Curriculum and Syllabi

M.Tech Degree Programme

STRUCTURAL ENGINEERING

(with effect from Academic Year 2010-2011)

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Programme Educational Objectives

1. To produce students with excellent academic qualities and related skills who will contribute to the ever increasing academic and research requirements of the country.
2. To impart to the students, in-depth knowledge of the modern skills and tools related to structural engineering so as to enable them to address the environmental aspects and sustainable issues related to infrastructure development of the country.
3. Provide a strong foundation in basic and advanced knowledge in structural engineering, enabling the students to excel in the various careers in structural engineering field of Civil Engineering both in the National / International level.
4. Understand use of various programming and software skills.
5. Enrich the students with strong communication and technical writing skills.
6. Provide expertise in laboratory and experimental work.
7. Help the students to develop teaching skills through regular teaching assistance.
8. Prepare the students to face challenges in industry by encouraging interaction with industry, carrying out industry based projects, involving them in consultancy projects etc.

Programme Outcomes

1. Post-Graduates will develop confidence for taking up research and teaching as a profession.
2. Post-Graduates will attain an ability to identify, formulate and solve complex structural engineering problems.
3. Post-Graduates will understand the impact of engineering solutions on the society and will also be aware of the environmental aspects and sustainable issues related to infrastructure development of the country.
4. Post-Graduates will be able to conduct investigations of complex problems in structural engineering using research based knowledge and tests/experiments.
5. Post-Graduates will exhibit skills to use modern engineering tools, software and equipment to analyse various problems in Structural Engineering domain.
6. Post-Graduates will be able to communicate effectively in both verbal and written forms.
7. Post-Graduates will develop confidence to face newer challenges in Industry.
8. Post-Graduates will develop confidence for self-education and ability for life-long learning.

Department of Civil Engineering

Curriculum for M.Tech in Structural Engineering

Semester 1

S.No.	Code	Title	L	T	P/S	C
1	CE6101	Theory of Elasticity and Plasticity	3	0	0	3
2	CE6102	Structural Dynamics	3	0	0	3
3	CE6103	Advanced Theory and Design of Concrete Structures	3	0	0	3
4	CE6191	Computational Lab	0	0	2	1
5	CE6192	Stress Analysis Lab	0	0	2	1
6		Elective	3	0	0	3
7		Elective	3	0	0	3
8		Elective	3	0	0	3
	Total Credits – 11 (Core) + 6 or 9 (Electives)					

Semester 2

S.No.	Code	Title	L	T	P/S	C
1	CE6111	Finite Element Method	3	0	0	3
2	CE6112	Theory of Plates and Shells	3	0	0	3
3	CE6113	Advanced Theory and Design of Metal Structures	3	0	0	3
4	CE6193	Structural Engineering Design Studio	0	0	2	1
6	CE6197	Seminar	0	0	2	1
7		Elective	3	0	0	3
8		Elective	3	0	0	3
		Elective	3	0	0	3
	Total credits– 11 (Core) + 6 or 9 (Electives)					

Semester 3

S.No.	Code	Title	L	T	P/S	C
1	CE7198	Project				8
2		Elective	3	0	0	3
3		Elective	3	0	0	3
	Total Credits – 8 (Core) + 0 to 6 (Electives)					

Semester 4

S.No.	Code	Title	L	T	P/S	C
1	CE7199	Project				12
2		Total credits				12

LIST OF ELECTIVES

S.No.	Code	Title	Credits
1	CE6121	Structural Optimisation	3
2	CE6122	Modelling, Simulation and Computer Application	3
3	CE6123	Earthquake Analysis and Design of Structures	3
4	CE6124	Analytical Dynamics	3
5	CE6125	Bridge Engineering	3
6	CE6126	Construction Project Management	3
7	CE6127	Forensic Engineering and Rehabilitation of Structures	3
8	CE6128	Multibody Dynamics and Applications	3
9	CE6129	Tall Structures	3
10	CE6130	Structural Health Monitoring	3
11	CE6131	Structural Reliability	3
12	CE6132	Concrete Shells and Folded Plates	3
13	CE6133	Random Vibrations	3
14	CE6134	Engineering Fracture Mechanics	3
15	CE6135	Advanced Prestressed Concrete Design	3
16	CE6136	Design of Plated Structures and Shells	3
17	CE6137	Mechanics of Composite Structures	3
18	CE6138	Advanced Finite Element Analysis	3
19	CE6139	Advanced Theory of Shells	3
20	CE6140	Theory of Plasticity	3
21	CE6221	Geographic Information System and Applications	3
22	CE6302	Stochastic Processes in Structural Mechanics	3
23	CE6313	Stability of Structures	3
24	CE6421	Advanced Design of Foundation	3

Minimum requirements:

1. A minimum of 60 credits have to be earned for the award of M.Tech degree in this programme.
2. Students to register for six electives in three semesters together with two or three electives each in the first two semesters and a maximum of two in the third semester. Fourth semester is reserved for project work only.
3. Industrial Training (1 credits) during summer term is optional

COURSE ASSESSMENT METHODS:

Assessment is carried out as per the Rules & Regulations formulated by the Institute, the relevant portions of which are given below.

Lecture based courses

Continuous Assessment is based on:

- A minimum of two mandatory tests (of minimum one hour each).
- Assignments/tutorials/presentations/course projects/reports etc as decided by the course faculty.
- Weightage: Normally between 40-60%, as decided by the course faculty.

End Semester Assessment is based on:

- One end semester examination of minimum three hours duration.
- Weightage: Normally between 40-60%, as decided by the course faculty.

Laboratory/practical /drawing courses

- Assessment shall be based on tests and the performance of students in the regular laboratory/practical/ drawing classes and will be decided by the course faculty.
- End semester examination is not mandatory.
- If end semester examination is planned, it shall be conducted before the last instructional day and the weightage for it should not exceed 40%.

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

BRIEF SYLLABUS

CE6101: Theory of Elasticity and Plasticity

Prerequisite: Nil

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Introduction to the mathematical theory of elasticity **-** Two-dimensional problems in rectangular coordinates - Two-dimensional problems in polar coordinates - Introduction to Cartesian Tensors - Stress and strain problems in three dimensions - Energy Theorems and Variational Principles of Elasticity - Torsion of straight bars- Introduction to plasticity: One-dimensional elastic-plastic relations, isotropic and kinematic hardening, yield function, flow rule, hardening rule, incremental stress-strain relationship, governing equations of elastoplasticity.

CE6102: Structural Dynamics

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Over view:- Basic features of dynamic loading and response – models for dynamic analysis – lumped mass, generalized displacements and finite element models - Formulation of equation of motion - Degrees of freedom – mass moment of inertia - Generalized single degree of freedom systems - Free vibration of single degree of freedom system - Negative damping - Single degree of freedom system – Response to impulsive loads - Approximate analysis - Response to general dynamic loading - Numerical analysis in the frequency domain, fast Fourier transform analysis - Multi degree of freedom system - analysis of multi- degree of freedom system- mode superposition analysis - Distributed Parameter System-Practical Vibration Analysis - Framed structures – Shear building concept and models for dynamic analysis.

CE6103: Advanced Theory and Design of Concrete Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Stress-strain characteristics of concrete under multi- axial stresses- confined concrete- Effect of cyclic loading on concrete and reinforcing steel - Ultimate Deformation and ductility of members with flexure- strength and deformation of members with tension -Control of deflections - Strut and Tie Models- Development- Design methodology-
Strength and ductility of concrete frames- analysis of shear walls- Behaviour and design of special RCC members- Design of concrete corbels- deep beams, ribbed, hollow block or voided slab- RCC walls.

CE6191: Computational Laboratory

L	T	P	C
0	0	2	1

Prerequisite: Nil

Total Hours : 28Hrs.

Introduction to Engineering Softwares - Introduction to O/S–storage and time optimisation - General purpose packages in Civil Engineering – Program Implementation.

CE6192: Stress Analysis Laboratory

L	T	P	C
0	0	2	1

Prerequisite: Nil

Total Hours : 28Hrs.

Measurement of Strain -Measurement of Deflection - Dial gauges - Linear Variable Differential Transducers - Principles of operations of UTM, hydraulic loading systems, force measuring devices etc . - Study of the behaviour of structural materials and structural members- Casting and testing of simple compression, tension and flexural members - Introduction to Non Destructive Testing of RCC members - New Reinforced Cement Composites:- Introduction to Steel fiber reinforced concrete – Ferrocement – Polymer concrete - Self Compacting Concrete – High Performance Concrete.

CE6111: Finite Element Method

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Introduction - The element characteristic matrix – Element assembly and solution for unknowns – Basic equations of elasticity – Strain-displacement relations – Theory of stress and deformation – Stress-strain-temperature relations - The Direct Stiffness Method - Stationary Principles, Rayleigh-Ritz Method and Interpolation - Introduction to Weighted Residual Method **-**Displacement-based Elements for Structural Mechanics - Formulas for element stiffness matrix and load vector - Straight-sided Triangles and Tetrahedra - The Isoparametric Formulation - Coordinate Transformation- Topics in Structural Mechanics: - D.o.f. within elements – Condensation – Condensation and recovery algorithm – Substructuring – Structural symmetry.

CE6112: Theory of Plates and Shells

L	T	P	C
3	0	0	3

Prerequisite: Theory of Elasticity

Total Hours : 42Hrs.

Introduction:- Assumptions in the theory of thin plates – Pure bending of Plates – Relations between bending moments and curvature - Particular cases of pure bending of rectangular plates, Cylindrical bending - immovable simply supported edges - Synclastic bending and Anticlastic bending – Strain energy - Laterally Loaded Circular Plates - Laterally Loaded Rectangular Plates- Navier solution for simply supported plates subjected to uniformly distributed load and point load – Levy's method of solution for plates having two opposite edges simply supported with various symmetrical boundary conditions along the other two edges loaded with u. d. l. - Approximate Methods.
Effect of transverse shear deformation - plates of variable thickness – Anisotropic plates- thick plates- orthotropic plates and grids - Large Deflection theory - Deformation of Shells without Bending - shells in the form of a surface of revolution - displacements, unsymmetrical loading - General Theory of Cylindrical Shells.

CE6113: Advanced Theory and Design of Metal Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Introduction - Plastic methods of analysis and design - Current and future design philosophies - Design of connections: Bolted connections - Welded connections - Stiffened beam seat connection - Design of light gauge steel structures -Design of industrial buildings: Design of members subjected to lateral loads and axial loads - Sway and non-sway frames, bracings and bents - Rigid frame joints - Knees for rectangular frames and pitched roofs - Knees with curved flanges - Valley joints - Rigid joints in multistorey buildings - Vierendeel girders - Design of Aluminum Structures.

CE6193: Structural Engineering Design Studio

L	T	P	C
0	0	2	1

Prerequisite: Nil

Total Hours : 28Hrs.

Concrete Structures - Analysis, design and detailing of solid slabs, beams, circular ring beam supporting an overhead water tank- ribbed slab floor system- Generation of interaction curves for RC rectangular columns- Design of slender columns subject to biaxial bending- Analysis, design and detailing of shear walls- Application of strut-and-tie method to design and detail various RC elements and junctions. Metal Structures - Design of Steel Industrial Building - Design of towers

CE6197: Seminar

L	T	P	C
0	0	2	1

Prerequisite: Nil

Total Hours : 28Hrs.

Each Student shall prepare a Paper and present a Seminar on any topic related to the branch of specialization under the guidance of a staff member. The student shall submit typed copy of the paper to the Department. Grades will be awarded on the basis of contents of the paper and the presentation.

CE6121: Structural Optimisation

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours : 42Hrs.

Problem formulation with examples- Single Variable Unconstrained Optimisation Techniques — Optimality Citeria - Interpolation methods -Gradient Based methods - Multi Variable Unconstrained Optimisation Techniques — Optimality Citeria. Unidirectional Search - Direct Search methods - Simplex method - Gradient based methods - Constrained Optimisation Techniques —Classical methods - Linear programming problem- Indirect methods- Direct methods- Specialized Optimisation techniques — Dynamic programming, Geometric programming, Genetic Algorithms.

CE6122: Modelling, Simulation and Computer Application

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Numerical Solution of Nonlinear Equations - Fixed point iteration – Newton-Raphson method – Broyden’s method - Functional Approximations-Finite Difference Method - Parabolic equations – Algebraic Eigenvalue Problem - Eigenvalue problem for a real symmetric matrix – Integral Equations - Simulation and Monte Carlo Methods - Random number generation –Random variate generation –

inverse transform method – composition method – acceptance-rejection method - Simulation of random vectors - inverse transform method – multivariate transform method – multinormal distribution. Simulation of stochastic fields – one-dimensional and multidimensional fields.

