedule):

- Lectures:
  1. Introduction to construction technologies 2
  2. The basics of regulations at the start of construction
  3. Earthworks and preparatory works
  4. Concrete and reinforcing works
  5. Scaffolding in building construction
  6. Formwork and formwork technologies
  7. Masonry works
  8. Prefabricated construction
  9. Midterm exam 1
  10. Safety at work
  11. Assembly technology
  12. Finishing-off operations – interior
  13. Assembly of wooden and steel structures
  14. Midterm exam 2
  15. Retest
- Exercises:

1. Auditory Construction preparation
2. Auditory Preparation of formwork
3. Fieldwork
4. Fieldwork
5. Construction
6. Construction
7. Auditory Introduction to assembly
8. Auditory Assembly planning
9. Fieldwork
10. Construction

11. Construction
12. Auditory Assembly works
13. Construction
14. Construction
15. Construction

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam, a minimum score of 60%
- Second midterm exam, a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam, a minimum score of 60%

Required reading:

1. Offrints and lectures
2. Web page //og.grad.hr
3. Mlinarić, V.: Tehnologija građenja, TVZ, Zagreb, 2017
4. Gojković : skele i oplate
5. Montažno građenje
6. Kayser - Technologie der industriellen Betonproduktion
7. Act on Construction and pertaining laws and regulations

INVESTMENT APPRAISALS IN CONSTRUCTION

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 6, computer: 24)

Course objectives:

- Acquisition of theoretical knowledge about company development strategy, investment policy and types of investments,
- Creation of an investment study.

Learning outcomes:

- Explain fundamentals of investing strategy in a company and the types of investments,
- Analyse the investor and the investment,
- Analyse the market and create a technical and technological analysis,
- Prepare the main financial statements, the economic and financial flow of the project,
- Check the profitability of the project,
- Carry out a sensitivity analysis of the project.

Course content (by course schedule):

- Lectures:
  1. BASICS OF INVESTMENT PLANNING - Introduction to Investment Studies
  2. Systematization and types of investments – Joint venture, concessions (BOT)
  3. Foreign investments in the Republic of Croatia
  4. Company development strategy and investments; T1. Investor analysis and investment analysis
  5. INVESTMENT PROJECT PLANNING T2. Environment/location analysis
  6. T3. Market analysis – sales market research, procurement market analysis, competition analysis
  7. T4. Technical and technological analysis of the project - technical aspects for creating an investment program / environmental protection
  8. T5. Economic and financial analysis
  9. T5. Economic and financial analysis
  10. EVALUATION OF INVESTMENT PROJECT T6. Project evaluation - static/dynamic
  11. T7. Sensitivity analysis
  12. T8. Probability analysis and risk analysis
  13. Final assessment of the Investment
  14. Presentation of the program
  15. Presentation of the program
- Exercises:
  1. Overview of Investment Studies / Content Structure of Investment Studies
  2. Systematization and types of investments – Joint venture, concessions (BOT) - example 187
  3. Foreign investments in the Republic of Croatia – an example
  4. T1. Investor analysis and investment analysis
  5. T2. Environment/location analysis
  6. T3. Market analysis – analysis of sales, procurement, competition analysis
  7. T4. Technical and technological analysis of the project
  8. 1st midterm exam
  9. T5. Economic and financial analysis
  10. T6. Project evaluation - static/dynamic
  11. T7. Sensitivity analysis
  12. T8. Probability analysis and risk analysis
  13. Final assessment of the Investment
  14. 2nd midterm exam
  15. Presentation of the program

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exams
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures

- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. HBOR, I-V.
2. Course book: Prof.dr.sc. Mariza Katavić, Osnove ekonomike za graditelje, Zagreb 2009.
3. Lecture Off-prints – Merlin

2nd year, 4th semester

Mandatory courses

BUSINESS STRATEGIES FOR CONSTRUCTION COMPANIES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 45

Course objectives:

- Introduce students to the concept of strategy, present the business environment and factors that influence construction company operations, analyse business ethics in construction, analyse the environment in which construction companies operate, and introduce students to different types of strategies.

Entry competences (prior knowledge, descriptive):

- Preferably knowledge of the basics of economics within the Business Economics course (elective course in the first year of undergraduate studies).

Learning outcomes:

- Explain the concept of a company's business strategy, the process of formulating a strategy and define the levels of strategy,
- Formulate the mission, vision and goals of the company,
- Describe the business environment and factors that influence the operations of construction companies,
- Create a SWOT analysis and Stakeholder analysis,
- Formulate the company's business strategy – corporate, generic, functional, and marketing strategy.

Course contents:

- Lectures:
  1. Introduction
  2. Definition of strategy
  3. Mission, vision and goals of the company
  4. Business environment of construction companies
  5. Factors influencing the operation of construction companies
  6. Analysis of the environment of construction companies
  7. Socially responsible operations of construction companies
  8. 1st midterm exam 2 Formulating the strategy of construction companies
  9. Corporate strategy and portfolio analysis
  10. Generic/business strategies
  11. Functional strategies
  12. Marketing strategies
  13. Strategies for construction companies entering foreign markets
  14. Strategy implementation and control

15. 2nd midterm exam

Student Evaluation - Continuous assessment:
- Program assignment submitted within the prescribed deadline
- 75% attendance at lectures
- Midterm exams
- Oral exam

Student Evaluation - Examination without Continuous Assessment:
- Program assignment submitted within the prescribed deadline
- 75% attendance at lectures
- Written exam
- Oral exam

Required reading:
1. Osnove ekonomike za graditelje, Mariza Katavić, Hrvatska sveučilišna naklada, Zagreb, 2009.
2. Strateški menadžment, Marijan Cingula, Darko Tipurić, Marin Buble, Marčelo Dujanić, Želimir Dulčić, Marli Gonan Božac, Lovorka Galetić, Franjo Ljubić, Sanja Pfeifer, Sinergija, Zagreb, 2005.
3. lectures (materials on Merlin) M. Katavić: *Osnove ekonomike za graditelje*, Hrvatska sveučilišna naklada, Zagreb, 2009.
4. Lecture notes (materials available on Merlin).

Additional reading:
1. Iluzija strategije, Darko Tipurić, Sinergija, Zagreb, 2014.
2. Menadžment, H.Weihrich, H.Koontz, (deseto izdanje) MATE d.o.o. Zagreb 1998.
3. Management for the Construction Industry, Stephen Lavender, Longman and The Chartered Institute of Building, Essex, England 1996.H.

PRACTICAL ON-SITE TRAINING

Credits (ECTS): 6

Hours (total per semester):
- Exercises: 60 (auditory: 6, fieldwork: 54)

Course objectives:
- Introduce students to the construction site, covering aspects such as site management, work organization, technological processes, construction process planning, and material procurement.

Entry competences (prior knowledge, descriptive):
- Knowledge of construction management.

Learning outcomes:
- Understanding the work organization of the construction site,

- Understanding the material procurement processes on the construction site,
- Understanding and planning the execution of works,
- Manging team work on-site.

Course contents:

- Students spend 6 weeks, dedicating 7 hours each day (totalling over 54 school hours), at the selected construction site to observe the processes, events, technology, techniques, work organization, and management systems in place.

- Exercises:
  1. Introduction to the course
  2. Safety at work and activities on the construction site
  3. Documentation on the construction site and activities on the construction site
  4. Obligations and activities performed by the construction site management, Activities on the construction site
  5. Activities and responsibilities of the supervising engineer, Activities on the construction site
  6. Organization and implementation of works on the construction site, Activities on the construction site
  7. Management and leadership on the construction site, Activities on the construction site
  8. Monitoring the progress of works on the construction site with documentation, Activities on the construction site
  9. Monitoring the progress of works on the construction site with documentation, Activities on the construction site
  10. Monitoring the progress of works on the construction site with documentation, Activities on the construction site
  11. Monitoring the progress of works on the construction site with documentation, Activities on the construction site
  12. Monitoring the progress of works on the construction site with documentation, Activities on the construction site
  13. Analysis of the works being carried out, Activities on the construction site
  14. Reporting on completed works, Activities on the construction site
  15. Final review and report presentations

Student Evaluation - Continuous assessment:

- Staying at a designated construction site according to the schedule
- Submission of weekly reports of partial project assignments according to the syllabus
- Submission of the final program assignment
- Public presentation and defence of the program assignment

Student Evaluation - Examination without Continuous Assessment:

- There is no exam.

Required reading:

1. ORDINANCE on the conditions and manner of keeping a construction diary and construction book

2. Mandatory and other construction site documentation according to current regulations in the Republic of Croatia; L. Plavšić, 2016

Elective courses

SUPERVISION AND MONITORING OF CONSTRUCTION PROJECTS

See elective courses of the 2nd semester of the specialization in Construction Management.

MANAGEMENT OF STRUCTURES

See elective courses of the 2nd semester of the specialization in Construction Management.

HEALTH & SAFETY IN CONSTRUCTION

Credits (ECTS): 4.5

Hours (total per semester):
- Lectures: 30
- Exercises: 15 (auditory: 5, design: 10)

Course objectives:
- Acquisition of theoretical and practical knowledge about occupational safety in construction.
- Train the student to plan and implement safety measures at work and to monitor whether the work is carried out in a safe manner.

Entry competences (prior knowledge, descriptive):
- Knowledge in the field of construction technology and organization acquired at the undergraduate programme in civil engineering.

Learning outcomes:
- Know the construction Health & Safety regulations and standards.
- Explain the importance of Health & Safety.
- Create a plan for carrying out work in a safe manner.
- Apply occupational safety methods in the construction industry and supervise their implementation.
- Calculate the costs of implementing occupational safety measures at the construction site.

Course content (by course schedule):
- Lectures:
  1. Introductory lecture, basics of Health & Safety
  2. Regulation of Health & Safety

3. The role of Health & Safety coordinator and occupational safety specialist
4. Health & Safety in the design phase
5. Construction hazards
6. Hazard identification and quantification
7. 7. 1st midterm exam
8. Health & Safety measures in construction
9. Planning and implementation of occupational safety measures. Health & Safety plan
10. Cost aspects of occupational health and safety
11. Health & Safety at work in production plants
12. Health & Safety during the exploitation phase
13. Advanced technologies in construction Health & Safety [2]
14. 2nd midterm exam [2]
15. Corrective exam [2]

- Exercises:

1. Hazard identification in construction
2. Hazard quantification
3. Identification and quantification of hazards in construction
4. Identification and quantification of hazards in construction
5. Identification and quantification of hazards in construction
6. Identification and quantification of hazards in construction
7. Health & Safety measures at work
8. Health & Safety measures at work
9. Health & Safety measures at work
10. Health & Safety plan
11. Creation of a Health & Safety plan
12. Creation of a Health & Safety plan
13. Cost and time aspects of occupational health and safety
14. Creation of a Health & Safety plan
15. Creation of a Health & Safety plan

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Program assignment submitted and defended within the prescribed deadline
- First midterm exam, a minimum score of 60%
- Second midterm exam, a minimum score of 60%

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Program assignment submitted and defended within the prescribed deadline
- Written exam, a minimum score of 60%

Required reading:

1. 1 Course lectures
2. Zou, P.X.W. and R.Y. Sunindijo, Strategic Safety Management in Construction and Engineering. 2015: John Wiley & Sons, Ltd. 253.

3. Holt, A.S.J., Principles of construction safety. 2001, Oxford, UK: Blackwell Publishing. 290

BUILDING RENOVATION AND STRENGTHENING TECHNOLOGIES

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 12, computer: 6, construction: 12)

Course objectives:

- The aim of the course is to equip students with knowledge of the regulatory framework for building renovation and strengthening, historical construction technologies, the causes of building deterioration, and the application of renovation and strengthening techniques. Students will also explore the effects of natural disasters and climate change on buildings in urban areas.

Entry competences (prior knowledge, descriptive):

- Fundamental knowledge of construction technologies and wooden, concrete, and masonry structures
- Basic understanding of construction organization.

Learning outcomes:

- Independently gather comprehensive data on building structures and systems.
- Conduct thorough visual inspections to analyse and identify structural and functional defects in buildings.
- Evaluate existing conditions and propose effective strategies for building renovation and structural reinforcement.
- Apply creative problem-solving skills to develop innovative solutions for building upgrades using established methodologies and best practices.
- Efficiently plan, manage, and oversee building renovation and strengthening projects from conception to completion.

Course content (by course schedule):

- Lectures:
  1. Legal frameworks for the construction, renovation and strengthening of buildings
  2. Impact of climate change on buildings and protection from natural disasters
  3. Risk assessments of buildings and the selection of priorities for protection, renovation and strengthening in the urban environment
  4. Guidelines and objectives of reconstruction and strengthening
  5. Digitization of the urban environment
  6. Analyses of the digital environment
  7. Analysis of the condition of existing buildings
  8. Basics of works for stabilization and strengthening of buildings
  9. Technologies applicable to the stabilization of buildings
  10. Technologies applicable to building renovation
  11. Planning works on existing buildings
  12. Execution of building renovation works 1

13. Execution of building renovation works 2
14. Economy and effectiveness of interventions on buildings
15. Midterm exam

- Exercises:
  1. Auditory Digitization of buildings
  2. Construction
  3. Auditory Processing of the digital environment
  4. On computers
  5. On computers
  6. Auditory Analysis of the digital environment
  7. On computers
  8. Auditory Stabilization and strengthening planning
  9. Construction
  10. Construction
  11. Auditory Analyses of Economy 185
  12. Construction
  13. Auditory Planning of interventions on buildings
  14. Construction
  15. Construction

Student Evaluation - Continuous assessment:

- Attendance of at least 75%
- Midterm exam with a minimum score of 60%
- Seminars – submitted and defended seminar paper

Student Evaluation - Examination without Continuous Assessment:

- Attendance of at least 75%
- Seminar paper submitted and defended
- Exam passed with a minimum score of 60%

Required reading:

1. Typische Baukonstruktionen von 186 bis 1960, R. Ahnert, K.H. Krause
2. Earthquake-Resistant Design of Masonry Buildings, M. Tomaževič
3. Building Maintenace & Preservation, E.D. Millis
4. Structural Renovation of Buildings, A. Newman
5. Potresno inženjerstvo - Obnova zidanih zgrada, M. Uroš; M. Todorić; M. Crnogorac; J. Atalić; M. Šavor Novak; S. Lakušić

Specialisation in TRANSPORTATION ENGINEERING

1st year, 1st semester

Mandatory courses

TRAFFIC NOISE

Credits (ECTS): 4.5

Hours (total per semester):
- Lectures: 30
- Exercises (construction): 15

Course objectives:
- Acquisition of theoretical and practical knowledge about the origin, spread and harmful impact of noise from road traffic and track guided vehicles,
- Review of protective measures against traffic noise in order to improve the quality of life and work of people in environments exposed to increased levels of traffic noise,
- Acquisition of basic knowledge about creating noise maps.

Entry competences (prior knowledge, descriptive):
- Knowledge of the basics of road design.

Learning outcomes:
- Describe the impact of traffic noise on humans and noise protection procedures and measures,
- Understand the mechanism of traffic noise and how protection works,
- Analyse traffic noise levels applying Croatian and European regulations,
- Use software specialized for the creation of Lima noise maps for the analysis of noise levels and the optimization of barriers where it is considered as a barrier protection measure,
- Critically evaluate the assumptions, arguments and solutions of noise protection,
- Solve simpler problems of traffic noise protection by applying noise protection barriers,
- Follow the professional literature and present professional topics in the field of traffic noise protection and apply the acquired knowledge in further training.

Course contents:
- Lectures:
  1. Introduction – Environmental noise, Historical development. Basic physical concepts about sound [2]
  2. Basic physical concepts about sound, Sources of sound, Effects of noise on humans [2]
  3. European Environmental Noise Directive [2]
  4. Regulations in the Republic of Croatia [2]
  5. Creation of noise maps [2]
  6. Road traffic noise – influencing parameters. Calculation methods [3]

7. Calculation methods [2]
8. 1ST MID-TERM EXAM [1]
9. Practical examples [2]
10. Noise measurement. Measures to reduce road traffic noise at the source [2]
11. Measures to reduce road traffic noise at the source [2]
12. Barriers for noise protection [2]
13. Other protective measures [2]
14. 2ND MID-TERM EXAM [1]
15. Practical examples [3]

- Exercises (construction):
  1. Preparation of data. Data entry into LIMA software [2]
  2. Assigning object attributes [4]
  3. Noise level calculations [2]
  4. Noise protection [4]
  5. Presentation of calculation results [2]
  6. Submission of program assignments [1]

Student Evaluation - Continuous assessment:

- Preparation and submission of program assignments within the prescribed deadline
- First midterm exam
- Second midterm exam
- Oral exam
- Lectures and exercises attendance

Student Evaluation - Examination without Continuous Assessment:

- Preparation and submission of program assignments within the prescribed deadline
- Written exam
- Oral exam
- Lectures and exercises attendance

Reading:

1. Dragčević, V., Ahac, S.; Traffic Noise – lectures, Zagreb, 2022., http://merlin.srce.hr
2. Ahac, S., Džambas T., Pintar, Ž.: Prometna buka - lecture notes, Zagreb, 2018., http://merlin.srce.hr
3. General Technical Requirements for Road Works, Hrvatske ceste, Zagreb, 2024
4. Instructions for using the software package LIMA™ Environmental Noise Calculation and Mapping Software, Version 5.1, Denmark, 2006.
5. Benz Kotzen, Colin Englih, Environmental noise Barriers, London, 1999.

TRANSPORTATION ENGINEERING

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (construction: 24, fieldwork: 6)

Course objectives:

- Acquisition of knowledge in the field of traffic flow theory,
- Acquisition of practical knowledge from the application of the theory of traffic flows in the procedures for calculating maximum capacity and service levels for different types of traffic structures.

Entry competences (prior knowledge, descriptive):

- Basic vehicle dynamics principles relevant to the determination of horizontal, vertical and transverse route geometry elements.

Learning outcomes:

- Analyse the traffic flows on different types of roads using modern methods and criteria,
- Design different elements of the road network,
- Use the basic principles of road transport system development,
- Evaluate existing data on roads and road traffic and their application,
- Create a road traffic development concept,
- Design the organization, management of supervision and traffic control,
- Design traffic flow management on the road network.

Course content (by course schedule):

- Lectures:
  1. Introduction to the theory of traffic flow: traffic, system, network, traffic engineering
  2. Categorization of road infrastructure in socio-economic, transport and construction terms, traffic survey
  3. Basic traffic flow variables: flow, speed and density
  4. Characteristics of traffic flow: complexity, type, composition
  5. Characteristics of traffic flow: spatial and temporal distribution
  6. Macroscopic models of traffic flow
  7. Descriptive flow variables, Microscopic models of traffic flow
  8. Qualitative and quantitative relationships of basic flow variables, maximum road capacity and levels of service
  9. Maximum capacity of multi-lane roads
  10. Maximum capacity of motorways
  11. Categorization of railway infrastructure and vehicles in the socio-economic, traffic and construction terms
  12. Influential factors of driving speed
  13. Vehicle braking and speed limit on downgrades
  14. Vehicle follow-up times, graphic timetables and railway line capacity
  15. Transport capacity of the railway
- Exercises (construction, fieldwork):
  1. Field survey, definition of network elements
  2. Field survey, definition of trajectories
  3. Traffic count on the network and recording the traffic lights operation
  4. Processing of traffic data
  5. Creating the layout of the spatial distribution of flows
  6. Development of a light signalling work plan
  7. Creation of a diagram of the movement of vehicles through the network
  8. Determining the level of service of a network segment
  9. Determining the level of service of a two-lane two-way road

10. Determining the level of service of a dual carriageway road
11. Calculation of resistances and ruling gradients
12. Determining the characteristics of the vehicle on the ruling upgrade
13. Speed limit on the ruling downgrade
14. Calculation of follow-up time and transport capacity
15. Defence and submission of the program assignment

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Reading:

1. Ahac, M.: Transportation Engineering - Lectures, Zagreb, 2017., http://merlin.srce.hr
2. Other materials http://merlin.srce.hr
3. Highway Capacity Manual, TRB, Washington, D.C., 2000.
4. Uputa 52 o tehničkim normativima i podatcima za izradu i provedbu voznoga reda, Službeni vjesnik HŽ-a br. 5/06., Zagreb 2006.

PLANNING AND DESIGN OF ROADS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 1, construction: 29)

Course objectives:

- Acquisition of theoretical knowledge about road planning and design procedures,
- Acquisition of practical knowledge about road planning and design procedures.

Entry competences (prior knowledge, descriptive):

- Knowledge of working with computer programs for technical drawing.

Learning outcomes:

- Plan and rank roads according to their position in the road network, social and economic significance, type and size of traffic, and connection task,
- Assess the degree of restriction of the terrain through which the road should pass or passes and identify the conflict zones of the road with the environment and other interventions in the space,
- Create a road project (plan elements and longitudinal and cross-section elements) according to current regulations.
- Create a road project taking into account the safety of traffic (sight distance and overtaking sight distance, relevant speed),
- Create a road project using a computer software specialized in road design,
- Combine and valorise variant road solutions in accordance with spatial limitations.
- Analyse and critically judge the literature and regulations in the field of road design

Course contents:

- Lectures:
  1. Introduction to the course. Public roads
  2. Spatial planning of public roads
  3. Surveying maps - digital relief and terrain models
  4. Computer software for road design
  5. Road design rules
  6. Basic features of vehicle movement
  7. Road design - horizontal alignment
  8. Road design - vertical alignment
  9. Road design - spatial alignment
  10. Cross-section of the road
  11. Clearance (traffic space, overhead and lateral safety spaces)
  12. Stopping sight distance (horizontal, vertical, passing sight distance)
  13. Project visualization. Types of road projects
- Exercises (auditory, construction):
  1. Introduction about the project assignment, program assignment and familiarization with the computer software for creating the project (basic commands)
  2. Working with the computer software for creating a road design (basic commands). Creation of a digital terrain model
  3. Zero line. Road plan (horizontal alignment)
  4. Road plan (horizontal alignment)
  5. Vertical (alignment) profile
  6. Vertical (alignment) profile. Operating speed calculation
  7. Operating speed calculation. Selection of the road variant
  8. Normal cross-sections. Carriageway widening
  9. Superelevation. Road embankments
  10. Carriageway pavement. Characteristic cross-sections.
  11. Road sight distance assessment
  12. Visualization of the road model
  13. Creating the layout
  14. Creating the layout, program assignment submission

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Reading:

1. Stančerić, I., Bezina, Š.: Projektiranje cesta. Online lecture notes - http://merlin.srce.hr. Zagreb, 2022.
2. Ordinance on the basic conditions for public roads outside the settlement and their elements
   to be met from the point of view of traffic safety (OG 110/01)
3. Stančerić, I.: Road design – notes for exercises. Web notes - http://merlin.srce.hr ,

Zagreb, 2025.
4. General Technical Requirements for Road Works, Hrvatske ceste, Zagreb, 2024.
5. Lorenc, H.: Projektovanje i trasiranje puteva i autoputeva, IRO građevinska knjiga, Beograd, 1980.
6. Kühn, W.: Fundamentals of Road Design. WIT Press 2013.
7. Dragčević, V., Korlaet, Ž.: Osnove projektiranja cesta, Zagreb, 2003.
8. Richter, T. Planung von Autobahnen und Landstraßen, Springer, 2016.

RAILWAY DESIGN AND CONSTRUCTION

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises (design: 1, construction: 29): 30

Course objectives:
- Acquisition of theoretical knowledge about traction calculation,
- Acquisition of theoretical and practical knowledge about railway design,
- Acquisition of practical knowledge about the phases of project creation,
- Acquisition of theoretical and practical knowledge about the evaluation of variant solutions,
- Acquisition of practical knowledge about designing the second railway track.

Entry competences (prior knowledge, descriptive):
- Knowledge of the basics of routing,
- Knowledge of the cross-sections and clearances,
- Knowledge of the basics of roadbeds.

Learning outcomes:
- Explain the calculation of railway track and vehicle resistance,
- Explain the calculation of the mass of the train, the traction force of the locomotive, and the braking force,
- Explain the structural elements of the railway,
- Explain the application of computer software for railway design,
- Explain the evaluation of variant solutions,
- Explain the railway capacity calculation,
- Explain the issue of building a second railway track alongside the existing railway.

Course content (by course schedule):
- Lectures:
  1. General characteristics of railways: the role of railways in the transport system, evaluation of railways
  2. Rail route: elements of routing, means of routing, better-known computer software for designing
  3. Rail route: shape and location of the station, use of facilities, stages of project development

4. Elements of the railway alignment: application and significance of curves, transition curves, deviation angles, intermediate straights
5. Elements of the railway alignment: superelevation and ramps, dependence of speed on the radius of the curve
6. Elements of the railway alignment: grade values, grade changes, grade in the station
7. Elements of the railway alignment: clearances, distance between railway tracks, trackbed formation
8. Basics of train traction calculations: forces acting on the train
9. Basics of train traction calculation: resistances to train movement
10. Railway buildings and structures: construction in the railway corridor, intersections of railway and other infrastructures
11. Protection of the railway and the environment
12. Evaluation of variant solutions: evaluation methods, analysis parameters
13. Reconstruction of single-track railways: basic determinants, choice of route parameters
14. Designing the second railway track: construction methods, position in relation to objects
15. High-speed railways: specifics, route elements

- Exercises (design, construction):
  1. Project preparation in Bentley Power Rail Track (BPRT): initial program settings and working with graphic models. Creating a digital terrain model: creating a new model, entering terrain data into the model, triangulating the model, saving, opening and displaying the model and project
  2. Creation of a digital terrain model: display of layers, loading of raster maps of the area Horizontal alignment design: calculation of station elements, calculation of steps and creation of zero lines
  3. Horizontal alignment design: control of zero lines, calculation of track and station elements, creation of a new geometry project, creation of a new horizontal geometry sub-project, creation of horizontal track elements, setting of the tangential polygon of the horizontal axis, saving, opening and displaying the horizontal geometry model
  4. Horizontal alignment design: editing the tangential polygon of the horizontal axis, determining the parameters of the horizontal curves
  5. Horizontal alignment design: editing the tangential polygon of the horizontal axis, defining horizontal curves and intermediate straights
  6. Horizontal alignment design: definition of chainage, presentation of elements of horizontal geometry
  7. Vertical alignment design: creating a new vertical geometry subproject, creating a terrain profile grade, setting the vertical axis tangential polygon, defining the characteristic points of the route axis – the beginnings and ends of the station plateaus, saving, opening and displaying the vertical geometry model
  8. Vertical alignment design: restrictions when setting the level of the track, editing the tangential polygon of the vertical axis
  9. Vertical alignment design: editing the tangential polygon of the vertical axis, determining vertical curves
  10. Vertical alignment design: defining the characteristic points of the route axis – objects and transitions

11. Horizontal design of the railway station: determination of intermediate straights and track spacing, calculation of railroad switches
12. Horizontal design of the railway station: creation and laying of switches on horizontal geometry [2]
13. Horizontal design of the railway station: assignment of shunt limits, printing of characteristic points
14. Creating a project report: blueprints and technical description. Defence of the program

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Reading:

1. Lakušić, S., Ahac, M.: Railway Design and Construction – lectures, Zagreb, 2021., http://merlin.srce.hr
2. Lakušić, S., Ahac, M., Haladin, I.: Railway Design and Construction - exercise handbook, Zagreb, 2017., http://merlin.srce.hr
3. Marušić, D.: Projektiranje i građenje željezničkih pruga, Građevinski fakultet Split, Split, 1994.
4. Other materials http://merlin.srce.hr

Elective courses

MATHEMATICS 3

See Chapter **Shared Courses**

STOCHASTIC PROCESSES

See Chapter **Shared Courses**

1st year, 2nd semester

Mandatory courses

MANAGEMENT FOR CONSTRUCTION INDUSTRY

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of theoretical knowledge about the basic principles of management, project management and business decision-making.
- Learning about the concept of a company, the results of operations and the business environment of the company and factors influencing the company's operations.

Entry competences (prior knowledge, descriptive):

- Preferably knowledge of the basics of economics within the Business Economics course (elective course in the first year of undergraduate studies).

Learning outcomes:

- Explain the basic principles of management, and the development and functions of management,
- Describe management as a process within the framework of planning, organizing, motivating and controlling,
- Explain the styles and methods of business decision-making,
- Definition of the types of companies, the limitations and principles of business operations, and the business itself through the process of reproduction and business assets,
- Differentiation between business costs, prices and calculations,
- Interpretation of indicators of business results,
- Analysis of the business environment of the company and the factors that affect the company's business operations.

Course contents:

- Lectures:
  1. Introduction
  2. 1. Basic principles of management and Functions of management
  3. Development of management and Schools of management
  4. 2. Management as a process – planning, organizing, motivating and controlling
  5. 1ST MID-TERM EXAM 3. Companies – introduction
  6. Companies – concept, types
  7. Companies – reproduction process, business assets of the company
  8. 4. Costs, prices and calculations
  9. 5. Business results – financial reports, success indicators
  10. 2ND MID-TERM EXAM 6. Business decision-making – methods and styles
  11. Business decision-making – communication

12. 7. Business environment of construction companies
13. 8. Business factors
14. Business factors of construction companies
15. 3RD MID-TERM EXAM

Student Evaluation - Continuous assessment:
- 75% attendance at lectures
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:
- 75% attendance at lectures
- Written exam
- Oral exam

Reading:
1. Katavić, M.: Osnove ekonomike za graditelje, Hrvatska sveučilišna naknada, Zagreb, 2009.
2. Sikavica, P., Bahtijarević-Šiber, F., Pološki vokić, N.: Temelji menadžmenta, Školska knjiga, Zagreb, 2008.
3. Sherratt, F., Farell, P.: Introduction to Construction Management, Routledge, NY; 2015.
4. Materials available on the e-learning system Merlin.

PAVEMENT STRUCTURES

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises: 30 (auditory: 1, construction: 29)

Course objectives:
- Acquisition of basic knowledge about the materials used in pavements construction, their properties and their behaviour in pavement layers as well as the behaviour of pavement as a whole,
- Acquisition of knowledge about the design and construction of flexible pavements,
- Acquisition of basic knowledge about rigid pavements.

Entry competences (prior knowledge, descriptive):
- Basic knowledge in the field of geomechanics,
- Basic knowledge about construction materials,
- Understanding of the concepts of stress, strain and internal forces.

Learning outcomes:
- Through the acquired knowledge about the characteristics of materials, their behaviour under different influences of traffic and the environment, as well as the procedures for carrying out works on the construction of pavements, to understand the behaviour of individual parts as well as the pavement as a whole,

- Analysing and solving of problems related to the design and construction of pavements from the engineering aspect, by applying the latest knowledge and solutions,
- Design of pavements in accordance with national and international design practice, using specialized software for pavement design (BISAR, CIRCLY, PAVERS),
- Critically assess, analyse and correctly select the appropriate types of pavements as well as choose their design methods in accordance with the purpose of the traffic areas,
- Fully apply the engineering approach to the design and construction of pavements using knowledge about pavement construction materials, the design and production technology of mixtures that are incorporated into the pavement, as well as the technology of the pavement construction, acquired through lectures and independent or group work during exercises,
- Be competent to participate in the management of works related to the construction and maintenance of roads, especially the part of the works related to pavements, in a creative way, using the communication skills acquired through this course, follow professional literature and present professional topics related to the design and construction of pavements, and apply the acquired knowledge in further improvement.

Course contents:

- Lectures:
  1. Introduction (overview of concepts related to pavements, pavement types, historical development)
  2. Pavement construction materials (aggregate, mixtures, binders, additives, water) [2]
  3. Flexible pavements, Subgrade
  4. Unbound granular base layer
  5. Cement treated base layer
  6. Asphalt layers (general, classification, introduction to bituminous mixtures), designation of bituminous mixtures
  7. Bituminous mixtures - Production, transportation and construction
  8. Midterm exam
  9. Physical and mechanical properties of bituminous mixtures
  10. Types of bituminous mixtures (bituminous mixtures for base, binder, wearing and protection layers) [3]
  11. Basics of rigid pavements
  12. Midterm exam

- Exercises (auditory, construction):
  1. Introduction, flexible pavements design basics
  2. Traffic load calculation [2]
  3. Flexible pavement design according to the AASHO method [2]
  4. Flexible pavement design according to the HRN method [2]
  5. Pavement stress-strain analysis - input parameters
  6. Pavement stress-strain analysis - BISAR [2]
  7. Pavement stress-strain analysis - CIRCLY [2]
  8. Calculation of the allowable number of load repetitions (Miner's rule)
  9. Checking the frost susceptibility of designed pavement

Student Evaluation - Continuous assessment:

- 75% attendance at lectures

- 100% attendance at exercises
- Preparation and submission of program assignments within the prescribed deadline
- First midterm exam
- Second midterm exam
- Oral exam
- Attendance at lectures and exercises

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation and submission of program assignments within the prescribed deadline
- Written exam
- Oral exam
- Attendance at lectures and exercises

Reading:

1. Babić, B. Projektiranje kolničkih konstrukcija. 1997. udžbenik Sveučilišta u Zagrebu, 1997, p. 197.
2. Babić, B.; Horvat, Z.: Građenje i održavanje kolničkih konstrukcija, udžbenik Sveučilišta u Zagrebu, 1983, p. 266.
3. Rukavina, T.; Domitrović, J.: Pavement Structures (lectures, PowerPoint presentations, materials for exercises), Zagreb, 2012, http://merlin.srce.hr
4. General Technical Conditions for Road Works, Croatian Roads and Croatian Motorways, Zagreb, 2001
5. Roberts, F. L.; Kandhal, P. S.; Brown, E. R.; Lee, D. Y.; Kennedy, T. W.: Vruće asfaltne mješavine - materijali, projektiranje i ugradnja
6. AASHTO Guide for Design of Pavement Structures, Published by American Association of State Highway and Transportation Officials, Washington D.C., USA, 1993
7. Thom, N.: Principles of pavement engineering, Thomas Telford Ltd, UK, 2008.

PERMANENT WAY

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 45
- Exercises (construction): 15

Course objectives:

- Acquisition of practical knowledge about basic railway track elements (rails, sleepers, railway ballast, fastening systems),
- Acquisition of theoretical and practical knowledge about railway superstructure calculation,
- Acquisition of theoretical and practical knowledge about track structures,
- Acquisition of practical knowledge about rail welding process
- Acquisition of practical knowledge about turnouts on tracks.

Entry competences (prior knowledge, descriptive):

- Knowledge of testing the mechanical properties of materials,

- Knowledge of the concepts of stress, deformation and internal forces.
- Knowledge of the terms stability of the structure and dynamic loads of the structure

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Railway Design and Construction.

Prerequisite for taking the exam:

- Course exam passed: Railway Design and Construction.

Learning outcomes:

- Explain in detail the elements of the railway superstructure: rails, sleepers, railway ballast, fastening systems (material properties, testing method, behaviour during the lifetime),
- Explain the calculation of the railway superstructure ,
- Explain in detail ballasted tracks and slab tracks,
- Explain in detail the rail welding methods, weld testing methods and continuous welded rails,
- Explain in detail the arrangement of the railway track in a curve,
- Explain in detail the turnouts and track connections on the railway tracks (manufacturing and installation method, safety of vehicle movement over the turnouts).

Course content (by course schedule):

- Lectures:
  1. General concepts of elements of the railway superstructure: rails, fastening systems, sleepers, railway ballast
  2. Rails: shape, type, testing and control
  3. Rails: wear, lubrication of rails in a curve
  4. Railway fastening systems: tasks and testing of fastening, rigid and elastic fastening systems
  5. Sleepers: wooden sleepers, reinforced concrete sleepers
  6. Railway ballast: tasks, shape and dimensions of the ballast, increasing the bearing capacity of the ballast
  7. Railway track arrangement: track gauge, cant of a railway track
  8. Railway track arrangement: transition curves, transition ramps
  9. Calculation of the railway superstructure: static calculation, dynamic calculation
  10. Slab tracks: requirements for such constructions, places of application
  11. Continuous welded rails (CWR): temperatures and stresses in CWR, stress relief of CWR
  12. Rail welding procedures: aluminothermic welding, electric resistance welding, weld testing
  13. High-speed railways: specific features, floor plan elements, profile grade elements
  14. Turnouts: parts of turnouts and their function, switch rails, turnouts' frogs [2]
- Exercises (construction):
  1. RAIL CANT IN A CURVE Creating a new horizontal geometry sub-model; Rail cant calculating Arranging the rail cant.
  2. Control and graphical representation of the change in the non-compensating lateral acceleration; Construction of curved superelevation ramp;
  3. CALCULATION OF THE CONSTRUCTION OF THE RAILWAY SUPERSTRUCTURE Technical parameters for the calculation of element stress; Track load Permissible stresses

4. Elements of the railway superstructure (rails, sleepers, railway ballast, protective layer of the track formation); Selection of elements and dimensions for the track structure;
5. CALCULATION OF STRESS AND DESIGN OF TRACK ELEMENTS; Selection of subgrade coefficient; Calculation of track elastic constant; Track structure for the required elastic constant;
6. Calculation of total track elasticity (coefficient of elasticity); Calculation of stresses in track elements for coefficient of elasticity and relevant dynamic wheel load; Stresses in the rail head induced by wheel load;
7. Bending moments on the rail from dynamic load; Maximum bending moment on the rail from the two-axle bogie
8. STABILITY CALCULATION OF THE CONTINUOUS WELDED TRACK: Proof of the stability of the geometric position of the track; Total stresses in the rail foot from bending and temperature change; Resistance of the track structure to displacement
9. NORMAL CROSS-SECTION: Calculated elements of railway superstructure; Slope gradients and drainage elements;
10. Template corrections; entering calculated track elements ;
11. CHARACTERISTIC CROSS-SECTIONS Determination of chainage of railway sections of different types of profiles;
12. Creating sections for different cross-sections; Applying predefined templates;
13. Defining control points; Modelling a railway track; Creating a track surface;
14. DRAWING CHARACTERISTIC CROSS-SECTIONS AND EDITING THE DRAWING Creation of viewport, determination of scale, plot
15. TECHNICAL DESCRIPTION, SUBMISSION AND GRADING OF THE PROGRAM ASSIGNMENT

Student Evaluation - Examination without Continuous Assessment:

- All program assignments submitted within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Lakušić, S.: Permanent Way – lectures, Zagreb, 2007.
2. Lakušić, S., Ahac, M., Haladin, I.: Permanent Way - exercises handbook, Zagreb, 2017.

