POLITEHNICA University of Timişoara - Faculty of Civil Engineering

Field of study: CIVIL ENGINEERING

MSc degree: ADVANCED DESIGN OF STEEL AND COMPOSITE STRUCTURES – ADS

Language of instruction: ENGLISH

Brief description: The focus of “Advanced Design of Steel and Composite Structures” Master Course is to provide attendees the engineering **ability and know-how to design and construct** safe steel and composite steel and concrete structures including environmental aspects, enhancing the sustainability and competitiveness of the industry.

The ADS Master Course represents an **educational program** that trains high-level specialists with the orientation towards the domain of steel and composite steel and concrete structures. The master program corresponds to the requirements of an international labour market, for which the master graduates can integrate activities specific to their grounding for finding the most favourable opportunities.

The program assures the **continuation and completion of the bachelor degree studies** through advanced analysis and design methods applied to steel and composite steel and composite structures. Robustness of structures, fire safety use of new structural materials and other topics related to safety of structures are addressed to students. The program allows the initiation of the trainees in the research activities.

Semester / Course name / Owner	Description/Content
I / Theory of Elasticity and Plasticity / Prof. V. Ungureanu	***Description:*** This course intends to provide students a comprehensive knowledge on the theory of elasticity and plasticity. The course focuses on the following topics: continuous medium, Cartesian tensors, deformation, displacement and strain tensors, compatibility conditions, external and internal forces, equilibrium, stress tensors, principal stresses, invariants and stress deviators, constitutive law, plasticity theory, yield and failure criteria, laws of mechanics, plane stress and plane strain problems. Students will obtain theoretical knowledge on stress in spatial and planar structural elements, walls, plates and shells on elastic and plastic properties of materials. By the end of the course, the students should have an idea about for what kinds of mechanics problem the analytical solutions exist and for which ones we must depend on numerical solutions. They have to be able to solve analytically a number of classical problems of elasticity. ***Content:*** **Torsion with restraint warping** in thin-walled bars with non-circular open cross section; **Basic equations of elasticity theory.** Three-dimensional problem of stress and strain state in the surrounding of a point in elastic body. Introduction, The State of Stress at a Point, The State of Strain at a Point, Basic Equations of Elasticity, Methods of Solution of Elasticity Problems, Spherical Co-ordinates, Principal Stresses and Principal Planes; **Two dimensional problems** in the theory of elasticity in Cartesian co-ordinates; Introduction, Formulation of all governing equations; Navier's equations; 2D stress states in Cartesian coordinates: plane stress, plane strain, Airy stress function: Bending of a cantilever loaded at the end; **Two-dimensional problems in polar co-ordinates.** Basic equations, 2D stress states in cylindrical coordinates: axisymmetry, strain-displacement relations, Airy stress function: Stress-concentration due to a Circular Hole in a Stressed Plate (Kirsch Problem), finite-difference methods (FDM); **Analysis of rectangular plates –** theory and methods, application of numerical methods. Introduction, Cylindrical Bending of Rectangular Plates, Type of stresses on rectangular flat plates, Determination of bending and twisting moments on any plane, finite-difference methods (FDM), Navier's solution for simply supported rectangular plates; **Analysis of rotationally symmetric circular plates** – methods of solution. Introduction, symmetrical bending of a circular plate, governing Equations for symmetric bending of circular plates, some typical solutions; **Theory of rotationally symmetric thin shells – membrane and bending theory.** Introduction, statics of shells - the stress resultants and stress couples in shells, the equilibrium equations, membrane theory of shells, geometry of shells of revolution; **Basic theory of plasticity. Theory of rupture:** (i) Plasticity in one dimensional stress states: material models for uniaxial tension/compression; Bauschinger effect; strain hardening; (ii) Yield criteria in two and three dimensional stress states: general expression of yield criterion; yield criteria for ductile material: Tresca, von Mises; fracture criteria for brittle materials: Rankine, Mohr-Coulomb, Drucker-Prager; (iii) Deformations in plastic regime: yield surface; incremental deformations; convexity of the yield surface; normality of plastic deformation increment to yield surface; plastic potential and flow rule.
I / Advanced Finite Element Analysis / Assoc.Prof. A. Dogariu	***Description:*** Finite element method is the most advanced tool for research and design. This course continues the class of Introduction in Finite Element analysis and introduces finite element methods for the analysis of solid, structural and heat transfer problems. The main objective of this course is to give students the principles of the finite element method, with a

