INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

CIVIL ENGINEERING

COURSE DESCRIPTOR

Course Title	FINITE ELEMENT METHOD IN STRUCTURAL ENGINEERING				
Course Code	BST001				
Programme	M.Tech(StructuralEngineering)				
Semester	II	CE			
Course Type	Core				
Regulation	IARE - R18				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	4	-	3
Chief Coordinator	Mr. Gude Ramakrishna, Assciate Professor				
Course Faculty	Mr. Gude Ramakrishna, Assciate Professor				

I.   COURSE OVERVIEW:

TheFiniteElementMethod(FEM)iswidelyusedinindustryforanalysingandmodellingstructuresandcontinua,whosephysicalbehaviourisdescribedbyordinaryandpartialdifferentialequations.TheFEMisparticularlyusefulforengineeringproblemsthataretoocomplicatedtobesolvedbyclassicalanalyticalmethods.ThemainobjectiveofthiscourseistointroducethemathematicalconceptsoftheFiniteElementMethodforobtaininganapproximatesolutionofordinaryandpartialdifferentialequations.InthiscourseyouwillattendlecturesonthefundamentalsoftheFiniteElementMethod.Thelearningprocesswillbeenhancedbycompletingassignmentsusingmathematicalsoftware.YouwillalsobeintroducedtoacommercialFiniteElementsoftwarepackage–ANSYS–duringlectureswithcomputerlaboratoriesprovidingopportunitiestopracticeon,andtocompletepracticalassignments,usingANSYS.

II.   COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
UG	ACE001	III	StrengthofMaterials–I
UG	ACE004	IV	Strength of Materials – II
UG	ACE008	V	Structural Analysis
PG	BST003	I	Computer Oriented Numerical Methods

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Finite element method in structural engineering	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	Chalk & Talk	✘	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✔	Mini Project	✔	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows: two full questions with 'either' 'or' choice will be drawn from each unit. Each question carries 14 marks.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks, with 25 marks for Continuous Internal Examination (CIE) and 05 marks for Technical Seminar and Term Paper.

Table 1: Assessment pattern for CIA

Component	Theory		Total Marks
Type of Assessment	CIE Exam	TechnicalSeminarandTermPaper	
CIA Marks	25	05	30

ContinuousInternalExamination(CIE):

The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

TechnicalSeminarandTermPaper:

TwoseminarpresentationsareconductedduringIyearIsemesterandIIsemester.Forseminar,astude ntunderthesupervisionofaconcernedfacultymember,shallidentifyatopicineachcourseandprepare thetermpaperwithoverviewoftopic.TheevaluationofTechnicalseminarandtermpaperisformaxim umof5marks.MarksareawardedbytakingaverageofmarksscoredintwoSeminarEvaluations.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineeringfundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Assignments
PO2	**Problemanalysis**:Identify,formulate,reviewresearchliteratur e,andanalyzecomplexengineeringproblemsreachingsubstanti atedconclusionsusingfirstprinciplesofmathematics,naturalsc iences,andengineeringsciences.	3	Assignments
PO 3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	3	Assignments
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and researchmethods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	2	Open ended experiments
PO5	**Moderntoolusage**:Create,select,andapplyappropriatetechni ques,resources,andmodernengineeringandITtoolsincludingp redictionandmodelingtocomplexengineeringactivitieswithan understandingofthelimitations.	1	Mini Project
PO 10	**Communication**:Communicateeffectivelyoncomplexengin eeringactivitieswiththeengineeringcommunityandwithsociet yatlarge,suchas,beingabletocomprehendandwriteeffectivere portsanddesigndocumentation,makeeffectivepresentations,a ndgiveandreceiveclearinstructions.	2	TechnicalSeminars/Term Paper
PO12	**Life-longlearning**:Recognizetheneedfor,andhavethepreparationa ndabilitytoengageinindependentandlife-longlearninginthebroadestcontextoftechnologicalchange.	3	Research Projects

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Engineering knowledge:** Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication	3	Lectures, Assignments
PSO 2	**Broadness and diversity:** Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage.	2	Projects

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 3	**Self-learning and service:** Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.	1	Guest Lectures

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Equip the students with the Finite Element Analysis fundamentals.
II	Enable the students to formulate the design problems into Finite Element Method (FEM).
III	Develop the ability to generate the governing finite element equations for systems.
IV	Enable to understand the different kinds of elements used while analysing the structure.
V	Understand the use of the basic finite elements for structural applications using truss, beam, frame and plate elements.

