6.1 CE0610 – Matrix Structural Analysis – One-Dimensional Finite Elements

(1) GENERAL

SCHOOL	ENGINEERING SCHOOL		
ACADEMIC UNIT	CIVIL ENGINEERING DEPARTMENT		
LEVEL OF STUDIES	UNDERGRADUATE		
COURSE CODE	**CE0610**	**SEMESTER**	**6**
COURSE TITLE	**Matrix Structural Analysis – One-Dimensional Finite Elements**		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
	5	6
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).		

COURSE TYPE *general background, special background, specialised general knowledge, skills development*	Specialization Course
PREREQUISITE COURSES:	Structural Analysis of Indeterminate Structures (CE0510) Strength of Materials (CE0320)
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Yes in the English language
COURSE WEBSITE (URL)	https://eclass.uniwa.gr/courses/PEY138/

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

The course presents the modern methods of Structural Analysis for the solution of any kind of structures and specifically the Direct Robustness (Stiffness) Method. The method is presented in detail for all plane bodies, such as trusses, grids and frames, but reference is also made to bodies in three dimensions, such as special trusses and spatial frames. All the steps of the method are presented In the theoretical part, where the basic matrices of transformations between axes and stiffnesses are determined from the basic knowledge of Classical Structural Analysis and the Strength of Materials for each type of element and structure and fundamental equations are derived for the calculation of the unknown quantities, which are the nodal displacements, the support reactions and internal forces of the members.

At the same time, the aforementioned matrices and all the necessary calculations are applied in real problems and specific structures are analyzed, while in the context of practical applications of the course, the corresponding computer software is developed with the participation of the whole group of students. In addition, during the academic semester, two projects are assigned to each student to work out and submit as part of their obligations in the course.

Upon completion of the course, students will be able to make use of all the concepts they have learned and understood, as well as the knowledge they have acquired by extending and applying all these to practical problems of their specialty. They can specifically do the following:

1. analyze structures using the specific software they have developed in the course of the semester,
2. develop the expertise in using software for the static and dynamic analysis of structures,
3. comprehend the application of computer based software for the structural analysis of real structures,
4. have the knowledge and develop the understanding for the implementation of the stiffness method to other well known concepts of applied mechanics for the solution of structural problems,
5. be qualified for the next step, which is the introduction to the finite element method, and
6. be prepared to implement this knowledge to other areas of their field of specialization.

The aim of this course is to provide students with a better and more thorough knowledge of the response of structures, through solving them through a computer code that they develop. Also, to acquaint students to the use of computer software in the solution of applied mechanics problems and comfortably extend this to other thematic areas of their specialty and special background courses.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?;.

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*

Specifically, students will be able to perform:

- Structural modeling and digitization of all given data
- Numerical solution of the structure
- Understand the individual steps in the process of solving structural problems through the use of software and computers
- Comprehend the influence of different loading and support conditions in the internal state of stress of structures

(3) SYLLABUS

1. Introduction. Overview of matrix structural analysis and design. Primary structural members and their modeling. Matrix structural analysis steps. Flexibility / stiffness methods. Computer programs and basic steps of programming the direct stiffness method. Degrees of freedom of plane and spatial structures.

2. Plane truss. Global and local systems of axes. Vectors of end-actions and end-translations of a plane truss element. Transformation matrix. Calculation of local-global stiffness matrix of a plane truss element: analytical and numerical (shape function, deformation matrix) methods. Vectors of nodal-forces and nodal-translations, global stiffness matrix of a plane truss. Modification of global stiffness matrix due to support conditions. Reordering matrix. Modification of global stiffness matrix of a plane truss due to inclined and elastic supports. Plane truss subjected to member loading. Restrained equivalent structure. Stress resultants of plane truss members.

3. Plane frame. Vectors of end-actions and end-displacements of a plane frame element. Transformation matrix. Calculation of local and global stiffness matrices of a plane frame element. Analytical and numerical (shape functions, deformation matrix) methods. Vectors of nodal-forces and nodal-displacements, global stiffness matrix of a plane frame. Modification of global stiffness matrix due to support conditions. Reordering matrix.