	detailed description of each step of the method. The governing continuum mechanics equations, conservation laws, virtual work, and variational principles are used to establish effective finite element discretizations and the stability, accuracy, and convergence are discussed. This course, together with the practical works intend to teach to students in using advanced finite element software, like ABAQUS©, for linear and nonlinear analyses. The term project involve use of the general purpose finite element analysis program ABAQUS. Applications include finite element analyses, modelling of problems, and interpretation of numerical results. At the end of this course, it is expected that students will be able to model and solve complex civil engineering structures. ***Content:*** **Review of finite element basics and of Theory of Elasticity and Plasticity:** Short history; basics of Finite Element Method; discretisation of structures; element stiffness matrix (beam, truss, and plate); assembling the global stiffness matrix of the structure. Matrix formulation used in theory of elasticity. Energetic methods used on structural analysis; **Advanced finite element software:** Overview of ABAQUS; Defining a model; Finite Elements, Materials, Linear and Nonlinear Analysis; Constrains and contacts; Dynamics and quasi-static analysis; Buckling and post-buckling analyses.
I / Research and Design Assisted by Testing / Sen.Lecturer Ioan Both / Assoc.Prof. T. Nagy-Gyorgy	***Description:*** From simple specimens to complex assemblies, testing represents the method to obtain experimental results characterizing the behaviour of isolated elements or structures subjected to mechanical loads. The aim of the course is to disseminate the knowledge, the devices and the techniques involved in testing. The students have to be able to identify and use the laboratory testing devices and to make proper testing setup for monitoring a measured variable. ***Content:*** **Basics:** Why we do/need tests, Types of tests, Equipment required and organizing tests, General system of measurement. Components, Steps of a test; **Features trap/transducers/sensors/gauges:** Measure and output signal, Types of transducers, Physical quantities influence, Metrology, Calibration; **Measurement Errors:** Types of errors, Statistical processing of results; **Displacement Transducers:** potentiometric linear transducer, Inductive transducers; **Strain Gauges:** Composition, Principle of Measurement, Transverse sensitivity, Types of gauges depending on the state of stress, Effects parasite involved in the operation of gauges, Connecting gauges acquisition instruments, Parasitic effects that occur in measuring deformations, Installing stamps; **Load Cells:** Types of load cells, Load cells based on the bending moment deformation, Load cells based on the axial force deformation. Applications: The practical work is performed in the testing laboratory as “hands-on” sessions, based on the information presented in the course. Experimental work implies calibration of transducers, setting up of tests, software use and results processing.
I / Life Cycle Analysis for Building Structures / Prof. D Grecea	***Description:*** Clear understanding of the concepts of Sustainable Development (SD) and Sustainable Construction; To understand the challenge of the application of the principles of SD to the construction sector; To identify the advantages and disadvantages of steel and steel construction in the context of SC; To take advantage of steel structures in the pursuit of SC; To provide essential knowledge in relation to methodologies and tools for the assessment of sustainability; To apply these skills in the promotion of steel buildings in the context of SC. ***Content:*** **Introduction:** Sustainable development aspects, key indicators, European directives, international standards; Sustainable construction: basic concepts, assessment tools, life cycle concepts, lifetime analysis; **Life-Cycle Analysis:** Methodologies and tools for the assessment of sustainability (life cycle approaches, rating systems BREAM, LEED, HQE, VALIDEO, etc); Definition, codes such as ISO standards (functional unit, system boundaries, cradle-to-gate, cradle-to-

