(Introduction to Finite Element Analysis) Course Catalogue

2023-2024

College	Erbil Technology College	
Department	Construction and Materials Technology Eng.	
Module Name	Introduction to Finite Element Analysis	
Module Code	FEA484	
Semester	8	
Credit	5	
Module type	Prerequisite ☐ Core ● Assist. ☐	
Weekly hours	3	
Weekly hours (Theory)	(3)hr Class	(135) hr Workload
Weekly hours (Practical)	( )hr Class	() hr Workload
Lecturer (Theory)		
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Lecturer (Practical)		
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Course Book

Course overview:

This course is designed to introduce the fundamental concepts of finite element modeling and enable the students to use a general-purpose finite element analysis software, Pro/ENGINEER/MECHANICA, to solve engineering problems mainly in Structure (some in Thermal) effectively.

Course objective:

o Understand the mathematical foundation of FEM

o Develop the weak form

o Impose common boundary conditions

o Understand the effect of basis function selection

o Write special-purpose finite element programs

o Utilize FEM to solve heat, elasticity, and wave propagation problems

Student's obligation

The student should attend the class so as to practice the software, absent student will lose activity marks, he/she must draw different drawings as a homework whenever required.

Forms of teaching

The form of teaching will be through using data show and white board for explanation, students will follow steps to use specific commands in the software to draw any sketch or model.

Assessment scheme

Breakdown of overall assessment and examination

Quiz (4 Quiz): 6% Home Work (4 Home Work): 12%

Reports& Seminar (2 Reports):10%

Absences: 2 % Mid-Term :30%

Pre-Final:60 m

Final: 40 m

Student learning outcome:

At a mastery level, students will be able to:

1. Understand the basic theory of finite-element method

2. Formulate, develop and apply the governing equations for basic finite-elements including bars, beams, frames and plane-stress elements.

At a basic understanding level, students will be able to:

3. Apply the finite-element method to transient problems in structural dynamics

At an exposure level, students will be aware of:

4. Isoperimetric formulation of finite-element problems for plane-stress and 3D problems

Course Reading List and References:

- A First Course in the Finite-Element Method, Daryl L. Logan, 5th ed., 2012
- Introduction to Finite Element Analysis and Design'', by N.H. Kim, B.V. Sankar, and A.V. Kumar, Wiley, 2nd Edition, ISBN: 9781119078739
- K. Bathe, Finite Element Procedures, 1 st Ed., Prentice Hall, 1996.
- T.R. Chandrupathla, Introduction to Finite Elements in Engineering, 2 nd Ed, Prentice Hall, 1997.
- - A. Askenazi, V. Adams, Building Better Products with Finite Element Analysis, 1997.
- R.D. Cook, et al., Concepts and Applications of Finite Element Analysis, 1996.

The Topics:	**Lecturer's name**
Practical Topics (If there is any)	

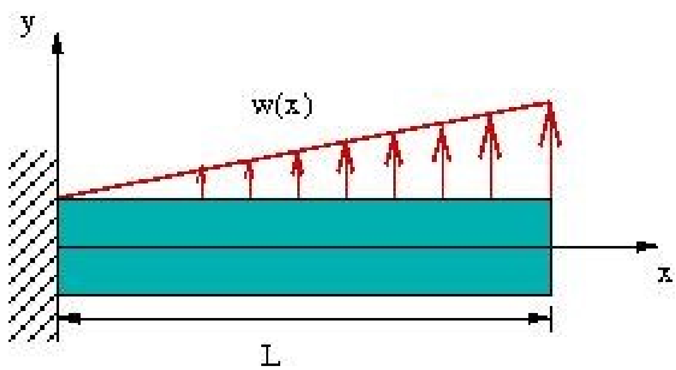
Chapter 1. Lecture 1: Background – Chapter 1 - What is FEM - Applications of FEM - Basic types of elements - Degrees of freedom	Week 1
Chapter 2. - Review of basic equations for bar and beam problems.	Week 2
Chapter 3 - Principle of minimum potential energy and approximate analysis.	Week 5,6
Chapter 4: - Learn about the displacement field and shape functions used in the formulation of a bar element. - Derive the stiffness matrix as well as load vector due to various load conditions acting on a bar element. - Develop numerical models for unidimensional problems using ProtaStructure.	Week 4
Chapter 5: - Derive the stiffness matrix as well as load vector due to various load conditions acting on a plane truss. - Learn about transformation matrix and relationship between local and global systems. - Develop numerical models for plane truss problems.	Week 5

Chapter 6: - Learn about the displacement field and shape functions used in the formulation of a beam element. - Derive the stiffness matrix as well as load vector due to various load conditions acting on a beam element. - Develop numerical models for beam and plane frame problems.	Week 6
Chapter 7: - This section will enable the student to understand the basic equilibrium and kinematic equations, the constitutive relations as well as the potential energy expression for 2-D plane stress and plane strain elasticity problems.	Week 7
Chapter 8: - Recognize various types of elements used to solve 2-D plane problems. - Develop numerical models to solve plane stress and plan strain problems.	Week 8
Chapter 9: - In this section, general guidelines for finite element modelling are presented.	Week 9
Chapter 10: Develop a three-dimensional computer model to idealize a cable-stay bridge for the evaluation of internal forces.	Week 10
Chapter 11: - Use the program ProtaStructure to develop three-dimensional computer models to idealize high-rise buildings under different types of loading.	Week 11

Chapter 12: Modelling: Joints, Contact,	Week 12
Chapter 13: FEA Validation	Week 13
Chapter 14: Static Analysis	Week 14

19. Examinations:

Problem #1



Given: A cantilevered beam has a length L, constant cross-sectional area A, constant moment of inertia , and a variable Young's modulus . It is loaded by a vertically upward line load . Assume that there is no body force present and that bending strain energy is the only significant contributor to internal work.