CE 6123: Earthquake Analysis and Design of Structures

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours : 42Hrs.

Introduction to engineering seismology – Seismic waves primary and secondary waves - Concept of Seismic design : Approach to earthquake resistant design – General principles of a seismic design – Review of IS 1893:2002 – Building equivalent static analysis –Guide lines for earthquake resistant design – Ductile detailing for seismic design - Special structures - Design of water tanks – Elevated tower supported tanks- Hydrodynamic pressure in tanks-Design of towers – Stack like structures – Chimneys – Design principles of retaining walls – Concept of design of bridges – Design of bearings

CE6124: Analytical Dynamics

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Fundamentals of Newtonian Mechanics: Newton's laws, impulse and momentum - generalised coordinates, systems with constraints, stationary value of a definite integral, principle of virtual work, D'Alembert's principle - Motion Relative to Rotating Reference Frames: Transformation of coordinates, rotating coordinate systems, moving references - Rigid Body Dynamics -Behaviour of Dynamical Systems- Introduction to Advanced Topics- non-autonomous systems, perturbation techniques, transformation theory, Hamilton-Jacobi equation.

CE 6125: Bridge Engineering

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours : 42Hrs.

Classification and components of bridges - Structural forms of bridge decks – Standard specifications for bridges – IRC loadings for road bridges – standards for railway bridges – design of RC slab, skew slab and box culverts. Design of T beam bridges – balanced cantilever bridges – rigid frame bridges – Arch bridges – bow string girder bridges - Design of plate girder bridges – steel trussed bridges – Introduction to long span bridges: cable stayed bridges and suspension bridges –instability - Forces on piers and abutments – Design of piers and abutments –

CE6126: Construction Project Management

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours : 42Hrs.

Project Management - Trends in Modern Management - Strategic Planning and Project Programming - Quality and Safety Concerns in Construction -Network techniques – bar charts – Citical path method – Programme evaluation and review technique – PERT and CPM-Software Development - Use of Management Software - Optimization techniques- Resource allocation – Materials management - planning and budgeting – inventory control – management of surplus materials - equipment control - Process control- The Cost Control Problem - The Project Budget - Costs Associated with Constructed Facilities - Approaches to Cost Estimation - Computer Aided Cost Estimation - Estimation of Operating Costs.

CE6127: Forensic Engineering and Rehabilitation of Structures

Prerequisite: Nil

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Failure of Structures: Review of the construction theory – performance problems – responsibility and accountability – causes of distress in structural members – design and material deficiencies – over loading - Diagnosis and Assessment of Distress- Environmental Problems and Natural Hazards- Modern Techniques of Retrofitting- strengthening by pre-stressing.

CE6128: Multi Body Dynamics and Applications

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Kinematics of Rigid Bodies - Momentum and Kinetic Energy of Rigid Bodies- Inertia Tensor and its Properties - Newtonian Dynamics: -Lagrangian Dynamics and Virtual Work- Introduction to Multibody System Dynamics - Computational Methods - Comparison of the different dynamic formulations for the determination of the equations of motion, investigation of their applicability to computer simulation of the dynamic behaviour of the mechanical systems, computer simulation using *MATLAB*, treatment of holonomic and nonholonomic constraints through various elimination and augmentation methods.

CE6129: Tall Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Design philosophy- materials- loading- Gravity loading- Wind loading- Earthquake loading - blast loading- Behaviour of various structural systems- modeling for approximate analysis, Accurate analysis and reduction techniques. Analysis of building as total structural systems considering overall integrity and major subsystem interaction, Analysis for member forces, drift and twist, computerised general three dimensional analysis- Shear wall frame interaction -Structural elements - Stability of tall buildings -Overall buckling analysis of frames- P- Delta analysis- Translational, torsional instability, out of plumb effects, effect of foundation rotation.

CE6130: Structural Health Monitoring

Prerequisite: Nil

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Review of Structural Modelling and Finite Element Models: Modelling for damage and collapse behaviour of structures - review of Signals, Systems and Data Acquisition Systems - Frequency and time domain representation of systems - Sensors for Health Monitoring Systems- Health Monitoring/Diagnostic Techniques - Vibration signature analysis, modal analysis, neural network-based classification techniques - Integrated Health Monitoring Systems: Intelligent Health Monitoring Techniques, Neural network classification techniques- Information Technology for Health Monitoring - Project Based Health Monitoring Techniques- condition monitoring of other types of structures.

CE6131: Structural Reliability

Prerequisite: Nil

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Concepts of structural safety - Basic Statistics - Probability theory - Resistance distributions and parameters - Probabilistic analysis of loads - Basic structural reliability - computation of structural reliability - Level 2 Reliability methods - Reliability based design - Monte Carlo study of structural safety -Reliability of Structural system - reliability analysis of frames

CE6132: Concrete Shells and Folded Plates

Prerequisite: Nil

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Classification of shells-General specification of shells- Analysis of shells- Membrane theory of cylindrical shells, perturbational stresses- bending theory, Design of cylindrical shell- Beam method- ASCE manual 31 method - Hyperboloid of revolution-
Hyperbolic paraboloid –General features- types- structural behaviour of folded plates- analysis of folded plates- ASCE task committee method- Whitney's method- Simpson's method- iteration method- beam method- design of folded plates- pre-stressed folded plates.

CE6133: Random Vibrations

Pre-requisite*:* Stochastic Processes in Structural Mechanics

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Basic Theory of Stochastic Processes - Stochastic Response of Linear SDOF Systems - Linear systems with multiple inputs and outputs - Stochastic response of linear continuous system. - Response of non-linear systems to random excitation - Fatigue damage of structure due to random loads.

CE6134: Engineering Fracture Mechanics

Prerequisite: A course on Theory of Elasticity

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Significance of fracture mechanics, Griffith energy balance approach, Irwin's modification to the Griffith theory, Stress intensity approach, Cack tip plasticity, Fracture toughness, sub-critical crack growth, Linear Elastic Fracture Mechanics (LEFM)-
Cack Tip Plasticity - LEFM Testing - Plane strain and plane stress fracture toughness testing, Elastic Plastic Fracture Mechanics (EPFM)- Fatigue Cack Growth - Sustained Load Fracture:- Time-to-failure (TTF) tests, Cack growth rate testing, Experimental problems, Practical Problems

CE6135: Advanced Prestressed Concrete Design

Prerequisite: Nil

Total Hours : 42Hrs.

L	T	P	C
3	0	0	3

Limit state design of statically determinate prestressed beams- Statically indeterminate structures - analysis and design of continuous beams and frames - Choice of cable profile - linear transformation – concordancy - Composite sections of prestressed concrete beam and cast in situ RC slab - Design of composite sections - Time dependant effects such as creep, shrinkage - Partial prestressing - Limit State design of partially prestressed concrete beams - Analysis and design of prestressed concrete pipes, tanks, slabs – one way and two way (numerical problems restricted to pipes and tanks only).

CE6136: Design of Plated Structures and Shells

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours : 42Hrs.

Cylindrical bending of plates – laterally loaded circular plates – uniformly loaded core with simple and fixed boundary conditions - Laterally loaded rectangular plate – differential equations – boundary conditions – Navier solution for simply supported plates subjected to uniform and point loads – Levy's method - Approximate methods of solution of plates – Rayleigh-Ritz method – Galerkin's method – finite difference method

Orthotropic plates – stiffened plates – stability of plates – design of plated structures.

Stressed skin surfaces – types – cylindrical shells thin shells – membrane theory – bending theory – theories due to Finster-Welder and Schorer – shells of revolution – membrane theory – paraboloid of revolution – analysis using polynomial stress function – hyperbolic paraboloids – rectangular hyperbolic paraboloid - Stiffened cylindrical shells – design curves for pressure hull buckling of cylindrical shells

CE6137: Mechanics of Composite Structures

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours : 42Hrs.

Composite beams- Elastic behaviour of composite beams- Design of composite beams - Composite floors - Structural elements-Profiled sheet decking-Bending resistance-Serviceability criteria-Analysis for internal forces and moments.

Composite columns: - Continuous beams and slab Hogging moment regions of composite beams- Design strategies

CE6138: Advanced Finite Element Analysis

L	T	P	C
3	0	0	3

Prerequisite: A basic course on Finite Element Analysis

Total Hours : 42Hrs.

Plate Bending: Shells: three- and four-noded shell elements, curved isoparametric elements - Error, Error Estimation and Convergence: - adaptive meshing.

Constraints**,** Penalty Forms, Locking and Constraint Counting - Finite Elements in Structural Dynamics and Vibrations - Modelling Considerations and Software Use - Physical behaviour versus element behaviour, element shapes and interconnections - Introduction to Nonlinear Problems - Stress Stiffening and Buckling: Stress stiffness matrices for beam, bar and plate elements, a general formulation for $[k_\sigma]$, bifurcation buckling, remarks on $[k_\sigma]$, its use, and on buckling and buckling analysis.

CE6139: Advanced Theory of Shells

L	T	P	C
3	0	0	3

Prerequisite: A course on Theory of Elasticity

Prerequisite: Nil

General theory of shells, deformation of shell, compatibility conditions, forces and moments, equilibrium equations, constitutive laws, boundary conditions, solution methods of shell problems, Membrane theory - Shells of revolution - Bending theory - Shallow shells.

CE6140: Theory of Plasticity

L	T	P	C
3	0	0	3

Pre-requisite: A course on Theory of Elasticity

Total Hours : 42Hrs.

Basic equations of theory of elasticity - Framework of Plastic Constitutive Relations - Plastic behaviour in simple tension, generalisation of results in simple tension - Initial Yield Surfaces for Polycrystalline Metals - Plastic Behaviour under Plane Stress Conditions - Plastic Behaviour of Bar Structures - The Theorems of Limit Analysis - Limit Analysis in Plane Stress and Plane Strain - Limit Analysis as a Programming Problem.

CE6101 Theory of Elasticity and Plasticity

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To understand the basis of mechanics of deformable solids with adequate mathematical vigour and thus appreciate the simplifying assumptions of *strength of materials theory*
2. To get familiarised with the index notation, a *language* extensively used in modern technical literature
3. To understand idealisations of elasticity as idealisations. The plane-stress, plane-strain, axisymmetric problems and their solutions based on the idealisations enable course registrants to comprehend the importance and necessity of such idealisations.
4. To understand energy theorems and variational formulations that provide an alternative problem formulation and that leads to a variety of numerical methods
5. To understand the behaviour of a non-circular prismatic bar subjected to torsion, thus appreciate the elementary torsion problem and its simple solution.
6. To get familiarised with the basic ingredients of theory of plasticity.

Module 1: (12 hours)

Introduction to the mathematical theory of elasticity**:** Elasticity, stress, strain, Hooke's law, two-dimensional idealisations, plane stress and plane strain problems, equations of equilibrium, strain-displacement relations, constitutive relations, compatibility conditions, displacement and traction boundary conditions.
Two-dimensional problems in rectangular coordinates: Stress function, solution by polynomials, Saint Vénant's principle, bending of a cantilever, determination of displacements.
Two-dimensional problems in polar coordinates: General equations, problems of axisymmetric stress distribution, pure bending of curved bars, effect of circular hole on stress distribution in plates, concentrated force at a point on a straight boundary.

Module 2: (10 hours)

Introduction to Cartesian Tensors: Transformation laws of cartesian tensors, special tensors and tensor operations, the Kronecker's delta, the permutation tensor, the e-δ identity, symmetry and skew-symmetry, contraction, derivatives and the comma notation, Gauss' theorem, the base vectors and some special vector operations, eigenvalue problem of a symmetric second order tensor, equations of elasticity using index notation.
Stress and strain problems in three dimensions: Principal stresses, principal strains, three-dimensional problems.

Module 3: (12 hours)

Energy Theorems and Variational Principles of Elasticity: Strain energy and complementary energy, Clapeyron's theorem, virtual work and potential energy principles, principle of complementary potential energy, Betti's reciprocal theorem, principle of linear superposition, uniqueness of elasticity solution.
Torsion of straight bars: Elliptic and equilateral triangular cross-section, membrane analogy, narrow rectangular cross-section, torsion of rectangular bars, torsion of rolled profile sections, hollow shafts and thin tubes.

Module 4: (8 hours)

Introduction to plasticity: One-dimensional elastic-plastic relations, isotropic and kinematic hardening, yield function, flow rule, hardening rule, incremental stress-strain relationship, governing equations of elastoplasticity.

References.