IX.   COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
CBST001.01	CLO 1	Understand the Concepts of FEM, steps involved merits and demerits.	PO 1	3
CBST001.02	CLO 2	Solve the problems using Raleigh-Ritz method of functional approximation.	PO 1	3
CBST001.03	CLO 3	Understand the concept of One dimensional FEM Stiffness matrix for beam and bar elements.	PO 1	3
CBST001.04	CLO 4	Know the generalized coordinates, shape functions.	PO 3	2
CBST001.05	CLO 5	Different types of elements for plane stress and plane strain analysis, displacement models.	PO 3	2
CBST001.06	CLO 6	Generalized coordinates, shape functions, convergent and compatibility requirements.	PO 4	2
CBST001.07	CLO 7	Understand the generation of element stiffness and nodal load matrices.	PO 4	2
CBST001.08	CLO 8	Know the natural coordinate system, area and volume coordinates.	PO 4	2
CBST001.09	CLO 9	Concept of Axisymmetric bodies of revolution, axisymmetric modeling.	PO 1	2
CBST001.10	CLO 10	Know the different 3-D elements strain, displacement relationship.	PO 4	2
CBST001.11	CLO 11	Concept of Axisymmetric bodies of revolution, axisymmetric modeling.	PO 1	3
CBST001.12	CLO 12	Understand the strain displacement relationship, formulation of axisymmetric elements.	PO 4	3
CBST001.13	CLO 13	Concept of isoparametric formulation, different isoparametric elements for 2D analysis.	PO 4	2
CBST001.14	CLO 14	Concept of Axisymmetric bodies of revolution, axisymmetric modeling.	PO 4	3
CBST001.15	CLO 15	Understand the strain displacement relationship, formulation of axisymmetric elements.	PO 3	2

CBST001.16	CLO 16	Concept of Plane Stress, CST Element, Plane Strain Rectangular Element	PO 3	3
CBST001.17	CLO 17	Understand the Principle Isoperimetric Formulation of the Plane Quadrilateral Element, Axi-Symmetric element.	PO 1, PO 4	2
CBST001.18	CLO 18	Introduction to Computer Implementation of FEM ,use of commercial FEA Software.	PO 1, PO 3	2

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X.   MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	3	2											1		
CLO 2	3	2											3		
CLO 3		3			3									2	
CLO 4			2										3		
CLO 5		3	3										1		
CLO 6		1			3							2	1		
CLO 7			3	2										2	
CLO 8		3		1									1		
CLO 9		3											1		
CLO 10				1										3	
CLO 11	2	1		3										2	
CLO 12					3								2		
CLO 13	1		3						2		2		3		
CLO 14					3								1		
CLO 15		1	3												
CLO 16		2							2						
CLO 17	1	1		2										3	
CLO 18		3											2		

3 = High; 2 = Medium; 1 = Low

XI.   ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1; PO 3; PO 4	SEE Exams	PO 1; PO 3; PO 4	Assignments	PO 3	Seminars	PO 4
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-

Term Paper	-						

XII. ASSESSMENT METHODOLOGIES-INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XIII. SYLLABUS

Unit-I	INTRODUCTION
History and Applications. Spring and Bar Elements, Minimum Potential Energy Principle, Direct Stiffness Method, Nodal Equilibrium equations, Assembly of Global Stiffness Matrix, Element Strain and Stress.	
Unit-II	**BEAM ELEMENTS**
Flexure Element, Element Stiffness Matrix, Element Load Vector.	
Unit-III	**METHOD OF WEIGHTED RESIDUALS**
Galerkin Finite Element Method, Application to Structural Elements, Interpolation Functions, Compatibility and Completeness Requirements, Polynomial Forms, Applications.	
Unit-IV	**TYPES**
Triangular Elements, Rectangular Elements, Three-Dimensional Elements, Isoparametric Formulation, Axi-Symmetric Elements, Numerical Integration, Gaussian Quadrature.	
Unit-V	**APPLICATION TO SOLID MECHANICS & COMPUTER IMPLEMENTATION**
Application to Solid Mechanics Plane Stress, CST Element, Plane Strain Rectangular Element, Isoparametric Formulation of the Plane Quadrilateral Element, Axi- Symmetric Stress Analysis, Strain and Stress Computations. Computer Implementationof FEM procedure, Pre-Processing, Solution, Post-Processing, Use of Commercial FEA Software.	

