Course guide
220133 - EFAE - Finite Elements in Structural Analysis

Last modified: 02/04/2024

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering.

Degree: BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN AEROSPACE VEHICLE ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2024 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Joaquín A. Hernández Ortega

Others: Joaquín A. Hernández Ortega

TEACHING METHODOLOGY

LEARNING OBJECTIVES OF THE SUBJECT

The goal of this course is to introduce finite elements in the context of structural analysis. We will consider the basic theory of the method as utilized as a structural engineering tool. Different structural topologies will be considered, from truss elements (based on the matrix structural analysis) to shell elements; passing through beam, solid, and axisymmetric elements. The primary tool we will use to learn about the basis of the method will be programming some elements in the software MATLAB. The key steps of the computer implementation will be presented in sufficient detail so that the student can understand what goes on behind the scenes of a typical commercial code.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	40.00
Self study	45,0	60.00

Total learning time: 75 h

CONTENTS

Module 1: Direct approach for discrete systems

Description:
Description of a single bar element
Displacement, strain, stress, constitutive relation
Internal and external forces
Equations for Assembly
Boundary Conditions and Solution of the system
2D and 3D Truss, transformation law

Full-or-part-time: 10h
Theory classes: 4h
Self study : 6h

Module 2: One-Dimensional element (FEM 1D)

Description:
One-dimensional elastic problem (strong form)
The weak form in one dimension with arbitrary boundary conditions
Equivalence between weak and strong forms
Spatial discretization. Shape functions in one dimension.
Elemental stiffness matrix. Assembling.
Global stiffness matrix
Development of discrete equation system
Convergence by numerical experiments

Full-or-part-time: 8h
Theory classes: 3h 12m
Self study : 4h 48m

Module 3: Beam element

Description:
Review of general concepts
Governing equations of the beam (strong form)
Weak form. Integration by parts.
Hermite polynomials for both the displacements and the derivatives of the displacements (rotations)
Discrete equations
Moments and shear forces diagrams

Full-or-part-time: 12h
Theory classes: 5h
Self study : 7h

Module 4: Finite element in solids

Description:
General review. Displacements, strains, stresses, Hooke law, equilibrium equations, boundary conditions
Virtual work principle (general case)
Plane stress. Plane strain
Triangular element. Quadratic element.
Numerical integration. Gauss quadrature in two dimensions

Full-or-part-time: 20h
Theory classes: 8h
Self study : 12h

Module 4: Solids of revolution

Description:
Elasticity relations for axial symmetry
Axisymmetric solid element
Discrete equations. Examples

Full-or-part-time: 10h
Theory classes: 4h
Self study : 6h

Module 5: Plate and shell elements

Description:
Reissner-Mindlin plate theory
Plate-bending elements
Doubly curved shells

Full-or-part-time: 15h
Theory classes: 6h
Self study : 9h

GRADING SYSTEM

The final grade is based on three assignements, each contributing 33.3% of the final mark. Students whose grade happens to be below 50% will be allowed to present a complementary work in order to raise their grade up to 50% (but not higher). The contents of the complementary work will be at the discretion of the teacher, depending of the circumnstances of each student. The deadline for delivering the complementary work will be 2 weeks after the end of the classes.

BIBLIOGRAPHY

Basic:
- Fish, J.; Belytschko, T. A first course in finite elements [on line]. Chichester: John Wiley & Sons, 2007 [Consultation: 13/05/2022]. Available on: https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/9780470510858. ISBN 9780470035801.
- Oñate, E. Cálculo de estructuras por el método de los elementos finitos : análisis estático lineal. 2ª ed. Barcelona: Centro Internacional de Métodos Numéricos en Ingeniería, 1995. ISBN 8487867006.
- Cook, R. [et al.]. Concepts and applications of finite element analysis. 4th ed. New York [etc.]: Wiley & Sons, 2002. ISBN 0471356050.