Modification of global stiffness matrix of a plane frame due to inclined and elastic supports. Plane frame subjected to member loading. Restrained equivalent structure. Stress resultants of plane frame members. 4. Spatial truss. Transformation matrix of a spatial truss element. Local and global stiffness matrices of a spatial truss element. Analytical and numerical methods. Steps of analysis of a spatial truss. 5. Spatial frame. Transformation matrix of a spatial frame element. Basic transformation matrix. Transformation matrix with special orientation. Different approaches for the construction of the transformation matrix. Formulation of transformation matrices of elements of other type of skeletal structures. Local stiffness matrix of a spatial frame element. Formulation, stiffness terms. Formulation of local stiffness matrices of members of all other types of skeletal structures. Vectors of nodal-actions and nodal-displacement of a spatial frame. 6. Grid. Analysis of a grid structure. Solving a grid structure as a special case of a spatial framed structure. 7. Rigid joints. Kinematic relations and equivalent actions between two points of a rigid body plane. Rigid joints in plane framed structure. Kinematic relations and equivalent actions between two points of space rigid structure. Rigid joints in space frame element. 8. Internal releases. Combined node method. Degrees of freedom of combined nodes. Assembly of total global stiffness matrix with combined nodes. Computation of nodal actions of restrained and equivalent structures with combined nodes. Elastic hinge. Internal releases and method of modified stiffness matrices. Modified matrices and internal releases. Restrained actions, equivalent actions. Static condensation method. Physical interpretation of static condensation. Qualitative examination of the stiffness coefficients of a hyper-element. Stiffness matrix and restrained actions with elastic hinge. 9. Elements of variable cross-section. Stiffness matrix, analytic evaluation and approximate computation. Restrained actions. Analytic evaluation and approximate computation.

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face-to-face
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	Communication via e-mail and an exclusive team on the MS-Teams platform with a specific course group. Additional material on the course is provided in a dedicated website. The learning process is supported by providing notes with selected additional exercises and illustrated examples on the website or the Ms-Teams team of the course. Teaching using information and communications technology (ICT), communication and electronic submission. In-class demonstration of the impementatrion of the Direct Stiff-ness Method for the solution of various types of structures using either MatLab or Excel. Assignment of two semester projects on different types of structural systems.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non- directed study according to the principles of the ECTS*	(see table below)

Activity	***Semester workload***
Lectures	30
Classwork	20
Personal Study (theory)	30
Personal Study (applications)	20
Assigned problems	15
Attendance of Computer Implementation & Application	25
Preparation of Semester Projects	40
Course total	**180**

STUDENT PERFORMANCE EVALUATION	
Description of the evaluation procedure *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open- ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	Language of evaluation: Greek Final examination: 100%, which includes: (a) presentation of the two semester projects (70%), (b) other crisis questions on the course material (30%). Each student is examined individually both on the two semester projects they have work on during the semester (software), as well as on the theoretical part of the course and the exercises. The exam combines demonstration of their work on the computer, as well as calculations based on the method. The resulting score concerns the whole course (100%). The evaluation criteria have been presented to the students before the examination, the individual grade for each excercise is given next to it and the final grade is accessible through the online platform of the University. In addition, students can see their exam paper, the analysis of grade for each problem and they are given clarifications about the exam questions. Finally, their mistakes are pointed out any they are explained. The language of assessment is Greek unless the students come from the Erasmus program, in which case the examination is in English.

(5) ATTACHED BIBLIOGRAPHY

Greek Bibliography:

1. Komodromos P., *Analysis of Structures – Computer Based Methods*, Papasotiriou A. Publications, 2009. (in Greek)
2. Papadrakakis M. and Sapountzakis E.J. (2016), *Analysis of One Dimensional Beam Structures Using Matrix Methods – Direct Stiffness Method*, Tsotras Athan. Publications, 2016. (in Greek)
3. Abramidis I., Athanatopoulou A. and Morfidis K., *The Finite Element Method – Modelling and Analysisof Structures*, “Sofia” Publications, 2016. (in Greek)
4. Mitsopooulou E., *Structural Analysis of One Dimensional Beam Systems*, “Sofia” Publications, 2009. (in Greek)
5. Meek John, *Matrix Structural Analysis*, Fountas Greg. Publications, Athens, 2010. (in Greek)
6. Nitsiotas G.M., *Statics of One Dimensional Beam Structures (Matrix Analysis)*, Volume 2, Ziti Publications, Thessaloniki, 1995. (in Greek)
7. Katsikadelis I.Th., *Dynamic Analysis of Structures*, Symmetry Publications, 2012. (in Greek)
8. Manolis G.D., Koliopoulos P.K. and Panagiotopoulos Ch.G., Dynamics of Structures, Greek University Electronic Publications “Kallipos”, Thessaloniki, Sept. 2015. (in Greek)
9. Chopra A.K., *Dynamics of Structures – Theory and Applications in Seismic Mechanics*, Giourdas Publications, 2008. (in Greek)