1. Timoshenko, S.P. and Goodier, J.N., Theory of Elasticity, Mc Graw Hill, Singapore, 1982.
2. Srinath, L.S., Advanced Mechanics of Solids, Second Edition, Tata McGraw Hill, India, 2003.
3. Ameen, M., Computational Elasticity—Theory of Elasticity, Finite and Boundary Element Methods, Narosa Publishing House, 2004.
4. Leipholz, H., Theory of Elasticity, Noordhoff International Publishing, Layden, 1974.
5. Sokolnikoff, I.S., Mathematical Theory of Elasticity, Tata Mc Graw Hill, India, 1974.
6. Xu, Z., Applied Elasticity, Wiley Eastern Ltd, India, 1992.
7. Chakrabarty, J, Theory of Plasticity, Elsevier, London, 2006.
8. Hill, R., Mathematical Theory of Plasticity, Oxford University Press, 1998.
9. Chen, W.F., and Han, D.J., Plasticity for Structural Engineers, Springer Verlag, 1998.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Mathematically formulate elasticity problems as a well posed boundary value problem
2. Solve simple engineering problems with mathematical rigour. Such solutions can act as bench-mark solutions for testing computational methods and software.
3. Appreciate the Cartesian Tensor notation, thereby understand modern technical literature, which otherwise would have appeared intricate.
4. Develop simple approximate methods based on variational formulations
5. Will be able to begin to understand advanced books on theory of plasticity

CE6102 Structural Dynamics

Prerequisite: Nil

Total Hours: 42 Hrs.

L	T	P	C
3	0	0	3

Course Objectives:

1. To understand the basics of dynamic loading and response and to mathematically formulate dynamic equation of equilibrium of structural systems.
2. To get familiarised with the free vibration analysis of single degree of freedom systems.
3. To understand response of single degree of freedom systems to harmonic loading, periodic loading and general dynamic loadings.
4. To understand free vibration analysis of multi degree of freedom systems and to study its response.
5. To get familiarised with dynamic analysis of distributed parameter systems.
6. To get familiarised with the practical vibration analysis viz. modelling of different types of structures, determination of natural frequency by approximate methods etc.

Module 1: (11hours)

Over view:- Basic features of dynamic loading and response – models for dynamic analysis – lumped mass, generalized displacements and finite element models
Formulation of equation of motion – Direct equilibration, principle of virtual displacement and Hamilton's principle.
Degrees of freedom – Translational and rotational systems - mass moment of inertia
Generalized single degree of freedom systems- rigid body assemblage determination of characteristic properties.
Free vibration of single degree of freedom system:- Solution of equation of motion, undraped free vibration - Damped free vibration, critically damped, under damped and over damped systems, Negative damping.

Module 2: (11hours)

Single degree of freedom system – Response:- Response to harmonic loading, Undamped system- damped system, Response to periodic loading -Fourier series expansion of the loading- response to Fourier series loading Exponential form of Fourier series loading and response- Complex frequency transfer functions
Response to impulsive loads :- Suddenly applied load, sine wave impulse, rectangular impulse, triangular impulse, spike loading, approximate analysis
Response to general dynamic loading:- Duhamel integral for undamped system – unit impulse response function – numerical evaluation, response of damped system- numerical evaluation, Numerical analysis in the frequency domain, fast Fourier transform analysis.

Module 3: (11hours)

Multi degree of freedom system:- Two degree of freedom system – equation of motion, characteristic equation, frequencies and mode shapes, coordinate coupling and choice of degree of freedom, orthogonality of modes, natural coordinates, superposition of natural modes , response of two degree of freedom system to initial excitation, beat phenomenon, response to harmonic excitation
Multi- degree of freedom system – analysis of multi- degree of freedom system- mode superposition analysis.
Distributed Parameter System: Partial differential equation of motion - Axial vibration of prismatic bars - Elementary case of flexural vibration of beams - Beam flexure including axial force effects.

Module 4: (9hours)

Practical Vibration Analysis:- Determination of frequency by Rayliegh's method, beam flexure – selection of shape- improved Rayliegh's method.
Framed structures – Shear building concept and models for dynamic analysis, discrete parameter system by Rayliegh's method , improvement of frequency, Stodola method for discrete parameter system, reduction of second and higher modes- Stodola method for continuous parameter system.

References.

1. Clough,R.W. and Penzien, J., Dynamics of structures, McGraw Hill
2. Chopra, A.K., Dynamics of structures – Theory and Application to Earthquake Engg., Prent. Hall.
3. IS 1893 – Criteria for Earthquake Resistant Design of Structures.
4. SP 22: Explanatory Handbook on Codes for Earthquake Engineering.
5. Meirovitch L., Elements of Vibration Analysis, Mc.Graw Hill.
6. Thomson W.T., Theory of Vibration with Applications, CBS Publ.
7. Craig, Jr. R.R., Structural Dynamics, John Wiley.
8. Hurty, W.C. and Rubinstein M.F., Dynamics of Structures, Prentice Hall.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Mathematically model a structural system for dynamic analysis of the system.
2. Carry out free vibration analysis of single degree of freedom.
3. Analyse a single degree of freedom systems to subjected to harmonic loading, periodic loading and general dynamic loadings.
4. Perform free vibration forced vibration analyses of multi degree of freedom.
5. Expose the students to the practical vibration analysis viz. modelling of different types of structures, determination of natural frequency by approximate methods etc.

CE6103 Advanced Theory and Design of Concrete Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To impart to the stakeholders in depth knowledge in the areas of serviceability limits and stress-strain behaviour of concrete.
2. To familiarise the principles of unified concrete theory and design of RCC structures using on strut and tie model concepts.
3. To expose the students to analysis and design of shear walls.
4. To acquire the knowledge on the design of special RCC members.

Module 1: (11hours)

Stress-strain characteristics of concrete under multi- axial stresses- confined concrete- Effect of cyclic loading on concrete and reinforcing steel.
Ultimate Deformation and ductility of members with flexure- strength and deformation of members with tension -Control of deflections- immediate and long term deflections-Control of cracking – classical theory of cracking- International codal procedures on crack-width computation.

Module 2: (11hours)

Strut and Tie Models- Development- Design methodology- selecting dimensions for struts- ACI Provisions- Applications- RCC beam – column joints- classification – shear strength- design of exterior and interior joints- wide beam joints.

Module 3: (10hours)
Strength and ductility of concrete frames- analysis of shear walls- distribution of lateral loads in uncoupled shear walls- Equivalent stiffness method- Shear wall frame interactions.

Module 4: (10hours)

Behaviour and design of special RCC members- Design of concrete corbels- deep beams, ribbed, hollow block or voided slab- RCC walls.

References.

1. Arthur. H. Nilson, David Darwin and Charles W Dolan, Design of Concrete Structures, Tata McGraw Hill, 2004
2. Park,R and Paulay T, Reinforced Concrete Structures, John Wiley & Sons, New York
3. Macleod, I.A, Shear Wall Frame Interaction. A design aid with commentary Portland Cement Association.
4. Thomas T. C. Hsu, Unified Theory of Reinforced Concrete, CRC Press, London,1993.
5. IS 456 –2000, Indian Standard for Plain and Reinforced Concrete- Code of Practice, New Delhi
6. ACI – 318: 2002, Building Code Requirements for Structural Concrete and Commentary, ACI Michigan.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Utilise the knowledge gained for the design of RCC structures
2. Carryout rational design of RCC structures using the strut and tie model concept.
3. Analyse and design any type of shear walls.
4. Design special RC structures such as deep beams, ribbed, hollow brick or void slabs, corbels and walls.

CE6191 Computational Laboratory

L	T	P	C
0	0	2	1

Pre-requisite: Nil

Total Hours: 28 Hrs.

Course Objectives:

1. To introduce various Engineering Softwares.
2. To introduce O/S, storage and time optimisation.
3. To familiarize with general purpose packages in Civil Engineering and Program Implementation.

Introduction to Engineering Softwares - Introduction to O/S–storage and time optimisation - General purpose packages in Civil Engineering – Program Implementation-

Course Requirement

Students are expected to know at least one high-level language. They will be imparted instructions for using available computer systems – Each student will be assigned a term project in his area of interest and shall develop an application program.

Assessment Methods:

Continuous Assessment	: 40 Marks
(Test 1: 15; Test 2: 25	
Class Works etc	: 60 Marks

Course Outcomes:

The student will be able to

1. Know at least one high-level language.
2. Develop computer programmes to solve typical problems in Structural engineering.
3. Use various scientific computing tools/softwares to solve problems in Structural engineering.

CE6192 Stress Analysis Laboratory

L	T	P	C
0	0	2	1

Pre-requisite: Nil

Total Hours: 28 Hrs.

Course Objectives:

1. To familiarise the latest methods of measuring deformations and strains.
2. To train the stakeholder in the operation of different loading systems and force measuring device operations.
3. To impart the principles of NDT techniques on the hardened concrete.
4. To expose the students to new reinforced cementitious composites.

Measurement of Strain: - Mechanical Strain Gauges- Electrical Strain gauges- Extensometers and Compressometers
Measurement of Deflection:- Dial gauges - Linear Variable Differential Transducers
Principles of operations of UTM, hydraulic loading systems, force measuring devices etc.
Study of the behaviour of structural materials and structural members- Casting and testing of simple compression, tension and flexural members.
Introduction to Non Destructive Testing of RCC members.
New Reinforced Cement Composites:- Introduction to Steel fiber reinforced concrete – Ferrocement – Polymer concrete - Self Compacting Concrete – High Performance Concrete.

Course Requirement

Number of suitable experiments will be designed involving the use of above instruments, so that a student on successful completion of the course shall be in a position to use any of these instruments for experiments and testing work. A student will be required to conduct specified number of experiments and submit a report/record of such work. The grades will be awarded based on the performance in the laboratory work, report/record of experiments and a viva-voce examination conducted at the end of the course.

Assessment Methods:

Continuous Assessment	: 40 Marks
(Test 1: 15; Test 2: 25	
Class Works etc	: 60 Marks

Course Outcomes:

The student will be able to

1. Measure deformation and strain in RCC structures during laboratory testing and in the field.
2. Carryout experimental research based on the knowledge gained.
3. Estimate strength and stiffness of RCC structures which will be useful in the areas of rehabilitation or retrofitting of structures.
4. Utilise the new composites such as steel fiber reinforced concrete, ferrocement, polymer concrete, SCC and HPC in the construction activities.

CE6111 Finite Element Method

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To review basics of elasticity and introduce finite element method of analysis.
2. To get familiarised with direct stiffness method, element stiffness, its assembly, boundary conditions solutions techniques etc.
3. Appreciate energy principles and development of element stiffness of one dimensional elements.
4. Development of element stiffness of two dimensional and solid elements.
5. To introduce topics like coordinate transformations, condensation techniques, sub-structuring etc.

Module 1: (10hours)

Introduction:- The Finite Element Method – The element characteristic matrix – Element assembly and solution for unknowns – Summary of finite element history.
Basic equations of elasticity – Strain-displacement relations – Theory of stress and deformation – Stress-strain-temperature relations.
The Direct Stiffness Method: - Structure stiffness equations – Properties of [K] – Solution of unknowns – Element stiffness equations – Assembly of elements – Node numbering to exploit matrix Sparsity – Displacement boundary conditions – Gauss elimination solution of equations – Conservation of computer storage – Computational efficiency – Stress computation – Support reactions – Summary of the finite element procedure.

Module 2: (11hours)

Stationary Principles, Rayleigh-Ritz Method and Interpolation: - Principle of stationary potential energy – Problems having many d.o.f – Potential energy of an elastic body – The Rayleigh-Ritz method – Piecewise polynomial field – Finite element form of Rayleigh-Ritz method – Finite element formulations derived from a functional – Interpolation – Shape functions for C^0 and C^1 elements – Lagrangian and Hermitian interpolation functions for one dimensional elements – Lagrangian interpolation functions for two and three dimensional elements
Introduction to Weighted Residual Method: **-**Some weighted residual methods – Galerkin finite element method – Integration by parts – Axially loaded bar – Beam – Plane elasticity.

Module 3: (11hours)

Displacement-based Elements for Structural Mechanics:- Formulas for element stiffness matrix and load vector – overview of element stiffness matrices – Consistent element nodal load vector – Equilibrium and compatibility in the solution – Convergence requirements – Patch test – Stress calculation – Other formulation methods.
Straight-sided Triangles and Tetrahedra:- Natural coordinates for lines, triangles and tetrahedra – Interpolation fields for plane triangles – linear and quadratic triangle – quadratic tetrahedron.
The Isoparametric Formulation:- Introduction – An isoparametric bar element – Plane bilinear element – Summary of Gauss quadrature – Quadratic plane elements – Direct construction of shape functions for transition elements – Hexahedral (solid) isoparametric elements – Triangular isoparametric elements – Consistent element nodal loads – Validity of isoparametric elements – Appropriate order of quadrature – element and mesh instabilities – Remarks on stress computation.