Additional reading:

1. Esveld, C.: Modern Railway Track, TU Delft, 2001.
2. Gospodarenje prometnom infrastrukturom, Građevinski fakultet, Zagreb, 2009.

EARTHWORKS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 30

Course objectives:

- Acquisition of theoretical and practical knowledge about the possibilities of designing road earthwork elements: cuts and embankments, road drainage, design and protection of slopes, retaining walls,
- Choice of optimal structural solutions of elements of normal cross-section,
- Elaboration of the elements of the preliminary design of the road (normal and characteristic cross-sections and mass calculation), which started during the course Planning and Design of Roads,
- Acquisition of basic practical knowledge required in design practice and construction of road infrastructure facilities.

Entry competences (prior knowledge, descriptive):

- Knowledge of rules and criteria for road design,
- Basic knowledge about the elements of a normal road cross-section.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Planning and Design of Roads

Learning outcomes:

- Design the road earthwork elements: cut and embankment, drainage, shaping and protection of slopes, retaining walls,
- Solve the simpler problems of drainage and stability of cuts and road embankments outside the settlement,
- Understand the behaviour of the parts and construction of the road earthworks elements as a whole, as well as the importance of sufficient and precise performance of investigative works and timely execution of individual phases of work,
- Use software specialized for road design OpenRoad and slope stability calculation W-SLOPE (Geostudio) and other common calculation tools for drawing, creating presentations and documents,
- Lead works related to the construction and maintenance of roads and solve engineering problems in a creative way,
- Follow professional literature in the field of road design and construction and apply the acquired knowledge in further training.

Course content (by course schedule):

- Lectures:
  1. General information about road infrastructure structures, Road infrastructure elements - basic terms and definitions [3]
  2. Normal cross-section, Selection of road cross-section [2]
  3. Previous works during the construction of roads - investigation and preliminary works [2]
  4. Soil classification procedures for the needs of road construction, Soil classification procedures according to sensitivity to freezing [2]
  5. The choice of slope, the shaping of the slope of the cut and embankment [2]
  6. Slope protection – Earth and mixed materials [2]
  7. Slope protection - stone materials, Slope protection with geosynthetic materials [2]
  8. 1ST MID-TERM EXAM [1]

9. Surface drainage, Underground drainage [3]
10. Culverts [2]
11. Retaining, abutment, and revetment walls [2]
12. Calculation and balancing of masses [2]
13. Mass line, Mass transport [2]
14. 2ND MID-TERM EXAM [1]
15. Creation of cuts, Creation of embankments [2]

- Exercises (construction):
  1. Testing the stability of cut and embankment slopes [4]
  2. Detailed elaboration of the normal cross-section [4]
  3. Characteristic cross-sections [4]
  4. Longitudinal and cross-section of a water culvert [4]
  5. Cross section of a retaining wall [4]
  6. Calculation of masses [4]
  7. Mass line and balancing of masses [4]
  8. Technical report [2]

Student Evaluation - Continuous assessment:

- Preparation and submission of program assessments within the prescribed deadline
- First midterm exam
- Second midterm exam
- Oral exam
- Attendance at lectures and exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation and submission of program assessments within the prescribed deadline
- Written exam
- Oral exam
- Attendance at lectures and exercises

Reading:

1. Dragčević, V., Rukavina, T.; Donji ustroj prometnica, Sveučilište u Zagrebu, Zagreb, 2006.
2. Dragčević, V., Korlaet, Ž.; Osnove projektiranja cesta, Zagreb 2003.
3. Ahac, S., Džambas, T., A. Čudina Ivančev, Stančerić, I.; Donji ustroj prometnica - skripta za vježbe, Zagreb, 2026., http://merlin.srce.hr
4. Opći tehnički uvjeti za radove na cestama, Hrvatske ceste i Hrvatske autoceste, Zagreb, 2001. god.
5. Stančerić, I.; Projektiranje cesta – skripta za vježbe, Upute za rad u računalnom programu OpenRoads Designer, Zagreb 2025., http://merlin.srce.hr
6. Mikulić J., Stipetić A.; Željezničke pružne građevine, Institut građevinarstva Hrvatske, Zagreb, 1999 g.

ROAD INTERSECTIONS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 1, construction: 29)

Course objectives:

- Acquisition of theoretical and practical knowledge about the design of at-grade and split-level intersections.

Entry competences (prior knowledge, descriptive):

- Knowledge of working with computer programs for technical drawing.

Learning outcomes:

- The ability to understand and respect the conditions of traffic safety and the satisfaction of maximum road capacity at road intersections,
- The ability to use valid domestic and foreign guidelines for the design of intersections and to follow professional and scientific literature in the field of design of road intersections,
- The ability to choose the type of intersection with regard to the position and conditions in the road network,
- The ability to dimension and shape individual elements of the intersection based on driving dynamics, assumptions related to driving speed, and the vehicle's movement trajectories,
- The ability to create construction projects of intersections (at-grade and split-level intersections) and projects of horizontal and vertical signalling at intersections.

Course content (by course schedule):

- Lectures:
  1. Traffic at intersections - channelling of traffic flows
  2. Classification of intersections
  3. Criteria for choosing the type of intersection
  4. Intersections - connections to the public road
  5. General information about the geometric design of three-leg and four-leg intersections
  6. Geometric design of elements of three-leg and four-leg intersections
  7. Geometric design of elements of three-leg and four-leg intersections
  8. Geometric design of roundabouts
  9. Trajectories of vehicle movements at intersections - design vehicles
  10. Trajectories of vehicle movement at intersections - swept path analysis
  11. Sight distance at intersections
  12. Multi-level intersections
  13. Multi-level intersections - ramps and their connection
  14. Combined intersections
  15. Traffic sign and signals at intersections
- Exercises (auditory, construction):
  1. Guidelines for intersection design. Creation of the initial scheme of the four-leg intersection
  2. Construction of a teardrop-shaped splitter island on a secondary road of intersection
  3. Construction of a teardrop-shaped splitter island on a secondary road of intersection
  4. Forming the right edge of the carriageway on the secondary road of intersection
  5. Shaping of the left edge of the carriageway and the triangular island on the secondary road of intersection. Designing an exit in the shape of gore

6. Designing additional lanes for left and right turns on the primary road of intersection
7. Creation of the initial scheme of a roundabout. Designing a roundabout
8. Design of dividing islands, entrances and exits on a roundabout
9. Checking the entrance angle and the sharpness of the road widening on roundabout
10. Creation of vehicle movement paths through intersections
11. Horizontal swept path analysis of the intersections
12. Horizontal swept path analysis of the intersections
13. Design of horizontal and vertical traffic signs at intersections
14. Design of horizontal and vertical traffic signs at intersections
15. Editing the layout

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assessments within the prescribed deadline
- Written exam
- Oral exam

Reading:

1. Stančerić, I.: Projektiranje cestovnih raskrižja. Web lecture notes. Zagreb, 2019. http://merlin.srce.hr
2. Stančerić, I., Džambas, T., Bezina, Š.: Geometrijsko oblikovanje cestovnih raskrižja, Lecture notes for creating program assignments for the course Road Junctions 2024.
3. Guidelines for the design of roundabouts on state roads, Faculty of Civil Engineering University of Rijeka, July 2014.
4. Richtlinien für die Anlage von Landstraßen (RAL), Plangleiche Knotenpunkte, FGSV, Koln, 2012, p. 172.
7. 5. Ordinance on conditions for the design and construction of connections and the accesses to a public road (OG 95/2014)
5. Ordinance on cycling infrastructure (OG 28/2016).
6. Ordinance on ensuring the accessibility of buildings for people with disabilities and reduced mobility (OG 78/13).
7. Guidelines for designing intersections in settlements from the point of view of traffic safety.
8. Faculty of Transport and Traffic Sciences, University of Zagreb, Hrvatske ceste d.o.o., Zagreb, January 2004.
9. Richtlinien für die Anlage von Autobahnen (RAA), Knotenpunkte, FGSV, Koln, 2008, p. 182.
10. Klemenčić A., Oblikovanje cestovnih čvorišta izvan razine, monografija, Građevinski institut, Zagreb, 1982., p. 109.

Elective courses

APPLIED GEOLOGY

See Chapter Specialisation in Geotechnics.

ENVIRONMENTAL PROTECTION

See Chapter Specialisation in Hydraulic Engineering.

2nd year, 3rd semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

TRANSPORTATION TUNNELS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (construction: 26, design: 4)

Course objectives:

- Acquisition of theoretical knowledge about tunnel design in terms of horizontal and vertical alignment and the tunnel's cross-section,
- Acquisition of practical knowledge about tunnel design procedures, rock mass classification, excavation methods and tunnel excavation support systems,
- Acquisition of theoretical and practical knowledge about the application of safety systems in tunnels.

Entry competences (prior knowledge, descriptive):

- Practical skills for technical drawing (computer aided design skills),
- Understanding and the ability to apply the conditions for equilibrium of forces in the plane.

Learning outcomes:

- To apply professional literature in the field of design and construction of tunnel structures and application of acquired knowledge in research work,

- To recognize the methods of determining the category of rock mass on which the approach to the construction of the tunnel structure is based,
- To recognize the rock mass excavation method,
- To apply the rock mass excavation support systems,
- To design a road, rail, and metro tunnel,
- To lead the construction of tunnel facilities.

Prerequisite for taking the exam:

- Course exam passed: Planning and Design of Roads and Railway Design and Construction

Course contents:

- Lectures:
  1. Introduction to the course. History of tunnelling. Classification of modern transportation tunnels.
  2. The process of designing transportation tunnels, investigation works and regulations
  3. Rock mass classifications
  4. Tunnel excavation technologies
  5. Stabilization of the excavation
  6. Classical methods of tunnel construction
  7. Modern approaches to tunnel design [2]
  8. Tunnel drainage and waterproofing
  9. Tunnel lining
  10. Ventilation and lighting of transportation tunnels
  11. Construction and technical characteristics of road tunnels
  12. Safety in road tunnels
  13. Construction and technical characteristics of railway and metro tunnels
  14. Maintenance and reconstruction of transportation tunnels
- Exercises (design, construction):
  1. Geometry of tunnel lining with structure gauge [3]
  2. Determining the amount of mountain pressure according to Protođakon method [2]
  3. Graphostatic testing of tunnel lining [2]
  4. Calculation of load forces [2]
  5. Tabular and graphical display of forces and stress
  6. Normal cross-section, excavation and construction method, safety in road tunnels
  7. Normal cross-section
  8. Excavation and construction method (scheme and stages of excavation and construction)
  9. Creation of a scheme of safety equipment
  10. Creating a text description

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises

- Written exam
- Oral exam

Reading:

1. Banjad, Ivan: Tuneli; Građevinski institut, Fakultet građevinskih znanosti Sveučilišta u Zagrebu; Zagreb, 1982.
2. Vrkljan, Ivan: Podzemne građevine i tuneli; Građevinski fakultet Sveučilišta u Rijeci, Institut građevinarstva Hrvatske d.d. Zagreb; Rijeka, 2003.
3. Mustapić, Ivan; Mikulić, Tanja; Šarić, Darko: Projektiranje cestovnih i željezničkih tunela, Projektiranje prometne infrastrukture, ed. Lakušić, Stjepan; Građevinski fakultet Sveučilišta u Zagrebu, Zavod za prometnice; Zagreb, 2011. 189
4. Marušić, Dušan: Projektiranje i građenje željezničkih pruga, Građevinski fakultet Split, Split, 1994.
5. Opći tehnički uvjeti za radove na cestama, KNJIGA V – CESTOVNI TUNELI, Hrvatske ceste i Hrvatske autoceste, Zagreb, 2001.
6. Majstorović, Igor; Stepan, Željko; Ahac, Saša: Traffic Tunnels - handbook for exercises, 2020. (http://merlin.srce.hr)
7. Ahac, Saša: Traffic Tunnels – lecture notes for the written part of the exam, 2023. (http://merlin.srce.hr)

AIRPORTS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 1, construction: 14): 15

Course objectives:

- Acquisition of basic knowledge about the design, construction and maintenance of airport operational areas,
- Acquisition of knowledge about the design and construction of rigid pavements.

Entry competences (prior knowledge, descriptive):

- Basic knowledge in the field of geomechanics,
- Basic knowledge about construction materials,
- Understanding of the concepts of stress, strain and internal forces.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Pavement structures

Learning outcomes:

- Through the acquired knowledge about the essential features of aircraft traffic on the ground and in the airspace of the airport, the student will be able to participate in the creation of project documentation for all the essential elements of the airport manoeuvring area, geometry, lighting, signalling as well as pavement, whether flexible or rigid,
- Participate in the analysis and problem-solving related to the design and construction of airports from an engineering point of view, applying all international regulations related to the field of design and construction of airports, applying the latest knowledge and solutions,

- Pavement design of airport manoeuvring area in accordance with national and international design practice, using specialized software (PAVERS),
- Participate in the preparation of critical assessments and analyses and the proper selection of appropriate pavement type, as well as choosing pavement design in accordance with the purpose of the traffic area,
- Apply an engineering approach to the design and construction of all traffic areas of the airport, especially the part that relates to rigid pavements, using the acquired knowledge of construction materials, design and construction technology, which are acquired through lectures and independent or group work within exercises,
- Competent (under the supervision of a mentor) to participate in the management of works related to the construction and maintenance of airport areas, especially the part of works related to pavements in a creative way, using the communication skills acquired during this course, follow professional literature and present professional topics related to pavements design and construction and apply the acquired knowledge in further training.

Course contents:

- Lectures:
  1. Introduction, history of aviation
  2. Civil air traffic and its organization, Air traffic system, airports and elements
  3. Definitions of terms used in standards and recommendations - according to ICAO
  4. Basics of meteorology for the needs of research, accommodation and exploitation of airports
  5. Airports – definition, development, classification, categorization and codification according to ICAO
  6. Airport manoeuvring area, runway, shoulder
  7. Stop way, clearway
  8. Declared distances, Runway safety area
  9. Taxiways, Aprons
  10. Obstacle restrictions
  11. Marking of the airport manoeuvring area
  12. Obstacles and their marking
  13. Classification of pavement surfaces for aircraft movement (loads, classification according to different methods)
  14. Dimensioning of pavement for aircraft movement (flexible pavements and rigid pavements)
  15. midterm exam
- Exercises (auditory, construction):
  1. Introduction, ACN-PCN classification, determining the relevant aircraft; determination of reference thickness of flexible and rigid pavement
  2. ACN-PCN classification, determination of the relevant aircraft; determination of reference thickness of flexible and rigid pavement [2]
  3. Classification according to the LCN method [2]
  4. Determining the number of operations of the reference aircraft [2]
  5. Preliminary design of flexible and rigid pavements [3]
  6. Design of rigid pavement using the Westergaard method [2]
  7. Rigid pavement stress-strain analysis [3]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam

Reading:

1. Horvat Z.: Aerodromi I, 1982.
2. Prager A.: Aerodromi I – izmjene i dopune, 1990.
3. Rukavina T.: Lecture notes, 2004.
4. Aerodromes, Annex 14 to the Convention on International Civil Aviation, ICAO, 1999.
5. Airport Pavement Design and Evaluation, Federal Aviation Administration, 1995.

Note: Lecture materials will be available on the e-course website (Merlin)

ROAD EQUIPMENT

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 45

Course objectives:

- Acquisition of theoretical and practical knowledge about the problem of installation and the level of equipping the road with traffic signs, road markings and other forms of protective equipment as one of the relevant factors of increasing the safety and comfort of traffic.

Entry competences (prior knowledge, descriptive):

- Knowledge of rules and criteria for road design,
- Basic knowledge about the elements of a normal road cross-section.

Learning outcomes:

- Describe the types, methods of operation and maintenance of traffic equipment (traffic signs, safety fences, equipment for marking the edge of the roadway and the top of the traffic island, traffic calming equipment, lighting),
- Understand the methodology of installation and design of traffic equipment, respecting the behaviour of road users (psychophysical characteristics of people), traffic conditions and vehicle characteristics,
- Critically evaluate assumptions, arguments and design solutions related to the choice of type and placement of traffic equipment,
- Follow professional literature and present professional topics related to the installation and design of traffic equipment and apply the acquired knowledge in further training.

Course contents:

- Lectures:
  1. Introduction, Road furniture, Basic principles for setting up traffic signals, Performance of road users [3]
  2. Vehicle movement, Stopping sight distance, Visibility [3]
  3. Vertical signs, Design and placement of traffic signs [3]
  4. Road markings – visibility and design recommendations [3]
  5. Road markings – materials and colours, execution [3]
  6. Examples of application of horizontal and vertical signs [3]
  7. Traffic lights [3]
  8. Variable traffic signs [3]
  9. Equipment for marking the edge of the carriageway, guiding and directing traffic in the area of works [3]
  10. Protective barriers [3]
  11. Other types of fences and shock absorbers [3]
  12. Other equipment [2]
  13. Road lighting [3]
  14. Wildlife crossings, Wind protection structures [3]
  15. Seminar paper presentations [3]

Student Evaluation - Examination without Continuous Assessment:

- Attendance at lectures
- Preparation and public presentation of a seminar paper within the prescribed deadline
- Written exam
- Oral exam

Reading:

1. Dragčević, V., Stančerić, S.; Prometna oprema – predavanja, Zagreb, 2016., http://merlin.srce.hr
2. Road Traffic Safety Act (OG 67/2008., 48/10, 74/11, 80/13, 158/13, 92/14, 64/15, 108/17, 70/19, 42/20, 85/22, 114/22, 133/23)
3. Rulebook on Traffic Signs, Signalling and Road Furniture (OG 92/2019)
4. General Technical Requirements for Road Work, Hrvatske ceste , Zagreb, 2024.

TRANSPORT SYSTEMS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 45

Course objectives:

- Multidisciplinary approach to planning, designing and maintaining an integral transport system.

Entry competences (prior knowledge, descriptive):

- Practical knowledge in the field of traffic flow theory,
- Practical knowledge in the field of transportation engineering.

Enrolment requirements (prerequisite):

- Course exam passed: Transportation Engineering.

Learning outcomes:

- The ability to determine the main features of the basic elements of the transport system and different types of transport,
- Participation in analysing the development of the overall transport system and its individual parts,
- The ability to design various elements of the transport system,
- The ability to analyse the basic principles of the functioning and development of the road transport system,
- The ability to assess and research existing data on the road transport system and their application in practice,
- Participation in the creation of the concept of the functioning of the transport system,
- Participation in the creation and maintenance of the transport system.

Course contents:

- Lectures:
  1. Traffic system: definitions, categorization, historical development
  2. Traffic-spatial planning and documents
  3. General technical characteristics of traffic infrastructure
  4. Main features of traffic users and travel
  5. Main traffic characteristics of infrastructures
  6. Urban spaces
  7. Urban transportation facilities
  8. Traffic flows and regulation
  9. Traffic loads
  10. Pedestrian traffic
  11. Bicycle traffic
  12. Public urban transport - development and elements of the system
  13. Public city transport - system features and levels of service
  14. Paratransit and traffic safety
  15. Traffic studies

Student Evaluation - Examination without Continuous Assessment:

- Preparation of a seminar paper within the prescribed deadline
- 75% attendance at lectures
- Written exam
- Oral exam

Reading:

1. Maletin, M.: Osnove projektiranja saobraćajnica u gradovima, Orion-Art, Beograd 2009.
2. Dadić, I.; Kos, G.: Prometno i prostorno planiranje, Fakultet prometnih znanosti, Zagreb 2007.
3. Highway Capacity Manual, Transportation Research Board (TRB), Washington, D.C., 2000. 199
4. Global Street Design Guide, The National Association of City Transportation Officials

(NACTO), New York, 2016.

5. Other materials http://merlin.srce.hr

Elective courses

DRAINAGE OF TRANSPORTATION FACILITIES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (construction: 12, design: 3)

Course objectives:

- Acquisition of theoretical and practical knowledge about the principles of surface and underground road drainage,
- Knowledge of the advantages and disadvantages of using different types of drainage devices,
- Acquisition of basic practical knowledge required in design practice for the selection of road drainage elements.

Entry competences (prior knowledge, descriptive):

- Knowledge of the rules and criteria for road design,
- Understanding the significance of the optimal design of the elements of the normal cross-section of the road for the functioning of the road as a whole.

Prerequisite for taking the exam:

- Course exam passed: Earthworks

Learning outcomes:

- To apply professional literature in the field of road drainage and to apply acquired knowledge in further training,
- To design surface and underground road drainage systems in the settlement and outside the settlement,
- To solve simpler road drainage problems in the settlement and outside the settlement,
- To analyse the effect of water on the road from the aspect of road safety, load-bearing capacity and stability of the elements of the subgrade and pavement structure, taking into account the ecological parameters of water protection,
- To use computer programs specialized for road design to develop drainage elements,
- To evaluate assumptions, arguments and design solutions related to the choice of road drainage devices,
- To manage construction and maintenance of road drainage elements and at the same time solve engineering problems in a creative way.

Course contents:

- Lectures:
  1. Introduction to the course. Hydrological concepts and data
  2. Hydrological data
  3. The relationship between roads and water in the environment

4. Drainage systems
5. Surface drainage of traffic areas
6. Devices for surface drainage [2]
7. Groundwater drainage
8. Storm sewers and inspection shafts
9. Culverts
10. Drainage buildings
11. Intersection drainage
12. Road drainage in urban areas [2]
13. Ecological parameters of water protection and an integral approach to the drainage of traffic areas

- Exercises (design, construction):
  1. Normal cross-section [2]
  2. Details of surface drainage devices
  3. Details of underground drainage devices
  4. Drainage solution in plan view and longitudinal section
  5. Devices for surface drainage (gutters, protective ditches)
  6. Elaboration of catch basins
  7. Elaboration of storm sewers and inspection manholes
  8. Culverts - location and type
  9. Culverts - longitudinal sections
  10. Longitudinal section of the storm sewer
  11. Characteristic cross-section and textual description
  12. Characteristic cross-sections [2]
  13. Creating a text description

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Reading:

1. Ahac, Saša: Drainage of Transportation Facilities – lectures 2023. (http://merlin.srce.hr)
2. RAS: Entwässerung, FGSV, Bonn, 2005.
3. Richard K. Untermann: Principles and practices of grading, drainage and road alignment: An ecologic approach, Prentice-Hall, Inc, 1978.
4. David Butler, John W. Davies: Urban Drainage, Spon Press, 2004.
5. Harry R. Cedergren: Drainage of highway and airfield pavements, Robert E. Krieger Publishing Company, 1987.

6. General Technical Conditions for Road Works, Croatian Roads and Croatian Motorways, Zagreb, 2001

ASPHALT PAVEMENT MAINTENANCE AND PRESERVATION

Credits (ECTS): 4.5

Hours (total per semester):
- Lectures: 30
- Exercises: 15 (construction: 14, auditory: 1)

Course objectives:
- Acquisition of basic knowledge about the planning of pavement maintenance.
- Acquisition of knowledge about design techniques and technologies used in the pavement maintenance.

Entry competences (prior knowledge, descriptive):
- Knowledge of construction materials
- Knowledge of pavement construction technologies
- Knowledge of computer software used for pavement design

Enrolment requirements (prerequisite):
- Teacher's signature for the course: Pavement structures

Learning outcomes:
- Identify problems in planning and carrying out routine and corrective maintenance of pavements
- Analyse the impact of the maintenance of road pavements on the social and economic aspects of society
- Apply acquired skills and necessary knowledge to identify, formulate and analyse pavement maintenance problems and find one or more acceptable solutions
- Review and select methods and procedures for maintaining road pavements depending on the functional and structural condition
- Interpret one's own ideas and projects to colleagues
- Apply acquired knowledge in a creative way when making decisions
- Accept responsibility for one's own decisions

Course contents:
- Lectures:
  1. Introduction
  2. Legal regulations
  3. Road management
  4. Road safety
  5. Pavement surface properties
  6. Pavement distresses - basic causes [2]
  7. Pavement condition assessment - visual inspection
  8. Routine maintenance – [3]
  9. Routine maintenance - repairs of areas < 3000 m2 and > 3000 m2
  10. Routine maintenance - repairs of surfaces > 3000 m2
  11. Corrective maintenance - ruts and levelling course

12. Corrective maintenance - construction of pavement widening
13. Corrective maintenance - recycling
14. Maintenance planning

- Exercises (construction):
  1. Introduction, program assignment
  2. Pavement condition assessment - visual inspection [2]
  3. Evaluation of investigation works [2]
  4. Evaluation of pavement condition
  5. Selection of rehabilitation technique
  6. Rehabilitation project [3]
  7. Evaluation of pavement structural capacity [2]
  8. Deflection analysis
  9. Selection of reconstruction technique
  10. Program submission

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- Preparation and presentation of the seminar paper within the prescribed deadline
- Oral exam

Reading:

1. Keller, M.: Održavanje cesta, Građevni godišnjak, HSIG, Zagreb, 2000.
2. Dragčević, V.; Korlaet, Ž.; Rukavina, T.:Katalog oštećenja asfaltnih kolnika, GF, Zagreb, 2004.
3. Domitrović, J. i Rukavina, T.: lecture notes, 2022.
4. Pearson, D.: Deterioration and Maintenance of Pavements, Institution of Civil Engineers, London, 2012
5. Mallick, R. B.; El-Korchi, T.: Pavement Engineering – Principles and Practice, CRC Press, London, 2009.
6. Janez Žmavc: Vzdržavanje cest, DRC, d.o.o., Ljubljana 2010.

VIBRATIONS IN TRANSPORTATION ENGINEERING

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 15

Course objectives:

- Adopt and apply theoretical and practical knowledge about vibrations caused by the traffic of road and railway vehicles (basic terms, mechanisms of origin, ways of propagation).

- Adopt and analyse the sources of vibrations in road and railway traffic (wheel-rail interaction, tyre-pavement interaction, roughness of pavement, horizontal curves, drive mechanics),
- Acquire knowledge about methods of detection, processing and evaluation of vibrations caused by vehicle traffic and analyse and interpret characteristic wavelengths, frequencies, intensity, time domain, frequency domain of vibrations,
- Adopt and differentiate systems and mechanisms for the prevention at source and suppression of propagation of vibrations on road and rail systems.

Entry competences (prior knowledge, descriptive):

- Basic knowledge of road and rail traffic, understanding of building elements of road and track structures

Prerequisite for taking the exam:

- Course exam passed: Permanent Way, Traffic Noise.

Learning outcomes:

- Use professional literature in the field of traffic vibrations and apply acquired knowledge.
- Interpret the effect of traffic vibrations on humans and the environment.
- Interpret and analyse the vibrations generation mechanisms from traffic sources, and the mechanisms of protection against excessive levels of vibrations.
- Measure and calculate the vibration level in accordance with Croatian and European regulations.
- Calculate and analyse the basic parameters of traffic vibrations using specialized computer software for signal analysis.
- Propose and plan methods for preventing generation and attenuating the spread of vibrations for individual cases of practical application.

Course contents:

- Lectures:
  1. Introduction to the topic of vibrations that occur in transport systems. Basic classification of vibrations, mechanisms of vibration generation, mechanisms of vibration propagation [3]
  2. Sources of vibrations in road traffic. Roughness of pavement, discontinuities of the driving surface, speed bumps, vehicle suspension and tire characteristics. [3]
  3. Sources of vibrations in railway traffic. Wheel-rail contact, rail corrugation, wheel roughness of railway vehicles, discontinuities in rail running surface, switches and crossings, suspension of railway vehicles. [3]
  4. The specifics of vibrations from underground transport structures (road, railway and metro tunnels) and the spread of vibrations to surrounding objects. [3]
  5. Determining the cause of vibration. Measurements of pavement roughness, determination of the characteristics of speed bumps, measurements of the rail roughness and corrugation, measurements of the railway wheel roughness, geometry of rail welds and switches. [3]
  6. Characteristics and description of vibrations from traffic. Basic quantities, way of describing vibrations, basic analysis and characterization (wavelengths, frequency, amplitude, time domain, frequency domain) [4]

7. Regulations and standards in the field of traffic vibrations (European regulations, Croatian regulations, world practice and trends). Human perception of vibrations, impact of vibrations on the environment. [2]
8. Ways of collecting vibration data. Data collection systems, data storage and processing systems, long-term monitoring [3]
9. Data processing computer software for signal analysis. Determination of RMS values, Fourier transformations, signal filtering, [3]
10. Measures to prevent generation and spread of unwanted vibrations [3]

- Exercises (construction):
  1. Determining the impact of speed bumps on vibration level and driving comfort
  2. Determining the influence of inspection shafts on the level of vibrations during traffic of road vehicles
  3. Determining the pavement roughness of newly built and reconstructed roads
  4. Analysis of vibrations of the tram vehicle bogie and determining the ride quality
  5. Analysis of vibrations of the railway vehicle chassis and determination of ride comfort
  6. Analysis of vibrations of tram tracks on different track structures
  7. Vibration analysis and determination of track vibration decay rate on classic railway tracks
  8. Analysis of the impact of tram switches and crossings on elevated vibration levels in urban areas

Student Evaluation - Examination without Continuous Assessment:

- Preparation of an individual program assignment
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam

Reading:

1. Lakušić, S.: Utjecaj ravnosti kolnika na vibracije vozila, Gospodarenje prometnom infrastrukturom / Lakušić, Stjepan (ed.). Građevinski fakultet, Zavod za prometnice, 2009. Pp. 7- 43.
2. Lakušić, S.; Ahac, M.: Vibracije od željezničkog prometa, Gospodarenje prometnom infrastrukturom / Lakušić, Stjepan (ed.). Građevinski fakultet, Zavod za prometnice, 2009. Pp. 371-416.
3. Lakušić, S.; Haladin, I.; Bogut, M.: Analiza vibracija tramvajskog kolosijeka s obzirom na tip konstrukcije i vrijeme uporabe, Mjerenja, ispitivanja i monitoring na prometnicama / Lakušić, Stjepan (ed.). Sveučilište u Zagrebu Građevinski fakultet, 2013. Pp. 287-312.

SOIL IMPROVEMENT METHODS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (construction: 14, auditory: 1)

Course objectives:

- Acquisition of knowledge about different procedures and methods of improving unstable soils,
- Acquisition of basic knowledge about the design and implementation of various stabilization procedures for unstable soils.

Entry competences (prior knowledge, descriptive):

- Basic knowledge in the field of geomechanics,
- Basic knowledge about construction materials.

Learning outcomes:

- Through the acquired knowledge about the essential characteristics of soils whose mechanical properties (bearing capacity) do not meet the requirements and about the materials used to improve their properties (cement, lime, bitumen, geosynthetic materials, various commercial products), students will understand the effect of these materials for soil improvement and will be able to evaluate the advantages or disadvantages of their application under certain conditions,
- Under the supervision of a mentor, participate in the work of a team that analyses and solves problems related to the design and construction of roads on poor load bearing soils with the application of valid European regulations that refer both to materials used to improve the characteristics of the basic material (soil) and to mixtures which are obtained, and which represent the constituent elements of the roadbed or pavement,
- Participate in the design of the composition of mixtures of poor load bearing soils and certain additives or elements that improve their properties in accordance with national and international design practice,
- Participate in the work of a team that critically evaluates, analyses and selects appropriate types of solutions as well as design methods in accordance with environmental and soil conditions,
- Apply an engineering approach to the design and construction of all traffic areas on poor load bearing soils using the acquired knowledge about the basic material - soil, additives, design and technology of making mixtures, as well as the technology of the construction, which is acquired during lectures,
- Competent, as part of a team and under the supervision of a mentor, to lead works related to the pavement construction in difficult performance circumstances in a creative way using the communication skills acquired during this course, follow professional literature and present professional topics related to the problems, which were introduced during this course and apply the acquired knowledge in further training.

Course contents:

- Lectures:
  1. Introduction (purpose, definitions, areas of application, application of soil stabilization)
  2. Concept and types of unstable soils [2]
  3. Choice of procedure (influential parameters when making a decision on soil improvement procedures)
  4. Principles of mechanical soil stabilization [2]
  5. Soil stabilization with lime
  6. Soil stabilization with mixtures of fly ash with lime or cement
  7. Soil stabilization with bitumen
  8. Soil stabilization with cement-lime and lime-bitumen mixtures
  9. Thermal soil stabilization procedures

10. Soil reinforcement with geosynthetics [2]
11. Other soil stabilization procedures [2]

- Exercises (auditory, construction):

1. Introduction, program assignments
2. Choice of soil improvement method
3. Mechanical stabilization [3]
4. Lime stabilization [3]
5. Stabilization with cement [3]
6. Reinforcement with geosynthetics [3]
7. Submission of program assignments

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of the program assignment within the prescribed deadline
- Preparation and presentation of the seminar paper within the prescribed deadline
- Oral exam

Reading:

1. Babić B., Horvat Z., Građenje i održavanje kolničkih konstrukcija, 1985.
2. Babić, B.: Geosintetici u prometnicama, Građevni godišnjak, HSGI, Zagreb, 1995.
3. Rukavina T.: Lecture notes
4. General technical conditions for road works, IGH, 2001.

ENGLISH IN CIVIL ENGINEERING 2

See Chapter Specialisation in Geotechnics.

GERMAN IN CIVIL ENGINEERING 2

See Chapter Specialisation in Geotechnics.

2nd year, 4th semester

Mandatory courses

PAVEMENT MANAGEMENT

Credits (ECTS): 3

Hours (total per semester):

- Lectures: 30

Course objectives:

- Acquisition of basic knowledge about the properties of pavements that affect the safety and comfort of traffic,
- Acquisition of knowledge about ways of maintaining pavements, methods and procedures,
- Learning about the basics of the pavement management system.

Entry competences (prior knowledge, descriptive):

- Knowledge of the field of design and construction of pavements,
- Knowledge of the properties of pavement construction materials,
- Acquired knowledge in the field of road geomechanics.

Learning outcomes:

- Through acquired knowledge about the essential properties of pavements and their changes during the time when their degradation manifests itself through the appearance of different types of distresses and the methods of their rehabilitation or repair, that is, the principles of maintenance or renewal, students will be able to actively participate in the application of the pavement management system from the examination and assessment of the situation until the final selection and application of the solution,
- Participate in analyses and problem-solving related to pavement maintenance from the engineering aspect, while being able to apply the latest knowledge, solutions and systems,
- Apply the acquired knowledge when creating road management system settings in accordance with world practice, whereby having basic knowledge of using one of the simpler specialized software (MicroPAVER),
- Under the supervision of a mentor, critically evaluate and analyse and choose appropriate ways of pavement maintenance in accordance with existing practice, considering the principles of rational pavement management as one of the most expensive elements of the road,
- Apply an engineering approach to pavement maintenance using knowledge of materials, construction technology, as well as methods of repair acquired during lectures and exercises in other courses that are directly related to the topic of pavements (Pavement Structures, Airports, Soil Improvement Methods),
- Participate in the team working on tasks related to the pavement management, from assessing their condition, designing solutions based on the obtained assessments, and carrying out work on their maintenance, whether it routine or corrective maintenance, in a creative way using communication skills acquired in this course, follow professional literature and present professional topics related to the design and construction of pavements and apply the acquired knowledge in further training.

