MIE 1804: FINITE ELEMENT METHOD IN MECHANICAL ENGINEERING:

THEORY AND APPLICATIONS

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Students undertaking this subject must possess a solid grasp of solid mechanics, mathematics, numerical analysis and programming

The course content may be changed from year to year without prior notice

This course is divided into two main components: fundamentals of the finite element method and applied finite element. Whilst some coverage of commercial codes is provided, this course does not teach students how to use ANSYS or ABAQUS. This is not our focus. The emphases in this course are on understanding the fundamentals of the finite element method, what it does and why, building your own finite element code, avoiding the pitfalls and applying it to real engineering problems.

Part I - Fundamentals of the Finite Element Method

Chapter 1: Introduction to the Finite Element Method

Discretization of a Continuum, Numerical Methods in Continuum Mechanics, Numerical Methods for Solving systems of PDEs, The Finite Difference Method, The Finite Element Method , The boundary Element Method, Example and Applications of FEM. Case Studies.

Chapter 2: Trial Functions

Boundary Value Problems, Variational Principle in FEM, Weighted Residual Method, Relevance to Finite Element and the Need for Discrete Systems, Examples.

Chapter 3: Fundamental Concept of the Finite Element Method

Fundamental Concept of the FEM, Finite Element Solution Steps, Interpolation or Shape Function, Basic FE Algorithms, The Spring Model, Case Studies and Examples.

Chapter 4: Review of Pertinent Elasticity Formulae

Strain - Displacement Relations**,** Stress - Strain Relation**,** Two Dimensional Elasticity Problems**,** Plane-Stress Problems**,** Plane-Strain Problems, Axisymmetric Problems, K-Matrix, B-Matrics and D-Matrics.

Chapter 5: Derivation of Element Stiffness Matrix for a General Bar Element

Element Stiffness Matrix for Bar Element Using Variational Method, Element Stiffness Matrix for Bar Element Using Galerkin Method, Formulation of Shape Function Using Lagrange Polynomial for a General Bar Element, The Element Stiffness Matrix for General Bar Element, Examples and Applications.

Chapter 6: Truss and Frame Elements

Review Of Typical Framed Structure 2-node Elements, Consistent loading principle, Typical Examples of Consistent Loading, The Need for Numerical Integration (Gaussian Quadrature), Pin-Jointed Finite Elements, Transformation Matrix, Derivation of the Element Stiffness Matrix in terms of the global coordinates, Assembly of Elements, Applications and Examples.

Chapter 7: Beam Bending Elements

Assumptions and simplifications, Hermitian Shape Functions. Derivation of Beam Element Stiffness Matrix, Consistent Loading, Assembly of Beam Elements, Applications and Examples.

Chapter 8: Finite Element Programming

Implementation of Finite Element Algorithms, Structure of FE Code, Data Files, Typical Algorithms Used, Element Stiffness Matrix Generator, Assembler Subroutine, Reducer, Solvers, General Remarks.

Chapter 9: Derivation of Element Stiffness Matrix for 2-D Plane Elements

Triangular Finite Element for Plane Elasticity, Development of Element Stiffness Matrix, Rectangular Element for Plane Elasticity, Development of Element Stiffness Matrix, Isoparametric Transformation, The Jacobian Matrix, Gaussian Quadrature in Two-Dimensions, Applications and Examples.

Chapter 10: Three Dimensional Elasticity ***Problems***

Types of Elements and D.O.F., Shape Functions, Element Stiffness Matrix in Three Dimensions, Applications and limitations.

Chapter 11: Dynamic Analysis of Structures

Eigenvalue Problem, Formulation of Elasto-Dynamic Systems, Development of Mass Matrix for Bar Element, Lumped Versus Consistent Mass Matrix, Development of Mass Matrix for Beam Element, Development of Mass Matrix for 2-D Elasticity Problems, Dynamic Analysis of Undamped Eigenvalue Problems.

Part II - APPLIED Finite Element Modelling

Chapter Twelve: Accuracy of the Finite Element Model

Basic Input Data, Geometry Definition, Material Properties, Displacement Constraints, Applied Forces, Problem Definition, Problem Details, Free Body Diagram, Approximation to Geometry, ***Finite*** Element Model, Element Density, Element Distortion, Refined Mesh Modelling, Boundary Conditions, Sources of Uncertainties, Check of input data, Check of Constitutive Model, Benchmark Case(s), Check with Existing Analytical Model(s), Stress and Strain Contours, Continuity of Displacements, Equilibrium of Interface Stress and Reactions, Examples and applications

FINITE ELEMENT PROJECTS

In support of the above syllabus, students will be assigned finite element projects. Two types of projects are offered:

Either

- Develop own FE code,

  or

- Use a commercial code to solve a 3D problem