Module 4: (10hours)

Coordinate Transformation:- Transformation of vectors – transformation of stress, strain and material properties – Transformation of stiffness matrices – Transformation of Flexibility to Stiffness – Inclined support – Joining dissimilar elements to one another – Rigid links – Rigid elements.
Topics in Structural Mechanics: - D.o.f. within elements – Condensation – Condensation and recovery algorithm – Substructuring – Structural symmetry.

References

1. Cook, R.D., et al, Concepts and Applications of Finite Element Analysis, John Wiley.
2. Desai, C.S., Elementary Finite Element Method, Prentice Hall of India.
3. Chandrupatla, T.R., and Belegundu, A.D., Introduction to Finite Elements in Engineering, Prentice Hall of India.
4. Bathe, K.J., Finite Element Procedures in Engineering Analysis, Prentice Hall of India.
5. Gallaghar, R.H., Finite Element Analysis: Fundamentals, Prentice Hall Inc.
6. Rajasekaran, S., Finite Element Analysis in Engineering Design, Wheeler Pub.
7. Krishnamoorthy, C.S., Finite Element Analysis – Theory and Programming, Tata Mc Graw Hill.
8. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vol. I and II, Mc Graw Hill.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Develop stiffness matrices of one dimensional, two dimensional and solid elements.
2. Develop structure stiffness matrix, load vector and solve the same after applying boundary conditions.
3. Develop computer programs for analysing different types of structures using finite element methods.

CE6112 Theory of Plates and Shells

L	T	P	C
3	0	0	3

Prerequisite: Theory of Elasticity

Total Hours: 42 Hrs.

<u>Course Objectives:</u>

1. To understand the classical theory and background mathematics of plates and shells.
2. To get exposed to different type of plate problems and the numerical solution techniques to obtain their behaviour.
3. To appreciate the general solution of plate problems and relate them with their simplified counter parts in strength of materials.
4. To understand the geometry and behaviour of thin shells and obtain solutions to practical problems.

Module 1: (8hours)

Introduction:- Assumptions in the theory of thin plates – Pure bending of Plates – Relations between bending moments and curvature - Particular cases of pure bending of rectangular plates, Cylindrical bending - immovable simply supported edges - Synclastic bending and Anticlastic bending – Strain energy in pure bending of plates in Cartesian and polar co-ordinates – Limitations.

Module 2: (8hours)

Laterally Loaded Circular Plates:- Differential equation of equilibrium – Uniformly loaded circular plates with simply supported and fixed boundary conditions – Annular plate with uniform moment and shear force along the boundaries.

Module 3: (15hours)

Laterally Loaded Rectangular Plates: - Differential equation of plates – Boundary conditions – Navier solution for simply supported plates subjected to uniformly distributed load and point load – Levy's method of solution for plates having two opposite edges simply supported with various symmetrical boundary conditions along the other two edges loaded with u. d. l. – Simply supported plates with moments distributed along the edges - Approximate Methods.
Effect of transverse shear deformation - plates of variable thickness – Anisotropic plates-thick plates- orthotropic plates and grids - Large Deflection theory .

Module 4: (11hours)

Deformation of Shells without Bending:- Definitions and notation, shells in the form of a surface of revolution, displacements, unsymmetrical loading, spherical shell supported at isolated points, membrane theory of cylindrical shells, the use of stress function in calculating membrane forces of shells.
General Theory of Cylindrical Shells:- A circular cylindrical shell loaded symmetrically with respect to its axis, symmetrical deformation, pressure vessels, cylindrical tanks, thermal stresses, inextensional deformation, general case of deformation, cylindrical shells with supported edges, approximate investigation of the bending of cylindrical shells, the use of a strain and stress function, stress analysis of cylindrical roof shells.

References

1. S.P Timoshenko and S.W Krieger, Theory of Plates and Shells, McGraw Hill
2. R. Szilard, Theory and Analysis of Plates – Classical Numerical Methods', Prentice Hall inc
3. N.K Bairagi, Plate Analysis, Khanna Publishers, New Delhi.
4. P.L Gould, Analysis of Shells and Plates, Springer-Verlag, New York, 1988.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Analyse different types of plates with various boundary conditions in the field of civil engineering and related fields.
2. Use numerical techniques in solving special plate problems.
3. Address complex problems in plates and shells which require a rigorous mathematical background.
4. Identify different type of shells and analyse shell structures for the stress resultants leading to an optimal design.

CE6113 Advanced Theory and Design of Metal Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To understand the principles of plastic design and LRFD concepts.
2. To expose the stakeholder to the advance types of connections.
3. To analyse and design of light gauge steel structures.
4. To familiarise the principles of analysis and design of industrial buildings and aluminium structures.

Module 1: (10hours)

Introduction - Plastic methods of analysis and design - plastic behavior under static and cyclic loading - static, kinematic and uniqueness theorems - shape factors - moment redistribution - Analysis of single and two bay portal frames - Plastic design with LRFD concepts - LRFD with elastic analysis - Current and future design philosophies.

Module 2: (11hours)

Design of connections: Bolted connections - Failure modes of a joint - High strength bolts - HSFG bolts - Seat angle and web angle connections - moment resistant connections - semi rigid connections - Design of framed beam connection - continuous beam to beam connection. Welded connections - Stiffened beam seat connection - Moment resistant joint - Tubular connections - Parameters of an in plane joint - Hotspots - Welds in tubular joints - Curved weld length at intersection of tubes - SHS and RHS tubes - design parameters - Advance types of welded connections.

Module 3: (10hours)

Design of light gauge steel structures: Introduction – Types of cross sections – Materials – Local and post buckling of thin elements – Stiffened and multiple stiffened compression elements – Tension members – Beams and deflection of beams – Combined stresses and connections.

Module 4: (11hours)

Design of industrial buildings: Design of members subjected to lateral loads and axial loads - Sway and non-sway frames, bracings and bents - Rigid frame joints - Knees for rectangular frames and pitched roofs - Knees with curved flanges - Valley joints - Rigid joints in multistorey buildings - Vierendeel girders.
Design of Aluminum Structures: Introduction – Stress-strain relationship – Permissible stresses – Tension members – Compression members – Laced and battened columns – Beams – Local buckling of elements of compression – Riveted and bolted connections.

References

1. Gaylord ., *Design of steel structures*, McGraw Hill, New York.
2. Dayaratnam, P., Design of steel structures, Wheeler Pub.
3. Wie-Wen Yu.,Cold-Formed Steel Structures, McGraw Hill Book Company.
4. SP : 6(5) : ISI Handbook for Structural Engineers - Cold Formed light gauge steel structures.
5. SP : 6(6) : Application of plastic theory in design of steel structures.
6. IS : 801 : Code of Practice for use of Cold-Formed light gauge steel structural members in general building construction.
7. Lothers, Advanced design in steel, Prentice Hall, USA.
8. Chen, W.F., and Toma,., Advanced Analysis of Steel Frames.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Carryout rational design of steel structures using plastic and LRFD methods.
2. Design different types of bolted and weld connections.
3. Design light gauge steel columns, beams and tension members.
4. Analyse and design industrial buildings and aluminium structures.

CE6193 Structural Engineering Design Studio

L	T	P	C
0	0	2	1

Pre-requisite: Nil

Course Objectives:

1. To introduce practical aspects of analysis and design of various structures.
2. To familiarize with the use of latest analysis and design tools and softwares.
3. To acquire practical knowledge in the design of a typical RC residential building, multi-storeyed building, overhead water tanks, ribbed floor systems, and shear walled building.
4. To acquire practical knowledge in the design of steel industrial building, steel bridges, and steel towers.

Total Hours : 28Hrs.

Concrete Structures: -
Analysis, design and detailing of solid slabs in a typical floor for a residential building- Analysis, design and detailing of beams in a typical intermediate floor of a multi-storey building- Analysis, design and detailing of circular ring beam supporting an overhead water tank- Analysis, design and detailing of a ribbed slab floor system- Generation of interaction curves for RC rectangular columns- Design of slender columns subject to biaxial bending- Analysis, design and detailing of shear walls- considering shear wall-frame interaction in a tall RC structure subject to wind loading- Application of strut-and-tie method to design and detail various RC elements and junctions.
Metal Structures: -
Design of Steel Industrial Building - Design of Steel Multi-storey Building - Design of Material Handling system - Design of steel Bridge - Design of pre-engineered buildings Design of storage structures - Design of towers

References

1. Arthur. H. Nilson, David Darwin and Charles W Dolan, Design of Concrete Structures, Tata McGraw Hill, 2004
2. Park,R and Paulay T, Reinforced Concrete Structures, John Wiley & Sons, New York
3. Macleod, I.A, Shear Wall Frame Interaction. A design aid with commentary Portland Cement Association.
4. IS 456 :2000, Indian Standard for Plain and Reinforced Concrete- Code of Practice, BIS, New Delhi
5. IS 13920 : 1993, Indian Standard for Ductile Detailing of Reinforced Concrete Structures subjected toSeismic Forces - Code of Practice, BIS, New Delhi
6. Gaylord ., Design of steel structures, McGraw Hill, New York.
7. Dayaratnam, P., Design of steel structures, Wheeler Pub.

Assessment Methods:

Continuous Assessment : 40 Marks
(Test 1: 15; Test 2: 25)
Class Works : 60 Marks

Course Outcomes:

The student will be able to

1. Use latest analysis and design tools and softwares.
2. Carry out practical design of a typical RC residential building, multi-storeyed building, overhead water tanks, ribbed floor systems, and shear walled building.
3. Perform practical design of steel industrial building, steel bridges, and steel towers.

CE6197: Seminar

L	T	P	C
0	0	2	1

Prerequisite: Nil

Total Hours: 28 Hrs.

Course Objectives:

1. To improve the communication skills.

2. To identify the recent developments taking place in structural engineering and prepare seminar talks in these areas.
3. Also to identify the topics for PG dissertation work.

Each Student shall prepare a Paper and present a Seminar on any topic related to the branch of specialization under the guidance of a staff member. The student shall submit typed copy of the paper to the Department. Grades will be awarded on the basis of contents of the paper and the presentation.

Course Outcomes:

The student will be able to

1. Address the structural engineering problems and convey the ideas efficiently.
2. Understand the current research and field application in structural engineering.
3. Directly involve in the dissertation work without wasting precious time.

CE7198/CE7199 Project

Course Objectives:

1. To formulate a focussed testable structural engineering research question that can be feasibly investigated within a specified time period.
2. To conduct an extensive literature survey on the research area selected and to identify the scope, objective and to formulate the methodology of research project.
3. To plan and design a suitable experimental/ analytical procedure, obtain data and properly analyse and interpret the data collected with appropriate conventional and modern methods / tools and to arrive at conclusions.
4. To familiarize with the preparation of research reports, power point presentations technical paper publications etc.

Course Outcomes:

The student will be able to

1. Develop the essential personal, organisational, management, theoretical and research skills to become independent researchers
2. Demonstrate a degree of analysis and a degree of originality in advanced investigations.
3. Develop understanding of research philosophies, design and terminology as well as personal transferable skills.
4. Describe a process that has previously been unexplained, difficult or poorly/ partially understood and to conduct an active, systematic process of inquiry.
5. To prepare professional documentation of research work carried out.

CE6121 Structural Optimisation

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To acquaint students with the techniques of structural optimum problem formulations.
2. To familiarize with the principles of single variable and multi variable optimisation techniques.
3. To understand the basic principles of unconstrained and constrained optimisation techniques.
4. To expose the students to the various specialised optimisation techniques like linear programming, dynamic programming, geometric programming and genetic algorithm.

Module 1: (11hours)

Introduction.Problem formulation with examples.
Single Variable Unconstrained Optimisation Techniques — Optimality Criteria.
Bracketing methods: Unrestricted search, Exhaustive search.
Region Elimination methods: Interval Halving methods, Dichotomous search, Fibonacci method, Golden section method.
Interpolation methods: Quadratic Interpolation method, Cubic Interpolation method.
Gradient Based methods: Newton-Raphson method, Secant method, Bisection method.

Module 2: (11hours)

Multi Variable Unconstrained Optimisation Techniques — Optimality Criteria.
Unidirectional Search.
Direct Search methods: Random search, Grid search, Univariate method, Hooke's and Jeeves' pattern search method, Powell's conjugate direction method, Simplex method.
Gradient based methods: Cauchy's (Steepest descent) method, Conjugate gradient (Fletcher-Reeves) method, Newton's method, Variable metric (DFP)method, BFGS method.