Required: Using the Rayleigh-Ritz method on the Principle of Virtual Displacements, derive an approximate expression for the vertical deflection of the beam's centerline using the approximating function , where , , and are unknown constants.

<u>Hint</u>: Bending strain is computed by The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location., and bending stress is computed by The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.. Be sure to write your volume integrals in the form The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location. and remember how is defined!

Solution: In the absence of body forces, the Principle of Virtual Displacements takes the following form:

$$\int_{surface} [\boldsymbol{\sigma}](\hat{\mathbf{n}})\bullet\boldsymbol{\delta}\mathbf{u}dA = \int_{volume} (\boldsymbol{\sigma})\bullet\boldsymbol{\delta\varepsilon}dV.$$

In words, the virtual work done by the external forces must equal the virtual strain energy stored in the beam. Let's start with the work done by external forces. Since both the applied load $w(x)$ and the expected displacement $v(x)$ are positive, the real work done is simply the product of $w(x)$ and $v(x)$ integrated over the beam. Hence, the virtual work is the product of $w(x)$ and $\delta v(x)$ integrated over the beam, where the virtual displacement is simply $\delta v(x) = \delta a_2 x^2 + \delta a_3 x^3 + \delta a_4 x^4$, where δa_2, δa_3, and δa_4 are arbitrary constants. Since $w(x)$ is a line load (and thus is already integrated over the beam's thickness), the integral over the surface becomes:

$$\int_{surface} [\boldsymbol{\sigma}](\hat{\mathbf{n}})\bullet\boldsymbol{\delta}\mathbf{u}dA = \int_0^L w(x)\delta v(x)dx = \int_0^L \frac{w_o x}{L} * \left\{\delta a_2 x^2 + \delta a_3 x^3 + \delta a_4 x^4\right\}dx.$$

$$\Rightarrow \int_{surface} [\boldsymbol{\sigma}](\hat{\mathbf{n}})\bullet\boldsymbol{\delta}\mathbf{u}dA = \frac{w_o}{L}\int_0^L \left\{\delta a_2 x^3 + \delta a_3 x^4 + \delta a_4 x^5\right\}dx = \frac{w_o}{L}\left\{\frac{\delta a_2 L^4}{4} + \frac{\delta a_3 L^5}{5} + \frac{\delta a_4 L^6}{6}\right\}.$$

As for the bending strain energy, we follow the information given in the hint:

$$\varepsilon(x) = -y\frac{d^2 v}{dx^2} = -y\left\{2a_2 + 6a_3 x + 12a_4 x^2\right\}.$$

$$\therefore \delta\varepsilon(x) = -y\frac{d^2\delta v}{dx^2} = -y\left\{2\delta a_2 + 6\delta a_3 x + 12\delta a_4 x^2\right\} \text{and } \sigma(x) = E(x)\varepsilon(x) = -yE_o\left(1+\tfrac{x}{L}\right)\left(2a_2 + 6a_3 x +\right.$$

$$\therefore \int_{volume} (\boldsymbol{\sigma})\bullet\boldsymbol{\delta\varepsilon}dV = \int_0^L \left\{\int_{area} -yE_o\left(1+\tfrac{x}{L}\right)\left(2a_2 + 6a_3 x + 12a_4 x^2\right)*(-y)\left(2\delta a_2 + 6\delta a_3 x + 12\delta a_4 x^2\right)dA\right\}dx$$

$$= E_o\int_0^L \left(1+\tfrac{x}{L}\right)\left(2a_2 + 6a_3 x + 12a_4 x^2\right)\left(2\delta a_2 + 6\delta a_3 x + 12\delta a_4 x^2\right)\left\{\int_{area} y^2 dA\right\}dx.$$

We recognize the integral over the area as the definition of I_z, which is a constant in this problem. Pulling this out and performing the resulting *x* integral is done in the following Matlab session:

```
>> syms x L a2 a3 a4 da2 da3 da4 wo Eo Iz

>> strainenergy = Eo*Iz*expand( int( (1+x/L)*(2*a2 + 6*a3*x +
12*a4*x^2)*(2*da2 + 6*da3*x + 12*da4*x^2),x,0,L))

strainenergy =

Eo*Iz*(264/5*L^5*a4*da4+162/5*L^4*da4*a3+162/5*L^4*a4*da3+14*L^3*da4
*a2+21*L^3*da3*a3+14*L^3*a4*da2+10*L^2*da3*a2+10*L^2*da2*a3+6*a2*da2
*L)
```

This expression minus the external virtual work must equal zero, according to PVD:

```
>> extwork = wo/L*(da2*L^4/4 + da3*L^5/5 + da4*L^6/6)

extwork =

wo/L*(1/4*da2*L^4+1/5*da3*L^5+1/6*da4*L^6)

>> pvd = strainenergy - extwork;
```

20. Extra notes:	
21. Peer review	