Course contents:

- Lectures:
  1. Introduction
  2. Basics of pavement management system [2]
  3. Road maintenance
  4. Characteristics of the pavement condition (distress types, data collecting, evaluation of the pavement condition) [2]
  5. Maintenance of flexible pavements [2]
  6. Maintenance of rigid pavements
  7. Reconstruction of flexible pavement (reinforcement, complete replacement of the existing pavement, combination of reinforcement and complete replacement) [2]
  8. Reconstruction of flexible pavement (reinforcement, complete replacement of the existing pavement, combination of reinforcement and complete replacement) [2]
  9. Reconstruction of rigid pavement
  10. Cuts and other damages/repairs caused by works on the utility infrastructure
  11. Structure and elements of the management system
  12. Pavement management models (HDM III, dTIMS/VIAPMS system, PAVERS)

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Preparation of the seminar paper
- Oral exam

Reading:

1. Sršen, M.: Održavanje cesta, Građevni godišnjak, HSGI, Zagreb, 2000.
2. Dragčević V., Korlaet Ž., Rukavina T., Katalog oštećenja asfaltnih kolnika, GF, Zagreb, 2004.
3. Keller, M.: Gospodarenje cestovnim kolnicima, Građevinski fakultet Sveučilišta u Zagrebu: DANI PROMETNICA 2009, Zagreb, 2009.
4. Rukavina, T.; Ožbolt, M.: Sustav gospodarenja kolnicima - prikupljanje podataka, Građevinski fakultet Sveučilišta u Zagrebu: DANI PROMETNICA 2009, Zagreb, 2009.
5. Rukavina T.: Lecture notes
6. OECD (Scientific Expert Group): Road Maintance Management Systems in Developing Countries, Organization for Economic Co-operation and Development, Paris, 1995

Elective courses

PARKING FACILITIES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 1, construction: 14)

Course objectives:

- Acquisition of theoretical knowledge about the design of parking facilities and their connection to the traffic network,
- Acquisition of practical knowledge about the design of parking facilities and their connection to the traffic network.

Entry competences (prior knowledge, descriptive):

- Knowledge of working with computer programs for technical drawing.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Transport Systems.

Learning outcomes:

- Determine the type, and the size of parking facilities based on urban planning and traffic needs,
- The ability to create a project of parking facility in accordance with the applicable guidelines and regulations,
- The ability to design the traffic areas at parking facilities according to the trajectories of vehicle movement,
- The ability to design the connection between parking facilities and the traffic network,
- The ability to evaluate possible solutions for parking facilities.

Course content (by course schedule):

- Lectures:
  1. Introduction to the course, Basic features of parking facilities [2]
  2. Basic features of parking facilities [2]
  3. Parking lots for cars [4]
  4. Parking lots for motorcycles and bicycles [2]
  5. Turnarounds [2]
  6. Geometric design of connections between parking facilities and road network [2]
  7. City and traffic [2]
  8. Traffic at parking garages [2]
  9. Typology of parking garages [2]
  10. Intermodal junctions and traffic at parking facilities I (bus) [2]
  11. Intermodal junctions and traffic at parking facilities II (railway) [2]
  12. Intermodal junctions and traffic at parking facilities III (airports) [2]
  13. Intermodal junctions and traffic at parking facilities IV (ports) [2]
  14. Submission of programs and presentations [2]
- Exercises (construction and auditory):
  1. Introduction [1]
  2. Geometric design of a parking facilities [8]
  3. Defining the internal organization of traffic at the parking facilities [4]
  4. Technical description [1]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of the program assignments within the prescribed deadline
- Written exam
- Oral exam

Reading:

1. Eger R. : Parking facilities – course notes, 2013.
2. AASHTO: A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington D.C., 2001.144
3. FGSV: Richtlinien für die Anlagen von Stadtstrassen, Forschungsgeselschaft fur Strassen und Verkehrswesen, Köln, 2006.
4. VSS: Schweizer Norm (SN) Band 4,5 - Entwurf der Verkehrsanlagen, Zürich, 2007.
5. Maletin, M., Andjus, V., Katanić, J.: Tehnička uputstva za projektovanje parkirališta (PGS-P/08), Građevinski centar Beograd, 2010.
6. Maletin, M., Andjus, V., Katanić, J.: Tehnička uputstva za projektovanje lokalne gradske putne mreže (PGS-LM/08), Građevinski centar Beograd, 2010.
7. Ordinance on Traffic Signs, Signaling, and Equipment on Roads. Ministry of the sea, transport and infrastructure, OG 92/2019.
8. GIVT mbh Berlin, International Consulting, Planning and Engineering Services for Parking and Traffic Development, http://www.givt.de/index.php/en/
9. S. Bašić, G. Poljanec – Prometne zgrade – internal course notes and lecture offprints
10. E. Neufert – Osnove projektiranja
11. Grawa Sigurd, Urban Transportation Systems: Choices for communities, McGraw-Hill, New York., 2002.
12. Dietrich Klose, Parkhauser und Tiefgaragen Metropolitan Parking structures, Verlag Arthur Niggli, Teufen AR, Schweiz, 1965
13. Otto Sill, Parkbauten, Bauverlag GMBH, Wiesbaden – Berlin, 1968.

RAILWAY TRACK MAINTENANCE

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 45

Course objectives:

- Acquisition of theoretical and practical knowledge about track maintenance,
- Acquisition of theoretical knowledge about the railway track condition assessment,
- Acquisition of practical knowledge about manual and mechanized track maintenance,
- Acquisition of theoretical knowledge about the maintenance of switches,
- Acquisition of theoretical knowledge about the maintenance of the track substructure,
- Acquisition of knowledge about the condition assessment and maintenance of railway infrastructure facilities.

Entry competences (prior knowledge, descriptive):

- Knowledge of types of permanent way structures,
- Knowledge of how switches work,
- knowledge of the track substructure.

Enrolment requirements (prerequisite):

- Course exam passed: Permanent Way.

Prerequisite for taking the exam: identical to the prerequisite for course enrolment.

Learning outcomes:

- Explain the track maintenance system,

- Explain track condition assessment,
- Explain the maintenance of the permanent way,
- Explain the maintenance of the track substructure,
- Explain the maintenance of switches,
- Explain the condition assessment and maintenance of railway infrastructure facilities,
- Explain track maintenance for high-speed railways.

Course content (by course schedule):

- Lectures:

1. General terms about railway maintenance
2. Track condition assessment: track and rail geometry
3. Track condition assessment: clearance profile, ballast bed
4. Types of track maintenance works: regular maintenance (current, investment), track overhaul
5. Maintenance of the permanent way: manual maintenance, mechanized maintenance
6. Maintenance of the permanent way: mechanical maintenance
7. Track maintenance for high speeds
8. Regeneration of track material: rails, switches, fastening system, sleepers, ballast bed
9. Maintenance of switches: maintenance of the switch rails device, maintenance of rail crossings
10. Maintenance of the substructure of the track: railway subgrade, sub-ballast layer, drainage
11. Condition assessment of railway track structures: bridges, culverts, tunnels, level crossings
12. Maintenance and renovation of railway infrastructure facilities
13. Management of the railway maintenance system using modern geographic information systems

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- Preparation of an individual seminar paper
- Written exam

Additional reading:

1. Esveld, C.: Modern Railway Track, TU Delft, 2001.
2. Gospodarenje prometnom infrastrukturom, Građevinski fakultet, Zagreb, 2009.
3. Tehnički, ekonomski i ekološki aspekti prometnica, Građevinski fakultet, Zagreb, 2008.

URBAN RAILWAYS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 15

Course objectives:

- Acquisition of theoretical and practical knowledge about track maintenance,

- Acquisition of theoretical knowledge about the control of the state of tracks,
- Acquisition of practical knowledge about manual and mechanical track maintenance,
- Acquisition of theoretical knowledge about the maintenance of switches,
- Acquisition of theoretical knowledge about the maintenance of the substructure of the track,
- Acquisition of knowledge about the control and maintenance of railway structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of designing and building railways,
- Knowledge of the permanent way,
- Knowledge of public city transport.

Enrolment requirements:

- Course exam passed: Railway Design and Construction

Learning outcomes:

- Explain the role of public city transport,
- Explain the tram transport system,
- Explain the metro system,
- Explain the urban light rail system,
- Explain the suburban transport system,
- Explain the types of track constructions for urban areas,
- Explain ways to reduce noise and vibrations from rail traffic in urban areas.

Course content (by course schedule):

- Lectures:
  1. General information about city railways
  2. Tram tracks
  3. Light urban railway
  4. Metro
  5. Suburban railway
  6. Types of rail vehicles in the urban environment
  7. Types of track structures
  8. Track construction in urban areas – tram
  9. Track construction in urban areas – metro
  10. Track construction in urban areas – light urban railway
  11. Noise and vibrations from rail traffic in an urban environment
  12. Revitalization of the city railway - route planning
  13. Revitalization of the city railway - arrangement of stops
  14. Basics of track monitoring in operation
- Exercises (construction):
  1. Reconstruction of the stops (extension, displacement, modernization) [2]
  2. Preliminary design of pedestrian underpasses for the needs of rail traffic in urban areas [2]
  3. Preliminary design of new rail traffic lines [3]
  4. Preliminary design for the revitalization of rail transport in urban areas [2]
  5. Preliminary design of unevenness of the intersection of road and rail traffic [2]
  6. Analysis of the influence of rail traffic in urban areas on noise level and vibration intensity [2]
  7. Creating a segmented track database [2]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Reading:

1. Lakušić, S.: Tramvajski kolosijeci, Građevinski fakultet Zagreb, Zagreb, 2006.
2. Light Rail In Germany, Federal Ministry of Transport, VDV Group, 2000.
3. Garbutt, P.: World metro system.
4. Taplin, M.; Russel, M.: Trams in western Europe, Capital Transport.
5. Bennet, D.: Metro, Octopus Publishing, 2004.
6. Other materials http://merlin.srce.hr

DESIGN OF URBAN STREETS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (construction): 15

Course objectives:

- Acquisition of theoretical and practical knowledge about the planning, design and maintaining city roads.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of road design and road construction,
- Knowledge of working with computer software for technical drawing.

Enrolment requirements:

- Course exam passed: Planning and design of roads.

Learning outcomes:

- Understanding the basic principles of traffic in cities,
- The ability to determine the main characteristics of urban transport subsystems and their interrelationships,
- Understanding the basic starting points and prerequisites for planning and designing the primary and secondary network of urban streets,
- Understanding the basic driving dynamics settings relevant for determining the horizontal, vertical and cross-sectional elements of urban streets,
- The ability to choose the type and class of urban intersection with regard to the location and conditions of the road network as well as its dimensions and geometric design,
- Acquisition of basic knowledge in the field of drainage, utility and infrastructure networks and traffic signals on urban streets,
- Ability to use project documentation in the construction of urban roads.

Course content (by course schedule):

- Lectures:
  1. Traffic and streets in cities [2]

2. City transport subsystems [2]
3. Starting points and prerequisites for designing city roads [2]
4. Primary city road network – cross-section elements [2]
5. Primary city road network – plan and elevation elements [2]
6. Secondary and special roads [2]
7. Designing urban intersections – at-grade intersections [2]
8. Designing urban intersections – split level junctions [2]
9. Curbs and road drainage [2]
10. Networks of communal installations [2]
11. Traffic signs, signalling and equipment [2]
12. Traffic surface illumination [2]
13. Maintenance of city roads [2]
14. Study-project documentation [2]
15. Sustainable and "smart" mobility in cities [2]

- Exercises (construction):
  1. Analysis of spatial plans [1]
  2. Analysis of a traffic and street network in accordance with the selected Urban Development Plan [1]
  3. Conceptual design of a selected (planned) city road [1]
  4. Defining elements of a cross-section within street lines [1]
  5. Creating a site plan [7]
  6. Creating a standard cross-section [3]
  7. Technical description [1]

Student Evaluation - Examination without Continuous Assessment:

- Preparation and submission of the program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Reading:

1. Legac, I. Gradske prometnice, Sveučilište u Zagrebu Fakultet prometnih znanosti, Zagreb, 2011.
2. Maletin, M. Planiranje i projektovanje saobraćajnica u gradovima, ORION-ART, Beograd, 2009.
3. Directives for the Design of Urban Roads - RASt 06, Forschungsgesellschaft für Straßenund Verkehrswesen (FGSV), Germany, 2012.
4. Other materials http://merlin.srce.hr

NUMERICAL MODELLING OF RAILWAY TRACK STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 3, construction: 12)

Course objectives:

- Acquisition of knowledge about the application of computer simulations in railway design using numerical methods (finite element method and discrete element method),
- Acquisition of theoretical knowledge about numerical modelling of static systems in the field of railways, as well as the problems accompanying the creation and calculation of numerical models,
- Acquisition of knowledge about the discretization of the calculation model for various numerical methods,
- Acquisition of practical knowledge in the interpretation of calculation results obtained by calculation on a computer using various numerical methods,

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of the permanent way,
- Knowledge of differential and integral calculus (including ordinary and partial differential equations) and linear algebra,
- Understand the theoretical foundations of variational procedures and the concept of area discretization

Learning outcomes:

- Apply knowledge of finite and discrete element methods to the assessment of railway structure behaviour,
- Analyse the impact of the implementation of elastic elements on increasing the elasticity of the system
- Formulate the problems of interaction of elements and load transfer within different types of track structures,
- Calculate the elements of the classic track structure and the track structure on a solid base using specialized computer software for the calculation of stresses and deformations of structures,
- Analyse and evaluate the results of the modelled behaviour of the segments of the track structure, as well as the permanent way as a whole,
- Create a stress and deformation project of the track structure with all elements (rails, sleepers, track accessories, curtain prism),
- Argue the steps of numerical modelling for a particular track problem

Course content (by course schedule):

- Lectures:
  1. Calculation elements of classic track structure [2]
  2. Guidelines and calculation methods of track structure [2]
  3. Analysis of the effect on the track structure [2]
  4. Initial and boundary conditions [2]
  5. Finite element method, discrete element method [2]
  6. Classic track structure - elements of the numerical model [2]
  7. Track structure on a rigid base - elements of the numerical model [2]
  8. Experimental tests for obtaining boundary conditions in numerical calculation [2]
  9. Numerical calculation of the rail as a continuum [2]
  10. Numerical calculation of track sleepers - dimensioning of concrete and wooden sleepers [2]

11. Numerical model of a rail clip - design of elements of fastening accessories [2]
12. Numerical model of a curtain prism - dimensioning of elements [2]
13. Interactions between elements of the track structure connected into a whole [2]
14. The influence of temperature on the behaviour of the track structure [2]
15. The influence of incorporating elastic elements into the track structure on the improvement of the elastic properties of the track [2]

- Exercises (auditory, construction):
  1. Basics of design and calculation. [1]
  2. Calculation of traffic load, determination of excitation function [1]
  3. General information on numerical calculation of track structure (FEM, DEM) [1]
  4. Initial and boundary conditions of the numerical model of the track structure [1]
  5. Contact stresses and deformations. Hertz formulas for contact stresses and deformations [1]
  6. Calculation of the basic elements of the track structure using the finite element method in a computer software and comparison of the structure of a classic track and a track on a rigid base [1]
  7. Checking the stress in the rails of the track structure with a computer software; rail bending, stress concentration [1]
  8. Checking the stress in the sleepers of the track structure with a computer software [1]
  9. Checking the tension of the fastening accessories of the track structure with a computer software [1]
  10. Checking the stress inside the curtain prism with a computer software [1]
  11. Calculation of different types of track structure foundations [1]
  12. Connection of track structure elements into a whole [1]
  13. Calculation of track structure settlement [1]
  14. Modelling the behaviour of the track structure under temperature effects [1]
  15. Modelling of elastic elements (elastic pads under the rail, sleeper, curtain) and their influence on the change of elastic properties of the track structure in buildings (bridge, viaduct) [1]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of an individual program assignment
- Written exam
- 75% attendance at lectures
- 100% attendance at exercises

Reading:

1. Esveld, C.: Modern Railway Track, Second Edition. MRT Productions, Zaltbommel, 2001.
2. Chapra, S. C.; Canale, R. P.: Numerical Methods for Engineers, McGraw-Hill, Sixth Edition, 2009.
3. Pravilnik o održavanju gornjeg ustroja željezničkih pruga HŽ (Pravilnik 314), (Službeni vjesnik,
   br. 20/91)
4. Selig, E., Waters, J. M., Track Geotechnology and Substructure Management, Thomas Telford,
   1994.

5. Cundall, P. A., Strack, O. D. L., A discrete numerical model for granular assemblies, Geotechnique, 1979.
6. Sorić, J.: Metoda konačnih elemenata, Golden Marketing, Tehnička knjiga, Zagreb, 2004.

NUMERICAL MATHEMATICS

See Chapter Shared Courses

PERSPECTIVE

See Chapter Shared Courses

GEOMETRY IN CIVIL ENGINEERING

See Chapter Shared Courses

WAVES AND OSCILLATIONS

See Chapter Shared Courses

Specialisation in THEORY AND MODELLING OF STRUCTURES

1st year, 1st semester

Mandatory courses

MATHEMATICS 3

See Chapter Shared Courses

RESEARCH METHODS

See Chapter Shared Courses

MECHANICS OF MATERIAL

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 4, laboratory: 11)

Course objectives:

- Acquisition of theoretical knowledge about the physical and mechanical properties of materials,
- Acquisition of theoretical and practical knowledge about conducting experiments, ability to analyse and apply results.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus,
- Knowledge of mechanics (statics and kinematics),
- Understanding the concepts of stress and strain analysis,
- Knowledge of stress and deformation calculations in elements loaded with internal forces (longitudinal and transverse, torsional moment and bending moment).

Learning outcomes:

- Become familiar with types of testing of mechanical properties of materials, methods and standards for testing,
- Explain the structure of matter, structurally sensitive and insensitive properties, selective and additive theory,
- Explain and interpret the methods of determining the mechanical properties of materials,
- Explain the strength of materials under cyclic loading,

- Recognize the meaning of rheology and fracture mechanics,
- Explain the concept of material hardness and test methods,
- Explain methods of non-destructive testing of materials and apply them,
- Apply experimental stress and deformation analysis when determining the physical and mechanical properties of materials.

Course content (by course schedule):

- Lectures:
  1. General considerations. Phenomenology. Classification of testing, loading speed of material samples. Interpretation of test results. Norms (standards) for testing. Material properties to be tested: chemical, physical and chemical, physical, and mechanical properties. Structure of solid materials. The influence of the material structure on the mechanical properties of the material. Probabilistic character of mechanical properties. Structural sensitivity and structural insensitivity. Selective and additive theory [2]
  2. Modelling and scale effect. Load, time, temperature. Test methodology. Mechanical properties of materials during stretching. Diagram F-Δl. Determination of the tensile strength of materials in a brittle state. Conventional material flow chart. Characteristics of material deformability. Ductile materials. Brittle materials [2]
  3. The actual working diagram of the material. Mechanical properties of materials under pressure loading. Schematization of the material working diagram. Elastic material, elastoplastic material with hardening, ideally elastoplastic material, rigid plastic material, rigid plastic material with hardening [2]
  4. The influence of various factors on the behaviour of materials under load: speed of load increase, Bauschinger effect, elastic hysteresis, creep, stress relaxation, influence of temperature. Permanent static strength. Basic types of rod breakage. Load types [2]
  5. Material strength under dynamic loading. Types of dynamic load. Impact strength or toughness of materials: Charpy and Föppl's method. External factors affecting the impact strength of materials. Material strength under cyclically variable load. Types of cyclically variable load [2]
  6. Appearance of material fatigue. Permanent dynamic strength, time dynamic strength. Determination of dynamic strength. Presentation of test results. Wohler, Smith, Launhardto-Weyrauch and Haigh diagrams [2]
  7. Influence of various factors on permanent dynamic strength. Calculation of strength under variable stress. Safety factor of permissible stress. Schematization of the Haigh diagram according to Serensen and Kinosošvili. Schematization of the Haigh diagram according to Goodman. Determination of permanent dynamic strength, safety coefficient and permissible stresses [2]
  8. Rheology. Rheological properties of materials and rheological models. Rheological equation of state of the material. The principle of superposition of time and temperature. Complex rheological models: Kelvin, Maxwell and Poynting-Thomson model [2]
  9. Bending test. Residual stresses. Testing of plastic properties: bend test and wire twist test. Torsion test. Shear test. [2]
  10. Fracture mechanics and material strength. Basic forms of crack development. Stress intensity factor. Fracture criteria. Fracture toughness. Material sensitivity to notch and cracks [2]

11. The hardness of the material. Martens process, Brinell process, Vickers process, Rockwell process, Shor process and Poldi process, sclerometer. Correlation of hardness and strength of materials. Non-destructive testing [2]
12. Acoustic procedures. Determination of material strength and elastic modulus. Application of the ultrasound method in defectoscopy [2]
13. Test by resonance vibration. Devices for measuring deformations. Experimental analysis of stress and deformation. [2]
14. Choice of measurement base and disposition of measurement locations. Interpretation of test results [2]
15. Midterm exam

- Exercises (auditory):
  1. Material fatigue. Influence of various factors on permanent dynamic strength. Calculation of strength under variable stress. Safety factor of permissible stress. [2]
  2. Rheological properties of materials and rheological models. Rheological equation of the state of the material. Fatigue of the material [1]
  3. Fracture mechanics and material strength. Stress intensity factor. Fracture criteria. [1]
- Exercises (laboratory):
  1. Determination of diagrams for static and dynamic loading. Bauschinger effect. Elastic hysteresis. Creep. Relaxation. [2]
  2. Determination of tensile strength of brittle material. Pressure test. Effect of sample size on material strength. The influence of the rate of increase in load. [2]
  3. Shear test. Bending test. Test of toughness by reverse bend test. [2]
  4. Twisting test of toughness.
     Impact strength according to Charpy and Föppl.
     Material fatigue.
     Material hardness: Martens, Brinell, Vickers, Rockwell, Poldi, sclerometer. [2]
  5. Fracture mechanics [2]
  6. Acoustic procedures.
     Determination of tension in the wire. [1]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam 60.00
- Oral exam 40.00

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam 60.00
- Oral exam 40.00

Required reading:

1. J. Krolo, D. Šimić: *Mehanika materijala*, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2011.
2. Šimić, V.: *Otpornost materijala II*, Školska knjiga, Zagreb, 2002.

3. M. Rak, I. Duvnjak, D. Damjanović: Teorija elastičnosti i plastičnosti s metodama rješavanja zadaća, Zagreb, 2020.

Additional reading:

1. Bazjanac, D., *Nauka o čvrstoći,* Tehnička knjiga, Zagreb, 1973.
2. Timošenko, S., *Otpornost materijala II,* Građevinska knjiga, Beograd, 1965.
3. Timošenko, S., *Mechanics of Materials*, Van Hostrand Reinhold Company, New York, 1972.

NONLINEAR STATICS OF ROD STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 5, design: 10)

Course objectives:

- Improve the understanding of the behaviour of structures and the limitations and applicability of linear theory,
- Acquaint the students with the procedures of non-linear calculation of rod structures and with the differences in assumptions and consequences of linear and non-linear calculations.

Entry competences (prior knowledge, descriptive):

- Knowledge of linear statics of rod structures: conditions of equilibrium of external and internal forces, displacement geometry, theorems of virtual work.

Learning outcomes:

- Recognize different types of nonlinearity: static, geometric, material,
- Explain the equilibrium conditions on a deformed rod and the differences compared to the equilibrium conditions on an undeformed rod,
- Apply calculation procedures that take static nonlinearity into account and understand the limitations and areas of applicability of linear calculations,
- Understand the meaning of constitutional functions,
- Apply the calculation procedures of limit loads.

Course content (by course schedule):

- Lectures:
  1. Idealization in linear statics of rod structures. Exact theory of displacement geometry and equilibrium on a deformed beam. [2]
  2. Relationships between linear and non-linear theory. [2]
  3. Differential relationships of forces and loadings in geometric nonlinearity [6]
  4. Equilibrium equations of nodes. [2]
  5. Nonlinear stiffness matrix. [4]
  6. The concept of imperfection [2]
  7. P-delta analysis. [2]
  8. Calculation of critical force [2]
  9. Physical nonlinearity. Idealizations in material nonlinearity [2]

10. Approximation of physically nonlinear tasks. [2]
11. General bilinear approximation. [2]
12. Interaction of internal forces in physical nonlinearity. [2]

- Exercises:
  1. Derivations and solutions of beam differential equations [2]
  2. Nonlinear stiffness matrix. [3]
  3. Engineering displacement method [3]
  4. Linearized calculation, P-delta calculation, Critical force calculation [3]
  5. Idealizations in material nonlinearity [1]
  6. Approximation of physically nonlinear tasks. [2]

Student Evaluation - Examination without Continuous Assessment:

- Regular attendance – 75% attendance at lectures, 100% attendance at exercises
- Preparation of a program assignment
- Oral exam

Required reading:

1. K. Fresl: *Bilješke i skice s predavanja*, http://master.grad.hr/nastava/gs/nls.
2. M.Meštrović: Nelinearna statika greda i okvira, GF, 2017.

Additional reading:

1. A. L. Nayfeh, P. F. Pai: *Linear and Nonlinear Structural Mechanics*, Wiley, Hoboken, NJ, 2004.
2. E. Rahm: *Stabtragwerke, Teil V, Nichtlineare Verfaren*, Universitaet Stuttgart, 1995.
3. W. Wunderlich, W. D. Pilkey: *Mechanics of Structures. Variational and Computational Methods*, CRC Press, Boca Raton, 2003.
4. T. Belytschko, W. Kam Liu, B. Moran: Nonlinear Finite Elements for Continua and Structures, Wiley, Chichester, England, 2000.

EXPERIMENTAL METHODS 1

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (laboratory): 30

Course objectives:

- Acquisition of theoretical and practical knowledge about the application of experiments as a basic research method in technical sciences,
- Learning about modern measuring equipment and methods in the experimental analysis of building materials, structural elements and structures,
- Acquisition of practical knowledge about metrology and standards in metrology.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic elements of statistics and probability theory,
- Ability to analyse data and determine basic statistical parameters,

- Knowledge of stress and deformation calculations due to longitudinal and transverse forces, torsion moment and bending moment.

Learning outcomes:

- Determination of measurement errors, accuracy class of measuring instruments and measurement uncertainty,
- Designing the experiment through the basic stages of preparation, implementation and analysis of the results,
- Selection of equipment and methodology in the implementation of experimental research on building materials, elements and structures,
- Experimental determination of displacements, relative deformations, angles of rotation, and basic dynamic parameters,
- Analysis of structures and structural elements using modern experimental methods.

Course content (by course schedule):

- Lectures:
  1. Introductory lecture, historical overview of the development of metrology [2]
  2. International and Croatian metrology infrastructure, standardization and norms [2]
  3. Measurement errors, measurement uncertainty, accuracy classes of measuring instruments [2]
  4. Measurement of physical quantities, measurement systems and their basic characteristics [2]
  5. Instrumentation and methods for measuring displacement and angles of rotation. [2]
  6. Instrumentation and methods of measuring force, pressure and temperature [2]
  7. Instrumentation and methods of measuring initial deformations. [2]
  8. Tests and measurement methods on prototypes and models. [2]
  9. Methods of measurement and verification of the behaviour of real structures. [2]
  10. Model testing and materials for model making [2]
  11. Dimensional analysis [2]
  12. Instrumentation and measurement methods for static and dynamic loading [2]
  13. Experiments with dynamic load action [2]
  14. Experimental determination of dynamic parameters. [2]
  15. Seminar submission [2]
- Exercises (laboratory):
  1. Getting to know the instruments and test devices in the construction testing laboratory. [2]
  2. Acquaintance with working on the software used in load application devices. [4]
  3. Preparation of models for tests under static excitation. [2]
  4. Tests of the model under static excitation. [4]
  5. Preparation of a life-size structure for testing under static excitation. [2]
  6. Construction testing under static excitation. [2]
  7. Preparation of models for tests under dynamic excitation. [2]
  8. Tests of models under dynamic excitation [2]
  9. Determination of dynamic parameters on the model. [2]
  10. Testing of the structure under dynamic excitation. [2]
  11. Determination of the dynamic parameters of the structure. [2]
  12. Simulation of in-situ structural testing. [4]

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. D. Damjanović: *Experimental Methods – Lecture notes*, http://www.grad.unizg.hr/predmet/eksmet1_a
2. J. Krolo, D. Šimić: *Mehanika materijala*, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2011.

Additional reading:

1. A. Kiričenko et al.: *Mjerenje deformacija i analiza naprezanja konstrukcija*, DIT-Zagreb, Zagreb, 1982.
2. Alfirević, I., Jecić, S.: Fotoelasticimetrija, Liber, Zagreb, 1983.
3. Aničić, D.:Ispitivanje konstrukcija, Građevinski fakultet Svučilišta u Osijeku, Osijek, 2002.
4. Papoulis, A.:Probability, random variables and stohastic processes, McGraw-Hill, Singapore,1987.

METAL STRUCTURES 2

See Chapter Specialisation in **Structural Engineering**.

1st year, 2nd semester

Mandatory courses

THEORY OF ELASTICITY AND PLASTICITY

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 30 (auditory: 20, laboratory: 4, design: 6)

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of real deformable bodies under load in the elastic and plastic area,
- Acquisition of theoretical knowledge in the field of analysis of displacements, deformations and stresses of real solid bodies,
- Acquisition of knowledge in the field of analytical and numerical procedures for the analysis of real solid bodies.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus, ordinary and partial differential equations, and vector and tensor analysis,
- Good knowledge of the elements of general theoretical mechanics and numerical mathematics,
- Knowledge of the elements of statics, dynamics and resistance of materials.

Learning outcomes:

- Recognize the appropriate boundary-value problem of the theory of elasticity and plasticity,
- Explain the conditions of equilibrium and compatibility in the analysis of deformations and stresses,
- Adequately formulate the boundary-value problem, express its solution through displacement and stress,
- Choose the optimal method of solving the corresponding boundary-value problems,
- Explain certain methods of solving boundary-value problems in plane and space,
- Explain the laws of material behaviour in the elastic and plastic regions.

Course content (by course schedule):

- Lectures:
  1. Introduction, classification and definition of real deformable body in continuum mechanics. Euclidean vector space E3 . Bases, space metrics and coordinate systems [3]
  2. Linear and homogeneous transformations in E3 space. Covariant and contravariant coordinates. Direct and inverse mapping within databases with the same origin. Definition of tensor. General tensors. Operations with tensors and their properties. Differential operators in tensor form. Stokes and Gauss theorem in tensor form [3]

3. Models of material continuum deformation. Material and spatial coordinates. Lagrange's and Euler's approach to the problem of deformation of the material continuum. [3]
4. Deformation gradients. Displacement gradients. Green's and Cauchy's metric tensor. Finite deformation tensors according to Lagrange and Euler and geometric nonlinearity. [3]
5. Linearization of tensors of finite deformations and restriction to small deformations. Transformational properties of strain tensors. Eigenvalues of the tensor of small deformations. Additive decomposition of small deformations and compatibility equations. [3]
6. The concept of external and internal forces on a solid body. Principal vector and principal moment of forces. Stress field around a point of a deformed body. Cauchy stress tensor and its definition. [3]
7. Static admissibility and differential balance equations. Transformation properties of the stress tensor. Eigenvalues and stress tensor decomposition [3]
8. Laws of state and thermodynamic processes on a real solid body. Energy function of a real deformable body. Tensor of material stiffness and tensor of material flexibility of a solid body. Anisotropic, orthotropic and isotropic real solid. Lame's and technical constants. [3]
9. Definition of marginal tasks in the theory of elasticity. Formulation of the solution of boundary value problems of a solid body. Statement of the solution of the boundary value problem by displacements (Lame-Navier). Statement of the solution of the boundary value problem by stresses (Beltrami-Michell). [3]
10. The virtual work equation. Energy principles and theorems. The principle of minimum total potential energy of deformation of a solid deformable body. The principle of minimum total complementary energy of deformation of a solid body. Other principles and theorems. [3]
11. Application of analytical and numerical procedures in solving marginal problems of elasticity theory. Infinite trigonometric series, variational methods, discretization methods of differential equations and residue methods. (Ritz method. Galerkin method. The least squares method. Collocation method. Finite difference method. Finite element method, etc.). [3]
12. State of plane strain and plane stress. Boundary-value problems on the plane and half-plane in rectangular and polar coordinates. Airy function. Harmonic and biharmonic partial differential equation as a solution of plane boundary value problems. Harmonic and biharmonic functions in solving boundary-value problems of the theory of elasticity and plasticity. [3]
13. Potential functions. Boundary value problems on space and half-space (Kelvin's, Boussiness's and Cerruti's problems). Torsion of a straight rod with a general cross-section shape (St. Venant's problem). Theory of rectangular thin plates in Cartesian coordinates. Theory of circular thin plates in polar coordinates. [3]
14. Introduction to plasticity theory and plasticity theory models. Basic material flow criteria. Rules of yielding. Drucker's postulates on the yield surface of materials. Material stability criteria during yielding. Equations of the theory of plasticity and the relationship between stress and deformation in the theory of plasticity. [3]

15. Basics of the theory of viscoelasticity and viscoplasticity. Viscoelastic and viscoplastic models. Creep and relaxation functions. The relationship between stress and deformation in the theory of viscoelasticity and viscoplasticity. [3]

- Exercises (auditory):
  1. Linear and homogeneous transformations in E3 space. Operations with tensors and their properties. Transformation properties of the stress tensor. Eigenvalues and stress tensor decomposition [2]
  2. Airy function of plane tasks in rectangular coordinates. [4]
  3. Airy function of plane tasks in polar coordinates. [2]
  4. Airy's function of plane problems [2]
  5. Torsion solution of a straight rod with a general cross-section and a multiply connected region [2]
  6. Torsion of a straight rod with a general cross-section and a multiple connected region [2]
  7. Rectangular thin plates in rectangular coordinates. [2]
  8. Circular thin plates in polar coordinates. [2]
  9. Thin plates [2]
  10. The Ritz method. Galerkin method. [2]
  11. Finite difference method. [2]
  12. Planar problems [4]
  13. Problems from the theory of plasticity. [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Continuous of preparation of assignments
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Continuous preparation of assignments
- Written exam
- Oral exam

Required reading:

1. M. Rak, I. Duvnjak, D. Damjanović: Teorija elastičnosti i plastičnosti s metodama rješavanja zadaća. Sveučilište u Zagrebu Građevinski fakultet, Zagreb 2020.

Additional reading:

1. T. Herman: Teorija elastičnosti i plastičnosti, Element, Zagreb, 2008.
2. I. Alfirević: Linear structural Analysis, Thin-walled Structures, Zagreb, 2006
3. M. H. Saad: Elasticity, Theory, Applications and Numerics, Elsevier, Oxford, 2005
4. I. Alfirević: Uvod u tenzore i mehaniku kontinuuma, Knjiga 6, Golden marketing, Zagreb 2003.
5. J. Brnić: Elastomehanika i plastomehanika, Školska knjiga, Zagreb, 1996. god.

6. Z. Kostrenčić: Teorija elastičnosti, Školska knjiga, Zagreb, 1982.
7. S. Timošenko, J. N. Gudier: Teorija elastičnosti, Građevinska knjiga Beograd, 1962.
8. G.E. Mase: Theory and Problems of Continuum Mechanics, McGrow-Hill Company, 1970.
9. S. Timošenko, J. N. Gudier: Teorija elastičnosti, Građevinska knjiga Beograd, 1962.

DYNAMICS OF STRUCTURES AND EARTHQUAKE ENGINEERING

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises: 24 (auditory: 14, construction: 4, on computers: 6)
- Seminars: 6

Course objectives:

- Acquiring theoretical knowledge of analytical and numerical procedures for determining dynamic responses of systems with a single degree of freedom,
- Gaining knowledge on the formulation of mathematical models for the dynamic analysis of real structures,
- Acquiring practical knowledge on the fundamentals of designing and calculating structures resistant to seismic forces.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basic procedures for solving differential equations,
- Knowledge of the fundamentals of engineering informatics (use of software packages for matrix calculation and numerical calculation methods),
- Understanding of calculation procedures of statically determinate and indeterminate structures.

Learning outcomes:

Students will be able to:

- Identify and explain problems related to various dynamic effects on buildings,
- Apply knowledge about the procedures for selecting a mathematical model for the dynamic analysis of a structure: selection of dynamic degrees of freedom, analysis of masses, stiffness, and flexibility,
- Apply mathematical knowledge to determine natural mode shapes and frequencies,
- Explain and apply the procedure for calculating the response of a system with multiple degrees of freedom due to the dynamic actions,
- Explain and perform spectral analysis of frame systems and buildings under seismic loads.
- Use computer programs for the numerical analysis of the structural response to dynamic loads.