	grave, cradle-to-cradle), impacts and damages, important steps of the analysis (normalization, sensitivity analysis, end-of-life management); Buildings specificities (operational energy, embodied energy, compactness, etc); Durability of steel structures (corrosion, fatigue, etc) and maintenance; Computational tools; **Sustainability Of Steel And Steel Constructions:** Contribution of steel buildings for the sustainability of the construction sector; Identifications of main barriers/drawbacks of steel construction; Life-cycle inventory (data sources for steel, transport, system boundaries "cradle-to-gate with end-of-life recycling credits", comparative illustrative data for steel, concrete and wood); Allocation of recycling materials: How to take the recycling into account (analytical formulation).
	Applications: Design of the building based on the requirement of minimum energy consumption; Life cycle assessment and optimization of a steel building considering environmental impact; Comparison of alternative designs (other structural solutions).
II / Robustness of structures under extreme actions / Prof. F. Dinu	***Description:*** The main aims of the course are: (i) to introduce to students concepts such as extreme actions, robustness, structural integrity, progressive collapse, resilience of built environment; (i) to give students the understanding of the role of structural robustness in avoidance of collapse in case of extreme actions (e.g. impact, blast, explosion); (iii) to present the rules given in the codes and practical guidance on robustness and collapse resistance against extreme actions (e.g. impact, blast, explosion); (iv) to present approaches for the modelling and assessment of robustness of structures under extreme actions (e.g. impact, blast, explosion). ***Content:*** **Introduction to robustness:** Concepts of robustness, structural integrity, redundancy; Failure modes, disproportionate and progressive collapse; Nature of the hazards, accidental actions, extreme events, probability of occurrence; Structural failure consequences; **Regulations, codes:** Introduction; Classification of structures (consequence/importance classes); Design requirements; Indirect design approaches (tie-force methods); Direct design approaches: key element design, alternative load path methods. (notional removal of members); Risk-based methods; Good detailing, best practice; **Advances on structural robustness and mitigation of progressive collapse:** Advances in modelling of extreme events (blast, explosion, impact); Dynamic factors (load factors, material factors); Modelling parameters and acceptance criteria; Probability-based approaches (uncertainty-based). Applications: Application of indirect methods to a frame building (tying method); Application of direct methods to a frame building (key element method, alternate load path method).

II / Perforamnce Based Seismic Design / Assoc.Prof. A. Stratan	***Description:*** The course objective is to introduce advanced topics in seismic design and analysis of civil engineering structures. After completion of the course, students should be capable of establishing a performance-based design framework for assessment of seismic performance of structures, as well as effectively use static and dynamic nonlinear analysis methods. ***Content:*** Short history of seismic-resistant design; Design procedure in modern seismic design codes; Performance based design: general framework and establishing performance objectives; Methods of structural analysis; Modelling of material nonlinearity for structural analysis under seismic action; Evaluation of seismic performance of the structure; Target displacement in a nonlinear static analysis: the N2 method; Engineering characterisation of ground motion. Factors affecting earthquake motion; Seismic hazard analysis; Design of non-structural components; Seismic response control. Applications: Design of a steel structure (moment-resisting frame, concentrically braced frame or eccentrically braced frame) using conventional code approach, followed by seismic performance assessment using nonlinear static and dynamic analyses within a performance-based design framework.
II / Advanced Design of Composite Steel-Concrete Structures / Assoc.Prof. A. Ciutina	***Description:*** The course focuses on the advanced design of composite steel and concrete composite elements, complementary to the course held in fourth year. Together with the applications, the course is oriented towards the practical design and optimization of composite beams (through efficient calculation of the connection between the two materials), the real advantages of the use of steel-reinforced composite columns (to axial bending and bi-directional bending), etc. The course also presents the design rules for structural composite joints, including the component method and the special requirements of composite structures located in seismic regions (typical for the whole territory of Romania). Practical applications will follow closely the issues presented in the course, and applications through manual calculations and computer program applications. ***Content:*** **Introduction** in composite structures: typologies, current usage ; **Composite beams**: Type of beams, Effective width of composite beams, modular ratio, Classification of composite cross-sections, Design principles, Elastic resistance in bending, Plastic resistance in bending, Verification to vertical shear, Design of shear connection, Design of continuous beams, Design at serviceability limit state; **Composite columns:** Design of columns under axial load; Design of columns under axial load and bending moment, Design of columns under axial load and bi-axial bending, Local buckling of steel elements, load introduction; **Composite connections:** Types of Composite Connections, Classification, and Determination of mechanical characteristics: capacity, stiffness; **Specific requirements for composite steel and concrete structures subjected to seismic loads:** design concepts, material requirements, Structural types and behaviour factors, Design criteria and detailing rules, Rules for members; **Composite floors:** Current Practice, Behaviour as Formwork, Composite Behaviour, Slim Floor Decking. Applications: Design of beams: comparison for a steel beam, non-supported composite beam, supported composite beam; Design of beams: total shear connection, partial shear connection; Design of beams: determination of cross-sectional characteristics: I+, I-, Mpl+, Mpl-; Design of columns: comparison for a steel column, total encased composite column, partial encased composite column; Design of columns: determination of interaction N-M diagram on strong axis, determination of interaction N-M diagram on weak axis, interaction N-M surface; Design of connections: Steel connections subjected to positive bending, steel connections subjected to negative bending; Design of composite floors.