Module 3: (10hours)

Constrained Optimisation Techniques
Classical methods: Direct substitution method, Constrained variation method, method of Lagrange multipliers, Kuhn-Tucker conditions.
Linear programming problem: Standard form, Simplex method.
Indirect methods: Elimination of constraints, Transformation techniques, and Penalty function method.
Direct methods: Zoutendijk's method of feasible direction, Rosen's gradient Projection method.

Module 4: (10hours)

Specialized Optimisation techniques — Dynamic programming, Geometric programming, Genetic Algorithms.

References

1. Rao S. S., Engineering Optimisation – Theory and Practice, New Age International.
2. Deb, K., Optimisation for Engineering Design – Algorithms and examples, Prentice Hall.
3. Kirsch U., Optimum Structural Design, McGraw Hill.
4. Arora J S. Introduction to Optimum Design, McGraw Hill
5. Rajeev S and Krishnamoorthy C. S., Discrete Optimisation of Structures using Genetic Algorithms, Journal of Structural Engineering, Vol. 118, No. 5, 1992, 1223-1250.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Distinguish different types of structural systems and to find the best concept design that meets the design requirement according to a preselected quantitative measure of effectiveness.
2. Exploit the available limited resources in a manner that maximises output and the structural performance in a manner that economises energy or minimise discomfort.
3. Select the best structural design from the large number of feasible designs in terms of minimum cost, minimum weight or maximum performance or combinations of these.
4. Analyse structures using optimisation techniques which replaces the time consuming and costly design iterations and hence reduces design development time and overall cost while improving design performance.

CE6122 Modelling, Simulation and Computer Application

L	T	P	C
3	0	0	3

Prerequisite: Nil.

Total Hours: 42 Hrs.

Course Objectives:

1. To numerically solve nonlinear equations using fixed point iteration and functional approximations method.
2. To use Finite Difference method to solve elliptic and parabolic equations.
3. To get familiarized with algebraic eigen value problems, integral equations, and Monte Carlo simulation methods

Module 1: (10hours)

Numerical Solution of Nonlinear Equations
Fixed point iteration – Newton-Raphson method – Broyden's method
Functional Approximations: - Choice of norm and model – linear least squares – nonlinear least squares – discrete Fourier transform – fast Fourier transform – FFT in two or more dimensions – inversion of Laplace transform – Chebyshev approximations.

Module 2: (11hours)

Finite Difference Method: - Elliptic equations – Laplace equation – solution techniques – boundary conditions – the control volume approach.
Parabolic equations – the heat conduction equation – explicit method – simple implicit method – parabolic equation in two spatial dimensions.

Module 3: (10hours)

Algebraic Eigenvalue Problem: - Eigenvalue problem for a real symmetric matrix – inverse iteration – QL algorithm for a symmetric tridiagonal matrix – reduction of a general matrix to Hessenberg form – Lanczos method – QR algorithm for a real Hessenberg matrix – errors.
Integral Equations: - Fredholm equations of the second kind – expansion methods – eigenvalue problem – Fredholm equations of the first kind – Volterra equations of the second kind – Volterra equations of the firs kind.

Module 4: (11hours)

Simulation and Monte Carlo Methods:
Random number generation – congruential generators – statistical tests of pseudorandom numbers.
Random variate generation – inverse transform method – composition method – acceptance-rejection method.
Simulation of random vectors - inverse transform method – multivariate transform method – multinormal distribution.
Simulation of stochastic fields – one-dimensional and multidimensional fields.

References

1. Antia, H.M., Numerical Methods for Scientists and Engineers, Tata McGraw Hill.
2. Chapra, S.C., and Canale, R.P., Numerical Methods for Engineers, Tata McGraw Hill.
3. Rubinstein, R.Y., Simulation and the Monte Carlo Method, John Wiley.
4. Press, W.H., et al., Numerical Recipes in C, Cambridge University Press.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to
1. Solve nonlinear equations.
2. Solve elliptic equations like Laplace equations and parabolic equations like heat conduction equations.
3. Solve algebraic eigenvalue problems
4. Introduced to important integral equations
5. Simulate random fields using Monte Carlo methods.

CE 6123 Earthquake Analysis and Design of Structures

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To introduce engineering seismology.
2. To get familiarised with general principles of seismic design of buildings.
3. To get acquainted with relevant BIS codes related to seismic design.

4. To understand the seismic design principles of special structures like elevated water tanks, towers, bridges.

Module 1: (10hours)

Introduction to engineering seismology – Seismic waves primary and secondary waves – Raleigh wave - Love wave – Magnitude of earthquake – Intensity

Module 2: (12hours)

Concept of Seismic design : Approach to earthquake resistant design – General principles of a seismic design – Review of IS 1893:2002 – Building equivalent static analysis – Vertical distribution of seismic forces and horizontal shears – Dynamic analysis – Design spectrums – Seismic weights – Modal combination – Load combinations and permissible stresses – Guide lines for earthquake resistant design – Ductile detailing for seismic design

Module 3: (10hours)

Special structures: Design of water tanks – Elevated tower supported tanks- Hydrodynamic pressure in tanks – examples

Module 4: (10hours)

Design of towers – Stack like structures – Chimneys – Design principles of retaining walls – Concept of design of bridges – Design of bearings

References

1. IS: 1893-2002, Indian Standard Criteria for Earthquake Resistant Design of Structures, Part I, General Provisions, BIS, New Delhi, p.39
2. IS:1893-1984, Indian Standard Criteria for Earthquake Resistant Design of Structures, BIS, New Delhi, p.77
3. IS: 4326-1993, Indian Standard Code of practice for Earthquake Resistant Design and Construction of Buildings, BIS, New Delhi, 1993
4. SP:22-1982, Explanatory Hand Book on Codes of Earthquake Engineering, BIS, New Delhi, 1982.
5. IS:13920-1993, Indian Standard Ductile Detailing of RCC Structures subjected to seismic forces – Code of practice, 1993, p.16
6. Lecture notes prepared by Department of Earthquake Engineering, IIT Roorkee, 2002
7. Short term course notes on Earthquake Resistant Design , by Sudhir K Jain & CVR Murthy, I.I.T Kanpur

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Understand basics of seismology, magnitude and intensity of earthquake.
2. Understand general principles of seismic design of buildings based on relevant design standard.
3. Carry out earthquake analysis and design of multi-storeyed buildings.
4. Carry out earthquake analysis and design of special structures like water tanks stack like structures, bridges etc.

CE6124 Analytical Dynamics

Pre- requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

<u>Course Objectives:</u>

1. To understand the basics of Newtonian and analytical dynamics
2. To get familiarised with formulation and methods of solution of problems of dynamics of rigid bodies
3. To understand energy theorems and variational principles of mechanics

Module 1: (10hours)

Fundamentals of Newtonian Mechanics: Newton's laws, impulse and momentum, angular momentum, work and energy, systems of particles.
Fundamentals of Analytical Mechanics**:** Degrees of freedom, generalised coordinates, systems with constraints, stationary value of a definite integral, principle of virtual work, D'Alembert's principle, Hamilton's principle, Lagrange's equations of motion, Lagrange's equations for impulsive forces, conservation laws, Routh's method for the ignoration of coordinates, Rayleigh's dissipation function, Hamilton's equations.

Module 2: (10hours)

Motion Relative to Rotating Reference Frames: Transformation of coordinates, rotating coordinate systems, moving references.

Module 3: (10hours)

Rigid Body Dynamics: Kinematics of a rigid body, linear and angular momentum of a rigid body, translation theorem for angular momentum, kinetic energy of a rigid body, Euler's equations of motion, Euler's angles, moment-free inertially symmetric body, general case of moment-free body, symmetric top, equations of motion referred to arbitrary system of axes.

Module 4: (12hours)

Behaviour of Dynamical Systems: Motion of single degree of freedom autonomous systems about equilibrium points, limit cycle, stability of linear multi-degree of freedom autonomous systems, Routh-Hurwitz criterion, Liapunov direct method, geometric interpretation, construction of Liapunov function.
Introduction to Advanced Topics: Introduction to the following topics: non-autonomous systems, perturbation techniques, transformation theory, Hamilton-Jacobi equation.

References

1. Meirovitch, L., Methods of Analytical Dynamics, McGraw-Hill, 1970.
2. Goldstein, H., Poole, C., and Safko, J., Classical Mechanics, Third edition, Pearson Education Inc., 2002.
3. Torok, J.S., Analytical Mechanics with an Introduction to Dynamical Systems, John Wiley, New York, 2000.
4. Baruh, H., Analytical Dynamics, McGraw-Hill, New York, 1999.
5. Greenwood, D.T., Classical Dynamics, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.
6. Shames, I.H., Engineering Mechanics: Dynamics, Fourth Edition, Prentice-Hall of India, 1996.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks

(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Formulate problems of dynamics using differential equation approach and variational approach.
2. Solve engineering problems with mathematical rigour. Such solutions can act as bench-mark solutions for testing computational methods and software.
3. Appreciate energy theorems and variational principles of mechanics, the most beautiful areas of mechanics. This will make the registrant more enthusiastic, both in studies and in dealing with real-life problems.
4. Formulate numerical solutions to mechanics problems based on variational formulations.

CE 6125 Bridge Engineering

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To understand various components and structural forms of bridges.
2. To familiarize with IRC and Indian railway loading standards for bridges.
3. To design RC bridges like slab culverts, box culverts, T beam bridges and rigid frame bridges. To design steel bridges like plate girder and truss girder bridges. To design bearings, piers and abutments.
4. To familiarize with the design principles of long span bridges like cable stayed and suspension bridges.

Module 1: (11hours)

Introduction–classification and components of bridges– layout and planning–
Structural forms of bridge decks – grillage analysis of slab decks, beam and slab decks, cellular decks.

Module 2: (13hours)

Standard specifications for bridges – IRC loadings for road bridges – standards for railway bridges – design of RC slab, skew slab and box culverts. Design of T beam bridges – balanced cantilever bridges – rigid frame bridges – Arch bridges – bow string girder bridges.

Module 3: (12hours)

Design of plate girder bridges – steel trussed bridges – Introduction to long span bridges: cable stayed bridges and suspension bridges –instability.

Module 4: (6hours)

Forces on piers and abutments – Design of piers and abutments – types of wing walls – types of bearings – design of bearings.

References

1. E.C. Hambly, Bridge deck behaviour, Chapman and Hall, London
2. E.J. O'Brien and D.L. Keogh, Bridge deck analysis, E& FN Spon, New York
3. D.Johnson Victor, Essentials of bridge engineering, Oxford & IBH publishing Co. Ltd., New Delhi.
4. N.Krishna Raju, Design of bridges, Oxford & IBH publishing Co. Ltd., New Delhi.
5. Jaikrishna and O.P Jain, Plain and reinforced concrete-vol.II, Nem Chnand & Bros,Roorkee.
6. IRC: 5 -1970, Standard specifications and code of practice for road bridges, Sections I to V, Indian Roads Congress, New Delhi.
7. Indian railway standard code of practice for the design of steel or wrought iron bridge carrying rail, road or pedestrian traffic, Govt. of India, Ministry of Railways, 1962.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Decide the structural form for a bridge depending on the functional requirements and site the conditions. Identify various structural components of the chosen bridge form.
2. Design various components of bridges based on relevant IRC and Indian railway loading standards.
3. Understand the design principles of long span bridges.
4. Design bearings, piers and abutments for bridges.

CE6126 Construction Project Management

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

<u>Course Objectives:</u>

1. To understand the trends in modern management.
2. To study various network techniques like bar charts, CPM and PERT and the use of management softwares.
3. To acquire knowledge of optimization techniques, material management and process control.
4. To study cost control problems and the use of computer aided cost estimation.

Module 1: (10hours)

Project Management - Trends in Modern Management - Strategic Planning and Project Programming - Effects of Project Risks on Organization - Organization of Project Participants - Traditional Designer-Constructor Sequence - Professional Construction Management - Owner-Builder Operation - Turnkey Operation - Leadership and Motivation for the Project Team - Interpersonal Behavior in Project Organizations - Perceptions of Owners and Contractors

Quality and Safety Concerns in Construction - Organizing for Quality and Safety - Work and Material Specifications - Total Quality Control - Quality Control by Statistical Methods - Statistical Quality Control with Sampling by Attributes - Statistical Quality Control with Sampling by Variables - Safety

Module 2: (11hours)

Network techniques :– bar charts – Critical path method – Programme evaluation and review technique – Time estimates- uncertainties of time - time computations – monitoring of projects – updating - Crashing and time-cost tradeoff
PERT and CPM-Software Development - Use of Management Software

Module 3: (11hours)

Optimization techniques:- Resource allocation – Heuristic approach - Linear programming – Graphical and Simplex methods – Optimality Analysis - Material transportation and Work assignment problems
Materials management :- planning and budgeting – inventory control – management of surplus materials - equipment control
Process control:- work study- crew size – job layout- process operation.