Course content (by course schedule):

- Lectures:
  1. Introduction to the structural dynamics. Problem formulation and procedures for solving systems with a single degree of freedom. [3]
  2. Formulation of a system with a single degree of freedom: dynamic characteristics and undamped oscillation of the system [3]

3. Damping in the systems: model of damping in the elastic and plastic response ranges [3]
4. Dynamic excitation and response of single degree of freedom systems to impulse, constant, linear and harmonic excitation [3]
5. Concept of response spectrum, determination of response spectrum for a given ground acceleration function. [3]
6. Response of elastic and elastoplastic systems to seismic excitation [3]
7. Generalized single degree of freedom system: Rayleigh quotient [3]
8. Formulation of systems with multiple degrees of freedom, definition of static and dynamic degrees of freedom, static condensation procedure, determination of dynamic characteristics of the system [3]
9. Damping in building structures: experimental determination of damping values, relative damping coefficients for structures. [3]
10. Modal analysis: formulation and determination of the dynamic response of the system with and without damping [3]
11. Dynamic response of a linear system with multiple degrees of freedom to harmonic excitation [3]
12. Dynamic response of a linear system with multiple degrees of freedom to earthquake excitation, numerical calculation methods and modal analysis. [3]
13. Design of earthquake-resistant structures: elastic and design spectrum, application of the response spectrum method to a system with multiple degrees of freedom, modal combination methods. [3]
14. Design of earthquake-resistant structures: structural design, influence of geometry, shape and size of building, position and dimensions of structural elements, criteria of regularity in floor plan and elevation. [3]
15. Design of earthquake-resistant structures: Load-bearing capacity of structural elements (walls, columns, beams, connecting beams) and design of connections, methods for strengthening structures. [3]

- Exercises:
  1. Defining the dynamical degrees of freedom (static and dynamic degrees of freedom of the system). Determination of stiffness of static systems. Determination of stiffness and flexibility matrix. Static condensation. [2]
  2. Determination of the differential equation of motion of a system with a single dynamic degree of freedom. Determination of frequency, period and mode shape of vibration. [2]
  3. Free undamped and damped vibration. Response to dynamic excitation. Analytical and numerical solution of the differential equation. Determination of internal forces. [2]
  4. Response of a single degree of freedom system to dynamic excitation (earthquake and spectrum). Eccentric loading of the system. Determination of response and internal forces. [2]
  5. Modelling of systems with a single dynamic degree of freedom. [2]
  6. A generalized single degree of freedom system. Rayleigh quotient. Systems with multiple dynamic degrees of freedom. Determination of frequencies, periods and eigenvectors. Formulation and solution of the frequency equation. [2]
  7. Problem-solving assignment in exercises (systems with a single degree of freedom). [2]

8. Free oscillation of a system with multiple degrees of freedom for given initial conditions. Response of systems with multiple degrees of freedom to dynamic excitation (modal analysis). Spectral analysis. Determination of internal forces. [2]
9. Modelling systems with multiple dynamic degrees of freedom. [2]
10. Seminar: Analysis of simple spatial structural system. Defining the mass and stiffness matrix (transformation into the global stiffness matrix and vice versa). Determination of natural frequencies, periods and eigenvectors. Determining the response of the system to the ground acceleration ug(t). Determination of internal forces. [2]
11. Seminar: Eurocode 8 guidelines and definition of dynamic action with regard to soil conditions and building location. Spectral analysis of the structure and determination of the peak values of forces and displacements. [2]
12. Modelling of a simple spatial structure using the program for numerical analysis of structures [2]
13. Problem-solving assignment (systems with multiple dynamic degrees of freedom) [2]
14. Midterm exam
15. Seminar presentation in front of teachers and students [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments in construction exercises
- First midterm exam
- Second midterm exam
- Seminar paper
- Theoretical part of the written exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of program assignments in construction exercises
- Seminar paper
- Written exam – practical and theoretical part
- Oral exam

Required reading:

1. Lazarević, D., Šavor Novak, M., Uroš, M.: Dinamika konstrukcija s uvodom u potresno inženjerstvo, (lecture notes), Katedra za statiku, dinamiku i stabilnost konstrukcija, Zavod za tehničku mehaniku, Građevinski fakultet, Sveučilište u Zagrebu, Zagreb, 2018, http://www.grad.unizg.hr/_download/repository/DK_skripta%5B2%5D.pdf
2. Lazarević, D., Demšić, M.: Dinamika konstrukcija s uvodom u potresno inženjerstvo, (lecture notes), Katedra za statiku, dinamiku i stabilnost konstrukcija, Zavod za tehničku mehaniku, Građevinski fakultet, Sveučilište u Zagrebu, Zagreb, 2020, prvi dio: http://www.grad.unizg.hr/_download/repository/DK1%5B1%5D.pdf, drugi dio: http://www.grad.unizg.hr/_download/repository/DK2%5B1%5D.pdf

3. Potresno inženjerstvo - Obnova zidanih zgrada, ed. Uroš, M.; Todorić, M.; Crnogorac, M.; Atalić, J.; Šavor Novak, M.; Lakušić, Građevinski fakultet Sveučilišta u Zagrebu, 2021.

Additional reading:

1. Chopra, A., Dynamics of Structures, Theory and Application to Earthquake Engineering, 3rd Edition, Prentice Hall, New Jersey, 2007.
2. Mihanović, A.: Dinamika konstrukcija, Građevinski fakultet Sveučilišta u Splitu, Split, 1995.
3. Čaušević, M.: Dinamika konstrukcija, diskretni sustavi, Školska knjiga, Zagreb, 2005.

FINITE ELEMENT METHOD

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 10, design: 20)

Course objectives:

- Deepening of theoretical knowledge about structure modelling for numerical calculations using the finite element method,
- Acquisition of practical knowledge about construction calculations using the finite element method,
- Acquisition of knowledge about the discretization of the calculation model for the finite element method,
- Acquisition of practical knowledge in the interpretation of calculation results obtained by calculation on a computer using the finite element method.

Entry competences (prior knowledge, descriptive):

- Understanding the basic equations of elasticity theory,
- Knowledge of mathematical models of physical phenomena from the field of elasticity theory,
- Knowledge of the displacement method,
- Understanding of the concept of virtual work and the theoretical basis of variation procedures,
- Basic mathematical knowledge in the field of ordinary and partial differential equations.

Learning outcomes:

- Apply the finite element method to the calculation of structures,
- Explain the theoretical bases of calculations using the finite element method,
- Explain the structural calculation model for structural calculation using the finite element method,
- Interpret calculation procedures for construction calculations using the finite element method,
- Interpret the results of calculations using the finite element method.

Course content (by course schedule):

- Lectures:
- Lectures:

1. Basic equations of elasticity theory, Variational formulation, Numerical integration, Solving system of equations, Optimization of area discretization, Generation of finite element mesh [4]
2. 1D finite elements [2]
3. Beam finite elements, Application to frame structures [4]
4. Beam finite elements according to Timoshenko bending theory [4]
5. Application of FEM to frame plane supports (walls) [4]
6. Finite elements for panels [4]
7. Finite elements for the second order theory of elasticity [4]
8. Finite elements for nonlinear calculation [2]
9. FEM error assessment. Mathematical formulation of FEM. [2]

- Exercises:
  1. Basic equations of the theory of elasticity in structural analysis [2]
  2. Numerical integration [2]
  3. Solving systems of linear equations [2]
  4. Calculation of the elementary stiffness matrix of the beam element [2]
  5. Beam and frame support [4]
  6. Beam finite elements according to Timoshenko bending theory [4]
  7. Calculation of the elementary stiffness matrix for wall finite elements [4]
  8. Calculation of wall girders [2]
  9. Calculation of the elementary stiffness matrix for plates [4]
  10. Calculation of the slab [2]
  11. Calculation of critical force [2]

Student Evaluation - Examination without Continuous Assessment:

- Regular attendance – 75% attendance at lectures, 100% attendance at exercises
- Seminar paper (prerequisite for taking the oral exam)
- Oral exam

Required reading:

1. M. Meštrović: MKE – *Lecture notes*, http://www.grad.hr/kolegiji/mke
2. Sorić: *Metoda konačnih elemenata*, Golden Marketing – Tehnička knjiga, 2004.
3. Kraetzig, Basar: *Tragwerke 3, Theorie und Anwendung der Methode der Finiten Elemente*, Springer, 1997.
4. Werkle: *Finite Elemente in der Baustatik*, Vieweg, 1995.
5. Hughes: *The Finite Element Method*: Linear Static and Dynamic Analysis, Dover, 2000.
6. Hartmann, Katz: *Statik mit finiten Elementen*, Springer, 2002.
7. Cook, Malkus, Plesha, Witt: *Concepts and Applications of Finite Element Analysis*, Wiley & Sons, 2001.

THEORY OF COMPOSITES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30

- Exercises: 15 (auditory: 9, on computers: 6)

Course objectives:

- Acquisition of theoretical knowledge about the production, types and properties of composites used in construction,
- Acquisition of practical knowledge about the application, design and quality control of composites used in construction.

Entry competences (prior knowledge, descriptive):

- Knowledge of basic concepts and laws of strength of materials.

Learning outcomes:

- Learn about different types of composites and their properties and production processes,
- Apply theoretical and experimental bases for sizing composites with an emphasis on polymer composites,
- Acquire examples of application of polymer composites in construction,
- Adopt the procedure of quality control and confirmation of the construction product on the example of structural bearings.

Course content (by course schedule):

- Lectures:
  1. Introduction; General information about composites; Matrices and reinforcement [3]
  2. Production of polymer composites [3]
  3. Properties of polymer composites [3]
  4. Application of polymer composites in construction [3]
  5. Fiber reinforced polymer materials (FRP materials) [3]
  6. Macromechanics of composite layer [6]
  7. Micromechanics of composite layer [3]
  8. Multilayer composites; Classical lamination theory [3]
  9. Failure criteria for multilayer composites [3]
- Exercises:
  1. Micromechanics of composites [2]
  2. Macromechanics of composite layer [2]
  3. Classical lamination theory in multilayer composites [3]
  4. Failure criteria for composites [1]
  5. FRP materials in the computer software Abaqus [6]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Šimunić, Ž.: *Polimeri u graditeljstvu*, Građevinski fakultet Sveučilišta u Zagrebu, 2006.

Additional reading:

1. Kollár, L. P.; Springer, G. S.: *Mechanics of Composite Structures*, Cambridge University Press, 2003.
2. Kaw, A. K.: *Mechanics of Composite Materials*, CRC Press, Taylor & Francis Group, 2006.

CONCRETE AND MASONRY STRUCTURES 2

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (design: 9, construction: 6)

Course objectives:

- Expansion of theoretical knowledge about the design of reinforced concrete and masonry elements and structures
- Expansion of practical knowledge about the design of reinforced concrete and masonry elements and structures, as well as making more complex calculations thereof.

Entry competences (prior knowledge, descriptive):

- Theoretical and practical knowledge of the basics of the design of reinforced concrete and masonry elements and structures.

Learning outcomes:

- Students have the knowledge and skills necessary for designing structural elements of reinforced concrete and masonry structures
- Students have the knowledge and skills necessary to apply the basic principles of conceptual design
- Students know how to analyse the behaviour of structural elements and load-bearing systems of reinforced concrete and masonry structures and design them according to the ultimate and serviceability limit states
- Students have the ability to analyse structural elements of reinforced concrete and masonry structures using modern methods and criteria of European standards.

Course content (by course schedule):

- Lectures:
  1. Structural details of masonry. Masonry. [2]
  2. Masonry buildings in seismic areas. [6]
  3. Simple rules for designing masonry buildings. [2]
  4. Reinforcement of walls. [2]
  5. First midterm exam in Masonry structures [2]
  6. Serviceability limit states. Limit states of stress. Limit states of the appearance of cracks. Limit states of crack width. [2]
  7. Serviceability limit states. Deflection limit state. Design example [2]
  8. 2nd midterm exam in Concrete structures. [2]
  9. Punching shear [2]

10. Torsion of reinforced concrete sections. [2]
11. Beams of variable height. Slab-beam joint. [2]
12. Slender columns. Biaxial bending. [2]
13. Wall girders. Walls. Foundations. [2]

- Exercises:
  1. Familiarization with the exercise program, the assignment and the method of its creation. Defining the load-bearing structure of the subject building and analysing the impact on the structure and marking the subject positions that need to be calculated (auditory) [1]
  2. Calculation of Fert ceiling and reinforced concrete roof beam [1]
  3. Calculation of the staircase with elaboration of the method of reinforcement [1]
  4. Submission of a part of the program assignment. [1]
  5. Calculation of a reinforced concrete two-way slab of a characteristic floor. Slab modelling using computer software. Elaboration of ceiling reinforcement details and connection with confining elements [2]
  6. Calculation of beams on the ceiling of a characteristic floor [1]
  7. Submission of a part of the program assignment. [1]
  8. Calculation of masonry for vertical load and horizontal load due to wind pressure perpendicular to the wall [2]
  9. Submission of a part of the program assignment. [1]
  10. Calculation of RC basement wall [1]
  11. Submission of a part of the program assignment. [1]
  12. Calculation of strip foundations [1]
  13. Submission of program assignments [2]

Student Evaluation - Continuous assessment:

- Preparation of program assignments within the prescribed deadline
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Preparation of program assignments within the prescribed deadline
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Sorić, Z., Kišiček, T.: "Betonske konstrukcije 2", Sveučilište u Zagrebu Građevinski fakultet, university handbook, Zagreb, 2018.
2. Sorić, Z., Kišiček, T.: "Betonske konstrukcije 1", Sveučilište u Zagrebu Građevinski fakultet, university handbook, Zagreb, 2014. ISBN 978-953-6272-75-4
3. Sorić, Z.: "Zidane konstrukcije", university handbook, self-published, Zagreb, 2016.
4. Technical Regulations for Building Structures (2017)

5. Croatian standards of the HRN EN 1996 series, standards for masonry structures (Eurocode 6)
6. Croatian standards of the HRN EN 1991 series, standards for structural loads (Eurocode 1)
7. Croatian standards of the HRN EN 1992 series, standards for concrete structures (Eurocode 2)

2nd year, 3rd semester

Mandatory courses

SPACE STRUCTURES

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises (design): 26
- Seminars: 4

Course objectives:
- Acquisition of theoretical knowledge about numerical modelling of spatial static systems, but also about the problems accompanying the creation and calculation of numerical models,
- Acquisition of practical knowledge about the load-bearing principles of spatial, primarily flat static systems.

Entry competences (prior knowledge, descriptive):
- Knowledge of differential and integral calculus (including ordinary and partial differential equations) and linear algebra,
- Knowledge of basic analytical and numerical procedures for linear calculation of rod structures,
7. Understanding of the fundamental components of the boundary value problem (continuum, geometric equations, equilibrium conditions, laws of behaviour and boundary conditions).

Enrolment requirements (prerequisite):
- Teacher's signature for the course: Concrete and Masonry Structures 2, Theory of Elasticity and Plasticity.

Learning outcomes:

After successfully completing the course, students will be able to:
- Apply the principles of higher technical mechanics and continuum mechanics,
- Apply knowledge from technical and engineering informatics,
- Explain the principles of bearing capacity of spatial structures,
- Design a spatial static system of greater range,
- Carry out construction calculation procedures,
- Create a good numerical model of the structure,
- Analyse the results of structural calculations,
- Follow the scientific and professional literature in the field of structural calculations,

Course content (by course schedule):
- Lectures:
  1. Construction achievements and design principles throughout history [2]
  2. Mathematical model of construction - a set of necessary approximations [2]

3. Methods of solving the boundary problem [2]
4. Submodels [2]
5. Approaches to structural calculations before the finite element method [2]
6. Control of numerical calculations [2]
7. Some problems of the finite element method [2]
8. Errors in the creation and calculation of numerical models [2]
9. Kinematic constraints [2]
10. Grillage [2]
11. Slabs [2]
12. Wall girders [2]
13. Composites [2]
14. Shells [2]
15. Spatial structures of a stadium [2]

- Exercises (design):
  1. Modelling of rod elements [2]
  2. Types of surface elements in models [2]
  3. Modelling of volume (spatial) elements [2]
  4. Application of rod and/or flat and/or volume elements [2]
  5. Modelling of wall girders [2]
  6. Interaction with the ground [2]
  7. Modelling of volume (spatial) elements [2]
  8. Modelling of composites [2]
  9. Dome modelling [2]
  10. Silo modelling [2]
  11. Analysis of examples from practice [2]
  12. Structural design [4]

Student Evaluation - Examination without Continuous Assessment:

- First seminar paper submitted within the prescribed deadline
- Second seminar paper submitted within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. Lazarević, D.; Atalić, J.: Plošni nosači. Lecture notes, http://www.grad.unizg.hr/predmet/plonos/predavanja
2. Dvornik, J.; Lazarević, D.; Bićanić, N.: O načelima i postupcima proračuna građevinskih konstrukcija, Sveučilište u Zagrebu Građevinski fakultet, Zagreb, 2019.
3. Timošenko, S.; Woinowsky–Krieger, S.: *Teorija ploča i ljuski*, Građevinska knjiga, Beograd, 1962.
4. Girkman, K.: *Površinski sistemi nosača*, Građevinska knjiga, Beograd, 1965.
5. Salvadori, M.: *Nosive konstrukcije u arhitekturi*, UPI-2M, Zagreb, 1995.
6. Senjanović, I.: *Teorija ploča i ljuski*, Sveučilišna naklada Liber, Zagreb, 1973.

Additional reading:

1. Sorić, J.: *Metoda konačnih elemenata*, Golden Marketing, Tehnička knjiga, Zagreb, 2004.

2. Gordon, J. E.: *Structures, or why things don't fall down*, Da Capo Press, Inc, New York 1978.
3. Gordon, J. E.: *The New Science of Strong Materials, or Why You Don't Fall through the Floor*, second edition, Princeton University Press, Princeton, 1988.

STRUCTURAL TESTING

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises (laboratory): 30

Course objectives:

- Deepening of theoretical and practical knowledge about the behaviour of structures under real loads,
- Learning about modern measuring equipment and methods in the field of testing building structures.

Entry competences (prior knowledge, descriptive):

- Knowledge of procedures for determining forces in structures,
- Knowledge of stress and deformation calculations due to longitudinal and transverse forces, torsion moment and bending moment,
- Knowledge of basic procedures for analysis and dimensioning of structures (concrete, metal, timber).

Learning outcomes:

- Analysing the behaviour of structural elements and load-bearing systems based on the conducted tests,
- Understanding the behaviour of structures under static and dynamic loading, environmental influences and rheological changes in the material,
- Selection and application of equipment, procedures and methods in structural testing,
- Planning procedures for proving the safety of structures,
- Assessment of the condition of structures and structural elements based on the conducted tests,
- Proving the ability of structures and structural elements to take on the expected loads,
- Use and application of standards in the field of testing building materials, structural elements and structures.

Course content (by course schedule):

- Lectures:
  1. Introduction. The purpose of structural testing. Classification of tests. Scientific and research. Control. Laboratory. Static and dynamic. Short-term and long-term [2]
  2. Mechanical and geometric quantities that are measured during structural testing. Absolute displacement of the point of structure. Change in the spacing of points of structure (deformation). Angle of rotation. Curvature. Relative deformations [2]
  3. Measurement of mechanical and geometric quantities. Elements of accessories. Enlargement. Accuracy. Reliability. Hysteresis. Sensitivity. Measurement area [2]

4. Measurement of mechanical and geometric quantities. Accessories for measuring: displacements, length changes (tensometers), angle changes, curvature changes. Calibration of accessories [2]
5. Tensometry. Classification of tensometer types: mechanical, optical-mechanical, optical, acoustic, electrical [2]
6. Electrical resistance strain gauges (ERSG) Types. Method of installation and connection. Sets of measuring instruments. Creation of auxiliary devices for measuring displacement, acceleration, pressure forces, etc. [2]
7. Analysis of plane state of stress by measuring deformations. Uniaxial state of stress. Biaxial state of stress. Biaxial stress state with known principal stress directions. General biaxial stress state. Rosettes. Triaxial state of deformation and stress [2]
8. Methods of analysing the state of deformation and stress of structures and their elements. Photoelasticity. Moire method. Process with brittle lacquers [2]
9. Methods of analysing the state of deformation and stress of structures and their elements. Holographic methods. Geodetic surveying. Modelling [2]
10. Material verification procedures and characteristics of the tested structure. Core extraction. Ultrasound. Sclerometer. Radiographic imaging [2]
11. Static testing of structures. Design. Execution [2]
12. Static testing of structures. Loading mode. Result evaluation. Norms and conditions of construction validity [2]
13. Dynamic testing. Design. Execution. Loading mode and dimensions to be measured [2]
14. Dynamic testing. Dynamic parameters of structures. Assessment of measurement results [2]
15. Delivery of a seminar with an overview, results and analysis of the conducted laboratory tests. [2]

- Exercises (laboratory):
  1. Measurement of the same quantity with a portable comparator (determining the accuracy of the instrument). [2]
  2. Dose calibration for force measurement (determining the instrument constant). [2]
  3. Calibration of the inductive sensor (LVDT) for displacement measurement (determining the instrument constant) [2]
  4. Processing and analysis of results [2]
  5. Measurement of deformations and deflections on the lattice and wall with openings model (plexiglass models) [2]
  6. Measurement of deformations and deflections on the lattice and wall with openings model (plexiglass models) [2]
  7. Photoelasticity method [2]
  8. Presentation and description of instruments for static and dynamic tests. [2]
  9. Determination of dynamic parameters (natural frequencies, damping coefficients and modal shapes) on models and structures. [2]
  10. Preparation of a structural testing program and a report on the conducted testing. [2]
  11. Preparation of a structural testing program and a report on the conducted testing. [2]
  12. Description and presentation of examples of structural testing in the Laboratory and data processing and analysis. [2]
  13. Description and presentation of examples of structural testing in the Laboratory and data processing and analysis. [2]

14. Description and presentation of examples of structural testing in the Laboratory and data processing and analysis. [2]
15. Description and presentation of examples of structural testing in the Laboratory and data processing and analysis. [2]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of the program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. Damjanović, D. : Structural Testing, Course notes, University of Zagreb, Faculty of Civil Engineering, 2017.
2. A. Kiričenko et al.: *Mjerenje deformacija i analiza naprezanja konstrukcija*, DIT-Zagreb, Zagreb, 1982.
3. D. Aničić: *Ispitivanje konstrukcija*, Osijek 2002.

Additional reading:

1. J. Krolo, D. Šimić: *Mehanika materijala*, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2011.
2. I. Alfirević, S. Jecić: *Fotoelasticimetrija*, Liber, Zagreb, 1983.
3. V. Brčić, R. Čukić: *Eksperimentalne metode u projektiranju konstrukcija*, Građ. knjiga, Beograd, 1988.
4. Papoulis, A.: Probability, random variables and stohastic processes, McGraw-Hill, Singapore, 1987.
5. Rohrbach, C.: Handbuch für experimentelle Spanungsanalyse, VDI, Düsseldorf, 1989.
6. Helstrom, C. W.: Probability and stohastic processes for engineers, Macmilan, New York, 1984.

STABILITY THEORY

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 26 (auditory: 18, on computers: 8)
- Seminar: 4

Course objectives:

- Acquisition of theoretical and practical knowledge about stability problems of static systems,
- Acquisition of theoretical and practical knowledge of non-linear analyses methods,
- Training for easier interpretation of regulations in the field of structural stability.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus, basics of numerical methods and linear algebra,

- Knowledge of the theory of linear and slightly nonlinear statics procedures of structures and resistance of materials,
- Knowledge of basic programming principles.

Learning outcomes:

- Recognize the characteristic balance states of the structure,
- Classify the static system according to the post-critical behaviour,
- Create a numerical model of the structure for stability analyses,
- Perform more complex structural stability analyses,
- Identify problems during the implementation of non-linear analyses and choose a suitable procedure.

Course content (by course schedule):

- Lectures:
  1. Basics about the phenomenon of stability and an introduction to the issue [2]
  2. Stability of rigid bodies connected by springs - four basic examples without imperfections - exact displacement geometry [2]
  3. Initial post-critical behaviour - Koiter division and linearization of the problem [2]
  4. The influence of geometric imperfection on stability - exact displacement geometry [2]
  5. The influence of plastic yielding on the loss of stability [2]
  6. Systems with multiple degrees of freedom - exact displacement geometry - assessment of post-critical behaviour [2]
  7. Second order theory and linearization of the stability problem [2]
  8. Numerical methods for solving stability problems - Newton Raphson, arc length method [2]
  9. Beam submodels - exact displacement geometry [2]
  10. Beam submodels - inextensible Bernoulli-Euler beam [2]
  11. Beam submodels - classic problem solution - beams and frames [2]
  12. The problem of loss of stability of arches [2]
  13. The problem of loss of stability of thin elastic plates [2]
  14. The problem of loss of shell stability [2]
  15. Loss of structural stability in the plastic domain [2]
- Exercises:
  1. Examples of loss of stability on basic mechanical models [2]
  2. Numerical methods for solving basic stability problems on a computer [2]
  3. Examples of calculation of loss of stability on elastic systems - columns, beams, frames [6]
  4. Solving problems of stability of columns, beams and frames on the computer [2]
  5. Numerical methods for nonlinear problems - Newton Raphson method and arc length method [2]
  6. Examples of loss of stability on elastic systems - arches and other planar static systems [2]
  7. Using a program based on the finite element method for the analyses of stability loss - preparation of a seminar [2]
  8. Solving stability problems using energy methods and examples of loss of stability in the plastic domain [2]

9. Analytical and numerical solution of planar systems with the influence of imperfections [2]
10. Creating seminar in the SAP2000 program - defining imperfection and plastic yielding [2]
11. Application of European regulations for stability calculation. Examples of lateral torsional buckling of open section elements [2]

- Seminars:
  1. Structural stability analyses and imperfection sensitivity analysis [4]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of the program assignment within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Lazarević, D., Uroš, M; Teorija Stabilnosti s uvodom u stabilnost konstrukcija, Građevinski fakultet u Zagrebu, course notes, 2015.
2. Timošenko, S. P.: *Teorija elastične stabilnosti*, Građevinska knjiga, Beograd, 1959.
3. Mihanović, A.: *Stabilnost konstrukcija*, DHGK, 1993.
4. Bažant, Z. B.: *Stability of structures – Elastic, inelastic, fracture and damage theories*, Dover publications, Inc.,New York, 1991.

Additional reading:

1. Jones, R. M.: *Buckling of bars, plates, and shells*, Bull Ridge Publishing, Virginia, 2006.
2. Mehdi, F.: *Stability of structures*, Elsevier Science B.V., Amsterdam, 1994.

Elective courses

METHODS OF THEORY OF ELASTICITY AND PLASTICITY

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 10, design: 5)

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of real deformable bodies under load in the elastic and plastic area,
- Acquisition of theoretical knowledge in the field of analysis of displacements, deformations and stresses of real solid bodies,
- Acquisition of knowledge in the field of analytical and numerical procedures for the analysis of real solid bodies.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus, ordinary and partial differential equations, and vector and tensor analysis,
- Good knowledge of the elements of general theoretical mechanics and numerical mathematics,
- Knowledge of the elements of statics, dynamics and resistance of materials.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Theory of Elasticity and Plasticity.

Prerequisite for taking the exam:

- Course exam passed: Theory of Elasticity and Plasticity.

Learning outcomes:

- Recognize the appropriate boundary-value problem of the theory of elasticity and plasticity,
- Adequately formulate the boundary-value problem, express its solution through displacement and stress,
- Explain analytical and numerical procedures in the theory of elasticity and plasticity,
- Choose the optimal method of solving the corresponding boundary-value problems,
- Apply certain methods of solving boundary-value problems in plane and space.

Course content (by course schedule):

- Lectures:
  1. Introduction. Tensors and vectors. Operations with tensors and vectors and their properties. Differential operators in tensor form. Stokes and Gauss theorem in tensor form. [2]
  2. Linearization of tensors of finite deformations and restriction to small deformations. Properties of tensors of small deformations [2]
  3. The concept of external and internal forces on a solid body. The stress and deformation field around the point of the deformed body. Cauchy stress tensor and its definition. [2]
  4. Differential equilibrium equation. Eigenvalues and stress tensor decomposition [2]
  5. Definition of boundary-value problems. Formulation of the solution of the boundary value problem of a solid body. Statement of the solution of the boundary value problem by displacements (Lame-Navier). Expression of the solution of the boundary value problem by stresses (Beltrami-Michell) [2]
  6. Energy principles and theorems. The principle of minimum total potential and complementary deformation energy of a solid deformable body. [2]
  7. Application of analytical and numerical procedures in solving marginal problems of elasticity theory. [2]
  8. 1st midterm exam
  9. Infinite trigonometric series, application of a complex variable, Green's function, variational methods, discretization methods of differential equations and residue methods. (Ritz method. Galerkin method. The least squares method. Collocation method. Finite difference method. Finite element method, etc.) [2]
  10. Boundary-value problems on the plane and half-plane in rectangular and polar coordinates. Airy function. Harmonic and biharmonic partial differential equation as a solution of plane boundary value problems. [2]

11. Harmonic and biharmonic functions in solving marginal problems of the theory of elasticity and plasticity [2]
12. Potential functions in the theory of elasticity and plasticity. Boundary value problems on space and half-space (Kelvin's, Boussinesq's and Cerruti's problems). [2]
13. Torsion of a straight rod with a general cross-section shape (St. Venant's problem). [2]
14. Theory of rectangular thin plates in Cartesian coordinates. Theory of circular thin plates in polar coordinates. [2]
15. 2nd midterm exam

- Exercises:
  1. Application of analytical and numerical procedures in solving boundary-value problem of elasticity theory. [2]
  2. Solving tasks using residual and energy methods (Ritz method, Galerkin method, least squares method, collocation method, etc.). [2]
  3. Discretization methods (finite differences, finite elements, boundary elements, etc.). [2]
  4. Application of Airy function of plane tasks in rectangular and polar coordinates. Application of infinite series and complex variables in solving marginal problems. [2]
  5. Potential functions of spatial tasks. Solutions in space and semi-space [2]
  6. Tasks of plasticity theory. Plastic analysis of beams and frames [1]
  7. Tasks of plasticity theory. Mechanisms, displacements of plane frames, limit analysis of spatial frames, limit analysis of plates [2]
  8. Tasks of plasticity theory. Cyclic loads [2]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation and presentation of the seminar paper
- Continuous preparation of assignments
- Midterm exams
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation and presentation of the seminar paper
- Continuous preparation of assignments
- Written exam
- Oral exam

Required reading:

1. M. Rak, I. Duvnjak, D. Damjanović: Teorija elastičnosti i plastičnosti s metodama rješavanja zadaća, Zagreb, 2020

Additional reading:

1. T. Herman: *Teorija elastičnosti i plastičnosti*, Element, Zagreb, 2008.
2. Z. Kostrenčić: *Teorija elastičnosti*, Školska knjiga, Zagreb, 1982.
3. S. Timošenko, J. N. Gudier: *Teorija elastičnosti*, Građevinska knjiga, Beograd, 1962.
4. I. Alfirević: *Uvod u tenzore i mehaniku kontinuuma*, Golden marketing, Zagreb, 2006.

5. J. Brnić: *Elastomehanika i plastomehanika*, Školska knjiga, Zagreb, 1996.
6. G. E. Mase: *Theory and Problems of Continuum Mechanics*, McGrow-Hill Company, 1970.

POLYMERS

Credits (ECTS): 4.5

Hours (total per semester):
- Lectures: 30
- Exercises: 15 (fieldwork: 6, laboratory: 6, computer: 3)

Course objectives:
- Acquisition of theoretical knowledge about the production, types and properties of polymer materials and composites used in construction,
- Acquisition of practical knowledge about the application, design and quality control of polymer materials and composites used in construction.

Entry competences (prior knowledge, descriptive):
- Knowledge of basic concepts and laws of strength of materials.

Learning outcomes:
- Get to know different types of polymer materials and composites and their properties and production processes,
- Differentiate between the field of application of polymer materials and composites in construction in relation to conventional materials,
- Adopt examples of application of polymer materials and composites in construction with an emphasis on bridge construction,
- Adopt the procedure of quality control and confirmation of the construction product on the example of structural bearings.

Course content (by course schedule):
- Lectures:
  1. General information about polymers [3]
  2. More significant types of polymer materials in construction [3]
  3. Processing and reshaping of polymers [3]
  4. Foamed polymer materials, Non-mechanical properties of polymers [3]
  5. Mechanical properties of polymeric materials and products – viscoelastic properties [3]
  6. Fiber reinforced polymer materials (FRP materials) [3]
  7. Numerical modelling of polymer materials [3]
  8. Application of polymer materials in construction: Bridge construction; Maintenance and renovation [3]
  9. Application of polymer materials in construction: Seismic insulation [3]
  10. Construction products from polymeric materials in the harmonized area [3]
- Exercises:
  1. Laboratory exercises: Testing mechanical properties of polymer materials and composites (e.g. structural bearings, expansion joints, plastomer pipes, etc.) in the Structural Testing Laboratory [6]

2. Modelling of polymer materials in numerical analysis software [3]
3. Fieldwork: Tour of companies and plants engaged in the production of polymer and composite products [6]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- First midterm exam
- Second midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Šimunić, Ž.: *Polimeri u graditeljstvu*, Građevinski fakultet Sveučilišta u Zagrebu, 2006.
2. Šimunić, Ž.; Skender, A.: *Elastomerni ležajevi*, Građevinski fakultet Sveučilišta u Zagrebu, 2007.

Additional reading:

1. McCrum, N. G.; Buckley, C. P.; Bucknall, B.: *Principles of Polymer Engineering*, 2nd edn, Oxford University Press, New York, 1997.
2. Naeim, F.; Kelly, J.: *Design of Seismic Isolated Structures*, Wiley & Sons, Inc., New York, 1999.

BASICS OF FRACTURE MECHANICS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory: 9, laboratory: 6)

Course objectives:

- Acquisition of knowledge about fracture mechanics as a special field of mechanics,
- Acquisition of knowledge about predicting the behaviour of structural elements with cracks.

Entry competences (prior knowledge, descriptive):

- Understanding the concepts of stress and strain analysis,
- Knowledge of stress and deformation calculations in elements loaded with internal forces,
- Knowledge of mechanics of materials.

Enrolment requirements (prerequisite):

- Teacher's signature for the course: Theory of Elasticity and Plasticity.

Prerequisite for taking the exam:

- Course exam passed: Theory of Elasticity and Plasticity.

Learning outcomes:

- Become familiar with the historical development of fracture mechanics,
- Recognize the importance of fracture mechanics and the danger of the presence of cracks in structural elements,
- Explain the influence of cracks on stress concentration,
- Explain the difference between linear elastic (LEFM) and elastoplastic fracture mechanics (EPFM),
- Explain the experimental methods of determining fracture mechanics parameters,
- Competence of analysis of cracks and other defects in the material structure on their impact on the safety of engineering structures.

Course content (by course schedule):

- Lectures:
  1. Introduction and historical development of fracture mechanics [3]
  2. Fracture physics. Ideal material strength. Ductility and brittleness. Ways of crack propagation. Basic parameters in fracture mechanics [3]
  3. Linear elastic fracture mechanics (LEFM). Basic equations. Effect of cracks on stress concentration [4]
  4. Griffith's condition for crack development (energy approach) and Irwin's modification. Energy release rate (G). Crack instability and R-curve [3]
  5. Basic forms of crack development. Stress and displacement field in the crack tip environment [2]
  6. Stress intensity factor (K) and its meaning. Geometry functions (form factors) [2]
  7. Fracture criteria. Fracture toughness. Toughness of the material. The relationship between the stress intensity factor and the energy release rate [2]
  8. Experimental methods of determining LEFM parameters [2]
  9. Elastic-plastic fracture mechanics (EPFM). The area of plasticity at the tip of the crack. Dugdale's model for elastoplastic materials [4]
  10. Crack tip opening displacement (CTOD). Rice's contour integral. Relation between CTOD and contour integral of Rice [3]
  11. Stable and unstable crack development. Fracture criteria [2]
  12. Experimental methods of determining EPFM parameters [2]
  13. Metal fracture mechanisms, ductile fracture. Fracture mechanisms of non-metals (plastic materials, ceramics, concrete and stone). Quasi-brittle fracture [2]
- Exercises (auditory):
  1. Solving simpler numerical examples from the field of linear elastic fracture mechanics [9]
- Exercises (laboratory):
  1. Experimental methods of determining LEFM parameters [6]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Midterm exam
- Oral exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Anderson, T. L.: *Fracture Mechanics: Fundamental and Aplications*, CRC Press LLC, N.W. Corporate Blvd., Boca Raton, Florida, 2000.
2. Krolo, J., Šimić, D.: *Mehanika materijala*, Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2011.

Additional reading:

1. Brnić, J., Turkalj, G.: *Nauka o čvrstoći II,* Sveučilište u Rijeci, Zigo, Rijeka, 2006.
2. Saxena, A.: "Advanced Fracture Mechanics and Structural Integrity", CRC Press - Taylor & Francis Group, 2019.
3. Janssen, M., Zuidema, J., Wanhill, R.: "Fracture Mechanics", CRC Press - Taylor & Francis Group, 2. edition, 2004.