II / Introduction to Fire Design / Prof. R. Zaharia	***Description:*** Fire is an accidental action in civil engineering structures and fire security is one key criterion in the design of a building. Among the requirements concerning fire security, a very important one is the fire resistance time of the resistant structure, i.e. how long a structure is able to withstand the applied loads during a fire. The aim of the course is to give to the students an understanding of the design models for fire design of structures within the specific Eurocodes. The lectures and the applications are concentrated on the fire design of steel and composite steel-concrete elements using the simplified calculation models of Eurocodes, but the course provides also more general information on the topic of fire design. After completion of the course, the student should be able to determine the fire resistance of a structural element according to the Eurocodes and to the specific Romanian National Annexes provisions. ***Content:*** **Introduction:** Relations between the different Eurocodes; Scope of the fire parts of the Eurocodes; Steps for a fire analysis; **Mechanical Loading:** Fundamental principles; **Thermal Action; Thermal Analysis, Temperature In Steel Sections:** Unprotected internal steelwork; Internal Steelwork Insulated by Fire Protection Material; Internal Steelwork in a Void Protected by Heat Screens; **Mechanical Analysis:** Choice of the structure to analyse; Three different calculation models; Load, time or temperature domain; Mechanical properties of carbon steel; Classification of cross-sections; How to calculate $R_{fi,d,t}$; Design in the temperature domain; **Connections; Fire Design Of Composite Steel And Concrete Elements**
III / Cold-formed Steel Structures / Prof. V. Ungureanu	***Description:*** Steel structures built by thin-walled cold-formed steel profiles represent the most dynamic sector of construction engineering. The use of thin-walled steel profiles implies solving a series of specific design matters that are not usual for the general steel structures made of hot-rolled or welded profiles. Present course gives students the necessary knowledge to tackle all the design matters that arises when dealing with the design of cold-formed steel structures. ***Content:*** Use of thin walled cold formed members in constructions; Basis of structural design; Geometric characteristics of effective sections for thin walled profiles; Strength design of profiles accounting for local buckling; Stability design of thin walled profiles in compression and/or bending; Connections; Diaphragm effect of corrugated sheeting; Structural applications of cold formed thin walled section profiles; Constructive solutions for residential buildings and industrial warehouses using cold formed thin walled section profiles. Applications: Project; Design of an industrial building made of thin-walled cold-formed steel profiles, following the principles and design steps presented in the course.
III / High-Rise Steel Buildings / Prof. D. Dubina	***Description:*** The main aim of the course is to give students the understanding of the design and evaluation of high-rise steel and composite structures for buildings. The common types of structural systems that are used for construction of high rise buildings are presented, focusing on the definitions, main principles and economic ways of designing such structures. The gravity load resisting systems (GLRS) and lateral load resisting systems (LLRS) for steel-framed tall buildings are comparatively presented. Details about gravity, wind and seismic loads on tall buildings are given. Details about fire safety are given. Advances in structural analysis and design of steel frames are presented. Advanced systems for mitigation of seismic and wind loads effects are presented. ***Content:*** Structural systems for high-rise buildings (earthquake-prone areas, wind-prone areas); Gravity load resisting systems, lateral load resisting systems, facades, foundations; Gravity loads, wind loads, seismic loads, accidental loads;