Module 4: (10 hours)

The Cost Control Problem - The Project Budget - Forecasting for Activity Cost Control - Financial Accounting Systems and Cost Accounts - Control of Project Cash Flows - Schedule Control - Schedule and Budget Updates - Relating Cost and Schedule Information.
Costs Associated with Constructed Facilities - Approaches to Cost Estimation - Type of Construction Cost Estimates - Effects of Scale on Construction Cost - Unit Cost Method of Estimation - Methods for Allocation of Joint Costs - Historical Cost Data - Cost Indices - Applications of Cost Indices to Estimating - Estimate Based on Engineer's List of Quantities - Allocation of Construction Costs Over Time - Computer Aided Cost Estimation - Estimation of Operating Costs.

References

1. Chitkara, K.K. Construction Project Management: Planning, Scheduling and Control, Tata McGraw-Hill Publishing Company, New Delhi, 1998.
2. Feigenbaum., L., “Construction Scheduling With Primavera Project Planner”, Prentice Hall Inc., 1999.
3. Halpin, D. W., Financial and Cost Concepts for Construction Management, John Wiley & Sons, New York, 1985.
4. Choudhury, S, Project Management, Tata McGraw-Hill Publishing Company, New Delhi, 1988.
5. A.K Datta, Materials Management , Prentice Hall , India.
6. Arnold, J.R Tony, Introduction to Materials Mangement, Prentice Hall, India
7. Joy, P.K., Total Project Management – The Indian Context, Macmillan India Ltd., New Delhi, 1992.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Acquire knowledge in modern trends in management.

2. Understand Network techniques like bar charts, CPM and PERT and the use of Management softwares.
3. Apply optimization techniques to materials management and work assignment problems.
4. Perform budget estimation and the use of cost control techniques. Use computer aided cost estimation.

CE6127 Forensic Engineering and Rehabilitation of Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To expose the stake holders to the problems faced by the construction industry.
2. To understand the diagnosis and assessment of distress in structural members.
3. To understand the problems in buildings due to environmental effects and the durability of RCC structures.
4. To familiarise the principles of retrofitting of structural members.

Module 1: (10hours)

Failure of Structures: Review of the construction theory – performance problems – responsibility and accountability – case studies – learning from failures – causes of distress in structural members – design and material deficiencies – over loading

Module 2: (11hours)

Diagnosis and Assessment of Distress: Visual inspection – non destructive tests – ultrasonic pulse velocity method – rebound hammer technique – ASTM classifications – pullout tests – Bremor test – Windsor probe test – crack detection techniques – case studies – single and multistorey buildings – Fibreoptic method for prediction of structural weakness

Module 3: (11hours)

Environmental Problems and Natural Hazards: Effect of corrosive, chemical and marine environment – pollution and carbonation problems – durability of RCC structures – damage due to earthquakes and strengthening of buildings – provisions of BIS 1893 and 4326

Module 4: (10hours)

Modern Techniques of Retrofitting: Structural first aid after a disaster – guniting, jacketing – use of chemicals in repair – application of polymers – ferrocement and fiber concretes as rehabilitation materials – strengthening by pre-stressing – case studies – bridges – water tanks – cooling towers – heritage buildings – high rise buildings.

References

1. Dovkaminetzky, Design and Construction Failures, Galgotia Publication, New Delhi,2001
2. Jacob Feld and Kenneth L Carper, Structural Failures, Wiley Europe.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Identify the causes of distress in RCC structures.
2. Assess the distress using non-destructive tests.
3. Give appropriate solutions to the environmental problems and damages on buildings due to natural hazards such as earthquakes.
4. Retrofit the structures under distress using modern techniques and application of polymers and new cementitious composites.

CE6128 Multi Body Dynamics and Applications

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To review kinematics of rigid bodies.
2. To get familiarised with inertia tensor, Newtonian dynamics and Lagragian Dynamics.
3. To get familiarised with dynamics of multi-body systems.
4. To introduce different dynamic formulations for the determination of the equations of motion and solution techniques.

Module 1: (9 hours)

1. Kinematics of Rigid Bodies: Angular velocity and acceleration, derivatives of a vector in multiple reference frames, addition rule for angular velocity, relative motion of two points fixed on a rigid body, motion of a point that is moving on a rigid body, Coriolis acceleration, orientation of a rigid body, Euler Angles.
2. Momentum and Kinetic Energy of Rigid Bodies: Angular momentum, kinetic energy.

Module 2:(11 hours)

3. Inertia Tensor and its Properties: Formal definition of inertia quantities, parallel axis theorem, rotation transformation, principal axes and principal moments of inertia.
4. Newtonian Dynamics: Moment-of-momentum equations for general motion of rigid bodies, Euler equations of motion, rotating mass imbalance, gyroscopic effects.
5. Lagrangian Dynamics and Virtual Work: Generalised forces and the principle of virtual work, Lagrange's equations of motion, linearisation of equations of motion about equilibrium points.

Module 3:(11 hours)

6. Introduction to Multibody System Dynamics: Systems of interconnected rigid bodies, equations of motion for systems of rigid bodies, kinematics for general multibody systems, modelling of forces in multibody systems, equations of motion, handling of constraints in multibody systems dynamics, linearisation and vibration analysis of multibody systems,

dynamics of multibody systems with terminal flexible links, dynamic analysis of multiple flexible-body systems, Lagrange's equations of motion with constraints.

Module 4:(11 hours)

7. Computational Methods: Comparison of the different dynamic formulations for the determination of the equations of motion, investigation of their applicability to computer simulation of the dynamic behaviour of the mechanical systems, computer simulation using *MATLAB*, treatment of holonomic and nonholonomic constraints through various elimination and augmentation methods, extraction of data from equations of motion, computational issues.

References

1. T. R. Kane and D. A. Levinson, Dynamics: Theory and Application,
2. J.H. Ginsberg, Advanced Engineering Dynamics, Second edition,
3. A.A. Shabana, Dynamics of Multibody Systems, Cambridge Press, 2nd Ed., 1998.
4. R. Huston, Multibody Dynamics, Butterworth-Heinemann, 1990;
5. F.M.L. Amirouche, Computational Methods in Multibody Dynamics, Prentice Hall 1991.
6. Meirovitch, L., Methods of Analytical Dynamics, McGraw-Hill, 1970.
7. Torok, J.S., Analytical Mechanics with an Introduction to Dynamical Systems, John Wiley, New York, 2000.
8. Baruh, H., Analytical Dynamics, McGraw-Hill, New York, 1999.
9. Greenwood, D.T., Classical Dynamics, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Determine relative motion of two points fixed on a rigid body, motion of a point that is moving on a rigid body, and Coriolis acceleration.
2. Determine inertia tensor of a rigid body and Moment-of-momentum equations for general motion of rigid bodies.
3. Carry out vibration analysis of multi-body systems.
4. Simulate the dynamic behaviour of the mechanical systems numerically.

CE6129 Tall Structures

L	T	P	C
3	0	0	3

Prerequisite: Nil.

Total Hours: 42 Hrs.

<u>Course Objectives:</u>

1. To introduce design philosophy of tall structures.
2. To get familiarised with different systems adopted for tall structures.
3. To perform analysis of tall structures, both by approximate and accurate methods.

4. To get familiarised with various serviceability conditions and effect of other secondary effects like creep, shrinkage, temperature.
5. To introduce the stability aspects in the analysis and design of tall structures.

Module 1: (9hours)

Design philosophy- materials- loading- Gravity loading- Wind loading- Earthquake loading- blast loading.

Module 2: (10 hours)

Behaviour of various structural systems- factors affecting growth, height and structural form- High rise behaviour, rigid frames, braced frames, infilled frames, shear walls, coupled shear walls, wall frames, tubulars, cores, futrigger-braced and hybrid mega system.

Module 3: (14hours)

Analysis and design :- modeling for approximate analysis, Accurate analysis and reduction techniques. Analysis of building as total structural systems considering overall integrity and major subsystem interaction, Analysis for member forces, drift and twist, computerised general three dimensional analysis- Shear wall frame interaction.
Structural elements :- Sectional shapes, properties and resisting capacity, deflection, cracking. Prestressing, design for differential movement, creep, and shrinkage effects, temperature effects and fire resistance.

Module 4: (9 hours)

Stability of tall buildings
Overall buckling analysis of frames- P- Delta analysis- Translational, torsional instability, out of plumb effects, effect of foundation rotation.

References

1. Taranath , B.S., Structural Analysis and design of Tall Building, Tata McGraw Hill.,
2. Wilf gang Schuller, High Rise Building Structures, John Wiley and Sons.
3. Lynn S. Beedle, Advances in Tall Buildings, CBS Publishers and Distributers, Delhi,
4. Brayan Stafford Smith, Alexcoull, Tall Building Structures, Analysis and Design,, John Wiley and Sons, 1991

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Understand design philosophy of tall structures.
2. Understand different systems adopted for tall structures.
3. Carry out analysis of tall structures, both by approximate and accurate methods.
4. Understand various serviceability conditions and effect of other secondary effects like creep, shrinkage, temperature.
5. Apply the stability aspects in the analysis and design of tall structures.

CE6130 Structural Health Monitoring

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. Familiarise modelling for damage and failure behaviour of structures.
2. To understand signals, data acquisition systems and sensors.
3. To acquire knowledge of diagnostic techniques.
4. To expose the stake holders in the areas of information technology for health monitoring.

Module 1: (9 hours)

1. Review of Structural Modelling and Finite Element Models: Modelling for damage and collapse behaviour of structures, finite element modelling, theoretical prediction of structural failures.

Module 2: (11 hours)

2. Review of Signals, Systems and Data Acquisition Systems: Frequency and time domain representation of systems, Fourier/Laplace transforms, modelling from frequency response measurements, D/A and A/D converters, programming methods for data acquisition systems.
3. Sensors for Health Monitoring Systems: Acoustic emission sensors, ultrasonic sensors, piezoceramic sensors and actuators, fibre optic sensors and laser shearography techniques, imaging techniques.

Module 3: (11 hours)

4. Health Monitoring/Diagnostic Techniques: Vibration signature analysis, modal analysis, neural network-based classification techniques.
5. Integrated Health Monitoring Systems: Intelligent Health Monitoring Techniques, Neural network classification techniques, extraction of features from measurements, training and simulation techniques, connectionist algorithms for anomaly detection, multiple damage detection, and case studies.

Module 4: (11 hours)

6. Information Technology for Health Monitoring: Information gathering, signal analysis, information storage, archival, retrieval, security; wireless communication, telemetry, real time remote monitoring, network protocols, data analysis and interpretation.
7. Project Based Health Monitoring Techniques: Health monitoring techniques based on case studies, practical aspects of testing large bridges for structural assessment, optimal placement of sensors, structural integrity of aging multistorey buildings, condition monitoring of other types of structures.

References

1. Philip, W., Industrial sensors and applications for condition monitoring, MEP, 1994.
2. Armer, G.S.T (Editor), Monitoring and assessment of structures, Spon, London, 2001.
3. Wu, Z.S. (Editor), Structured health monitoring and intelligent infrastructure, Volumes 1 and 2, Balkema, 2003.
4. Harris, C.M., Shock vibration handbook, McGraw-Hill, 2000.
5. Rao, J.S., Vibratory condition monitoring of machines, Narosa Publishing House, India, 2000.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Distinguish different models for damage assessment.
2. Understand systems and sensors for health monitoring of structures.
3. Carry out different techniques for health monitoring of structures.
4. Make use of IT concepts for health monitoring of structures such as multi-storied building, bridges, etc.

CE6131 Structural Reliability

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To highlight importance of probabilistic structural analysis.
2. To review the basic theory of probability, random variables and probability distribution/density functions.
3. To identify different random variables those occur in nature and to know its probability structures.
4. To familiarize with basic structural reliability theory and different methods of computing the same.
5. Development of reliability based design criteria and optimal safety factors.
6. To introduce structural system reliability and its computation.

Module 1: (9hours)

Concepts of structural safety
Basic Statistics:- Introduction, data reduction
Probability theory: Introduction, random events, random variables, functions of random variables, moments and expectation, common probability distributions.