PROGRAMMING STRUCTURAL ANALYSIS PROCEDURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (on computers): 15

Course objectives:

- Familiarization with the basic structure of computer software for structural calculations,
- Familiarization with the consequences of different approximations and limited accuracy of numerical calculations,
- Training for independent design and writing of simpler programs and for cooperation with programming teams.

Entry competences (prior knowledge, descriptive):

- Knowledge of linear construction calculation procedures, primarily the general displacement method,
- Knowledge of the structure of a computer software (variables, branches, loops, functions).

Learning outcomes:

- Understand and explain the structure of the structural calculation program,
- Understand and explain the consequences of unavoidable approximations in construction modelling and the limited (finite) accuracy of numerical calculations,
- Design and write a simpler computer program for structural calculation,
- Modify, adapt and upgrade the computer program for structural calculation available in the source code,
- Cooperate in a team or with a team that designs and writes a complex computer program for construction calculations.

Course content (by course schedule):

- Lectures:
  1. Programming paradigms and programming languages, syntax and semantics, Turing machine [2]
  2. Basic data types and basic operations [1]
  3. Representation of real numbers (IEEE standard), realization of algebraic operations, rounding and accuracy [4]
  4. Program flow management: loops and branching [2]
  5. Vectors and matrices (full and sparsely filled) [2]
  6. Program implementation of linear algebra operations [4]
  7. The structure of the program implementation of the finite element method (FEM): topological relations in the finite element network [2]
  8. FEM: stiffness matrices of elements and structures; load vector [2]
  9. FEM: coordinate systems and coordinate transformation [2]
  10. FEM: balance equations - composition of the stiffness matrix of the structure and the load vector [2]
  11. FEM: solving system of equations; use of program libraries [2]
  12. Relaxation and gradient procedures [2]
  13. Force density method [2]
  14. Iterative application of the force density method [4]
- Exercises:
  1. Introduction: the Newton-Raphson method (for a nonlinear equation with one unknown) [1]
  2. Newton-Raphson method: rounding and accuracy [1]
  3. Branching and loops [1]
  4. Display of vectors and matrices [1]
  5. Solving systems of linear equations [2]
  6. Finite element method [5]
  7. Relaxation and gradient procedures [1]
  8. Force density method [3]

Student Evaluation - Examination without Continuous Assessment:

- Regular attendance - 75% attendance at lectures, 100% attendance at exercises
- Preparation of the program assignment
- Oral exam

Required reading:

1. Course materials sage.grad.hr:1234
2. Ž. Ban, J. Matuško, I. Petrović: Primjena programskog sustava MATLAB za rješavanje tehničkih problema, Graphis, Zagreb, 2010.
3. H. P. Langtangen: A Primer on Scinetific Programming with Python, Springer, 2016.
4. D. R. Brooks: Problem Solving with Fortran 90 for Scientists and Engineers, Springer, 1997.

Additional reading:

1. R. de Borst, M. A. Crisfield, J. J. C. Remmers, C. V. Verhoosel: *Non-linear Finite Element Analysis of Solids and Structures*, Wiley, 2012.

2. M. L. Overton: *Numerical Computing with IEEE Floating Point Arithmetic*, SIAM, Philadelphia, 2001.
3. J. J. Barton, L. R. Nackman: *Scientific and Engineering C++*, Addison--Wesley, Reading, 1994.

NUMERICAL METHODS IN STRUCTURAL ANALYSIS

Credits (ECTS): 4.5

Hours (total per semester):
- Lectures: 30
- Exercises: 15 (auditory)

Course objectives:
- Deepening of theoretical knowledge about the modelling of constructions for calculation using various numerical methods,
- Acquisition of practical knowledge about construction calculation using various numerical methods,
- Acquisition of knowledge about the discretization of the calculation model for various numerical methods,
- Acquisition of practical knowledge in the interpretation of calculation results obtained by calculation on a computer using various numerical methods.

Entry competences (prior knowledge, descriptive):
- Understanding the basic equations of elasticity theory,
- Knowledge of mathematical models of physical phenomena from the field of elasticity theory,
- Understand the theoretical foundations of variational procedures and the concept of area discretization,
- Basic mathematical knowledge in the field of ordinary and partial differential equations.

Learning outcomes:
- Apply numerical methods to construction calculation tasks,
- Explain the theoretical bases of calculations using numerical methods,
- Explain the calculation model of the structure for the calculation of the structure using various numerical methods,
- Interpret calculation procedures for construction calculations using various numerical methods.

Course content (by course schedule):
- Lectures:
  1. Motivation and basic equations in structural analysis [2]
  2. Newton's method [4]
  3. Finite difference method [2]
  4. Integration methods in time [2]
  5. One-step methods [2]
  6. Multistep methods [4]
  7. Differential quadratic methods [4]
  8. Decomposition methods [4]
  9. Boundary element method [6]

- Exercises:
  1. Newton's method [3]
  2. One-step methods [3]
  3. Multi-step methods [3]
  4. Finite difference method [3]
  5. Decomposition methods and quadrature methods [3]

Student Evaluation - Examination without Continuous Assessment:
- Regular attendance – 75% attendance at lectures, 100% attendance at exercises
- Preparation of the program assignment
- Oral exam

Required reading:
1. Bittnar, Šejnoha: *Numerical Methods in Structural Engineering*, ASCE Press, 1996.
2. Chang Shu: *Differential Quadrature and Its Application in Engineering*, Springer, 2000.
3. Banerjee: *The Boundary Element Methods in Engineering*, McGraw-Hill, 1993.

STOCHASTIC PROCESSES

See Chapter **Shared Courses**.

2nd year, 4th semester

Elective courses

SELECTED TOPICS ON STRENGTH OF MATERIALS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises (auditory): 15

Course objectives:

- Deepening theoretical knowledge about the behaviour of structures under impact loads - axial and torsional,
- Acquisition of practical knowledge about modelling structures from non-linear and bilinear elastic material,
- Acquisition of theoretical knowledge about the calculation of contact stresses and deformations,
- Acquisition of theoretical knowledge on the calculation of stress and deformation in thick-walled pipes.

Entry competences (prior knowledge, descriptive):

- Understanding and determining the mechanical properties of materials,
- Knowledge of the basic procedures for determining stress and deformation in structural elements made of elastic, homogeneous, linear material,
- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra.

Learning outcomes:

- Explain the transverse normal stresses when bending a rod with a transverse load,
- Calculate the stresses of a rod made of nonlinear and bilinear elastic material loaded in bending,
- Calculate the stresses and deformations of the rods under impact load,
- Apply Herz formulas for the calculation of contact stresses and deformations,
- Analyse the general case of contact between two bodies under pressure,
- Explain and calculate stresses and deformations in thick-walled pipes under the action of internal and external pressure,
- Calculate the stresses in assembled thick-walled pipes and their optimal overlap.

Course content (by course schedule):

- Lectures:
  1. Bending of rods of a variable section. Local change in the shape and dimensions of the section. Rods of stepwise variable cross-section Rods of stepwise variable cross-section. Girders of equal strength. [2]
  2. Transverse normal stresses in bending a rod by transverse loading. Stress concentration during axial load, torsion, bending [2]

3. Modelling of structures made of non-linear elastic material. Axially loaded rod structures. Torsion [2]
4. Bending of a rod made of nonlinear elastic material. Bending of a rod made of bilinear elastic material [2]
5. Dynamic tasks. Stresses in structural elements during movement with acceleration. The force of inertia, internal forces. Bending [2]
6. Impact theory. General assumptions. Calculation of stress and deformation of rods under impact load. Axial impact load. Stresses during the longitudinal impact of a rod into a rigid base [2]
7. Torsional impact load. Impact load during bending. Stresses during the transverse impact of the support on rigid bearings [2]
8. Calculation of strength under variable stresses. Multiaxial variable stress. Application of strength theory [2]
9. Contact stresses and deformations. General assumptions. Herz formulas for contact stresses and deformations [2]
10. Two balls under pressure. Two cylinders under pressure. The general case of contact between two bodies under pressure. Contact pressure check [2]
11. Thick-walled pipes. General definitions and assumptions. Differential equations and boundary conditions for an axially symmetric body [2]
12. Stresses and deformations in thick-walled pipes under the action of internal pressure. Stresses and deformations in thick-walled pipes under the influence of external pressure [2]
13. Stresses and deformations in thick-walled pipes under the action of internal and external pressure. Thermal stresses in thick-walled pipes [2]
14. Assembled thick-walled pipes. Introductory considerations. Contact pressure between the inner and outer thick-walled pipe. Stresses in assembled thick-walled pipes. Determining the optimal overlap [2]
15. Stresses in assembled thick-walled pipes. Determining the optimal overlap. [2]

- Exercises (auditory):
  1. Bending of a rod with a gradually changing section [1]
  2. Girders of equal strength [1]
  3. Calculation of transverse normal stresses when bending a rod by transverse loading [1]
  4. Bending a rod made of nonlinear elastic material [1]
  5. Bending a rod made of bilinear elastic material [1]
  6. Calculation of stress and deformation under impact load. Axial impact load. Stresses during the longitudinal impact of a rod into a rigid base [2]
  7. Stresses and deformations of girders under impact load [1]
  8. Stresses during the transverse impact of the support on rigid bearings [1]
  9. Calculation of strength under variable stresses. Multiaxial variable stress. Application of strength theory [1]
  10. Contact stresses and deformations of two spheres under pressure [1]
  11. Contact stresses and deformations of two rollers under pressure. Contact pressure check [1]
  12. Stresses and deformations in thick-walled pipes under the action of internal and external pressure [2]
  13. Stresses and deformations in assembled thick-walled pipes [2]

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Prepared and defended seminar paper
- Oral exam

Required reading:

1. Šimić, V.: *Otpornost materijala I,* Školska knjiga, Zagreb, 2002.
2. Šimić, V.: *Otpornost materijala II,* Školska knjiga, Zagreb, 2002.
3. Alfirević, I.: *Nauka o čvrstoći II,* Golden marketing, Zagreb, 1999.
4. Bazjanac, D.: *Nauka o čvrstoći,* Tehnička knjiga, Zagreb, 1973.
5. Brnić, J.; Turkalj, G.: *Nauka o čvrstoći II,* ZIGO, Rijeka, 2006.

Additional reading:

1. Alfirević, I.: *Nauka o čvrstoći I,* Tehnička knjiga, Zagreb, 1989.
2. Timošenko, S.: *Otpornost materijala I,* Građevinska knjiga, Beograd, 1965.
3. Timošenko, S.: *Otpornost materijala II,* Građevinska knjiga, Beograd, 1966.
4. Case, J.; Chilver, A.: *Strength of Materials and Structures,* Edward Arnold, 1985.

STOCHASTIC ANALYSIS OF STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15 (auditory)

Course objectives:

- Deepening theoretical knowledge about the indeterminacy of structures,
- Acquisition of practical knowledge about stochastic calculation of structures,
- Acquisition of knowledge about the discretization of the calculation model for the stochastic finite element method,
- Acquisition of practical knowledge in the interpretation of calculation results obtained by stochastic calculation.

Entry competences (prior knowledge, descriptive):

- Understanding the basic equations of elasticity theory,
- Knowledge of mathematical models of physical phenomena from the field of elasticity theory,
- Knowledge of the finite element method,
- Understanding of the concept of virtual work and the theoretical basis of variation procedures,
- Basic mathematical knowledge in the field of ordinary and partial differential equations and probability theory.

Learning outcomes:

- Apply the stochastic finite element method to the calculation of structures,

- Explain the theoretical bases of calculations using the stochastic finite element method,
- Explain the calculation model of the structure in terms of the uncertainty of the input parameters for the calculation of the structure,
- Define the calculation procedures for the structure calculation using the stochastic finite element method,
- Interpret the results of calculations using the finite element method.

Course content (by course schedule):

- Lectures:
  1. Basic concepts of probability theory [4]
  2. Deterministic method of finite elements [4]
  3. Variability of input parameters [6]
  4. Beam finite elements – stochastic calculation [8]
  5. Finite elements for panels – stochastic calculation [8]
- Exercises (auditory):
  1. Application of stochastic finite element method on numerical examples [5]
- Exercises (in the computer room):
  1. Calculation of elasticity theory tasks using the stochastic finite element method. Independent definition of calculation procedures [10]

Student Evaluation - Examination without Continuous Assessment:

- Regular attendance, 75% attendance at lectures, 100% attendance at exercises
- Written exam

Required reading:

1. Elishakoff, I. : *Probabilistic Theory of Structures.*
2. Haldar, A.; Guran, B.; Ayyub, M.: *Uncertainty Modelling in Finite Elements, Fatigue and Stability of Systems.*
3. Haldar, A.; Mahadevan, S.: *Reliabilty Assessment Using Stochastic Finite Element Analysis.*

HANGING FABRIC AND CABLE STRUCTURES

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 6, on computers: 24)

Course objectives:

- Acquisition of theoretical knowledge about prestressed tensile structures as load-bearing systems.
- Acquisition of theoretical and practical knowledge about the process of searching for the equilibrium shape and the static calculation of prestressed cables and compressive spatial grids.

Entry competences (prior knowledge, descriptive):

- Understanding and ability to apply equilibrium conditions in space.

- Knowledge of the statics of statically determinate and indeterminate systems.
- Knowledge of the basics of nonlinear statics of rod structures

Learning outcomes:

- Propose the optimal shape of the planar lattice with regard to the input parameters.
- Compare possible equilibrium positions of networks of prestressed cables with regard to input data in the form finding process.
- Determine the optimal equilibrium positions (shapes) of single-layer spatial lattices with regard to the input data using the tension-compression analogy.
- Determine the similarities and differences between the physical and numerical models of the network of prestressed cables and the single-layer spatial grid.
- Based on the static calculation of the network of prestressed cables and single-layer spatial grids, select the necessary dimensions of the load-bearing elements (cables and pressure rods), and propose a complementary construction.

Course content (by course schedule):

- Lectures:
  1. Historical development of hanging structures made of canvas and ropes in the world and in Croatia. [2]
  2. Input assumptions and equilibrium conditions of the free node of the network of prestressed cables. Geometric stiffness. [2]
  3. Lagrange's and Laplace's equation. Minimal area and minimal mesh. Rectilinear networks, regular and irregular cable networks. [2]
  4. The process of searching for the shape of prestressed cable networks (physical and numerical models). [2]
  5. Numerical methods for determining the equilibrium position of a free network node (Newton-Raphson method, force density method, dynamic relaxation method). [2]
  6. Iterative application of the force density method. [2]
  7. Increasing the efficiency of the iterative application of the force density method. [2]
  8. Static calculation and dimensioning of the network of prestressed cables. Calculation of dynamic loads (wind). [2]
  9. The problem of complementary construction of hanging structures made of canvas and ropes. [2]
  10. Principles of executing tensile prestressed structures. [2]
  11. Application of the hanging cloth analogy for the design and optimization of single-layer pressure gratings. [2]
  12. The problem of stability of pressure gratings. [2]
  13. Other load-bearing systems depending on the shape (tensegrity, bending active structures). [4]
  14. Application of optimization principles (materials and shapes) in the design of standard load-bearing systems. [2]
- Exercises:
  1. Introduction about the content of the course. [2]
  2. Input assumptions and equilibrium conditions of the free node of the network of prestressed cables. Geometric stiffness. [2]
  3. Lagrange's and Laplace's equation. Minimal area and minimal mesh. Rectilinear networks, regular and irregular cable networks. [2]
  4. The process of searching for the shape of prestressed cable networks (physical and numerical models). [2]

5. Force density method [2]
6. Iterative application of the force density method. [4]
7. Increasing the efficiency of the iterative application of the force density method. [4]
8. Static calculation and dimensioning of the network of prestressed cables. Calculation of dynamic loads (wind). [4]
9. Application of the hanging cloth analogy for the design and optimization of single-layer pressure gratings. [2]
10. The problem of stability of pressure gratings. [2]
11. Other load-bearing systems depending on the shape (tensegrity, bending active structures). [2]
12. Application of optimization principles (materials and shapes) in the design of standard load-bearing systems. [2]

Student Evaluation - Examination without Continuous Assessment:

- Regular attendance – 75% attendance at lectures, 100% attendance at exercises
- Preparation of the program assignment
- Oral exam

Required reading:

1. Fresl, K.: Structural Analysis 2 (lecture script, chapter 5, 2017), http://master.grad.hr/nastava/gs/gs2/gs2.pdf
2. Dvornik J., Lazarević D., Bićanić N.: O načelima i postupcima proračuna građevinskih konstrukcija (2019),
3. Fresl, K.: Nelinearna statika štapnih nosača (lecture notes, 2020.), http://master.grad.hr/nastava/gs/nls/index.html
4. Gidak, P., Šamec, E.: Statički neodređeni sistemi (e-course book, available at https://urn.nsk.hr/urn:nbn:hr:237:724696 , 2022.),

Additional reading:

1. Rothwell A.: Optimization Methods in Structural Design (2017),
2. Lewis, W.: Tension Structures: Form and behaviour. Thomas Telford, London. (2003).

STRUCTURAL ASSESSMENT AND SEISMIC PERFORMANCE OF EXISTING BUILDINGS

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 20 (fieldwork: 4, on computers: 16)
- Seminars: 10

Course objectives:

- Acquisition of theoretical and practical knowledge about the behaviour of existing structures during earthquakes.
- Application of modern analysis methods for the assessment of the load-bearing capacity and stability of existing buildings.

Entry competences (prior knowledge, descriptive):

- Knowledge of the basics of structural dynamics and earthquake engineering; creation of a dynamic model of the structure with single or multiple dynamic degrees of freedom and determination of dynamic parameters.
- Knowledge of the basic procedures of linear dynamic analysis of simpler static systems.
- Knowledge of the basics of seismic analysis of structural systems: the lateral force method and the response spectrum method

Learning outcomes:

- Identify failure modes of masonry and reinforced concrete structural elements.
- Assess the level of reliability of the mechanical parameters of the structure.
- Choose and apply the appropriate analysis method for assessing the state of bearing capacity and static stability of the structure.
- Calculate the parameters that lead to local failure of structural elements.
- Assess the load capacity and static stability of the existing structure.
- Choose and use different methods of repair and strengthening of structural elements.

Course content (by course schedule):

- Lectures:
  1. Introduction to the course. General information about earthquakes and seismic hazard. Impact of earthquakes on buildings. Ways of describing earthquakes: magnitude and intensity. Seismic hazard in the Republic of Croatia. [2]
  2. The concept of designing in seismically active areas. Approaches to the problem of analysis of earthquake resistance of new buildings. Seismic analysis methods of buildings contained in the Eurocode 8 regulation; limit states. [2]
  3. Lateral force method. Response spectrum method – application to elastic and inelastic systems. Description of parameters and method. [2]
  4. Approaches to the problem of resistance assessment for existing buildings. Material characteristics and data necessary for assessing the resistance of existing buildings. Methods of testing buildings. Description of the typology. [4]
  5. Damage to buildings in an earthquake. Failure mechanisms of structural elements. Capacity curves of elements, experimental results and failure criterion of structural elements (walls, columns, beams, connecting beams). [4]
  6. Approaches to structural modelling; method of plastic hinges, method of macroelements. [2]
  7. Local failure mechanisms. [2]
  8. Pushover method [2]
  9. Nonlinear dynamic analysis method; basics of the method, selection of time histories, implementation of dynamic analysis of the numerical model. [4]
  10. Repair and strengthening methods; conservation conditions for cultural heritage buildings. [2]
  11. Ways of reducing dynamic influences on the structure and its response: seismic isolation, braces and dampers. [2]
- Exercises:
  1. Field visits to damaged buildings and buildings under reconstruction. [2]
  2. The concept of designing in seismically active areas, regularity of structures, other characteristics. Lateral force method. Response of elastic systems using the response spectrum method. [2]
  3. Response of inelastic systems using the response spectrum method. [2]

4. Failure criterion of structural elements (walls, columns, beams, connecting beams). Load capacity curves. [2]
5. Approaches to structural modelling; method of plastic hinges. [2]
6. Approaches to structural modelling; macroelement method. [2]
7. Local failure mechanisms. [2]
8. Pushover method. [2]
9. Nonlinear dynamic analysis method and seismic isolation. [2]
10. Data collection in the field. [2]
11. Seminar: Creation and presentation of the program assignment. [10]

Student Evaluation - Examination without Continuous Assessment:

- Preparation of seminar assignments within the prescribed deadline
- 75% attendance at lectures
- 100% attendance at exercises
- Written exam
- Oral exam

Required reading:

1. Potresno inženjerstvo - Obnova zidanih zgrada, ed. Uroš, M.; Todorić, M.; Crnogorac, M.; Atalić, J.; Šavor Novak, M.; Lakušić, S. Sveučilište u Zagrebu, 2021.
2. Crnogorac, M.; Todorić, M.; Uroš, M.; Atalić, J.: Urgentni program potresne obnove: Građevinska tehnička rješenja, Građevinski fakultet Sveučilišta u Zagrebu, Hrvatska komora inženjera građevinarstva, 2020.
3. Lazarević, D., Šavor Novak, M., Uroš, M.: Dinamika konstrukcija s uvodom u potresno inženjerstvo, (lecture notes), Katedra za statiku, dinamiku i stabilnost konstrukcija, Zavod za tehničku mehaniku, Građevinski fakultet, Sveučilište u Zagrebu, Zagreb, 2018, http://www.grad.unizg.hr/_download/repository/DK_skripta%5B2%5D.pdf

Additional reading:

1.
2. Čaušević, M.: Nelinearne seizmičke analize konstrukcija prema EN 1998-1: 2004, Dinamika konstrukcija-potresno inženjerstvo, aerodinamika, konstrukcijske euronorme, Golden markenting, Tehnička knjiga, Zagreb, str. 327-412, 2010.
3. HZN (2011), HRN EN 1998-1:2011+/Ispr.2:2015+A1:2014+NA:2011, Eurocode 8: Design of structures for earthquake resistance -- Part 1: General rules, seismic actions and rules for buildings, Zagreb, Hrvatska
4. HZN (2011), HRN EN 1998-3:2011 + NA:2011, Eurocode 8: Design of structures for earthquake resistance -- Part 3: Assessment and retrofitting of buildings, Zagreb, Hrvatska

NUMERICAL MATHEMATICS

See Chapter **Shared Courses**

PERSPECTIVE

See Chapter Shared Courses

WAVES AND OSCILLATIONS

See Chapter Shared Courses

GEOMETRY IN CIVIL ENGINEERING

See Chapter Shared Courses.

ENGLISH IN CIVIL ENGINEERING 2

See Chapter Specialisation in Construction Materials.

GERMAN IN CIVIL ENGINEERING 2

See Chapter Specialisation in Construction Materials.

Specialisation SUSTAINABLE CONSTRUCTION AND EARTHQUAKE ENGINEERING

1st year, 1st Semester

Mandatory courses

RESEARCH METHODS

See Chapter Shared Courses

BASICS OF SUSTAINABLE SPATIAL PLANNING

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Seminars: 15

Course objectives:

- The aim of the course is to provide students with basic knowledge about spatial and urban planning, the methodology of making plans, the legal framework, the interaction of all participants involved in the planning process, and spatial planning standards, the application of which makes the space in which we live sustainable.

Learning outcomes:

- explain the basic concepts and principles of spatial and urban planning,
- express the principles of sustainability in planning,
- as a team member, participate in the development of the plan
- recognize and present peculiarities and problems in space,
- recognize different engineering risks in the proposals of different types of plans,
- use various types of spatial plans in professional work.

Course content (by course schedule):

- Lectures:

1. Introduction to sustainable planning. Explanation of basic concepts of sustainable planning, review of the situation in the Republic of Croatia, ISPU.
2. City and space. Origin, development and characteristics of urban spaces, problems and trends of certain periods.
3. Cultural heritage. Protection of cultural assets through spatial planning documentation, research and valorisation of cultural heritage, conservation bases

4. City and region. Principle of subordination of spatial plans, specific objectives of individual levels of spatial planning.
5. Principles of spatial planning, Integral approach, respect for scientifically and professionally established facts, spatial sustainability of development and quality of construction, realization and protection of public and individual interest, horizontal integration in spatial protection, vertical integration, publicity and accessibility of data and documents significant for spatial planning.
6. Spatial planning methodology. Actors in the development of spatial plans, goals and steps of actors in the development of spatial plans, recording limitations.
7. Relationship between built structure and infrastructure. Plan of area use, relationship between density and network.
8. Sustainable infrastructure. Analysis of examples of sustainable infrastructure and their impact on the city.
9. Waste management. Spatial aspects of possible waste management solutions.
10. Challenges of natural and other disasters. Vulnerability of existing urban structures and planning methods for mitigating possible negative impacts.
11. Climate. Urban microclimate, energy balance of urban spaces, air flow, material characteristics of built urban structures, impact of greenery and water surfaces.
12. Revitalization and renewal of urban and rural areas. Revitalization models, brownfield locations, protection of rural heritage.
13. Elements of urban ecology. Blue and green infrastructure, urban networks and densities
14. Principles of sustainable planning. Quality of the built environment, coherence of development policies, "healthy cities", environmental protection, use of renewable sources, social inclusion, protection of cultural heritage
15. Instruments/strategies of sustainable planning. Relationship between development strategies and spatial plans / Development of blue and green infrastructure, smart growth, sustainable transport systems, energy efficiency, water management.

Student Evaluation - Continuous assessment:

- Seminar paper
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Handbook on mitigating urban heat islands, https://mpgi.gov.hr/UserDocsImages/dokumenti/NPOO/ZIKGP_NPOO/Prirucnik_UHI.pdf

2. Smart and Sustainable Planning for Cities and Regions: Results of SSPCR 2022 Bisello, Adriano ; Vettorato, Daniele ; Bottero, Marta ; Kolokotsa, Dionysia; Vettorato, Daniele ; Kolokotsa, Dionysia ; Bottero, Marta ; Bisello, Adriano 2024 https://library.oapen.org/bitstream/20.500.12657/86885/1/978-3-031-39206-1.pdf
3. Naselja, gradovi i prostori, Marinović-Uzelac, A., Zagreb, Tehnička knjiga (1986.)
4. Prostorno planiranje, Marinović-Uzelac, A., Zagreb, Dom i svijet (2001.)
5. Sustainable urban planning principles https://www.paulsoninstitute.org/wp-content/uploads/2017/12/Sustainable-Urban-Planning_EN_vF.pdf

Additional reading:

1. Wheeler, S.M., Beatley, T., eds. (2009.): The Sustainable Urban Development Reader; Routledge
2. Foletta, N., Field, S. (2011.): Europe's Vibrant New Low Car(bon) Communities; New York: Institute for Transportation & Development Policy.
3. Colthorpe P. (2011.): Urbanism in the age of climate change, Island Press (2011.)
4. Mumford, L. (1989.): The City in History, A Harvest Book, Harcourt Inc.

DYNAMICS OF STRUCTURES WITH AN INTRODUCTION TO EARTHEQUAKE ENGINEERING

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- Acquisition of theoretical knowledge about the behaviour of structures under dynamic loading.
- Acquisition of theoretical and practical knowledge of dynamic calculation procedures.
- Acquiring practical knowledge of the basics of design and calculation of earthquake-resistant structures.

Learning outcomes:

- Apply the principles of structural dynamics.
- Carry out calculation procedures for dynamically loaded structures.
- Use computer software to calculate a structure's response to dynamic actions.
- Analyse the results of dynamic structural calculations.
- Explain and perform the seismic analysis of frame structures using linear analysis methods.

Course content (by course schedule):

- Lectures:

1. Introduction to structural dynamics. Problem formulation and solution procedures for single-degree-of-freedom (SDOF) systems.
2. System damping: damping models in the elastic and plastic range.

3. Single-degree-of-freedom system: free vibration with and without damping. Coulomb friction.
4. Single-degree-of-freedom system: harmonic excitation.
5. Single-degree-of-freedom system: harmonic excitation.
6. Single-degree-of-freedom system: response of a linear system to earthquake excitation.
7. Single-degree-of-freedom system: response of a linear system to earthquake excitation.
8. Single-degree-of-freedom system: response of an elasto-plastic system to earthquake excitation.
9. Generalized single-degree-of-freedom system: Rayleigh quotient.
10. Multi-degree-of-freedom (MDOF) system: system formulation; definition of static and dynamic degrees of freedom; static condensation of degrees of freedom; determination of dynamic characteristics; calculation procedures.
11. Multi-degree-of-freedom system: free vibration with and without damping.
12. Damping in civil engineering structures: experimental determination of damping; relative damping ratios for structures.
13. Multi-degree-of-freedom system: force excitation.
14. Multi-degree-of-freedom system: response of a linear system to earthquake excitation.
15. Multi-degree-of-freedom system: response of a linear system to earthquake excitation.

Student Evaluation - Continuous assessment

- Midterm exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Lazarević, D., Šavor Novak, M., Uroš, M.: Dinamika konstrukcija s uvodom u potresno inženjerstvo, (skripta), Katedra za statiku, dinamiku i stabilnost konstrukcija, Zavod za tehničku mehaniku, Građevinski fakultet, Sveučilište u Zagrebu, Zagreb, 2018, http://www.grad.unizg.hr/_download/repository/DK_skripta%5B2%5D.pdf
2. Lazarević, D., Demšić, M.: Dinamika konstrukcija s uvodom u potresno inženjerstvo, (bilješke i skice s predavanja), Katedra za statiku, dinamiku i stabilnost konstrukcija, Zavod za tehničku mehaniku, Građevinski fakultet, Sveučilište u Zagrebu, Zagrebu, 2025, https://modle.srce.hr/2025-2026/pluginfile.php/11573371/mod_resource/content/3/DK_predavanja_2025.pdf
3. Obnova zgrada nakon potresa, uz. Uroš, M.; Todorić, M.; Crnogorac, M.; Atalić, J.; Šavor Novak, M.; Lakušić, S. Sveučilište u Zagrebu, 2021. (poglavlja A i D)

Additional reading:

1. Mihanović, A.: Dinamika konstrukcija, Građevinski fakultet Sveučilišta u Splitu, Split, 1995.
2. Čaušević, M.: Dinamika konstrukcija, diskretni sustavi, Školska knjiga, Zagreb, 2005

PRINCIPLES OF SUSTAINABLE CONSTRUCTION

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- The aim of the course is to prepare students for advanced and integrated understanding of sustainable construction, enabling them to independently and critically analyse, evaluate, and optimise building materials, structural systems, and technical solutions from the perspective of environmental impacts, circular economy principles, and durability, while applying relevant standards and tools for the objective validation of sustainability.

Learning outcomes:

- Describe and evaluate the principles of sustainable and regenerative construction across all life-cycle stages.
- Interpret legal and regulatory framework for a sustainable built environment.
- Identify and assess environmental impacts at different project stages and across building life cycles.
- Evaluate and apply life cycle assessment and methods for the objective validation of environmental performance.
- Apply and critically analyse strategies for reducing environmental impacts throughout project phases and life cycles.

Course content (by course schedule):

- Lectures:

1. Introduction to the concepts of linear and circular economy and role of civil engineering; key aspects of sustainable construction: environmental, economic, socio-cultural, and technological dimensions
2. Legislative and standardization framework for a sustainable built environment (from building to product level)
3. Sustainability principles during construction planning — phase A0
4. Sustainability principles during design — phase A
5. Sustainability principles in material selection — phase A
6. Sustainability principles during operation and maintenance — phase B
7. Sustainability principles at the end of a building's service life — phase C
8. Construction waste management strategies; recycling and reuse of buildings, their materials, and components after demolition — phase D
9. Application of Life Cycle Thinking (LCT) methodology

10. Regenerative construction
11. Introduction to Life Cycle Assessment (LCA) for phases A–D — goal, scope, and inventory definition
12. Introduction to Life Cycle Assessment (LCA) for phases A–D — calculation, analysis, and interpretation
13. Tools for objective sustainability validation
14. International green building certification systems (LEED, BREEAM, DGNB, Level(s))
15. Case studies of sustainable and regenerative construction

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Design
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Serdar, M., Štirmer, N., Carević, I.: 3.1. Core training materials (radni materijali razvijeni kroz projekt GREENCO), Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2024., ISBN: 978-953-8168-69-7 https://static1.squarespace.com/static/657ebc271843535d6d6f9e44/t/6728cb1963847176fb0eec41/1730726702798/D3.1.+Core+training+material+-+za+web_compressed.pdf
2. Carević, I., Serdar, M., Ottosen, L. M., Štirmer, N., Andersen, R.: D3.3. Integration of the new learning unit structure and topics at UNIZG FCE and DTU (radni materijali razvijeni kroz projekt GREENCO), https://static1.squarespace.com/static/657ebc271843535d6d6f9e44/t/6840460e0a46c53f03883498/1749042704930/D3.3.+Project+based+learning+-+HEI.pdf
3. Serdar, M., Carević, I., Štiremer, N., Banjad Pečur, I. (2025): D3.2. Educational materials for „Green Building" course. Zenodo. https://doi.org/10.5281/zenodo.17424576
4. Hauschild, M. Z., Rosenbaum, R. K., Olsen, S. I.: Life Cycle Assessment theory and practice", Springer
5. Marengo, P. (2019): Sustainable construction guidlines for public authorities – A circular economy perspective, https://www.acrplus.org/en/news/sustainable-construction-guidelines-for-public-authorities-a-circular-economy-perspective-2287
6. Regulation (EU) 2024/3110 of the European Parliament and of the Council of 27 November 2024 laying down harmonised rules for the marketing of construction products and repealing Regulation (EU) No 305/2011 https://eur-lex.europa.eu/legal-content/HR/TXT/HTML/?uri=OJ:L_202403110
7. HRN ISO 21930 Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services https://repozitorij.hzn.hr/
8. HRN ISO 21931-1 Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of

construction works as a basis for sustainability assessment — Part 1: Buildings https://repozitorij.hzn.hr/
9. HRN EN 17680 Sustainability of construction works – Evaluation of the potential for sustainable refurbishment of buildings https://repozitorij.hzn.hr/
10. HRN EN 15804+A2 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products https://repozitorij.hzn.hr/
11. HRN EN 15978 Sustainability of construction works -- Assessment of environmental performance of buildings https://repozitorij.hzn.hr/
12. HRN EN ISO 14040 Environmental management – Life cycle assessment – Principles and framework https://repozitorij.hzn.hr/
13. HRN EN ISO 14044 Environmental management – Life cycle assessment – Requirements and guidelines https://repozitorij.hzn.hr/
14. HRN ISO 15686 Buildings and constructed assets -- Service life planning https://repozitorij.hzn.hr/

Additional reading:

1. Kubba, Sam: Handbook of Green Building Design and Construction, LEED, BREEAM, and Green Globes, Second Edition, Elsevier, 2017
2. Level(s) common framework - https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/412/documents
3. Framework for carbon neutral buildings and sites, DGNB, 2020., https://www.dgnb.de/en/sustainable-building/climate-action/framework-for-carbon-neutral-buildings-and-sites

SEISMIC DESIGN OF CONCRETE ANF MASONRY BUILDINGS

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 45
- Exercises: 15

Course objectives:

- Acquiring theoretical knowledge of technical regulations for the design of earthquake-resistant building structures
- Acquiring theoretical and practical knowledge of structural ductility, behavior factor, and structural response to horizontal loads
- Acquiring theoretical knowledge of seismic action standards, seismic maps, and return periods
- Acquiring practical knowledge of conceptual design of earthquake-resistant building structures
- Acquiring theoretical and practical knowledge of the design of simple masonry buildings
- Acquiring theoretical and practical knowledge of the design of masonry buildings
- Acquiring theoretical and practical knowledge of the design of reinforced concrete buildings resistant to seismic action

- Acquiring theoretical and practical knowledge of the dimensioning of structural elements under seismic loads.

Learning outcomes:

- Practically apply standards and regulations for the seismic design of concrete and masonry building structures
- Select and apply an appropriate method for calculating the seismic resistance of a structure
- Determine the effect of seismic action based on site properties and the building's structural system
- Determine the behaviour factor based on the load-bearing system and building characteristics
- Develop the conceptual design of a building during the design phase
- Perform the dimensioning of concrete and masonry building structures in seismic regions.

Course content (by course schedule):

- Lectures:

1. Earthquake as an action and its impact on the built environment (3h)
2. Seismic maps, return periods, and earthquake standardization (3h)
3. Structural response, basic concepts, and ductility (2h)
4. Behaviour factor (2h)
5. Seismic design according to Eurocode 8 (4h)
6. Conceptual building design (4h)
7. Calculation methods (4h)
8. Simple masonry buildings (3h)
9. Design of earthquake-resistant masonry buildings (3h)
10. Design of earthquake-resistant concrete buildings (4h)
11. Dimensioning of reinforced concrete elements (8h)
12. Special rules for concrete and masonry structures (3h)
13. Midterm exam (2h)

- Exercises:

1. During the exercises, students will solve tasks related to lecture topics through practical examples.

Student Evaluation - Examination without Continuous Assessment:

- Design
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Sorić, Z., Kišiček, T.: "Betonske konstrukcije 2", Sveučilište u Zagrebu Građevinski fakultet, university handbook, Zagreb, 2018.