Text Books:

1. Finite Element Analysis, Seshu P., Prentice-Hall of India, 2005.
2. Concepts and Applications of Finite Element Analysis, Cook R. D., Wiley J., New York, 1995.

Reference Books:

1. Fundamentals of Finite Element Analysis, Hutton David, Mc-Graw Hill, 2004.
2. Finite Element Analysis, Buchanan G.R., McGraw Hill Publications, New York, 1995.
3. Finite Element Method, Zienkiewicz O.C. & Taylor R.L. Vol. I, II & III, Elsevier, 2000.
4. Finite Element Methods in Engineering, Belegundu A.D., Chandrupatla, T.R., Prentice Hall, India, 1991.

XIV. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1-2	Introduction, Concepts of FEM, steps involved merits and demerits	CLO 1	T1:3.1, 2.4,6.1
3-5	Energy principles, discrimination	CLO 1	T1:3.9
6-8	Raleigh, ritz method of functional approximation.	CLO 1	T1:3.3
9	Principles of Elasticity: Stress equations, strain displacement relationships in matrix form plane stress	CLO 1	T1:3.4
7	Study about precautions in blasting	CLO 1	T1:3.4
8-9	Study of dressing of stone.	CLO 1	T1:3.7
10	Axi-symmetric bodies of revolution with axi-symmetric loading.	CLO 2	T1:2.7
11-13	One dimensional FEM: Stiffness matrix for beam and bar elements. shape functions for ID elements	CLO 2	T1:2.9
14-15	Different types of elements for plane stress and plane strain analysis, displacement models	CLO 4	T1:6.2, 6.12
16-17	Geometric invariance, natural coordinate system, area and volume coordinates	CLO 1	T1:6.8
18-20	Isoparametric formulation: Concept, different iso-parametric elements for 2D analysis.	CLO 4	T1:6.9
21	Isoparametric formulation: Concept, different iso-parametric elements for 2D analysis.	CLO 5	T1:5.1,5.2
22-24	Formulation of 4-noded and 8-noded isoparametric quadrilateral elements.	CLO 5	T1:5.9
25-26	lagrange elements, serendipity elements.	CLO 6	T1:10
27-28	Axi Symmetric Analysis.	CLO 6	T1:10.17
29-31	Formulation of axi symmetric elements. Three dimensional FEM: Different 3-D element strain	CLO 7	T2:9.1
32-34	Displacement relationship, formulation of hexahedral and isoparametric solid element.	CLO 8	T2:12
35-36	Bodies of revolution of Axi Symmetric element.Analysis.	CLO 10	T2:9.2
37	Analysis, axi symmetric modeling, strain displacement relationship.	CLO12	T1:4.4
38-39	Explainabout Application to Solid Mechanics Plane Stress.	CLO 14	T1:4.14, 4.17
40	CST Element, Plane	CLO 14	T2:11
41	CST Element, Plane Strain Rectangular Element	CLO 16	T2:8
42-43	Introduction to Isoperimetric Formulation of the Plane Quadrilateral Element, Axi- Symmetric element.	CLO 14	T2:8
44	Explain Introduction to Computer Implementation of FEM ,	CLO 17	T2:9
45	Applications for commercial FEA Software.	CLO 18	T2:14

XV. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S no	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Experimental analysis of Structure and the behaviour under loads	Seminars/Guest Lectures/NPTEL	PO 1	PSO 1
2	Finite Element Analysis of using Software packages	Seminars/Guest Lectures/NPTEL	PO 3	PSO 1

3	Thermal analysis of a structures using FEM	Assignments / Laboratory Practices	PO 4	PSO 1

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