Module 2: (10hours)

Resistance distributions and parameters: - Introduction, Statistics of properties of concrete, steel and other building materials, statistics of dimensional variations, characterization of variables, allowable stresses based on specified reliability.
Probabilistic analysis of loads: gravity loads, wind loads

Module 3: (12hours)

Basic structural reliability:- Introduction, computation of structural reliability.
Level 2 Reliability methods: Introduction, basic variables and failure surface, first order second moment methods (FOSM)
Reliability based design: Introduction, determination of partial safety factors, development of reliability based design criteria, optimal safety factors

Module 4: (11hours)

Monte Carlo study of structural safety: -General, Monte Carlo method, applications
Reliability of Structural system: Introduction, system reliability, modelling of structural systems, bounds of system reliability, reliability analysis of frames

References

1. R. Ranganathan., Reliability Analysis and Design of Structures, Tata McGraw Hill, 1990.
2. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. I Basic Principles, John Wiley & Sons, 1975.
3. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. II Decision, Risks and Reliability, John Wiley & Sons, 1984.
4. Jack R. Benjamin & C. Allin Cornell., Probability, Statistics and Decision for Engineers, McGraw-Hill.
5. H. O. Madsen, S. Krenk & N. C. Lind, Methods of Structural Safety, Prentice-Hall, 1986.
6. R. E. Melchers. Structural Reliability - Analysis and prediction, Ellis Horwood Ltd, 1987.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Identify deterministic and random variables associated with structures and quantify the degree of randomness.
2. Perform reliability basic structural elements under different safety criterion.
3. Develop reliability based design criteria of any structure and determine optimal safety factors.
4. Perform system reliability analysis of simple structures.

CE6132 Concrete Shells and Folded Plates

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours: 42 Hrs.

Course Objectives:

1. To understand the different types of shells, study their geometry and learn the simplified design approaches.
2. To gain experience in the design of special structures such as cooling towers and hypar shells
3. To learn the fundamentals for the analysis and design of folded plate structures and also to get familiarity with the various simplified design approaches.
4. To gain confidence in the design of special structural systems involving folded plates and shells.

Module 1: (10hours)

Introduction- Classification of shells-General specification of shells- Analysis of shells-Membrane theory of cylindrical shells, perturbational stresses- bending theory, Design of cylindrical shell- Beam method- ASCE manual 31 method.

Module 2: (10hours)

Hyperboloid of revolution-hyperbolic shells-analysis of membrane forces- design of hyperbolic cooing towers.

Module 3: (11hours)

Hyperbolic paraboloid – general features – geometry of hyper shell-analysis of membrane forces- design of hyperbolic paraboloid roofs – pre-stressed concrete shells.

Module 4: (11hours)

General features- types- structural behaviour of folded plates- analysis of folded plates- ASCE task committee method- Whitney's method- Simpson's method- iteration method- beam method- design of folded plates- pre-stressed folded plates.

Note: Each student shall submit a term project.

References

1. Kelkar.V.S and Sewell R.T, Fundamentals of the Analysis and Design of Shell Structures, Prentice Hall, Inc.
2. Billington,D.P, Thin Shell Concrete Structures, McGraw hill Book Co.
3. Gibson, J.E, Linear Elastic Theory of Thin Shells, Pergamon Press.
4. Hass.M, Design of Thin concrete Shells (vol.I&II). John Wily and Sons Inc.
5. Ramaswamy,G.S, Design and Construction of Concrete Shell Roofs, Tata – McGraw Hill Book Co.LTD.
6. Design of cylindrical Concrete Shell Roofs (ASCE manual 31), Committee on masonry and reinforced concrete of the structural division.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Design shell structures using simplified approaches.
2. Analyse and design special structures such as cooling towers and hapar shells.
3. Analyse and design folded plate structures with the help of simplified methodologies.
4. Confidently design special structures using shells and folded plates combining aesthetics and cost effectiveness.

CE6133 Random Vibrations

Pre-requisite*: Stochastic Processes in Structural Mechanics*

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To highlight importance of probabilistic analysis and stochastic dynamic analysis of structures.
2. To familiarize the stake holders with the basic probability concepts and basic theory of stochastic processes.
3. To acquire knowledge of various mathematical theories associated with stochastic processes which are essential for the stochastic dynamic analysis of structure and for finding important design properties of the stochastic processes.
4. To introduce different models of stochastic processes representing various physical phenomena that occurs in nature.

Module 1: (9hours)

Basic Theory of Stochastic Processes (*A review*): Introduction, statistics of stochastic processes, ergodic processes, some properties of the correlation functions, spectral analysis, Wiener-Khintchine equation

Module 2: (11hours)

Stochastic Response of Linear SDOF Systems: Deterministic dynamics, evaluation of impulse response function and frequency response function, impulse response function and frequency response function as Fourier Transform pairs, stochastic dynamics, response to stationary excitation, time domain analysis, frequency domain analysis, level crossing, peak, first passage time and other characteristics of the response of SDOF Systems

Module 3: (11hours)

Linear systems with multiple inputs and outputs: Linear MDOF Systems, uncoupled modes of MDOF systems, stochastic response of linear MDOF Systems – time domain and frequency analysis.
Stochastic response of linear continuous system.

Module 4: (11hours)

Response of non-linear systems to random excitation: Approach to problems, Fokker-Plank equation, statistical linearization, perturbation and Markov Vector Methods.
Fatigue damage of structure due to random loads.

References

1. Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA, 1983.
2. Loren D Lutes & Shahram Sarkani., Stochastic Analysis of Structural and Mechanical Vibrations, Prentice Hall, NJ, 1997.
3. J Solnes, Stochastic Processes & Random Vibration, Theory and Practice, John Wiley,1997
4. Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill.
5. Bendat & Piesol., Random Data Analysis and Measurement Procedure, John Wiley, 1991.
6. Meirovitch, L., Elements of Vibration Analysis, McGraw Hill, 1986.
7. Papoulis, A., Probability, Random Variables and Stochastic Processes, McGraw Hill, 1991.
8. Ray W Clough & Joseph Penzien,. Dynamics of Structures, McGraw Hill, 1993.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Distinguish deterministic and random variables associated with structural analysis and response.
2. Quantify the randomness or uncertainties in the variables associated with structural analysis and response.
3. Model different physical phenomena by appropriate stochastic processes.
4. Apply the various mathematical theories associated with stochastic processes representing various natural phenomena to find important properties that are useful at design stage.

CE6134 Engineering Fracture Mechanics

Prerequisite: A course on Theory of Elasticity

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To understand the basic principles of Fracture Mechanics
2. To familiarize with the concepts of Linear Elastic Fracture Mechanics (LEFM)
3. To incorporate the effects of plasticity at the tip of cracks
4. To use Energy Balance Approach, J-integral and Crack opening displacement (COD) approach to solve practical problems.
5. To get familiarized with the experimental methods for LEFM
6. To incorporate the effects of fatigue using stress intensity factor (SIF)

Module: (11hours)

Introduction:- Significance of fracture mechanics, Griffith energy balance approach, Irwin's modification to the Griffith theory, Stress intensity approach, Crack tip plasticity, Fracture toughness, sub-critical crack growth, Influence of material behaviour, I, II & III modes, Mixed mode problems.
Linear Elastic Fracture Mechanics (LEFM):- Elastic stress field approach, Mode I elastic stress field equations, Expressions for stresses and strains in the crack tip region, Finite specimen width, Superposition of stress intensity factors (SIF), SIF solutions for well known problems such as centre cracked plate, single edge notched plate and embedded elliptical cracks.

Module 2: (12hours)

Crack Tip Plasticity:- Irwin plastic zone size, Dugdale approach, Shape of plastic zone, State of stress in the crack tip region, Influence of stress state on fracture behaviour.
Energy Balance Approach:- Griffith energy balance approach, Relations for practical use, Determination of SIF from compliance, Slow stable crack growth and R-curve concept, Description of crack resistance.

LEFM Testing:- Plane strain and plane stress fracture toughness testing, Determination of R-curves, Effects of yield strength and specimen thickness on fracture toughness, Practical use of fracture toughness and R-curve data.

Module 3: (10hours)

Elastic Plastic Fracture Mechanics (EPFM):- Development of EPFM, J-integral, Crack opening displacement (COD) approach, COD design curve, Relation between J and COD, Tearing modulus concept, Standard J_{Ic} test and COD test.
Fatigue Crack Growth:- Description of fatigue crack growth using stress intensity factor, Effects of stress ratio and crack tip plasticity – crack closure, Prediction of fatigue crack growth under constant amplitude and variable amplitude loading, Fatigue crack growth from notches – the short crack problem.

Module 4: (10hours)

Sustained Load Fracture:- Time-to-failure (TTF) tests, Crack growth rate testing, Experimental problems, Method of predicting failure of a structural component, Practical significance of sustained load fracture testing.
Practical Problems:- Through cracks emanating from holes, Corner cracks at holes, Cracks approaching holes, fracture toughness of weldments, Service failure analysis, applications in pressure vessels, pipelines and stiffened sheet structures.

References

1. Ewalds, H.L. & Wanhill, R.J.H., Fracture Mechanics – Edward Arnold Edition
2. Broek, D. Elementary Engineering Fracture Mechanics – Sijthoff & Noordhoff International Publishers.
3. Broek, D. The Practical Use of Fracture Mechanics – Kluwer Academic Publishers.
4. Hellan, D. Introduction to Fracture Mechanics – McGraw Hill Book Company.
5. Kumar, P. Elements of Fracture Mechanics – Wheeler Publishing.
6. Simha, K.R.Y. Fracture Mechanics for Modern Engineering Design, University Press.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to
1. Solve problems of fracture mechanics using Energy approach, SIF, J-integral approach and COD approach.
2. Analyse problems involving fatigue.
3. Solve practical problems like Service failure analysis, applications in pressure vessels, pipelines, stiffened sheet structures, etc.

CE6135 Advanced Prestressed Concrete Design

L	T	P	C
3	0	0	3

Prerequisite: Nil

Total Hours: 42 Hrs.

<u>Course Objectives:</u>

1. To understand the basic principles of Prestressed Concrete Design using Limit State Method
2. To familiarize with the design recommendations given in IS 1343
3. To understand and design prestressed concrete members for serviceability and ultimate limit states like cracking, deflection, flexure, shear and torsion.
4. To design anchorage zones.
5. To design prestressed concrete flexural members, composite members and statically indeterminate members.
6. To design partially prestressed concrete members.

Module 1: (11hours)

Limit state design of statically determinate prestressed beams - limit state of collapse against flexure, shear, torsion - limit state of serviceability - Design of end block - Anchorage zone stresses for post tensioned members.

Module 2: (11hours)

Statically indeterminate structures - analysis and design of continuous beams and frames - Choice of cable profile - linear transformation - concordancy.

Module 3: (6hours)

Composite sections of prestressed concrete beam and cast in situ RC slab - analysis of stresses - differential shrinkage - deflections - Flexural and shear strength of composite sections - Design of composite sections.

Module 4: (14hours)

Time dependant effects such as creep, shrinkage - Partial prestressing - Limit State design of partially prestressed concrete beams - Balanced moment capacity of rectangular and flanged sections - Crack and crack width computations. Analysis and design of prestressed concrete pipes, tanks, slabs – one way and two way (numerical problems restricted to pipes and tanks only).

References

1. N.Krishna Raju, Prestressed Concrete, Tata Mc.Graw-Hill Company Ltd., New Delhi.
2. Lin T.Y., Prestressed Concrete Structures, John Wiley.
3. Y. Guyon, Prestressed Concrete vol.I and II, Contractors Record Ltd., London.
4. S.K.Mallick and A.P.Gupta, Prestressed concrete, Oxford and IBH Publishing Co., New Delhi.
5. Abels P.W., An Introduction to Prestressed Concrete, Vol.I and II', Concrete Publications Ltd., London.
6. IS : 1343 – 1980, Code of Practice of Prestressed Concrete, Indian Standards Institution.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)

End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Analyse prestressed concrete structural members and estimate the losses of prestress
2. Analyse and design of prestressed concrete structural elements as per IS 1343
3. Design prestressed concrete flexural members, composite members, statically indeterminate members, partially prestressed concrete members, pipes, tanks and slabs.

CE6136 DESIGN OF PLATED STRUCTURES AND SHELLS

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To understand the classical theory and background mathematics of plates and shells.
2. To get exposed to different type of plate problems and the numerical solution techniques to obtain their behavior.
3. To get familiarity with the approximate methods for plate problems.
4. To learn the theoretical background of orthotropic plates and plate stability problems.
5. To understand the geometry and behavior of shells and obtain solutions to practical problems.

Module 1: (11 hours)

Cylindrical bending of plates – laterally loaded circular plates – artificial systems of equilibrium – uniformly loaded core with simple and fixed boundary conditions.

Laterally loaded rectangular plate – differential equations – boundary conditions – Navier solution for simply supported plates subjected to uniform and point loads – Levy's method

Module 2: (11 hours)

Approximate methods of solution of plates – Rayleigh-Ritz method – Galerkin's method – finite difference method
Orthotropic plates – stiffened plates – stability of plates – design of plated structures.