2. Sorić, Z., Kišiček, T.: "Betonske konstrukcije 1", Sveučilište u Zagrebu Građevinski fakultet, university handbook, Zagreb, 2014.
3. Tehnički propis za građevinske konstrukcije (2017)
4. Croatian standards series HRN EN 1992, standards for concrete structures https://repozitorij.hzn.hr/
5. Croatian standards series HRN EN 1996, standards for masonry structures https://repozitorij.hzn.hr/
6. Croatian standards series HRN EN 1991, standards for actions on structures https://repozitorij.hzn.hr/
7. Croatian standards series HRN EN 1998, standards for design of structures for earthquake resistance https://repozitorij.hzn.hr/
8. Offprints from lectures and exercises https://moodle.srce.hr/

Additional reading:

1. Fardis, M.N.: Seismic design, assessment and retrofitting of concrete buildings, based on EN-Eurocode 8, Springer, 2009.
2. Penelis, George G., Penelis Gregory G.: Concrete buidings in Seismic Regions, CRC Press, 2014.
3. Sorić, Z.: "Zidane konstrukcije", university handbook, self-published, Zagreb, 2016.

Elective courses

MATHEMATICS 3.

See Chapter **Shared Courses**

STOCHASTIC PROCESSES

See Chapter **Shared Courses**

1st year, 2nd semester

Mandatory courses

GREEN AND BLUE INFRASTRUCTURE

Credits (ECTS): 6.0

Hours (total per semester):
- Lectures: 30
- Exercises: 30

Course objectives:
- To enable students to understand the concept of "sponge cities" and the role of green and blue infrastructure in stormwater management, increasing water quality, reducing urban heat islands, improving air quality, and increasing the resilience of cities to climate change.

Learning outcomes:
- Explain the concepts of green and blue infrastructure and sponge cities.
- Identify the problems caused by climate change in urban areas (heat islands, precipitation, droughts).
- Analyse spatial and water management aspects of the urban environment.
- Propose, conceptualise and design technical solutions for green and blue infrastructure (e.g. BMP – Best Management Practices, LID – Low Impact Development, SUDS – Sustainable Urban Drainage Systems, NBS – Nature-Based Solutions).
- Develop an interdisciplinary proposal for planning or redesigning urban space

Course content (by course schedule):
- Lectures:

1. Introduction: Cities and climate change – problems and pressures
2. The concept of “sponge cities” – best international practices
3. Urban hydrology: stormwater, torrents, sewage
4. Green roofs, facades, parks, rain gardens, individual solutions at the household level
5. Blue infrastructure: canals, lakes, retention basins, bioretentions, grassed ditches, biolinear stormwater drainage
6. Water quality
7. Regulatory frameworks and Methodology for applying the combined approach
8. Precipitation-runoff modelling in urban environments
9. Modelling and simulation of pollution retention
10. Protection of surface and groundwater in engineering projects
11. BIM and GIS tools in green infrastructure planning
12. Successful case studies: Copenhagen, Rotterdam, Amsterdam, Valencia, Singapore, Melbourne

13. Regulatory framework in the EU and Croatia: ZPU, ZGO, NPOO, guidelines
14. Conceptualisation and design of green infrastructure elements
15. Presentation of student works.

Student Evaluation - Continuous assessment:

- Design
- In-class activity
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Design
- In-class activity
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Green and blue infrastructure (lectures) https://moodle.srce.hr/
2. Butler, D. & Davies, J. W. (2018). Urban Drainage (4th ed.). CRC Press / Taylor & Francis. https://www.taylorfrancis.com/books/mono/10.1201/9781315272535/urban-drainage-david-butler-john-davies
3. Smjernice za tehničko projektiranje i procjenu socioekonomske izvedivosti mjera zelene infrastrukture u smanjenju rizika od poplava (VEPAR) (VITA PROJEKT d.o.o., prosinac 2022.) https://www.voda.hr/sites/default/files/dokumenti/PUVP3%20-%20URP%20-%200010.pdf
4. Metodologija primjene kombiniranog pristupa (Hrvatske vode, rujan 2025.) https://www.voda.hr/sites/default/files/2025-09/METODOLOGIJA%20PRIMJENE%20KOMBINIRANOG%20PRISTUPA.pdf
5. Malus, D., Vouk, D. (2012. Priručnik za učinkovitu primjenu biljnih uređaja za pročišćavanje sanitarnih otpadnih voda, Sveučilište u Zagrebu Građevinski fakultet https://www.scribd.com/document/395763238/1-Prirucnik-Malus-Vouk-print-1-pdf

Additional reading:

1. Fletcher, T. et al. (2014). Blueprint for a Water Sensitive City. Cooperative Research Centre for Water Sensitive Cities (CRCWSC).
2. Sirishantha, U., Rathnayake, U. (2017). Sustainable urban drainage systems (SUDS) – What it is and where do we stand today?, DOI:10.14456/easr.2017.36
3. Novotny, V., Brown, P. (2007). Cities of the Future: Towards Integrated Sustainable Water and Landscape Management. IWA Publishing
4. Environmental Protection Act (OG 80/13, 153/13, 78/15, 12/18, 118/18)

5. Water Act (OG 66/19, 84/21, 47/23)
6. National Environmental Protection Strategy
7. Sustainable Development Strategy of the Republic of Croatia
8. Waste Management Strategy of the Republic of Croatia
9. Decree on Environmental Impact Assessment (OG 61/14 i 03/17)
10. River Basin Management Plan 2022–2027
11. Ordinance on limit values of wastewater emissions (NN 26/20)
12. Water Quality Standard Regulation (OG 96/19, 20/23 i 50/23-ispravak)

SUSTAINABLE TRANSPORT INFRASTRUCTURE IN URBAN ENVIRONMENT

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Acquiring knowledge of the characteristics of transport infrastructure in urban areas,
- Acquiring knowledge of the requirements for accessibility, safety, functionality, and sustainability of urban transport infrastructure, which directly influence the design elements of networks and corridors.

Learning outcomes:

- Select design elements for transport infrastructure and facilities based on site conditions, spatial requirements, and urban transport needs.
- Evaluate the functional characteristics of existing and planned urban transport corridors, networks, and systems.
- Propose objectives and management methods for urban transport infrastructure, considering accessibility, safety, functionality, and sustainability categories.

Course content (by course schedule):

- Lectures:

1. Classification of urban transport networks; multimodal corridors (2h)
2. Programming and design requirements – street network cross-sections (2h)
3. Programming and design requirements – street network horizontal design elements (2h)
4. Programming and design requirements – street network vertical design elements (2h)
5. Sustainable urban intersections – selection criteria for intersection types (2h)
6. Sustainable urban intersections – design elements (2h)
7. Areas and corridors for non-motorized transport (2h)
8. Public transport – restricted right-of-way systems in shared corridors (2h)
9. Public transport – dedicated right-of-way systems in separate corridors (2h)
10. Stationary traffic – individual transport and intermodal passenger terminals (2h)
11. Efficiency analysis of the urban transport network (2h)
12. Fundamentals of transport infrastructure maintenance (2h)

13. Proactive maintenance, climate neutrality, and Life Cycle Assessment (LCA) of transport infrastructure (2h)
14. Vulnerability assessment of transport infrastructure to extreme events and emergency maintenance (2h)
15. Impact of transport infrastructure on the quality of life in urban areas (2h)

- Exercises:

1. Methods for developing and applying strategic and operational transport documentation in sustainable urban infrastructure planning (6h)
2. Design fundamentals in sustainable urban transport infrastructure development planning (6h)
3. Potentials for redesigning secondary corridors to enhance safety and sustainability in urban areas (6h)
4. Inclusive mobility and solutions for increasing public transport accessibility (6h)
5. Case study: Transport infrastructure maintenance plan based on sustainable management principles (6h)

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- In-class activity
- Written exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Maletin, M.: Osnove projektiranja saobraćajnica u gradovima, Orion-Art, Beograd, 2009. str. 54-101 http://merlin.srce.hr
2. Legac, I.: Gradske prometnice, Sveučilište u Zagrebu Fakultet prometnih znanosti, Zagreb, 2011., str. 49-56, 57-73, 166-179, 180-219
3. Gospodarenje prometnom infrastrukturom, Zavod za prometnice Građevinskog fakulteta Sveučilišta u Zagrebu, Zagreb, 2009. str. 45-175 http://merlin.srce.hr
4. Lectures material http://merlin.srce.hr

Additional reading:

1. Pearson, D.: Deterioration and Maintenance of Pavements, Institution of Civil Engineers, London, 2012.
2. Mallick, R. B.; El-Korchi, T.: Pavement Engineering – Principles and Practice, CRC Press, London, 2009.
3. Thompson, D. Railway Noise and Vibrations. (Elsevier Ltd, 2009).
4. Esveld, C.: Modern Railway Track, Second Edition. MRT Productions, Zaltbommel, 2001.
5. Hrvatske ceste: Opći tehnički uvjeti za radove na cestama
6. Global Street Design Guide, The National Association of City Transportation Officials (NACTO), New York, 2016.
7. Smjernice za projektiranje kružnih raskrižja na državnim cestama, Građevinski fakultet Sveučilišta u Rijeci, Rijeka, srpanj 2014.

8. Ordinance on Cycling Infrastructure (OG 28/2016)
9. Ordinance on Bus Stops (OG 119/2007)
10. Ordinance on Technical Conditions and Elements for Designing, Constructing and Improving Railway Lines of the City Railway (42/1990)
11. Technical Regulation on Accessibility of Buildings to Persons with Disabilities and Reduced Mobility (OG 12/23)
12. Richtlinien für die Anlage von Landstraßen (RAL), Plangleiche Knotenpunkte, FGSV, Koln, 2012., str.172.
13. Richtlinien für die Anlage von Autobahnen (RAA), Knotenpunkte, FGSV, Koln, 2008., str.182.
14. Highway Capacity Manual, Transportation Research Board (TRB), Washington, D.C., 2000.

GEOTECHNICAL MONITORING AND EARLY WARNING SYSTEMS (AI/IoT)

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- to familiarise students with the concept of geotechnical monitoring and early warning systems (measurement → analysis → thresholds/decision-making → warning → response)
- to link geotechnical processes and triggers (rainfall/water levels, changes in pore-water pressures, displacements; including seismic loading) with measurable indicators and instrumentation
- to enable students to select measured quantities, sensors and a basic configuration of monitoring systems for typical geotechnical structures and works
- to develop skills in basic processing and quality control of data (calibration, filtering, missing data, measurement reliability)
- to introduce students to the application of time-series analytics and AI-based approaches (e.g. anomaly detection) for early warning
- to enable students to define thresholds and warning levels and to develop a simple warning logic and recommended response procedures
- to develop the ability to professionally communicate monitoring results and recommendations to stakeholders (designers, supervision, infrastructure managers, civil protection services)

Learning outcomes:

- explain the role of geotechnical monitoring and early warning systems in ensuring the stability, safety and serviceability of geotechnical structures and works
- identify and relate typical geotechnical processes and triggers (rainfall/water levels, pore-water pressures, deformations; including seismic loading) to measurable indicators in the field

- design a monitoring concept (what to measure, where and how often) and select suitable instrumentation and system configuration (sensors, layout, installation method, power supply and communication) with a clear justification of limitations and risks
- perform basic processing and quality control of monitoring data (calibration, noise filtering, detection of outliers and missing data) and assess measurement reliability
- apply basic time-series analysis methods and AI/ML approaches suitable for early warning (e.g. anomaly detection, state classification, trend tracking) with a critical assessment of false alarms and missed detections
- define thresholds, warning levels and a simple decision logic, and propose operational procedures and methods of notifying relevant stakeholders
- prepare and present a project solution (case study) and communicate results and recommendations through a technical report and graphical outputs (e.g. dashboard) within a team and an interdisciplinary environment

Course content (by course schedule):

- Lectures:

1. Introduction: geotechnical monitoring and early warning systems (EWS); link with site investigation and the observational method.
2. Geotechnical processes and triggers: rainfall/water levels, pore-water pressures, deformations; including seismic loading as one of the possible triggers.
3. Investigation and monitoring programme: how an EWS plan is built upon field and laboratory investigations (baseline, target quantities, critical zones).
4. Measurement systems and uncertainties: accuracy, resolution, drift, robustness, QA/QC, data reliability.
5. Soil classification tests: soil classification; water content, bulk density, particle density; grain-size distribution; Atterberg limits (use in interpreting behaviour and parameters).
6. Oedometer tests: compressibility and consolidation; interpretation (Cc, Cr, cv) and relationship to settlement and changes in pore-water pressures.
7. Shear and triaxial tests: direct shear and triaxial tests (drained/undrained), strength parameters and their role in stability assessment and threshold definition.
8. Soil permeability: laboratory methods and the concept of filtration/seepage; link with piezometer monitoring and instability triggers.
9. Soil compaction: Proctor test, optimum water content, degree of compaction; influence on embankment structures, retention basins and post-construction behaviour.
10. Field investigations – basics: trial pits and boreholes, sampling, groundwater level; in-situ tests (SPT/CPT/DCP, DMT/PMT – overview and application).
11. Pile testing: capacity (static/dynamic load tests, interpretation) and integrity testing; how results are incorporated into monitoring during construction and service.
12. Geophysical investigations in geotechnics: MASW, seismic refraction and reflection, electrical resistivity tomography (ERT), GPR – role and possibilities for repeated measurements (baseline/monitoring).

13. Instrumentation for monitoring: piezometers, inclinometers (V/H), extensometers, crack gauges, GNSS/geodetic observations, earth pressure cells – what they measure and how results are interpreted.
14. IoT system architecture: data acquisition, communication, power/energy management, data storage and cyber security; interoperability and links to BIM.
15. Analytics and AI/ML for EWS: time-series analysis, anomaly detection, data fusion from multiple sources; thresholds, warning levels, SOPs and communication with stakeholders.

- Exercises:

1. Introduction to monitoring data (computer-based): data import, plotting, descriptive statistics, metadata.
2. Soil classification tests (laboratory): w, γ/ρ, Gs, grain-size distribution, Atterberg limits; classification and interpretation.
3. Oedometer test (laboratory/computer-based): e–logσ', Cc/Cr/cv, settlement assessment.
4. Direct shear test (laboratory/computer-based): $\tau-\delta$, peak/residual, $c'-\varphi'$.
5. Triaxial test (laboratory/computer-based): UU / selected CD/CU, su, effective parameters; selection of representative values.
6. Permeability (laboratory/computer-based): constant/falling head; influence on seepage and pore-water pressures.
7. Compaction – Proctor test (laboratory/computer-based): wopt, γd,max; degree of compaction; implications for embankment/retention deformations.
8. Field documentation and logging (field/computer-based): borehole/pit logs, soil description, groundwater level; selection of critical zones for monitoring.
9. In-situ data (computer-based): CPT/SPT/DCP (selected) – interpretation of profiles, stratification, identification of critical layers.
10. Piezometry and triggers (field/computer-based): piezometer readings + rainfall/water levels; trends and indicators of pore-water pressure changes.
11. Deformations (field/computer-based): GNSS/geodetic observations and/or inclinometer data – displacement rates, regime changes, thresholds.
12. Piles – capacity and integrity (computer-based): interpretation of load–settlement curves and/or integrity signals; acceptance criteria and monitoring during construction.
13. Geophysics: MASW (Vs profile), refraction/reflection, ERT sections, GPR; role of the baseline and repeat surveys.
14. Project (1): design of a monitoring system for a selected case (objectives, measured quantities, instruments, layout, power supply/communication).
15. Project (2) and presentations: analysis of real or realistic time-series data, definition of thresholds and warning levels, presentation of results (plots/dashboard mock-up); defence of the proposed solution.

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Practical work

- short tests/practical assignments in exercises
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Jurić Kačunić, D.; Kovačević, M. S.: Mehanika tla – laboratorijski pokusi. Sveučilište u Zagrebu, Građevinski fakultet, Zagreb, 2025.

Additional reading:

1. Dunnicliff, J. (1993). Geotechnical Instrumentation for Monitoring Field Performance. John Wiley & Sons, New York.
2. Phoon, K.-K., & Tang, C. (Eds.). (2024). Databases for Data-Centric Geotechnics: Site Characterization (1st ed.). CRC Press, Boca Raton. doi:10.1201/9781003441946
3. Nguyen, H., Bui, X.-N., Topal, E., Zhou, J., Choi, Y., & Zhang, W. (Eds.). (2023). Applications of Artificial Intelligence in Mining and Geotechnical Engineering (1st ed.). Elsevier.
4. Ilinca, V., Chitu, Z., & Şandric, I. (Eds.). (2024). Earth Observation Applications to Landslide Mapping, Monitoring and Modeling: Cutting-edge Approaches with Artificial Intelligence, Aerial and Satellite Imagery (1st ed.). Elsevier.

BUILDING INFORMATION MODELING - BIM

See Chapter Specialisation Construction management.

ASSESSMENT OF THE SEISMIC PERFORMANCE OF EXISTING BULIDINGS

Credits (ECTS): 6.0

Hours (total per semester):

- Lectures: 30
- Exercises: 30

Course objectives:

- Acquisition of theoretical and practical knowledge on the behaviour of existing structures under earthquake action.
- Application of modern analysis methods for assessing the load-bearing capacity and stability of existing buildings.

Entry competences (prior knowledge, descriptive):

- teacher's signature for the course: Dynamics of Structures with an Introduction to Earthquake Engineering

Learning outcomes:

- Identify failure mechanisms of masonry and reinforced concrete structural elements.
- Compare and evaluate calculation methods for assessing the mechanical resistance and stability of a structure.
- Calculate parameters leading to local failure of structural elements.
- Identify parameters affecting the mechanical resistance and stability of a structure.

Course content (by course schedule):

- Lectures:

1. Approaches to the problem of load-bearing capacity assessment; structural systems.
2. Concept of a building's load-bearing capacity.
3. Assessment of earthquake damage to buildings.
4. Building testing methods.
5. Building testing methods.
6. Numerical modelling of a building.
7. Numerical modelling of a building.
8. Methods for seismic design/analysis of buildings included in Eurocode 8.
9. Eurocode 8: limit states and design/analysis methods.
10. Out-of-plane failure of walls in masonry buildings – mechanism identification and calculation of the activation factor.
11. Nonlinear static method – N2 pushover method.
12. Global and local structural failure mechanisms.
13. Criteria for assessing building performance.
14. Measures to reduce dynamic effects on a structure and its response: seismic isolation, bracing, dampers, and vibration isolation.
15. Measures to reduce dynamic effects on a structure and its response: seismic isolation, bracing, dampers, and vibration isolation

Student Evaluation - Continuous assessment:

- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Lecture materials; Merlin, https://moodle.srce.hr/2024-2025/course/section.php?id=2503421

2. Obnova zgrada nakon potresa, ur. Uroš, M.; Todorić, M.; Crnogorac, M.; Atalić, J.; Šavor Novak, M.; Lakušić, S. Sveučilište u Zagrebu, 2021. (poglavlja B, C, D, E, F i H)

Additional reading:

1. Crnogorac, M.; Todorić, M.; Uroš, M.; Atalić, J.: Urgentni program potresne obnove: Građevinska tehnička rješenja, Građevinski fakultet Sveučilišta u Zagrebu, Hrvatska komora inženjera građevinarstva, 2020.
2. Fardis(2009), Seismic Design, Assessment and Retrofitting of Concrete Buildings Based on EN-Eurocode 8, Geotechnical, geological and earthquake engineering, Vol. 8, Springer.
3. Čaušević, M.: Nelinearne seizmičke analize konstrukcija prema EN 1998-1: 2004, Dinamika konstrukcija-potresno inženjerstvo, aerodinamika, konstrukcijske euronorme, Golden marketing, Tehnička knjiga, Zagreb, str. 327-412, 2010.
4. ASCE (2014), Seismic Evaluation and Retrofit of Existing Buildings, ASCE/SEI 41-13, American Society of Civil Engineers, Reston, Virginia, USA

2nd year, 3rd semester

Mandatory courses

DEEP ENERGY RENOVATION OF BUILDINGS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- Introducing students to methods for proper assessment of the condition of the building envelope.
- Acquiring knowledge for assessing the energy efficiency of existing buildings and selecting appropriate methods for sustainable energy renovation of buildings.
- Acquiring knowledge for raising the level of energy efficiency and thermal comfort of the existing building stock by applying proven and economically justified renovation measures.
- Introducing students to different approaches in the analysis and assessment of the energy efficiency of buildings.
- Introducing students to materials, technical systems and their properties, related to durability, safety and fire protection and energy efficiency.
- Developing group work skills by applying the team learning method.

Learning outcomes:

- Develop a condition assessment of existing buildings.
- Analyse the properties of building materials, products and systems for renovation, with an emphasis on durability, fire behaviour and energy efficiency.
- Develop a building deep energy renovation design project.

Course content (by course schedule):

1. 1. Introduction to energy renovation, Legal framework – recommendations and obligations (2)
2. Basics of building physics (2)
3. Environmental impacts, damage and durability of building materials (4)
4. Basics of the origin and development of fires in enclosed spaces and protection strategies (4)
5. Analysis of the current state of buildings (2)
6. Shortcomings and needs in the renovation of the existing building stock (2)
7. Models of sustainable building renovation (2)
8. Overview of possible strategies for energy renovation of buildings (2)

9. Technical systems in buildings, lighting, control systems (2)
10. Proper selection of materials and technical systems for energy renovation of the existing building stock (2)
11. Proper selection of materials and technical systems for energy renovation respecting fire protection requirements (2)
12. Hygrothermal calculation of building components (2)
13. Calculation of the building energy balance (2)

Student Evaluation - Examination without Continuous Assessment:

- Design
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Hugo Hens. Applied Building Physics: Ambient Conditions, Building Performance and Material Properties. Ernst & Sohn. 2010
2. Hugo Hens. *Performance Based Building Design 1: From Below Grade Construction to Cavity Walls*. Ernst & Sohn. 2012
3. Hugo Hens. *Performance Based Building Design II: From Timber-framed Construction to Partition Walls*. Ernst & Sohn. 2013
4. Christopher Gorse, David Highfield. *Refurbishment and Upgrading of Buildings*, Spon Press, 2009
5. Colwell S., Baker T., *Fire Performance of external thermal insulation for walls of multistorey buildings, British research establishment, 3rd Edition*. 2013 https://www.designingbuildings.co.uk/wiki/Fire_performance_of_external_thermal_insulation_for_walls_of_multistorey_buildings,_third_edition_(BR_135)
6. Jelčić Rukavina, M., Carević, M., Banjad Pečur, I.: Zaštita pročelja zgrada od požara - Priručnik za projektiranje i izvođenje, Građevinski fakultet Sveučilišta u Zagrebu, 2017. https://www.grad.unizg.hr/oldwww/zavod_za_materijale/sigurna_uporaba_toplinsko-izolacijskih_materijala_u_gradevinama_s_aspekta_zastite_od_pozara
7. Jelčić Rukavina, M., Carević, M., Veršić, Z.: Sigurna upotreba toplinsko-izolacijskih materijala s aspekta zaštite od požara, Građevinski fakultet Sveučilišta u Zagrebu, 2020. https://www.grad.unizg.hr/oldwww/zavod_za_materijale/sigurna_uporaba_toplinsko-izolacijskih_materijala_u_gradevinama_s_aspekta_zastite_od_pozara
8. Croskills priručnici - *Kontinuirana izobrazba građevinskih radnika u okviru energetske učinkovitosti - Priručnik za trenere (svesci: Zajednički dio, fasader, zidar, tesar, krovopokrivač, soboslikar-ličilac, monter suhe gradnje),* Građevinski fakultet, Sveučilišta u Zagrebu, 2017. https://croskills-reload.grad.hr/hr/dokumenti/

Additional reading:

1. E-course materials (available on the Merlin system): Building Physics, Technology of Repair and Strengthening, and Fire Protection.

STRUCTURAL RETROFITTING OF EXISTING STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 0

Course objectives:

- Acquiring theoretical knowledge of technical regulations for the reconstruction and retrofitting of existing structures
- Acquiring theoretical and practical knowledge on various methods for seismic upgrading of existing structures
- Acquiring theoretical and practical knowledge on various methods for structural validation of retrofitted structures
- Acquiring theoretical knowledge on retrofitting cost estimation and analysis

Learning outcomes:

- Practical application of standards and regulations for seismic retrofitting and upgrading of existing structures
- Selection and application of appropriate method for seismic retrofitting based on structure type and characteristics
- Determination of suitable retrofitting level i corresponding significant damage index
- Application of acquired knowledge in conceptual retrofitting design of existing structures
- Application of acquired knowledge for retrofitting cost estimation for existing structures.

Course content (by course schedule):

- Lectures

1. Introduction to existing RC and masonry structures (2h)
2. Eurocode HRN EN1998-3 (3h)
3. Reconstruction act, program of measures for damaged structures, retrofitting levels, EMS damage levels, technical code for civil engineering structures (NN 75/20, 7/22) (4h)
4. Index of significant damage (SD), damage limitation index (LD) (2h)
5. Methods for seismic assessment of existing RC and masonry structures (3h)
6. Conceptual approach for global retrofitting of masonry structures (4h)
7. Conceptual approach for global retrofitting of RC structures (4h)
8. Design of retrofitting elements in masonry structures (4h)
9. Design of retrofitting elements in RC structures (4h)
10. Retrofitting design using advanced materials (FRP, TRM, CRM) (4h)
11. Case studies and practical examples of retrofitted structures (2h)
12. Seminar (4h)
13. Construction site visit (3h)
14. Midterm exam (2h)

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Technical Regulation for Building Structures (2017), https://narodne-novine.nn.hr/clanci/sluzbeni/2017_02_17_403.html
2. Croatian standards series HRN EN 1992, Eurocode 2: Design of concrete structures, https://repozitorij.hzn.hr/
3. Croatian standards series HRN EN 1996, Eurocode 6: Design of masonry structures
4. Croatian standards series HRN EN 1991, Eurocode 1: Actions on structures
5. Croatian standards series HRN EN 1998, standards for designing structures for earthquake resistance
6. Potresno inženjerstvo : obnova zidanih zgrada / [urednici Mario Uroš ... et al.], Sveučilište u Zagrebu Građevinski fakultet, 2021.
7. Lecture materials, https://moodle.srce.hr/

Additional reading:

1. Seizmičke obnove i rekonstrukcije (2025)
2. Emergency Seismic Reconstruction Program – UPPO (2020)
3. Ammendments to the Technical Regulation for Building Structures (OG 75/20; 7/22)
4. Programme of Measures for the Reconstruction of Earthquake-Damaged Buildings in the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County (OG 154/24)
5. Act on Reconstruction of Earthquake-Damaged Buildings in the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County (OG 28/23)
6. Act on the Reconstruction of Buildings Damaged by the Earthquake in the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County (OG 21/23)

Elective courses

HAZARDS, RISKS AND RESILIENCE OF WATER AND WASTEWATER SYSTEMS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- Understand natural and technological hazards affecting water and wastewater infrastructure.
- Adopt methods for risk and vulnerability assessment of water supply and drainage systems.
- Develop the ability to plan measures for improving system resilience and security.
- Familiarize themselves with crisis management practices and climate change adaptation strategies.
- Integrate technical, environmental, and organizational aspects of water system management.

Learning outcomes:

1. Explain the types of hazards (natural and technological) affecting water and wastewater infrastructure.
2. Conduct basic and advanced risk analyses for specific system components.
3. Model the impacts of failures and extreme events on the functioning of water supply and drainage networks.
4. Assess system vulnerability and identify critical infrastructure elements.
5. Develop action plans to increase system resilience to hazards.
6. Apply crisis management concepts in cases of supply interruptions or contamination.
7. Evaluate the economic feasibility of risk reduction measures and prioritize investments.
8. Interpret and apply national and international guidelines regarding critical infrastructure security.
9. Critically analyse case studies and propose profession-based solutions.

Course content (by course schedule):

1. Introduction to hazards and risks in water and wastewater infrastructure.
2. Functioning of water and wastewater systems.
3. Natural hazards and their impact on water and wastewater infrastructure.
4. Technological and operational hazards.
5. Contamination and sanitary risks.
6. Quantifying greenhouse gas emissions.

7. Climate change and extreme events.
8. Risk assessment methodologies.
9. Modelling and system vulnerability analysis.
10. Critical infrastructure and system security.
11. Resilience of water and wastewater systems.
12. Technologies for increasing resilience.
13. Flood risk assessment in water and wastewater systems.
14. Economic risks and decision-making.
15. Benchmarking and sustainability assessment of water and wastewater infrastructure

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Course Materials
2. Donald Hyndman, David Hyndman: Natural Hazards and Disasters, 6th edition, 2025.
3. Nicholas J. Bahr: System Safety Engineering and Risk Assessment, 2nd edition, CRC Press 2015.
4. Enrique Cabrera, Jr.; Peter Dane; Scott Haskins; Heimo Theuretzbacher-Fritz: Benchmarking Water Services: Guiding water utilities to excellence, IWA Publishing, 2011.
5. Trevor M. Letcher: Climate Change - Observed Impacts on Planet Earth, Elsevier, 2nd edition, 2015
6. Petri Juuti; Harri Mattila; Riikka Rajala; Klaas Schwartz; Chad Staddon: Resilient Water Services and Systems: The Foundation of Well-being, IWA Publishing, 2019.

Additional reading:

1. Legal Framework
2. Roberto Setola, Eric Luiijf, Marianthi Theocharidou: Critical Infrastructures, Protection and Resilience, Springer Open, 2017.
3. Charles Ainger; Richard Fenner: Sustainable Infrastructure: Principles into Practice, ICE Publishing, 2014.
4. Simon Dresner: The Principles of Sustainability, 2nd Edition, Routledge, 2012.

ENVIRONMENTAL ENGINEERING AND PROTECTION OF WATER SYSTEMS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- The primary objective of the course is to provide students with theoretical and practical knowledge of the importance and principles of water and environmental protection in general, as well as of structural and non-structural measures aimed at reducing negative environmental impacts, with particular emphasis on impacts on water bodies.
- Additional objectives of the course are to equip students with the ability to understand, analyse, and apply engineering solutions to problems related to environmental protection and water resources management, with a focus on integrated management approaches, impact assessment, modelling, and the application of modern water treatment technologies.
- Upon successful completion of the course, students will be able to: understand the fundamental principles of environmental engineering and water resources management; interpret and apply the regulatory framework for environmental and water protection in the Republic of Croatia and the European Union; conduct analyses and prepare environmental impact assessments (EIA) using standard methodological tools; interpret surface water and groundwater quality indicators; analyse monitoring data and assess the status of water bodies; identify major point and diffuse sources of pollution and assess their impacts on the environment and water resources; apply a combined approach (technological measures together with quality and emission standards) in water protection planning; understand and use basic numerical models for simulating pollutant transport in water systems; develop engineering solutions for the protection of surface and groundwater within infrastructure and construction projects; understand soil–water–pollutant interaction processes and their implications for environmental engineering; be familiar with technologies for mechanical pretreatment as well as primary, secondary, tertiary, quaternary, and advanced wastewater treatment; evaluate methods for sludge treatment, disposal, and sustainable waste management; understand protection measures in incident, emergency, and hazardous situations; and integrate acquired knowledge through case studies while developing a multidisciplinary approach to environmental and water protection.

Learning outcomes:

- Upon successful completion of the course, students will have knowledge of fundamental ecological concepts and the principles of rational use of natural resources, as well as basic measures and procedures for environmental protection. Students will be able to solve professional problems in the field of environmental protection.
- Students will possess basic knowledge of the natural environment and of anthropogenic impacts on water quality. They will be familiar with national and European legislation and regulatory frameworks related to water protection.
- Students will be familiar with modern mathematical modelling tools, including the assessment of the assimilative capacity of water bodies, the evaluation of key water

quality parameters, and the modelling of mixing processes between wastewater and receiving waters.

- Students will have knowledge of structures and facilities used for water protection. They will be able to apply water quality assessment methods and models, including the basic Streeter–Phelps model, the QUAL mathematical model, and others.
- Students will acquire the necessary knowledge and skills to conduct environmental impact assessments and to prepare supporting documentation for effective strategic decision-making in catchment management.
- Students will be able to apply and design appropriate solutions for the collection, treatment, and disposal of runoff from transportation infrastructure, with due consideration of environmental protection and mitigation of adverse impacts.
- Students will be able to assess anthropogenic impacts on water quality and to define measures for reducing or eliminating these impacts.

Course content (by course schedule):

1. Introduction to Environmental Engineering and Water Area Management
2. Regulatory Framework for Environmental and Water Protection (EU and the Republic of Croatia)
3. Environmental Impact Assessment (EIA)
4. Water Quality: Indicators, Standards, and Monitoring
5. Sources of Water and Environmental Pollution: Diffuse and Point Sources
6. Methodology for the Application of the Combined Approach
7. Modelling and Simulation of Pollutant Transport
8. Protection of Surface and Groundwater in Engineering Projects
9. Soil Protection and Soil–Water–Pollutant Interactions
10. Wastewater Treatment Technologies: Mechanical Pretreatment and Primary Treatment
11. Wastewater Treatment Technologies: Secondary and Tertiary Treatment
12. Wastewater Treatment Technologies: Quaternary Treatment and Advanced Wastewater Treatment Processes
13. Sustainable Waste Management and Sludge Treatment
14. Environmental and Water Protection Measures and Procedures in Incident and Hazardous Situations
15. Case Studies and an Integrated Engineering Approach to Environmental and Water Protection

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Design
- Written exam
- Oral exam
- 75% attendance at lectures

- 100% attendance at exercises

Required reading:

1. Environmental Engineering and Protection of Water Systems (lectures)
2. G. Tyler Miller, Scott Spoolman: Living in the Environment: Principles, Connections, and Solutions, 17th Edition, Cengage Learning, 2011.
3. David M. Hassenzahl, Mary Catherine Hager, Nancy Y.Gift, Linda R. BErg, Peter H. Raven, 10th Edition, Wiley, 2018.
4. Regulatory Framework:
5. Environmental Protection Act (Official Gazette of the Republic of Croatia, Nos. 80/13, 153/13, 78/15, 12/18, 118/18)
6. Water Act (Official Gazette of the Republic of Croatia, Nos. 66/19, 84/21, 47/23)
7. National Environmental Protection Strategy
8. Sustainable Development Strategy of the Republic of Croatia
9. Waste Management Strategy of the Republic of Croatia
10. Regulation on Environmental Impact Assessment (Official Gazette of the Republic of Croatia, Nos. 61/14 and 03/17)
11. River Basin Management Plan until 2027
12. Ordinance on Limit Values of Wastewater Emissions (Official Gazette of the Republic of Croatia, No. 26/20)
13. Regulation on Water Quality Standards (Official Gazette of the Republic of Croatia, Nos. 96/19, 20/23, and 50/23 – corrigendum)
14. Methodology for the Application of the Combined Approach (Hrvatske vode – Croatian Waters, September 2025)
15. Tedeschi, S.: Water protection
16. German Guidelines for the Design of Activated Sludge Plants (DWA-A 131)

Additional reading:

1. Herceg, N., Stanić-Koštroman, S., Šileg, M.: Čovjek i okoliš
2. van Loosdrecht, M. C. M., Nielsen, P. H., Lopez-Vazquez, C. M., Brdjanovic, D.: Eksperimentalne metode u obradi otpadnih voda (IWA Publishing, hrvatsko izdanje, 2016.)

SEISMIC RESISTANCE OF HYDRAULIC ENGINEERING STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Learning outcomes:

- Acquisition of theoretical and practical knowledge on the structural design of hydraulic structures and their structural analysis, with particular emphasis on their seismic resistance.

Learning outcomes:

- to understand the basic principles and key issues of seismic design of hydraulic structures,
- to analyse seismic actions on hydraulic structures,
- to calculate structural elements and systems of hydraulic structures,
- to apply design principles in the structural analysis of elements and systems of hydraulic structures.