	Fire safety, principles, and requirements; Principles of conceptual design of steel and composite structures, main requirements for members and joints. Global structural analysis; Code based design (force based design, response spectra approach); Non-linear static and dynamic analysis of steel and composite framed buildings (modelling parameters, acceptance criteria, performance levels); Advanced technologies and systems for mitigation of wind and seismic load effects: high-strength materials, response control damping systems (active, semi-active, passive); Improved structural systems for wind and seismic resistant frame structures; Future developments, challenges and trends in construction of high rise buildings. Applications: Design of a high rise building: a. Code base design (force based design); b. Static non-linear analysis, dynamic non-linear analysis; Comparative analysis, limitations.
III / Metallic Shell Structures / Assoc.Prof. A. Dogariu	***Description:*** This course presents an overview of design philosophy as used in civil engineering shell structures, the forms of different kinds of structure, the relationship between the form and the functions, material behaviour, imperfections and their impact on structural behaviour, and different methods of evaluating the strength of a shell structure according with European Norms. During classwork hours will be review methods of evaluating the strength of a shell structure according with EN 1993-1-6. Hand calculations and computer applications will be done. At the end of this course it is expected that students will be able to recognize typical shell structures and their behaviour under different loading conditions and to design them applying the appropriate EN 1993-1-6 regulations. ***Content:*** Introduction. Objective and scope of course. General consideration; Shell structural forms used in constructions; Architectural considerations. Examples of shell structures. Behaviour of shell structures under loads. Loads on shell structures; Elasticity and Plasticity of shell structures; Buckling of shell structures; Curved latticed structures – general aspects. Eurocode 3: Design of steel structures - Part 1-6: Strength and Stability of Shell Structures. Modelling of shell; Material assumptions; Geometric tolerances and imperfections; Limits states for shell structures: Plastic limit state (LS1); Cyclic plasticity limit state (LS2); Buckling limit state (LS3); Fatigue limit state (LS4). Applications: Stress design – Hand calculations: Cylindrical shells of constant wall thickness; Cylindrical shells of stepwise variable wall thickness; Shells under wind loading; Conical shells and truncated shells; Spherical shells under uniform external pressure; Cylindrical shells with ring stiffeners; Cylindrical shells with longitudinal stiffeners. Finite element numerical analysis.
III / Advanced Fire Design / Sen.Lecturer D. Pintea	***Description:*** The course aims to teach students advanced skills in the field of Fire Design. The students will learn how to model the fire using parametric fire curves or two zone model curves.The course will present the Finite Element Method applied to Fire Design. The two parts of the FEM analysis, the Thermal response of the cross section and the Mechanical response of the structure will be discussed. Practical design examples using the SAFIR program will be computed. ***Content:*** Performance based Fire Modelling; Fire Modelling; Fire curves, Parametric Fire Curves, Natural Fire Curves; Localised Fires; Two Zone Model; Fire Modelling using the Finite Element Method; The SAFIR program; Thermal Analysis using FEM; Structural Analysis at Fire Limit State using FEM. Applications: Parametric Fire Curve Calculation; Localised Fire curves calculation; Using Ozone to compute two zone model fire curves; Finding the temperature evolution on the cross section using the FEM method; Modelling the structure in fire situation; Displacements and stress evolution under fire of structures using the FEM method.

IV / Research Activity (7 weeks)	
IV / Development and Defence of Master Thesis (7 weeks)	

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