Course content (by course schedule):

- Lectures:
  1. Hydraulic structures after the Zagreb and Petrinja earthquakes
  2. Structural characteristics of hydraulic structures with emphasis on seismic resistance
  3. Lock structures
  4. Drainage system structures
  5. Fundamentals of seismic action and structural analysis of hydraulic structures
  6. Concrete structures of hydraulic engineering works
  7. Retaining structures of hydraulic engineering works
  8. Foundations of hydraulic structures
  9. Quay wall structures
  10. Pumping station structures
  11. Culvert structures
  12. Water towers and reservoirs
  13. Floating structures
  14. Practical case studies
  15. Practical case studies
- Exercises:
  1. Introduction to the exercise programme. Assignment of the Lock task
  2. Development of the Lock task
  3. Review and submission of the Lock task
  4. Assignment and development of the Shaft task
  5. Review and submission of the Shaft task
  6. Assignment and development of the Retaining wall task
  7. Review and submission of the Retaining wall task
  8. Midterm exam 1
  9. Assignment and development of the Quay wall task
  10. Review and submission of the Quay wall task
  11. Assignment and development of the Diaphragm wall task
  12. Review and submission of the Diaphragm wall task
  13. Assignment and development of the Pile task
  14. Review and submission of the Pile task

15. Midterm exam 2

Student Evaluation - Continuous assessment:

- Design
- In-class activity
- Midterm exams
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Design
- In-class activity
- Written exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:
Lectures and exercises offprints

1. Standards of the HRN EN 199i series; i = 0, 1, 2, 7, 8
2. Petar Stojić, Hydraulic Structures I, II and III, 1997.
3. Sorić, Z.; Kišiček, T., Concrete Structures 1, Faculty of Civil Engineering, Zagreb, 2014.
4. Radić, J., Concrete Structures – Solved Examples, Zagreb, 2006.

Regulatory framework:

5. Building Act (Official Gazette Nos. 53/13, 20/17, 39/19, 125/19, 145/24)
6. Technical Regulation for Building Structures (Official Gazette Nos. 17/17, 75/20, 7/22)
7. Maritime Domain and Seaports Act (Official Gazette No. 83/2023)
8. Water Act (Official Gazette Nos. 66/19, 84/21, 47/23)

CLIMATE CHANGE AND STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- Acquisition of theoretical knowledge about climate change and its effects on loads, mechanical resistance, stability, and durability of structures.
- Acquisition of theoretical knowledge of current regulations, the integration of climate change into the second generation of Eurocodes, and projections of climate scenarios relevant to the design and maintenance of structures.

- Development of the ability to analyse extreme and progressive climatic influences on structures and to recognise multi-hazard environments.
- Acquisition of theoretical and practical knowledge on the application of methods for the service life prediction and carbon footprint calculation of structures.
- Acquisition of theoretical knowledge about methods of adaptation to climate change during the design, construction, and maintenance of structures.
- Acquisition of theoretical and practical knowledge about climate change risk management.
- Acquisition of theoretical and practical knowledge of inspections and diagnostics of structures before and after extreme events caused by climate change.
- Acquisition of theoretical and practical knowledge of climate-resilient structures based on analyses of existing examples of failure and successful adaptations to climate change.

Learning outcomes:

- Explain the basics of climate change and its impact on the design, construction, and maintenance of structures.
- Recognise and analyse extreme and long-term climate impacts and assess their consequences for the safety, durability, and stability of structures.
- Apply methods of risk assessment, service life prediction, degradation evaluation, and assessment of changes in load-bearing capacity of structures due to climate change.
- Perform basic calculations of the impact of climate scenarios on the service life and performance of structures.
- Propose measures to reduce greenhouse gas emissions and adaptation measures to climate change through the design, construction, and maintenance of structures.
- Assess the condition of structures after extreme events.
- Critically analyse case studies of structural failures related to climate impacts and formulate conclusions for the improvement of new and existing structures.
- Apply the principles of design for future climate and multi-hazard environments, and sustainable maintenance of structures, to a given engineering problem.

Course content (by course schedule):

- Lectures
  1. Introduction (climate change and its global context; basic terminology; international and national regulations; legal obligations of designers; climate models and scenarios; expected trends until 2070)
  2. Impact of climate change on structures: extreme weather conditions (analysis of the increase in frequency, intensity and spatial distribution: storms, heat waves, extreme precipitation, floods, wind, fires; the impact of these phenomena on structures)
  3. Impact of climate change on structures: progressive changes (increase in temperature and relative humidity, sea level rise, prolonged drought, increase of freeze-thaw cycles.

4. Impact of climate change on mechanical resistance and stability of structures (climate change in the 2nd generation of Eurocode, inclusion of climate change in loads and combinations of actions on structures; changes in the reliability of structures.)
5. Impact of climate change on the service life of structures – part 1 (climatic conditions as a factor of accelerated aging of structures; degradation of concrete, steel, timber and composite structures; models for simulation of degradation mechanisms; calculation of the service life of structures; life cycle assessment models)
6. Impact of climate change on the service life of structures – part 2 (climatic conditions as a factor of accelerated aging of structures; degradation of concrete, steel, timber and composite structures; models for simulation of degradation mechanisms; calculation of the service life of structures; life cycle assessment models)
7. Structures in a multi-hazard environment (combination of two or more accidental loads/extreme events, urgent measures; failure mechanisms; acceleration of degradation mechanisms; numerical simulations; impact on the rescue of people and assets)
8. Diagnostics and methods of monitoring structures in a changing climate (inspections after extreme climate events, structural health monitoring (SHM) for climate-resilient structures; digital twins; analysis of performance in changing climate conditions)
9. Measures to reduce greenhouse gases during design, construction and maintenance of structures (Calculation of the carbon footprint of structures; Sustainable design strategies; the choice of materials and construction systems with a low carbon footprint; circular economy in construction; LCA)
10. Climate change adaptation measures during design of structures (climate-informed design; multi-hazard approach in numerical analysis; selection of a structural system resistant to extreme conditions e.g. frames with higher ductility, systems with redundancy; designing for robustness and tolerance to unexpected events: robustness design, fail-safe concept and progressive collapse resistance, climate-resistant materials and details; role of structural design: aerodynamic shaping to reduce wind activity, raising the level of the building due to floods, introducing controlled failure zones; integration of security elements)
11. Climate change adaptation measures during the construction of structures (execution in accordance with climate-resistant design solutions; installation of materials and systems more resilient to future climatic conditions; performance technologies adapted to extreme conditions; integration of digital and supervision systems in the construction phase)
12. Climate change adaptation measures during maintenance of structures (increasing quality of details crucial for protection of structure; proactive and preventive maintenance; maintenance of vulnerable zones; strengthening, rehabilitation and reconstruction)
13. Assessment and management of risks on structures related to climate change (methodologies for identifying and quantifying climate risks, risk management)

14. Case studies of failure of structures due to environmental and climate action (analysis of case studies of collapse and damage related to climate impacts; lessons learned)
15. Case studies of climate-adapted structures (examples of good practices – successful structures and infrastructure designed for future climate conditions; innovative solutions and global trends; modern technologies in construction for climate resilience – advanced materials, smart constructions, digital technologies, automation and robotization in structural engineering.)

- Exercises:

1. Construction exercises - Introduction
   Introduction to the topic of the course and the way of performing exercises through student seminars/projects /engineering studies in small groups. Consideration and selection of seminar topics and case studies:
   Group A: Impact of climate change on the service life of the selected structure
   Group B: Climate change risk assessment on the example of a new or existing structure
2. Construction exercises – assignment development
   Group A: models for predicting the service life of structures
   Group B: Climate change risk assessment on the example of a new or existing structure
3. Construction exercises – assignment development
   Group A: analysis of the impact on the structure, analysis of the conducted investigation works
   Group B: identification of risks
4. Construction exercises
   Group A: Preparation for the 1st midterm exam
   Group B: Preparation for the 1st midterm exam
5. Construction exercises – assignment development
   Group A: Calibration of the model
   Group B: Scenario description for defined risks related to climate change
6. Construction exercises
   Group A: 1st midterm exam (lectures 1-5)
   Group B: 1st midterm exam (lectures 1-5)
7. Construction exercises – assignment development
   Group A: Analysis of climate change scenarios
   Group B: Risk comparison
8. Construction exercises – assignment development
   Group A: Calculation of the service life of the structure for the optimistic scenario (RCP2.5 or RCP4.5)
   Group B: Risk assessment
9. Construction exercises – assignment development
   Group A: Calculation of the service life of the structure for the pessimistic scenario (RCP6.5 or RCP8.5)
   Group B: Climate change adaptation measures

10. Construction exercises – assignment development
    Group A: Analysis of the results
    Group B: Selection of climate change adaptation methods
11. Construction exercises
    Seminar presentations. Discussion: questions and comments from teachers and other students.
12. Construction exercises
    Seminar presentations. Discussion: questions and comments from teachers and other students.
13. Construction exercises
    Preparation for the 2nd midterm exam. Seminar presentations. Discussion: questions and comments from teachers and other students.
14. Construction exercises
    2nd midterm exam (lecture 6-13).
15. Construction exercises
    Submission of the seminar with oral examination.

Student Evaluation - Continuous assessment:

- In-class activity
- Seminar paper
- Midterm exams
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Seminar paper
- Written exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Kušter Marić: Klimatske promjene i konstrukcije, Lectures and offprints for exercises

Additional reading:

2. Climate Adaptation Engineering Risks and Economics for Infrastructure Decision-Making (2019). E. Bastidas-Arteaga & M. G. Stewar. Elsevier. 387 pp. DOI 10.1016/C2017-0-00942-4
3. Climate Change Adaptation Strategy in the Republic of Croatia for the Period up to 2040 with a view to 2070. Zagreb: Official Gazette, OG 46/2020

STRUCTURAL ROBUSTNESS

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- Acquisition of theoretical and practical knowledge regarding the robustness of structures.
- Acquisition of theoretical knowledge on the ability to identify and analyse extraordinary loads and damage scenarios.
- Acquisition of theoretical and practical knowledge for the analysis of local element failure and disproportionate (progressive) collapse.
- Acquisition of theoretical and practical knowledge for the assessment and improvement of robustness in both new and existing structures

Learning outcomes:

- identify key factors related to the robustness of structures
- identify accidental actions and design situations relevant to robustness
- analyse local member failure and the potential for disproportionate collapse
- apply alternative load path methods and the tie force method
- assess the influence of stabilisation and structural system redundancy on robustness
- propose measures to enhance structural robustness

Course content (by course schedule):

- Lectures:

1. Introduction to structural robustness (2 hours)
2. Hazards and damage scenarios (2 hours)
3. Robustness approach according to standards (2 hours)
4. Robustness of structures made of different materials (2 hours)
5. Simplified analysis of progressive collapse (2 hours)
6. Analysis of structures exposed to multiple hazards (2 hours)
7. Direct design methods (2 hours)
8. Indirect design methods (2 hours)
9. Nonlinear behaviour and ductility (2 hours)
10. Existing structures and robustness (2 hours)
11. Strategies for improving structural robustness (2 hours)
12. Assessment of the consequences of member failure (2 hours)
13. Methods for assessing collapse consequences (2 hours)
14. Robustness in seismic design (2 hours)
15. Robustness in fire design (2 hours)

- Exercises:

1. Introduction of the structure and load-bearing system (1 hour)
2. Classification of the structure according to consequence classes (1 hour)
3. Identification of potential causes of local damage (1 hour)
4. Definition of member removal scenarios (1 hour)
5. Modelling of the undamaged structure (1 hour)
6. Element removal: basic analysis of alternative load path (2 hours)
7. Influence of ductility and redistribution (1 hour)
8. Extended damage scenarios (1 hour)
9. Assessment of collapse consequences (1 hour)
10. Identification of critical members (1 hour)
11. Proposal of measures to improve robustness (2 hours)
12. Critical discussion and submission of the project (2 hours)

Student Evaluation - Examination without Continuous Assessment:

- Design
- Written exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Guidance on the design for structural robustness https://publications.jrc.ec.europa.eu/repository/handle/JRC138689
2. Eurocode 0: Basis of structural design
3. Eurocode 1: Actions on structures

Additional reading:

1. Haynes, R. et al: Structural robustness and disproportionate collapse in buildings, 9781906335670, 47-58 Bastwick Street, London, IStructE, UK, 2023

PRINCIPLES OF BUILDING RENOVATION

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- The aim of the course is to provide students with basic knowledge of the methodology of rehabilitation, reconstruction and complete renovation of buildings as part of regular maintenance, improvement of building properties or after natural disasters and

catastrophes. The course also emphasizes the restoration and protection of architectural heritage.

Learning outcomes:

Upon completion of the course, students will be able to:

- independently understand the basic concepts and principles of building renovation,
- understand the complexity of the problems of protecting architectural heritage.
- understand the principles of sustainability,
- participate independently in design as a team member,
- identify and present problems in renovation, and propose solutions,
- recognize various engineering risks in proposed building renovation solutions.

Course content (by course schedule):

1. Introduction to building renovation.
   Adaptation, renovation, reconstruction or complete renovation of buildings.
2. Architectural heritage
   Basic knowledge about the protection of architectural heritage, with special emphasis on contemporary global and Croatian examples of architectural heritage restoration.
3. Documenting buildings without status and those with cultural property status
   Building documentation - development, methods, examples. Standardization of documentation, documentation as part of an information system.
4. Analysis and valuation of the current (existing) situation
   Determining the basic characteristics of a building.
5. Principles and methodology of restoration
   Principles of building renovation (without the status of cultural property).
6. Principles and methodology of architectural heritage restoration
   History, theory, doctrines and practice of architectural heritage protection.
7. Revitalization and restoration of architectural heritage
   Revitalization typology, definitions, examples.
8. Models and principles of renovation of structural parts of buildings
   Traditional and modern renovation solutions, modern materials.
9. Models and principles of renovation of non-structural parts of buildings
   Traditional and modern renovation solutions, modern materials.
10. Fire protection
    Active and passive protection measures and their impact on the building structure.
11. Energy recovery
    Principles and differences of renovation of buildings without status and those with the status of cultural property.
12. Building infrastructure Improvement I
    Infrastructure systems, sustainable infrastructure, smart buildings
13. Building infrastructure Improvement II

Interrelationships of routes and positions of various building infrastructure systems

14. Sustainability principles
    Principles of sustainability in building renovation.
15. Management and maintenance of architectural heritage
    Management and maintenance of architectural heritage; examples in the world and Croatia.

Student Evaluation - Continuous assessment:

- Seminar paper
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Guidelines for the Energy Renovation of Buildings with Cultural Heritage Status Ministry of Culture and Media Ministry of Physical Planning, Construction and State Assets (2023.) https://min-kulture.gov.hr/UserDocsImages/dokumenti/_Smjernice%20za%20energetsku%20obnovu%20zgrada%20sa%20statusom%20kulturnog%20dobra.pdf
2. Manual for Seismic Retrofitting of the Existing Masonry Buildings (2020.) https://www.arhitekt.hr/files/radovi/privitak/347/ZA%20DIGITALNU%20OBJAVU%20_%20202007 07%20_%20PRIRU%C4%8CNIK0.pdf
3. Urgent Earthquake Reconstruction Programme – UERO (2020.) https://www.hkig.hr/Strucno-usavrsavanje/Strucna-izdanja-Komore/Izdanja/Prirucnik-Urgentni-program-potresne-obnove-UPPO/18
4. Marasović J., Metodologija obrade graditeljskog nasljeđa, Split- Krug, Zagreb – Arhitektonski fakultet (2007.) https://www.academia.edu/24390819/Metodologija_obrade_graditeljskog_naslije%C4%91a
5. Antolović, J. Zaštita i očuvanje kulturnih dobara, Zagreb : Hadrian, 2009.

Additional reading:

1. Peulić, Đ.: Konstruktivni elementi zgrada I. i II., Tehnička knjiga, Zagreb, 1980. ili Peulić, Đ.: Konstruktivni elementi zgrada, Croatia knjiga, Zagreb, 2002.
2. Neufert, P.: Elementi arhitektonskog projektiranja, Golden marketing, Zagreb, 2002.

REGULATION IN SUSTAINABLE AND CIRCULAR CONSTRUCTION

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- The aim of the course is to introduce students to the regulatory framework of sustainable and circular construction and to train them to understand and apply European and national regulations, strategies and technical standards in the planning, design, construction, renovation and management of buildings. Special emphasis is placed on the role of regulations in encouraging circular models, public and green procurement, extending the lifespan of buildings and reducing environmental burdens throughout the life cycle of the building.

Learning outcomes:

- Explain the basic principles of sustainable and circular construction in the context of European and national regulations.
- Analyse the impact of key EU directives, regulations and policies (e.g. EU Taxonomy, EPBD, CPR, CSDDD) on the planning, design, construction and renovation of buildings.
- Apply regulatory requirements and instruments when making technical and organizational decisions in construction projects.
- Assess the impact of the regulatory framework on the choice of materials, energy systems and circular solutions in construction.
- Analyse the role of public and green procurement in the implementation of sustainable and circular construction.
- Prepare an analysis or proposal of a regulatory-compliant solution for a specific construction or infrastructure project.

Course content (by course schedule):

- Lectures:

1. Introduction to Sustainable and Circular Construction. Conceptual framework, sustainability goals, circular economy in the built environment, global and EU context.
2. European policies for sustainable and circular construction. The European Green Deal, the Circular Economy Action Plan, "Fit for 55", the role of construction.
3. Regulatory framework of the European Union. Directives, regulations and strategies relevant to construction (EPBD, CPR, EU Taxonomy, CSDDD).
4. National Regulatory Framework and Transposition of EU Regulations. Transposition of EU directives, national regulations, technical regulations and regulations.
5. Technical Standards and Standardization in Construction. EN and ISO standards, the role of standardization in sustainable and circular solutions; voluntary schemes and

certification frameworks (e.g. LEED, BREEAM, DGNB, Level(s)) as a complement to the regulatory framework

6. Regulation and Management of Material Flows. Secondary raw materials, waste in construction, reuse of construction products.
7. Circular Models in Construction and Regulatory Requirements. Design for disassembly, service life extension, adaptive reuse.
8. Regulatory requirements throughout the life cycle of a building. Planning, design, construction, use, renovation and removal of buildings.
9. Regulation and Life Cycle Analysis (LCA/LCC). LCA/LCC to support regulatory and policy decisions.
10. Energy regulation and decarbonization of buildings. Energy requirements, nZEB, decarbonization goals, climate policies.
11. Public and Green Procurement in Sustainable and Circular Construction. Legal framework, sustainability criteria, practical examples; the role of certification systems (LEED, BREEAM, DGNB, Level(s)) as reference tools in public and green procurement.
12. Regulatory barriers, risks and incentives. Administrative barriers, market and institutional incentives, innovation.
13. Change management and institutional coordination. Multi-level governance, role of public institutions, stakeholder coordination.
14. International Examples and Comparative Analyses. Case studies from the EU and the international environment.
15. Development of a regulatory-compliant solution. Integration of regulations, policies and circular principles on a specific project.

Student Evaluation - Continuous assessment:

- In-class activity
- Seminar paper
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Seminar paper
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Kibert, C. J. (2022). Sustainable construction: Green building design and delivery (5th ed.). John Wiley & Sons.

2. Bragança, L., Cvetkovska, M., Ungureanu, V., Tsikaloudaki, K., Marchesi, M., Andabaka, A., Borg, R. P., & Cervantes, C. (Eds.). (2026). Shaping circular transitions in the built environment: From barriers to enablers (Springer Tracts in Civil Engineering). https://doi.org/10.1007/978-3-032-02834-1 Springer.
3. Iyer-Raniga, U. (2024). Circular practices in buildings and construction to achieve the Sustainable Development Goals. Edward Elgar Publishing. https://doi.org/10.4337/9781035338870
4. Adams, K., & Hobbs, G. (2017). Material resource efficiency in construction: Supporting a circular economy. IHS BRE Press.
5. International Organization for Standardization. (2019). ISO 15392:2019 Sustainability in buildings and civil engineering works – General principles. ISO.

Additional reading:

1. The Routledge Handbook of Catalysts for a Sustainable Circular Economy. (2023). Ujedinjeno Kraljevstvo: Taylor & Francis.

USE OF TIMBER AND BIO-BASED MATERIJALS IN CONSTRUCTION AND REHABILITATION

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- To acquire theoretical knowledge on sustainable construction using timber and bio-based materials in the context of basic requirements for structures according to EN 1990.
- To acquire theoretical knowledge of the technical regulations for the design of earthquake-resistant timber structures and structures incorporating bio-based materials.
- To acquire theoretical and practical knowledge of the seismic behaviour of timber structures (ductility, behaviour factor, structural response, etc.).
- To understand the specific aspects of seismic design of timber structures, with an emphasis on ductility and energy dissipation.
- To acquire theoretical and practical knowledge of the seismic behaviour of different types of timber structural systems.
- To acquire theoretical and practical knowledge of modern seismic protection systems for timber structures (damping, base isolation, anti-uplift systems, etc.).
- To acquire theoretical and practical knowledge of principles for condition assessment of existing timber structures and their rehabilitation.
- To acquire theoretical and practical knowledge of reconstruction, extension, vertical addition and rehabilitation of existing structures using timber and hybrid systems.
- To develop the ability for conceptual design of construction and rehabilitation using CLT, LVL and other massive timber systems, as well as systems with bio-based materials.
- To develop the ability for a synergistic approach to design in cooperation with architects.

Learning outcomes:

- Apply contemporary standards and guidelines for the design of timber structures and structures using bio-based materials.
- Apply knowledge in the sustainability assessment of timber and bio-based construction in relation to basic structural requirements.
- Apply knowledge of the seismic behaviour of light-frame, panel and massive timber structural systems in design.
- Apply knowledge of the behaviour of structures incorporating bio-based materials in design.
- Apply acquired knowledge in the conceptual design and calculation of connections with the required level of ductility in timber structures.
- Apply knowledge in the selection and design of appropriate seismic protection systems for timber structures.
- Apply acquired knowledge in the analysis and assessment of existing timber structures.
- Apply acquired knowledge creatively in the design of reconstruction, extension, vertical addition and rehabilitation of existing structures using timber and hybrid systems.
- Apply knowledge of timber and bio-based construction in interdisciplinary design collaboration.

Course content (by course schedule):

- Lectures

1. Sustainability of timber and bio-based construction in the context of EN 1990 (2 Seismic behaviour of light-frame and panel systems and systems with bio-based materials (2 h) Seismic behaviour of massive timber frame systems (2 h)
2. Seismic behaviour of CLT and LVL systems (prEN 1995-1-1) (4 h)
3. Seismic behaviour of massive linear timber structures (2 h)
4. Seismic protection of timber structures – supplemental damping (2 h)
5. Seismic protection of timber structures – base isolation (2 h)
6. Seismic protection using anti-uplift systems for timber elements (2 h)
7. Design of timber connections with the required level of ductility (4 h)
8. Condition assessment of existing structures and criteria for rehabilitation using timber systems (2 h)
9. Seismic rehabilitation of timber and hybrid floor systems (timber–concrete, timber–LVL, timber–CLT) (2 h)
10. Vertical extensions and horizontal expansions of existing structures using CLT systems (2 h)
11. Site visit (2 h)

- Exercises:

1. Introduction to the design project: overview of timber structural systems and selection of a reference system (2 h)

2. Conceptual design, analysis and numerical modelling of light-frame and panel systems and systems with bio-based materials under seismic action (4 h)
3. Conceptual design, analysis and numerical modelling of timber frame systems under seismic action (4 h)
4. Conceptual design, analysis and numerical modelling of massive panel (CLT and LVL) timber systems under seismic action (4 h)
5. Design of timber connections in seismic conditions (4 h)
6. Evaluation and application of seismic protection systems for timber structures (2 h)
7. Conceptual solutions for reconstruction and rehabilitation of existing structures using timber and hybrid systems (8 h)
8. Presentation and defence of the design project (2 h)

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Seminar paper
- Design
- Written exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. HRN EN 1990: Basis of structural design
2. HRN EN 1995-1-1: Eurocode 5 -- Design of timber structures -- Part 1-1: General rules and rules for buildings
3. HRN EN 1998-1 i HRN EN 1998-3: Eurocode 8: Design of structures for earthquake resistance
4. Course materials prepared by the teacher (lecture notes, presentations, catalogues and design examples)
5. Crocetti, R.; Johansson, M.; Johansson, H.; Kliger, R.; Martensson, A.; Norlin, B.; Pousette, A.; Thelandersson, S.: Design of timber structures I-III; Swedish Wood, Stockholm, 2022.
6. Borgström, E.; Fröbel, J.: The CLT Handbook; Swedish Wood, Stockholm, 2019.
7. The Seismic Behaviour of buildings Erected on Solid Timber Construction; Institute of Timber Engineering and Wood Technology; 2012.
8. Performance of Bio-based Building Materials; Woodhead Publishing; 2017.
9. Bio-Based Building Materials; Springer, 2023.
10. Branco, J., Dietsch, P., Tannert, T.: Reinforcement of Timber Elements in Existing Structures; Springer, 2021.

Additional reading:

1. Group of authors: Seizmičke obnove i rekonstrukcije; Hrvatski centar za potresno inženjerstvo – Interventna služba, Zagreb, 2025.
2. Technical regulation for building constructions (OG 75/20 i 7/22)

3. Blass, H. J.; Sandhaas, C.: Ingenieurholzbau - Grundlagen der Memessung; KIT Scientific Publishing, Karlsruhe, 2016.
4. Stepinac, M.; Šušteršič, I.; Gavrić, I.; Rajčić, V. Seismic Design of Timber Buildings: Highlighted Challenges and Future Trends. Appl. Sci. 2020, 10, 1380. https://doi.org/10.3390/app10041380
5. Reinforcement of Timber Structures: Standardization Towards a New Section for EC 5; Springer, 2021.

VIBRATIONS IN TRANSPORTATION ENGINEERING

See Chapter Specialisation Transportation Engineering.

ASPHALT PAVEMENT MAINTENANCE AND PRESERVATION

See Chapter Specialisation Transportation Engineering.

HERITAGE STRCTURES

Credits (ECTS): 3.0

Hours (total per semester):
- Lectures: 30
- Exercises: 0

Course objectives:
- Obtain theoretical knowledge on the classification and systematization of built cultural heritage structures with respect to their historical, typological, and structural characteristics.
- Obtain theoretical knowledge on the specific structural elements in built heritage structures (domes, vaults, towers, and aggregate buildings).
- Gaining proficiency to identify failure mechanisms and critical structural elements of historic buildings that influence their seismic resistance.
- Obtain theoretical knowledge and practical skills in modern technologies for the investigation and documentation of build cultural heritage — including unmanned aerial vehicles (UAVs), laser scanning, photogrammetry, and LiDAR systems.
- Obtain theoretical knowledge and practical skills in damage assessment and assessment of the usability of historic buildings and aggregates

Enrolment requirements (prerequisite):
- teacher's signature for the course Dynamics of Structures with an Introduction to Earthquake Engineering,
- teacher's signature for the course Seismic design of concrete and masonry buildings

Learning outcomes:

- Classify and systematize built cultural heritage structures according to their historical, typological, and structural characteristics.
- Identify failure mechanisms of specific structural elements in historic buildings.
- Identify critical elements of historic structures that influence their seismic resistance, including plan and vertical irregularities, material degradation, and accumulated damage.
- Apply preservation principles in the protection of built cultural heritage structures with regard to the level of legal protection assigned to an individual building.
- Classify and interpret damage levels of structural elements in historic buildings based on various data sources (aerial imagery, laser scanning, and photogrammetric models).
- Operate a laser scanner for the proper documentation of architectural and structural heritage features.
- Document and interpret architectural and structural features of a building using digital models and spatial data.

Course content (by course schedule):

- Lectures:

1. Introduction to Built Cultural Heritage Structures: definition and significance of built cultural heritage; overview of the historical development of construction; the role of the civil engineer in the protection of historic buildings; international and national guidelines for the protection of historic structures (ICOMOS, ISCARSAH) (3h)
2. Historic Buildings and Traditional Construction Techniques: building techniques, historic construction materials, typology, and structural systems (3h)
3. Structural and Architectural Elements of Historic Buildings: load-bearing walls, columns, arches, vaults and domes, floor structures, towers, etc. (3h)
4. Damage and Failure Mechanisms of Specific Structural Elements in Built Heritage Structures: types of damage to structural elements and material degradation; local and global failure mechanisms; typical failure mechanisms of historic buildings under seismic action; the influence of pre-existing damage on assessment of structural behaviour; damage level classification (3h)
5. Contemporary Methods for Documentation and Visualization of Historic Buildings: visual inspections and engineering judgment; application of aerial imagery, photogrammetry, and laser scanning; integration of multiple data sources in condition assessment and the development of digital models of historic structures (3h)
6. Fundamental Principles of Conservation Practice: preservation of authenticity, minimal intervention, reversibility, material compatibility, and a holistic approach (3h)
7. Methods of Repair and Reconstruction of Historic Buildings: traditional and modern strengthening techniques; examples of good and poor practice; harmonizing structural requirements with conservation principles (3h)
8. Religious Heritage, Towers, and Special-Purpose Structures (3h)
9. Practice-Based Case Studies (3h)
10. Aggregate buildings (3h)

Student Evaluation - Continuous assessment:

- Seminar paper
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. EARTHQUAKE ENGINEERING - Retrofitting of Masonry Buildings. Uroš, M., Todorić, M., Crnogorac, M., Atalić, J., Šavor Novak, M., & Lakušić, S. (Eds.). Zagreb: University of Zagreb, Faculty of Civil Engineering. ISBN: 978-953-8168-43-7. 2021.
2. Seismic Retrofit and Structural Reconstruction, Pojatina, J. (ed.). Zagreb: Croatian Centre for Earthquake Engineering – Intervention Service. ISBN: 9789534667705, 2025.

TESTING AND ASSESSMENT OF EXISTING STRUCTURES

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- To acquire theoretical and practical knowledge of methods for determining the mechanical properties of construction materials used in existing structures (concrete, masonry, timber, and steel).
- To acquire theoretical and practical knowledge of static and dynamic methods for structural testing.
- To acquire practical knowledge in developing initial and updated numerical models of civil engineering structures based on investigative works conducted on structures.

Learning outcomes:

- Classify basic measurement equipment used in the field of structural testing.
- Distinguish basic methods for determining the mechanical properties of construction materials in existing structures.
- Propose methods for static and dynamic testing of structures.
- Analyse and interpret the results of experimentally determined parameters.

- Develop and calibrate numerical models of structures using test results.

Course content (by course schedule):

- Lectures:

1. Regulations in the field of structural testing.
2. Metrology: historical overview, measurement errors, measurement uncertainty, and measurement traceability.
3. Measurement techniques and measuring instruments.
4. Measurement techniques and measuring instruments.
5. Methods for determining the mechanical properties of materials (concrete, masonry, timber, steel).
6. Methods for determining the mechanical properties of materials (concrete, masonry, timber, steel).
7. Standardized methods in the testing of construction materials and structures.
8. Application of static testing methods and performance of controlled tests on structural elements, structural models, and real structures.
9. Introduction to dynamic testing of structures.
10. Experimental determination of basic dynamic parameters of structures (natural frequencies, mode shapes, damping ratios) using classical experimental modal analysis and operational modal analysis.
11. Experimental determination of basic dynamic parameters of structures (natural frequencies, mode shapes, damping ratios) using classical experimental modal analysis and operational modal analysis.
12. Introduction to the basic structural systems and typology of existing masonry and reinforced concrete structures.
13. Introduction to the issues of correlating results from experimental investigations on structures with results obtained through numerical modelling of structures.
14. Development of initial numerical models of existing structures based on investigative works and obtained input data.
15. Updating and improving numerical models of structures based on test results.

Student Evaluation - Continuous assessment:

- Seminar paper
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Damjanović, D. : Ispitivanje konstrukcija, Skripta, Sveučilište u Zagrebu, Građevinski fakultet, 2017.
2. Aničić, Dražen: Ispitivanje konstrukcija, Građevinski fakultet, Osijek, 2002.
3. Obnova zgrada nakon potresa, ur. Uroš, M.; Todorić, M.; Crnogorac, M.; Atalić, J.; Šavor Novak, M.; Lakušić, S. Sveučilište u Zagrebu, 2021.
4. Crnogorac, M.; Todorić, M.; Uroš, M.; Atalić, J.: Urgentni program potresne obnove: Građevinska tehnička rješenja, Građevinski fakultet Sveučilišta u Zagrebu, Hrvatska komora inženjera građevinarstva, 2020.
5. M. Rak, I. Duvnjak, D. Damjanović: Teorija elastičnosti i plastičnosti s metodama rješavanja zadaća, Zagreb, 2020.
6. J. Krolo, D. Šimić: Mehanika materijala, Zagreb, 2011.

SOIL DYNAMICS AND GEOTEHNICAL EARTQUAKE ENGINEERING

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- gaining theoretical knowledge on the dynamic behaviour of soils and geotechnical structures under seismic and other dynamic loading
- gaining theoretical and practical knowledge of geotechnical seismic analysis and design methods, including pseudostatic, linear, equivalent-linear, and nonlinear approaches

Learning outcomes:

- explain the origin of earthquakes, seismic hazard, and the basic parameters of ground motion relevant to geotechnical analyses
- explain the propagation of seismic waves in soil and half-space, including amplification, deamplification, and resonance effects
- understand and analyse stress–strain relationships in cyclically loaded soils, including pore pressure development and damping
- perform calculations of dynamically loaded shallow and deep foundations, retaining structures, slopes, and earth structures using pseudostatic and nonlinear methods
- assess the liquefaction potential of water-saturated soils using empirical, analytical, and numerical approaches
- apply deterministic and probabilistic approaches to seismic analysis of soils and geotechnical structures
- use specialised software for the analysis of soil response and geotechnical structures
- apply applicable standards and codes in geotechnical seismic design calculations

Course content (by course schedule):

- Lectures

1. Introduction to geotechnical earthquake engineering, including an overview of seismic hazard, causes and mechanisms of earthquake generation, intensity measures, and characteristics of seismic events and their effects on geotechnical structures. [2]
2. Overview of dynamic analyses, including linear, equivalent-linear, and nonlinear approaches.
3. Theoretical foundations of wave propagation in soils and half-spaces, wave types and equations, and their role in geotechnical structure behaviour, including amplification and deamplification phenomena.
4. Characteristics of ground motion, such as PGA, PGV, PGD, spectral measures, dominant period, cyclic deformation, strong motion duration, and frequency content, including an introduction to GMPE models and parameter estimation.
5. Mechanical properties of soils and rocks under cyclic loading, including hysteresis, stiffness, strength, pore pressure development, and damping, and their relation to analysis methods. Laboratory and field-testing methods and their interpretation are also covered. [3]
6. Overview of deterministic and probabilistic analyses, PSHA procedure, pseudostatic analyses, 1D site response analyses in linear, equivalent-linear, and nonlinear frameworks with deconvolution procedures, and overview of 2D and 3D analyses using numerical and approximate methods. [3]
7. Constitutive models for nonlinear numerical analyses and general behaviour of walls, slopes, and deep foundations during earthquakes using pseudostatic (classical pseudostatic and pushover analyses) and nonlinear approaches. [2]
8. Liquefaction, laboratory and field simulation of liquefaction, assessment methods for liquefaction potential, and mitigation techniques.
9. Final part – legal requirements and applicable standards, including HRN EN 1998 series and their synergy with HRN EN 1997 series.

- Exercises

1. Processing of earthquake records and application of basic soil dynamics equations, including motion and wave equations, and an overview of attenuation relations. Analysis of ground motion characteristics using computational software, including determination of duration, PGA, PGV, PGD, frequency distribution, and intensity. Preparation and interpretation of spectral acceleration diagrams, and behaviour of damped and undamped oscillators.
2. Wave analysis in elastic media and computation of transfer functions using software, application to real records, and assessment of amplification, deamplification, and deconvolution in equivalent-linear and nonlinear approaches. [2]

3. Determination of the fundamental vibration period of soils and geotechnical structures.
4. Pseudostatic design of retaining walls, slope stability analysis using pseudostatic and spectral pseudostatic methods, including the Newmark approach. Pushover analysis of laterally loaded piles. [3]
5. Selection of appropriate earthquake records from databases based on target spectrum, magnitude, and distance characteristics.
6. Numerical estimation of seismic amplification and soil response, determination of fundamental periods in 2D analyses, and preparation of numerical models by defining geometry, boundary conditions, input motion, and numerical parameters. [3]
7. Liquefaction assessment using cyclic stress methods and nonlinear numerical models, including selection of appropriate constitutive models. [2]
8. Earthquake simulations on shake tables (examples and exercises) and in geotechnical centrifuge experiments (examples).
9. Fundamentals of probabilistic approaches, including PSHA and use of tools such as OpenQuake, as well as advanced structural response analyses under strong earthquakes, including IDA, CA, MSA, and development of fragility functions.

Student Evaluation - Continuous assessment:

- In-class activity
- Practical work
- Midterm exam
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Practical work
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Kramer, S. L., Stewart, J.P.: Geotechnical Earthquake Engineering. CRC Press, 2024.
2. Teaching Materials: lectures – PowerPoint presentations

Additional reading:

1. Das, B. M., Ramana, G.V.: Principles of Soil Dynamics. Cengage Learning, 2011.

SUSTAINABLE GEOENGINEERING

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- gaining specific knowledge of geotechnical aspects of environmental protection and circular waste management in geotechnics
- gaining theoretical and practical knowledge on waste disposal and landfills
- gaining theoretical and practical knowledge on geo-energy structures and thermal behaviour of soils
- gaining theoretical and practical knowledge on climate triggers (extreme rainfall, floods, extreme temperatures) and their impact on soils and geotechnical structures

Learning outcomes:

- explain the relationships between geotechnics and the environment, including the impact of geotechnical projects on the environment, resource use, and principles of circular geotechnics
- define the concept of waste and modern waste management approaches, including the civil and geotechnical aspects of contemporary landfills
- identify and apply relevant mechanical and physico-chemical properties of waste and alternative materials (recycled or innovative materials) in geotechnical analyses
- analyse the stability of landfills and associated geotechnical structures under static and seismic conditions, including interaction with geosynthetics
- explain and numerically model contaminant transport through soil and rock, and analyse and optimise remediation measures
- analyse and design geo-energy structures, taking into account the thermo-mechanical behaviour of soils and long-term cyclic thermal loading
- analyse the impact of climate change and extreme climatic events on soil behaviour and the safety of geotechnical structures using analytical and numerical methods

Course content (by course schedule):

- Lectures

1. Impact of construction on the environment – life cycle of buildings, carbon footprint of geotechnical projects, "green" approaches in geotechnics, the role of geotechnics in environmental impact assessments and environmental protection reports.
2. Circular geotechnics – waste as a resource in geotechnical applications: fly ash, slag, sludges; mechanical and chemical properties. Construction waste in geotechnical applications. Use of recycled tires in geotechnical applications.
3. Innovative materials – geopolymer materials, recycled aggregates, bio-stabilisation, and bio-cementation. Application of geosynthetics (geotextiles, geomeshes, geogrids, geomembranes, GCL, geocells) in geotechnics and infrastructure projects.

4. Geotechnical characteristics of municipal waste – back-analyses and laboratory testing. Landfills – system overview: geometry, cover, drainage, barriers, gases, leachates. Geotechnical aspects of landfills – slope stability (static and seismic), interaction with geosynthetics, differential settlements. Monitoring of landfills – monitoring systems, testing methods, case studies of failures.
5. Contaminant transport through soil – migration mechanisms through soil and rock, dispersion, diffusion, advection. Remediation – hydraulic barriers, reactive barriers, in-situ chemical and biological techniques.
6. Renewable energy in geotechnics – geothermal energy, subsurface heat flows. Thermo-mechanical behaviour – interaction between heat and stress in soils, long-term heating–cooling cycles.
7. Geo-energy structures – piles, tunnels, retaining walls; integration of heat exchangers into the structure.
8. Design of geo-energy structures – numerical methods, FEM modelling, standards. Construction and monitoring of geo-energy structures. Selection of relevant parameters from TRT tests.
9. Basics of climate change – trends, intense rainfall, heat waves, extreme events. Hydrology in a changing climate – increased rainfall intensity, groundwater, soil saturation, erosion changes.
10. Impact of climate change on geotechnical structures – changes in soil strength due to increased moisture and temperature, landslide risk, degradation of geotechnical structures. Expansive soils, permafrost thaw, and global case studies of damage.
11. Numerical modelling of climate impacts – rainfall, infiltration, variable groundwater levels, climate–soil interaction models. Climate adaptation of geotechnical structures – new safety philosophies, design with adaptive factors, maintenance under climate variability.

- **Exercises**

1. Settlement calculations of landfill bodies. Stability analysis of landfill structures. Selection of relevant waste and interaction parameters with engineered and natural layers. Stability under static conditions (2D/3D). Stability under seismic conditions (slip circle analysis, pseudostatic approach). [2]
2. Modelling of contaminant transport through soil (dispersion, diffusion, advection). Selection of advanced constitutive models and relevant boundary conditions. Optimisation of remediation measures (reactive barriers, sealing layers). [2]
3. Analysis of energy structures – parameter selection for design. Analytical methods to determine stress, deformation, and displacement in thermally loaded geo-structures. [2]
4. Advanced thermo-mechanical constitutive models. Selection of relevant thermal and mechanical soil properties. Thermal boundary conditions. FEM analyses of geo-energy structures with result interpretation.

5. Analysis of geothermal piles, groups of mechanically and thermally loaded piles. Thermally loaded retaining walls. Impact of thermal loading on geothermal tunnels. [2]
6. Analysis of meteorological data (hourly/daily rainfall series), extreme events, climate scenarios.
7. Advanced constitutive models for climate–soil interaction, selection of relevant input parameters.
8. Transient analyses of extreme rainfall impacts on saturated/unsaturated soils, effects on slope stability. [2]
9. Analytical and numerical simulation of erosion and foundation undermining due to floods and high flows.
10. Analysis of extreme temperature effects on soil behaviour and geotechnical structures.

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Seminar paper
- Practical work
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. ISSMFE Technical Committee TC 5: Environmental Geotechnics, Report, Bochum, 1997
2. Znidarčić, D., Kovačić, D., Kvasnička, P., Mulabdić, M.: "Geotehnologija pri odlaganju komunalnog otpada", Hrvatsko društvo građevinskih inženjera, Građevni godišnjak, 1996
3. Laloui, Lyesse, and Alessandro F. Rotta Loria. Analysis and Design of Energy Geostructures: Theoretical Essentials and Practical Application. Academic Press, 2019. ISBN 9780128206232.
4. Teaching Materials: lectures – PowerPoint presentations

Additional reading:

1. M. L. McKinney, R.M.Schoch: Environmental Science (Systems and Solutions), 3rd ed., Jones and Bartlett Publishers, Boston, 2003.

2nd year, 4th semester

Elective courses

MANAGEMENT OF STRUCTURES

See Chapter Specialisation Construction Management.

DESIGN OF URBAN STREETS

See in Chapter Specialisation Transportation Engineering.

RAILWAY TRACK MAINTENANCE

See in Chapter Specialisation Transport Engineering.

SUSTAINABLE PROJECT MANAGEMENT

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- To provide students with thorough knowledge of integrating contemporary methods, tools, and processes from construction project management with sustainability and ESG criteria.
- To understand sustainability throughout the entire project life cycle and align project objectives with the sustainability goals and strategies of the entire organization.
- To introduce tools for assessing and developing the integration of sustainability into projects, as well as the impact of projects on sustainability elements.
- To develop a project management plan in accordance with sustainability and ESG criteria.

Learning outcomes:

- Understand the fundamentals of project management.
- Understand the core concepts of sustainability and their importance in project management.
- Apply basic sustainability requirements to projects and project management processes.
- Analyse project impacts on sustainability throughout the entire project life cycle.
- Develop a project management plan in accordance with sustainability requirements.

- Align the social and environmental impacts of a project with the organization's sustainability goals and strategy.
- Comprehend emerging trends in project sustainability.

Course content (by course schedule):

- Lectures

1. Introduction to Sustainable Project Management
2. Sustainability in the Context of Projects
3. Stakeholders and Corporate Social Responsibility (CSR) in Projects
4. Integrating Sustainability into the Project Life Cycle
5. Sustainable Resource and Cost Planning
6. Managing Sustainability Risks and Opportunities
7. Sustainable Project Teams and Leadership
8. Measuring and Reporting on Project Sustainability
9. Digitalization and Innovation for Sustainable Projects
10. Case Studies and the Future of Sustainable Project Management

- Exercises:

1. Introductory Exercise: The Project and Sustainability
2. Linking Projects with Sustainable Development Goals (SDGs)
3. Stakeholder Analysis and Management in Sustainable Projects
4. Sustainability in Project Initiation and Definition
5. Sustainable Resource and Cost Planning
6. Managing Sustainability Risks
7. Sustainable Leadership and the Project Team
8. Monitoring, Measuring, and Reporting on Project Sustainability
9. Digital Tools and Innovations for Sustainable Projects
10. Final Exercise: Integrated Case Study

Student Evaluation - Continuous assessment:

- Seminar paper
- Project
- In-class activity
- Practical work
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Project
- In-class activity
- Practical work
- Written exam

- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Vukomanović, M. i Radujković, M – Poslovna izvrsnost u građevinarstvu RH, Sveučilište u Zagrebu, Građevinski fakultet i Hrvatska udruga za organizaciju građenja, 2011.
2. Silvius, G., Schipper, R. (2014). Sustainability in Project Management. Gower Publishing.
3. Radujković, M; Burcar Dunović, I; Dolaček Alduk, Z,; Nahod, M.M.; Vukomanović, Mladen. Organizacija građenja, Zagreb : Građevinski fakultet Sveučilišta u Zagrebu, 2015.
4. Radujković, Mladen; Car-Pušić, Diana; Ostojić Škomrlj, Nives; Vukomanović, Mladen; Burcar Dunović, Ivana; Delić, Davor; Meštrović, Hrvoje. Planiranje i kontrola projekata, Sveučilište u Zagrebu, Građevinski fakultet, 2012.
5. IPMA (2025). IPMA Guide on Sustainable Project Management
6. Kerzner, H. (2022). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Wiley.
7. IPMA (2016). Individual Competence Baseline (ICB4). International Project Management Association.
8. PMI (2021). A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – 7th Edition. Project Management Institute.

Additional reading:

1. United Nations (2015). Transforming our World: The 2030 Agenda for Sustainable Development.
2. ISO 21502:2020 Project, Programme and Portfolio Management — Guidance on Project Management.
3. ISO 14001:2015 Environmental Management Systems.
4. GRI (Global Reporting Initiative). GRI Sustainability Reporting Standards.

TECHNOLOGIES FOR BUILDING RENOVATION AND SUSTAINABLE DEVELOPMENT

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

- The primary objective of the course is to train students for critical thinking and technical problem-solving in building renovation through the lens of sustainable development. This implies not only technical excellence in dimensioning reinforcements but also the ability to assess the environmental footprint of selected solutions. The teaching process is designed to stimulate the resolution of real-world problems through work on practical examples.

Learning outcomes:

- Comprehensively understand regulatory frameworks related to the renovation and sustainable development of buildings.
- Apply acquired knowledge and skills in the planning, design, construction, supervision, and maintenance of complex civil engineering structures, interventions, and systems in the renovation and strengthening of buildings from the standpoint of stability, safety, serviceability, environmental protection, and costs.
- Apply acquired skills and necessary knowledge to identify, formulate, and analyse problems and find one or more acceptable solutions for the renovation and strengthening of buildings.
- Develop the field of building renovation and strengthening, taking into account insights from other scientific disciplines.

Course content (by course schedule):

- Lectures;

1. Legal framework of construction, renovation, and strengthening of buildings
2. Rights, obligations, responsibilities, and participants in the process
3. Building risk assessment and choice of priorities in protection, renovation, and strengthening in an urban environment
4. Guidelines and goals of renovation and strengthening
5. Digitalization of the urban environment
6. Condition analysis and planning of works on existing buildings
7. Technologies applicable for building strengthening
8. Execution and planning of building strengthening works
9. Technologies applicable for building renovation according to building typology and the requirements of other disciplines
10. Economy and efficiency of building interventions

Student Evaluation - Continuous assessment:

- Seminar paper
- Design
- Research
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- Design
- Research
- Written exam

- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Typische Baukonstrukktionen von 186 bis 1960, R. Ahnert, K.H. Krause
2. Earthquake-Resistant Design of Masonry Buildings, M. Tomaževič
3. Building Maintenace & Preservation, E.D. Millis
4. Structural Renovation of Buildings, A. Newman
5. Euro Standards
6. Laws and regulations

URBAN MICROCLIMATE

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 30
- Exercises: 15

Course objectives:

The aim of the course is to familiarize civil engineering students with the physical processes that govern the urban microclimate (the fields of temperature, wind, radiation and humidity in the spaces between buildings) and with their influence on building energy performance, thermal comfort and the resilience of urban areas to climate extremes.

The specific objectives are to enable students to:

- understand the energy balance of the urban environment and the role of buildings in shaping it,
- identify and quantify the influence of urban form and density, materials, vegetation and wind on the microclimate,
- understand the comfort need of pedestrians and the links between the urban microclimate and buildings' heating/cooling needs,
- acquire the ability to use basic models and tools for analysing microclimate and energy (measurements, simple calculations, selected numerical models),
- develop the ability to integrate the results of microclimate and energy analyses into the design and refurbishment of urban spaces and buildings.

Learning outcomes:

Explain the fundamental concepts of urban climate and microclimate (urban heat island, urban boundary layer, street canyon) and the physical processes that govern them (radiation, convection, conduction, turbulent exchange).

- Analyse the energy balance of urban spaces and buildings and the main components of heat exchange (radiation, sensible and latent heat, heat storage).
- Describe and quantify the influence of urban geometry, materials, vegetation and wind on air and surface temperatures and on human thermal comfort.
- Assess the state of the urban microclimate for the purposes of determining the comfort of urban spaces using simplified calculations, measurements and basic numerical/empirical models (UHI, shading, street-canyon winds).
- Propose and compare alternative urban and architectural solutions (geometry, materials, green infrastructure) aimed at improving the urban microclimate and reducing buildings' energy needs.

Course content (by course schedule):

1. Introduction to Urban Microclimate and Building Energy. Concepts: urban climate, microclimate, differences between city and surroundings; motivation: building energy, thermal comfort, climate adaptation.
2. Basics of the Urban Energy Balance. Energy balance of surfaces and volumes; radiation (short-wave/long-wave), sensible and latent heat, heat storage in constructions.
3. Urban Boundary Layer and Wind Around Buildings. Wind profile over the city, roughness, turbulence; flow in streets, effects of street canyons on wind speed and direction.
4. Urban Heat Island and Spatial Variability of Microclimate. Mechanisms of urban heat island formation, diurnal and seasonal cycles, examples of measurements and impacts on building energy use and health.
5. Materials, Albedo, Emissivity and Heat Storage. Role of roofs, façades and pavements; "cool" materials; water bodies; interaction with building energy.
6. Vegetation, Water and Green Infrastructure. Evapotranspiration, shading, green roofs, street trees; quantification of their impact on microclimate and energy.
7. Basics of Outdoor Thermal Comfort. PMV/UTCI and related indices; role of wind, radiation and humidity; link to spatial/urban design.
8. Microclimate and Buildings' Energy Needs. Degree-day concept, heating and cooling loads; influence of external climatic and microclimatic conditions on the thermal balance of a building.
9. Introduction to Numerical Modelling of Urban Microclimate. Overview of tools (urban climate models, CFD, ENVI-met, UCM, UWG) basic principles, temporal and spatial scales.
10. Numerical Modelling of Urban Microclimate. Analysis of tools (urban climate models, CFD, ENVI-met, UCM, UWG).
11. Urban microclimate recording and measuring. Instruments and measurement stations; measurement campaign planning, data processing (basic statistics, spatial maps).

12. Case study: existing urban area. Group work: microclimate analysis, collection of available data, problem identification (overheating, poor ventilation).
13. Development of Proposed Solutions and Impact Assessment. Variants of urban and building interventions; qualitative assessment of impacts on microclimate and energy.
14. Presentation of design assignments (I). Student presentations (1st part), discussion, feedback, connection to theory.
15. Presentation of design assignments (II). Student presentations (2nd part), knowledge synthesis, preparation for the final exam.

Student Evaluation - Continuous assessment:

- In-class activity
- Design
- Experimental work
- Midterm exams
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- In-class activity
- Design
- Experimental work
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. Urban Microclimate: Designing the Spaces Between Buildings https://www.taylorfrancis.com/books/mono/10.4324/9781849775397/urban-microclimate-evyatar-erell-david-pearlmutter-terence-williamson
2. Urban Microclimate Modelling for Comfort and Energy Studies https://link.springer.com/book/10.1007/978-3-030-65421-4
3. Urban Heat Stress and Mitigation Solutions: An Engineering Perspective https://www.routledge.com/Urban-Heat-Stress-and-Mitigation-Solutions-An-Engineering-Perspective/Costanzo-Evola-Marletta/p/book/9780367493677?utm_source=chatgpt.com

Shared Courses

MATHEMATICS 3

Credits (ECTS): 7.5

Hours (total per semester):

- Lectures: 45
- Exercises (auditory): 30

Course objectives:

- Acquisition of theoretical knowledge about basic linear models of mathematical physics and their application in civil engineering,
- Acquisition of basic practical knowledge and skills for analytical and numerical solution of such models.

Entry competences (prior knowledge, descriptive):

- Knowledge of differential and integral calculus (including ordinary differential equations) and linear algebra.

Learning outcomes:

- Understanding the conditions and limitations of applicability of linear models,
- The ability to recognize and choose a suitable model,
- The ability to solve simpler models, analytically and/or numerically,
- The ability to qualitatively analyse solutions.

Course content (by course schedule):

- Lectures:
  1. Review of mathematical analysis content.
  2. Review of linear algebra content.
  3. Fourier series.
  4. Boundary problem for wire balance.
  5. Wave equation. A boundary value problem for transverse wire oscillations.
  6. Fourier method for the wave equation.
  7. Heat conduction equation. A boundary value problem for heat conduction through a rod. Fourier method.
  8. Laplace's equation. Harmonic functions and their properties. Boundary-value problems for membrane equilibrium. Fourier method.
  9. Poisson's equation. Boundary problems for membrane oscillations. Fourier method.
  10. Numerical methods for ordinary differential equations - Cauchy problem. Euler's method. The Runge-Kutta method.
  11. Midterm exam.
  12. Numerical methods for ordinary differential equations - the boundary value problem of the equilibrium of a wire in a medium with resistance. Finite difference method.
  13. Numerical methods for partial differential equations - boundary value problem of wire oscillation and heat conduction through a rod. Finite difference method (network method).
  14. Numerical methods for partial differential equations - membrane equilibrium boundary value problem. Finite difference method.

15. Finite Element Method
- Exercises:
  The exercises follow lectures

Student Evaluation - Continuous assessment:
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:
- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:
1. T. Došlić, D. Pokaz, T. Slijepčević-Manger, K. A. Škreb, Mathematics 3, Lecture notes for internal use Faculty of Civil Engineering.
2. T. Slijepčević-Manger, Zbirka zadataka iz Matematike 3, Lecture notes for internal use Faculty of Civil Engineering.
3. E. Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons Ltd.,1999.
4. F. Scheid, Numerical Analysis, Schaum's Outline Series in Mathematics, McGraw-Hill Book.1.

STOCHASTIC PROCESSES

Credits (ECTS): 7.5

Hours (total per semester):
- Lectures: 45
- Exercises (auditory): 30

Course objectives:
- Acquisition of theoretical knowledge about the basic features of random processes and their application in civil engineering,
- Acquisition of basic practical knowledge and skills for setting up and solving simple mathematical models of such processes.

Entry competences (prior knowledge, descriptive):
- Knowledge of the elements of differential and integral calculus, probability theory and linear algebra.

Learning outcomes:
- Understanding the general features of random processes,
- Understanding the limitations and conditions of applicability of individual models,
- The ability to recognize and choose a suitable model,
- The ability to pose problems in terms of Markov chains,
- The ability to analyse the behaviour of Markov chains and other types of random processes.

Course content (by course schedule):
- Lectures:

1. Revision of linear algebra and mathematical analysis content
2. Revision of probability and statistics content.
3. Markov chains. Definitions and examples.
4. Markov chains with a finite set of states.
5. Markov chain state classification.
6. Recurrence/transience. Periodicity.
7. Stationary distributions and boundary behaviour.
8. Output distributions and times.
9. Markov chains with a countable set of states.
10. Simple and complex Poisson processes.
11. Midterm exam.
12. Continuous-time Markov chains.
13. Queueing theory I
14. Queueing theory II
15. Time series

- Exercises:
  The exercises follow lectures

Student Evaluation - Continuous assessment:

- First midterm exam
- Second midterm exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Student Evaluation - Examination without Continuous Assessment:

- Written exam
- Oral exam
- 75% attendance at lectures
- 100% attendance at exercises

Required reading:

1. N. Berglund, Slučajni procesi i primjene, Lecture notes for internal use, Faculty of Civil Engineering.
2. D. P. Bertsekas, J.N. Tsitsiklis, Introduction to Probability, Online lecture notes, M.I.T., 2000.
3. R. Durrett, Essentials of Stochastic Processes, Springer, N. Y., 1999.
4. N. Elezović, Statistika i procesi, Element, Zagreb, 2007.
5. J. Fan, Q. Yao, Nonlinear Time Series, Springer, Berlin, 2003.

RESEARCH METHODS

Credits (ECTS): 1.5

Hours (total per semester):

- Lectures: 15

Course objectives:

- Familiarize students with the basics of scientific and research work,

- Prepare students for writing the master thesis.

Learning outcomes:

Upon completion of the course, students will be able to:

- Writing essays, seminars and critical reviews,
- Selecting scientific methods for research,
- Collecting literature and data, and developing hypotheses and research methodology,
- Presenting research results,
- Writing the master thesis.

Course content (by course schedule):

- Lectures:
  1. Introduction to research work
  2. Collection and systematization of literature and information
  3. Review of online databases of scientific journals and other literature; Concept, types and hypothesis testing
  4. Concept and purpose of creating seminar papers and critical reviews
  5. Essential elements and structure of seminar papers and critical reviews
  6. Methods of collecting data for the purpose of scientific processing
  7. Data analysis and presentation of research results
  8. Concept of research methodology; Introduction to scientific research methods
  9. Overview of basic scientific research methods: Modelling method; Statistical methods; Simulation method
  10. Experimental method; System theory; Case study; Method of observation
  11. Questionnaire survey and interviews; Delphi method
  12. Types of scientific and professional papers; Code of ethics and plagiarism
  13. Citing literature: basic Harvard and Vancouver styles (Numbering System)
  14. Bibliography and software for literature storage (EndNote, Mendeley)
  15. Structure of the master thesis; Master thesis presentation.

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- Successfully passed test at the end of semester – a minimum score of 60% of the total points

Required reading

1. Zelenika, R., "Metodologija i tehnologija izrade znanstvenog i stručnog djela", Ekonomski fakultet Sveučiliša u Rijeci, Rijeka, 1999.

Additional reading

1. Creswell, J.S., Creswell, J.D., "Research Design: Qualitative, Quantitative, and Mixed Methods Approaches", (5th ed.), Sage Publications, Newbury Park, California, 2017.
2. Fellows, R., Liu, A., "Research Methods for Construction", (4th ed.), John Wiley & Sons, Chichester, 2015.
3. Knight, A., Ruddock, L., "Advanced Research Methods in the Built Environment", WileyBlackwell, Oxford, 2008.
4. Mejovšek, M., "Uvod u metode znanstvenog istraživanja u društvenim i humanističkim znanostima", Naklada Slap, Zagreb, 2003.
5. Silobrčić, V., "Kako sastaviti, objaviti i ocijeniti znanstveno djelo", (6. izd.), Medicinska naklada Zagreb, Zagreb, 2008.

6. The Open University, ''OU Harvard guide to citing references'', Milton Keynes, The Open University, 2014.

NUMERICAL MATHEMATICS

Credits (ECTS): 6

Hours (total per semester):
- Lectures: 30
- Exercises (auditory): 30

Course objectives:
- Acquisition of theoretical knowledge about the basic types of numerical methods and their application in civil engineering,
- Acquisition of basic practical knowledge and skills for setting up and numerically solving simple problems.

Entry competences (prior knowledge, descriptive):
- Knowledge of the elements of differential and integral calculus and linear algebra.

Learning outcomes:
- Understanding of general features of numerical methods,
- Understanding the limitations and conditions of applicability of individual methods,
- The ability to recognize and choose an appropriate method,
- The ability to set up and numerically solve simpler engineering problems.

Course content (by course schedule):
- Lectures:
  1. Introduction
  2. Methods of solving nonlinear equations – bisection and fixed-point method
  3. Methods of solving nonlinear equations – Newton-type methods
  4. Interpolation – interpolation polynomials
  5. Interpolation – splines
  6. Numerical integration – Newton-Cotes formulas
  7. Numerical integration – Gaussian formulas
  8. Numerical integration – cubature formulas
  9. Numerical methods for ODE – one-step methods
  10. Numerical methods for ODE – multistep methods
  11. Numerical methods for solving linear systems I
  12. Numerical methods for solving linear systems II
  13. Numerical methods for the eigenvalue problem I
  14. Numerical methods for the eigenvalue problem II
  15. Analysis of the program assignment
- Exercises
  The exercises follow lectures.

Student Evaluation - Examination without Continuous Assessment:
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. T. Došlić, Numerical Mathematics, Lecture notes for internal use Faculty of Civil Engineering, Zagreb, 2017.
2. B.P. Demidovich, I.A. Maron, Computational Mathematics, Mir, Moscow, 1976.
3. W.H. Preuss, S.A. Teukolsky: Numerical Recipes, CUP, Cambridge, 1992.

PERSPECTIVE

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (construction 8, design 22)

Course objectives:

- Expansion of theoretical knowledge on geometric objects and their relations,
- Developing the ability to favourably determine perspective parameters and read a perspective image,
- Application of knowledge in computer CAD modelling.

Entry competences (prior knowledge, descriptive):

- Knowledge of parallel projection methods.

Learning outcomes:

- Mastering basic constructive procedures in perspective,
- Knowledge of perspective image construction methods,
- Knowledge of geometric properties of higher-order surfaces,
- The ability to construct a perspective image of construction objects.

Course content (by course schedule):

- Lectures:
  1. Central projection. Perspective. [10]
  2. Surfaces: quadrics, rotational and translational surfaces. [2]
  3. Surface modelling in the CAD program. [4]
  4. Surface coverings, domes and vaults.[4]
  5. Line space. Rectilinear surfaces of the 2nd degree. [2]
  6. Rectilinear surfaces of the 3rd and 4th degrees. [4]
  7. Coil and coil surface. [2]
  8. Road in fieldwork. [2]
- Exercises (construction and design):
  1. Solving problems - perspective. [10]
  2. Body modelling in Rhino. [4]
  3. Domes and vaults – computer modelling. [4]
  4. Rectilinear surfaces of the 2nd degree – computer modelling. [2]
  5. Rectilinear surfaces of the 3rd and 4th degree – computer modelling. [2]
  6. Covering with rectangular surfaces – computer modelling. [4]

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises

- Preparation of 5 program assignments within the prescribed deadline
- Midterm exam
- Oral exam – grade confirmation

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation of 5 program assignments within the prescribed deadline
- Written exam
- Oral exam

Required reading:

1. Kurilj, N. Sudeta, M. Šimić: Perspektiva, Arhitektonski fakultet, Zagreb, 2005.
2. V. Niče: Perspektiva, Školska knjiga, Zagreb, 1978.
3. H. Brauner, W. Kickinger: Geometrija u graditeljstvu, Školska knjiga, Zagreb,1980.
4. B. Kučinić et al.: Oble forme u graditeljstvu, Građevinar, Zagreb, 1992.

WAVES AND OSCILLATIONS

Credits (ECTS): 6

Hours (total per semester):

- Lectures: 30
- Exercises: 30 (auditory: 15, laboratory: 15)

Course objectives:

- Master the skill of finding equations of physical models of vibrations, oscillations and deformations,
- Gain knowledge of setting up physical tests and computer simulations of physical problems,
- Master the skills of computer setup and problem solving.

Entry competences (prior knowledge, descriptive):

- Undergraduate mathematics including differential equations,
- Basics of programming

Learning outcomes:

- Mastering the equations from the given problems: free vibrations of simple systems – wires, plates; waves and wave propagation in one, two and three dimensions; deformations;
- Understanding the physical basis of equations processed in specialized and mathematical courses;
- Possibility of finding equations through the physical properties of the problem: coupled oscillations and vibrations, propagation of acoustic waves, acoustic insulation;
- Harmonic oscillator modelling;
- Computer modelling of individual physical models of problems dealt with in specialized and mathematical courses;
- Understanding the physical properties of forced oscillations and Interference;

- Understanding the physical basis of certain measurements in the profession.

Course content (by course schedule):

- Lectures:
  1. Free oscillations of simple systems. Examples.
  2. Free oscillations of a system with several degrees of freedom.
  3. Forced vibrations.
  4. Waves. Wave propagation in one and more dimensions. Sound.
  5. Reflection and transmission of waves. Pulses and wave packets.
  6. Polarization of waves.
  7. Electromagnetic vibrations and waves.
  8. Interference and diffraction of waves.
- Exercises:

Student Evaluation - Examination without Continuous Assessment:

- Seminar paper
- 75% attendance at lectures
- 100% attendance at exercises
- Oral exam

Required reading:

1. F. S. Crawford, Waves: Berkeley physics course v.3, McGraw-Hill College, 1968.
2. H. Georgi, The Physics of Waves, Prentice-Hall, 1993. 3. Henč-Bartolić, V.; Kulišić, P.: Valovi i optika, Školska knjiga, Zagreb, 1989.

GEOMETRY IN CIVIL ENGINEERING

Credits (ECTS): 4.5

Hours (total per semester):

- Lectures: 15
- Exercises: 30 (design: 30)

Course objectives:

- Deepening theoretical knowledge about curves and surfaces of Euclidean space,
- Application of geometric knowledge in computer CAD modelling,
- Acquire a complete picture of the creation process of an object, starting with knowledge of geometry, through parametric modelling in the programs Rhinoceros and Grasshopper, to the final stage of model making, i.e. digital fabrication (BIM methodology).

Entry competences (prior knowledge, descriptive):

- Knowledge acquired from undergraduate mathematics courses (Descriptive Geometry, Mathematics 1 and Mathematics 2)

Learning outcomes:

- Acquire basic knowledge about curves and surfaces of Euclidean space,
- Recognize and evaluate the geometric properties of different types of surfaces,
- Use acquired knowledge in geometry in construction,
- Apply geometric concepts in parametric modelling,

- Apply parametric modelling in the creation of curves and surfaces in a CAD program and prepare a model for digital production.

Course content (by course schedule):

- Lectures:
  1. Introduction to CAD modelling (Rhino/Grasshopper)
  2. Extended Euclidean space. Curves in plane and space. Parametrization of the curve with a general parameter, analytical processing of curves
  3. Surfaces. Analytical processing of surfaces. Surface representation in the CAD software.
  4. Surfaces of the 2nd degree - quadrics.
  5. Line space. Rectilinear surfaces of the 2nd degree.
  6. One-plane hyperboloid and hyperbolic paraboloid.
  7. Formation of rectilinear surfaces. Modelling of rectilinear surfaces in the CAD software
  8. Rotational and translational surfaces
  9. Surfaces obtained by a combination of rotation, translation and homothety (spiral, trans-scale surfaces).
  10. Surface coverings – computer modelling
  11. Shell grids. Surface approximations with grids of planar polygons
  12. Lamella - surfaces.
  13. Free-form surfaces. Discrete representations of surfaces
  14. Preparation of CAD models for digital fabrication and creation of cardboard models with a laser cutter
  15. Presentation of programs and models.
- Exercises:
  1. Introduction to CAD modelling (Rhino/Grasshopper). Solving problems.
  2. Plane and spatial curves. Graphics and modelling in Rhino and Grasshopper.
  3. Surfaces. Surface modelling in Rhino and Grasshopper. Solving problems. Project assignment
  4. Solving problems (Surfaces of the 2nd degree - cone, cylinder).
  5. Solving problems (Level 2 surfaces - ellipsoids, paraboloids, hyperboloids)
  6. Solving problems (one-plane hyperboloid)
  7. Solving tasks (hyperbolic paraboloid)
  8. Solving problems (translational and rotational surfaces)
  9. Solving problems (surfaces obtained by translation, rotation and homothety)
  10. Overlays - computer modelling
  11. Solving problems. Approximation of surfaces by polygons.
  12. Solving problems (Lamella surfaces).
  13. Solving problems (Free-form surfaces).
  14. Preparation of CAD models for digital fabrication and creation of cardboard models with a laser cutter
  15. Design submission

Student Evaluation - Continuous assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation and submission of the design within the prescribed deadline
- Midterm exam

Student Evaluation - Examination without Continuous Assessment:

- 75% attendance at lectures
- 100% attendance at exercises
- Preparation and submission of the design within the prescribed deadline
- Oral exam

Required reading:

1. Kurilj, N. Sudeta, M. Šimić: Perspektiva, Arhitektonski fakultet, Zagreb, 2005.
2. V. Niče: Perspektiva, Školska knjiga, Zagreb, 1978.
3. H. Brauner, W. Kickinger: Geometrija u graditeljstvu, Školska knjiga, Zagreb,1980.
4. B. Kučinić i suradnici: Oble forme u graditeljstvu, Građevinar, Zagreb, 1992
5. H. Schrober: Transparentshells from topology structure, Ern&sohn, 2015
6. A. Tedeschi: AAD - Algorithms - Aided design, Le Penseur Publisher, 2014.
7. D. Lopez-Perez: R. Buckminster Fuller Pattern-thinking, Lars Muller Publishers, 2020.

Additional reading:

1. J. Beban-Brkić: online lecture notes, www.grad.hr/itproject_math/Links/jelena/index.html.
2. V. Niče: Perspektiva, Školska knjiga, Zagreb, 1978.
3. P. Kurilj, N. Sudeta, M. Šimić: Perspektiva, Arhitektonski fakultet, Zagreb, 2005.
4. Gorjanc, Sonja: Pravčaste plohe. online lecture notes, www.grad.hr/itproject_math/Links/sonja/pravcaste/pravcaste.html
5. Gray, A.: Modern Differential Geometry of Curver and Surfaces With Mathematica, CRS Press, Boston, London, 1998.

STUDY PROGRAMME ORGANISATION

Organisation of courses and student workload

The curriculum for full-time students is based on the student workload of 40 hours a week, which includes classes, practical exercises and other forms of instruction and the time needed for student preparation.

The instruction is organized in semesters according to the curriculum.

The academic year regularly consists of 44 working weeks, 30 of which are dedicated to teaching and 14 to consultations, exam preparation and exams, with no other mandatory forms of classes.

Total weekly workload of students in classes can reach a maximum of 20 hours.

A regular student enrols from 25 to 35 ECTS credits per semester.

Particularly successful students may be allowed to enrol into more than 35 ECTS credits in order to complete their studies more quickly or to have a broader education.

List of courses and/or modules that students can choose from other study programmes

Students can enrol in elective courses in agreement with department heads.

List of courses and/or modules that can be taught in a foreign language

Courses specified in the syllabus of a particular academic year can be taught in a foreign language.

Enrolment in the second year of study

Students can enrol only in those courses for which they have acquired prerequisites according to the programme and study plan.

Prerequisites for taking exams and attending graduate study courses are prescribed by a special decision of the Faculty Council.

Undergraduate students acquire the right to enrol into the higher year of study when they fulfil the study obligations prescribed by the Faculty's general legal act, which determines the rules of studying at the Civil Engineering undergraduate study programme.

Students who do not meet the aforementioned requirements can continue their studies according to the rules prescribed by the Faculty's general legal act, which lays down the rules of studying at the Civil Engineering undergraduate study programme.

Lectures and exercises

Students are obliged to attend the forms of teaching that are specified by the study programme and syllabus, and in addition to fulfilling other obligations in classes and achieving appropriate results on knowledge tests, it is a requirement for obtaining the teacher's signature.

Exams and other forms of testing

Students' knowledge can be tested and evaluated during classes (midterm exams, practical assignments, etc.), and the final grade is determined in the exam.

The exam from one course can be taken an unlimited number of times in the academic year. Students who do not pass a course exam are obliged to re-enrol into that course.

The syllabus can determine that some forms of teaching are conducted without assessment, that they are assessed descriptively, or that the final grade can be determined by testing and evaluating during the course, or that students' knowledge assessments in certain forms of teaching are included in the final assessment of the students' knowledge of the course achieved in the exam and/or other tests.

The teacher who teaches the course has the right to test and evaluate the students' knowledge in every form of teaching.

Exam dates and methods of conducting the exam

Exam dates are: winter, summer and autumn. Examination periods last at least 4 weeks. In each exam term, there are at least two exam dates for each course.

When justified, the dean can also set extraordinary exam dates.

The exam can be taken by a student who has fulfilled all the prescribed obligations set out in the syllabus. Students have the right to take course exams for courses they enrolled into and the attendance of which has been confirmed by the teacher's signature.

Completion of studies

The graduate study is completed by writing and defending a graduate thesis on a selected topic within the scope of an engineering course in the study program. Courses from which the graduate thesis cannot be taken are listed in a separate general legal act of the Faculty.

Final Assignment

Students submit applications for graduate theses when enrolling in the fourth semester of graduate studies.

At the suggestion of the teacher, students can write a graduate thesis from scientific research programs and topics organized and carried out at the Faculty of Civil Engineering of the University of Zagreb.

The mentor prepares the subject of graduate thesis, and the student must be informed about it no later than 6 weeks after the start of instruction in the last semester.

The preparation and defence of the graduate thesis earn 18 ECTS credits, and it must be such that the student can produce it in 540 effective hours of work.

The Committee for Graduate and Final Examinations can recognize an invention, technical improvement, etc. as a graduate thesis, if its significance corresponds to a graduate thesis.

The Committee for Graduate and Final Examinations takes care of the procedure for preparation and defence of the diploma exam.

If the candidate fails to defend the thesis, the Committee refers them to a defence in the next period, and if they fail to defend the thesis even then, the Committee refers them to reapply for a new thesis topic.

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