Module 3: (11 hours)

Stressed skin surfaces – types – cylindrical shells thin shells – membrane theory – bending theory – theories due to Finster-Welder and Schorer – shells of revolution – membrane theory – paraboloid of revolution – analysis using polynomial stress function – hyperbolic paraboloids – rectangular hyperbolic paraboloid.

Module 4: (9 hours)

Stiffened cylindrical shells – design curves for pressure hull buckling of cylindrical shells

References

1. S.P Timoshenko and S.W Krieger, Theory of Plates and Shells, McGraw Hill

2. R. Szilard, Theory and Analysis of Plates – Classical Numerical Methods', Prentice Hall inc
3. W. Flugge, Stresses in Shells, Stringer- Verlag
4. Ramaswamy, G.S, Design and Construction of Concrete Shell Roofs, Tata McGraw Hill.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Analyse different types of plates with various boundary conditions in the field of civil engineering and related fields.
2. Use numerical techniques in solving special plate problems.
3. Able to use approximate methods for the solution of plate problems.
4. Identify different type of shells, analyse and design shell structures for the stress resultants leading to an optimal design.
5. Confidently design special structures using shells combining aesthetics and cost effectiveness.

CE6137 Mechanics of Composite Structures

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To understand elastic behaviour of composite beams and design of the same.
2. To expose the stake holders to composite floors.
3. To familiarise the concepts of analysis and design of composite columns.
4. To acquire knowledge of analysis and design of continuous beams.

Module 1: (11hours)

Introduction: - Composite beams- Elastic behaviour of composite beams- No interaction case- Full interaction case-Shear connectors-Characteristics of shear connectors-Ultimate load behaviour-Serviceability limits-Basic design considerations-Design of composite beams.

Module 2: (10hours)

Composite floors: - Structural elements-Profiled sheet decking-Bending resistance-Serviceability criteria-Analysis for internal forces and moments.

Module 3: (11hours)

Composite columns: - Materials-Structural steel-Concrete-Reinforced steel-Composite column design-Fire resistance-Combined compression and uniaxial bending

Module 4: (10hours)

Continuous beams and slab Hogging moment regions of composite beams-Vertical shear and moment-Shear interaction-Global analysis of continuous beams-Design strategies.

References

1 Johnson,R.P, Composite Structures of Steel and Concrete,Vol.1Beams,Slabs,Columns and Frames in Buildings, Oxford Blackwell Scientific Publications, London.

2 INSDAG teaching resource for structural steel design, Vol 2, INSDAG, Ispat Niketan, Calcutta.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Design composite beams with shear connectors.
2. Analyse and design composite floors.
3. Design composite columns using different materials.
4. Analyse and design continuous beams.

CE6138 Advanced Finite Element Analysis

Prerequisite: A basic course on Finite Element Analysis

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To develop element stiffness matrix of shell elements.
2. To get familiarised with error estimates and convergence in finite element method of analysis.
3. To apply finite element method in structural dynamics and vibration problems.
4. To get familiarised with various modelling consideration and software use.
5. To introduce finite element method for solving non-linear problems.

Module 1: (11 hours)

Plate Bending: Plate behaviour, Kirchhoff and Mindlin plate elements, boundary conditions. Shells: Shells of revolution, general shells, three- and four-noded shell elements, curved isoparametric elements.

Module 2: (9 hours)

Error, Error Estimation and Convergence: Sources of error, ill-conditioning, condition number, diagonal decay test, discretisation error, multimesh extrapolation, mesh revision methods, gradient recovery and smoothing, a-posteriori error estimate, adaptive meshing.

Constraints, Penalty Forms, Locking and Constraint Counting: Explicit constraints, transformation equations, Lagrange multipliers, penalty functions, implicit penalty constraints and locking, constraint counting, modelling incompressible solids.

Module 3: (11hours)

Finite Elements in Structural Dynamics and Vibrations: Dynamic equations, mass and damping matrices, consistent and lumped mass, natural frequencies and modes, reduction of the number of degrees of freedom, modal analysis, Ritz vectors, harmonic response, direct integration methods, explicit and implicit methods, stability and accuracy, analysis by response spectra.
Modelling Considerations and Software Use: Physical behaviour versus element behaviour, element shapes and interconnections, test cases and pilot studies, material properties, loads and reactions, connections, boundary conditions, substructures, common mistakes, checking the model, critique of computed results.

Module 4: (11 hours)

Introduction to Nonlinear Problems: Nonlinear problems and some solution methods, geometric and material nonlinearity, problems of gaps and contacts, geometric nonlinearity, modelling considerations.
Stress Stiffening and Buckling: Stress stiffness matrices for beam, bar and plate elements, a general formulation for $[k_\sigma]$, bifurcation buckling, remarks on $[k_\sigma]$, its use, and on buckling and buckling analysis.

Reference

1. Cook, R.D., et al, Concepts and Applications of Finite Element Analysis, Fourth Edition, John Wiley & Sons Inc., Singapore, 2003.
2. Desai, C.S., and Kundu, T., Introductory Finite Element Method, CRC Press, London, 2001
3. Bathe, K.J., Finite Element Procedures, Prentice Hall of India.
4. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vols. I and II, Mc Graw Hill.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Develop element stiffness matrix of shell elements.
2. Carry out error estimates and convergence study in finite element method of analysis.
3. Apply finite element method in structural dynamics and vibration problems.
4. Study various modelling consideration and software use.
5. Solve non-linear problems using finite element method.

CE6139 Advanced Theory of Shells

L	T	P	C
3	0	0	3

Prerequisite: A course on Theory of Elasticity

Total Hours: 42 Hrs.

Course Objectives:

1. To understand the general shell theory and advanced topics in the analysis of shells.
2. To carry out a detailed study of membrane theory for shells of revolution.
3. To learn the geometry of shells of revolution in detail and obtain the solutions for general problems.
4. To learn the beam theory for cylindrical shells, circular shells and shallow shells.

Module 1: (11hours)

Theory of surfaces:- general theory of shells, Kirchhoff-Love's assumptions, deformation of shell, compatibility conditions, forces and moments, equilibrium equations, constitutive laws, boundary conditions, solution methods of shell problems, basic equations of Reissner-Mindlin's shell theory.

Module 2: (10hours)

Membrane theory:- basic equations, membrane theory of shells of revolution.

Module 3: (11hours)

Shells of revolution:- differential equations, symmetrical deformation of shells of revolutions, integration of differential equation, internal forces and displacements.

Module 4: (10hours)

Bending theory:- basic equations, circular cylindrical shells, shells of revolution, shallow shells.

References

1. Novozhilov, V.,V., Thin Shell Theory, Noordhoff, Groningen 1964.
2. Gould, P. L., Analysis of Shells and Plates, Springer-Verlag, New York 1988.
3. Flügge, W., Stresses in Shells, Springer-Verlag, 1960.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Deal with the advanced topics in the analysis of shells.
2. Apply the concepts of membrane theory for all types of shells of revolution.
3. Able to appreciate all kinds of geometry of shells or revolution and will be able to analyse such shells.
4. Apply beam theory for varieties of geometries including cylindrical, circular and shallow shells.

CE6140 Theory of Plasticity

Pre-requisite: A course on Theory of Elasticity

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

<u>Course Objectives:</u>

1. To review basic equations of theory of elasticity and introduce framework of plasticity.
2. To get familiarised with yield surfaces for polycrystalline metals and plastic behaviour under plane stress conditions.
3. To study plastic behaviour of one dimensional structures.
4. To understand limit analysis of bodies in plane stress and plane strain conditions.

Module 1: (11hours)

Preliminaries: Basic equations of theory of elasticity:- Index notation, equations of equilibrium, constitutive relations for isotropic bodies, strain-displacement relations, compatibility, displacement and traction boundary conditions, admissibility of displacement and stress fields, plane stress and plane strain problems.
Framework of Plastic Constitutive Relations:- Plastic behaviour in simple tension, generalisation of results in simple tension, yield surfaces, uniqueness and stability postulates, convexity of yield surface and normality rule, limit surfaces.

Module 2: (12hours)

Initial Yield Surfaces for Polycrystalline Metals:- Summary of general form of plastic constitutive equations, hydrostatic stress states and plastic volume change in metals, shear stress on a plane, the von Mises initial yield condition, the Tresca initial yield condition, consequences of isotropy.
Plastic Behaviour under Plane Stress Conditions:- Initial and subsequent yield surfaces in tension-torsion, the isotropic hardening model, the kinematic hardening model, yield surfaces made of two or more yield functions, piecewise linear yield surfaces, elastic perfectly plastic materials.

Module 3: (10hours)

Plastic Behaviour of Bar Structures:- Behaviour of a three bar truss, behaviour of a beam in pure bending, simply supported beam subjected to a central point load, fixed beams of an elastic perfectly plastic material, combined bending and axial force.
The Theorems of Limit Analysis: Introduction, theorems of limit analysis, alternative statement of the limit theorems, the specific dissipation function.

Module 4: (9hours)

Limit Analysis in Plane Stress and Plane Strain:- Discontinuities in stress and velocity fields, the Tresca yield condition in plane stress and plane strain, symmetrical internal and external notches in a rectangular bar, the punch problem in plane strain, remarks on friction.
Limit Analysis as a Programming Problem:- Restatement of limit theorems, application to trusses and beams, use of finite elements in programming problem, incremental methods of determining limit load.

References

1 Martin, J.B., Plasticity: Fundamentals and General Results, MIT Press, London.
2 Kachanov, L.M., Fundamentals of the Theory of Plasticity, Mir Publishers, Moscow.
3 Chakrabarty, J, Theory of Plasticity, McGraw Hill, New York.
4 Hill, R., Mathematical Theory of Plasticity, Oxford University Press.
5 Chen, W.F., and Han, D.J., Plasticity for Structural Engineers, Springer Verlag.

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Understand Constitutive Relations of a material under plastic state.
2. Understand different failure theories and plastic behaviour of metals under plane stress condition.
3. Cary out plastic analysis of bars under tension and bars under flexure.
4. Carry out limit analysis of bodies in plane stress and plane strain conditions.
5. Carry out limit analysis of trusses and beams, apply finite elements limit analysis problem, and incremental methods of determining limit load.

CE6313 STABILITY OF STRUCTURES

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 42 Hrs.

Course Objectives:

1. To highlight importance of concept of stability in the structural analysis and design.
2. To familiarize with the stability analysis of beam-columns subjected to different loadings and to develop design interaction formula.
3. To acquire knowledge of buckling analysis of columns using different methods and to develop design formula as given in various design Codes of practice.
4. To perform stability analysis of simple framed structures.
5. To carryout stability analysis thin walled sections, lateral buckling of beams, plates and shells.

Module 1 (10 hours)

Introduction:- Concept of stability – Static, Dynamic and Energy criterion of stability
Beam Columns - Differential Equation of Equilibrium of Beam-Columns – Concentrated Loads – Continuous Uniformly Distributed Lateral Loads – Different End Conditions – The Effect of Initial Curvature on Deflections – Interaction formula.

Module 2 (12 hours)

Elastic Buckling of Bars – Review of Euler Column Theory for Four Different End Conditions – Evaluation of Critical Loads of Column Using Determinant – Approximate Methods of Evaluation of critical Loads of Columns – Energy Method – Rayleigh Ritz Method – Finite Difference Method – Newmark's Deflection Comparison Method - Buckling of Bars with Changes in Cross Section Using the Approximate Methods Such as Successive Approximations – The Effect of Shearing Force on the Critical Load – Buckling of Built up Columns – Various Empirical Formulae for Column Design.

Module 3 (10 hours)

Stability of Rigid Bars having Linear or Rotational Springs - Stability of System of Rigid Bars Using Equilibrium and Principle of Stationary Potential Energy
Buckling of Frames:- Portal, Rectangular and L-shaped Frames under Non-sway Conditions - Beams Subjected to Compressive Loads by Matrix Approach and Stability Functions

Module 4 (10 hours)

Pure Torsion of Thin walled Bars of Open Cross-section – Torsional Buckling – Determination for Warping displacement for a Thin Walled Channel Section – Examples of Section with Thin Elements in which there is no Warping.
Lateral Buckling of Beams in Pure Bending – Lateral Buckling of Simply Supported I-beams.
Introduction to stability of Plates and Shells: Buckling of plates, buckling of shells.

References

1. Timoshenko, S.P., and Gere, J.M., Theory of Elastic Stability, McGraw Hill, Singapore, 1963.
2. Chajes, A., Principles of Structural Stability Theory, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1974.
3. Brush, D.O., and Almorth, B.O., Buckling of Bars, Plates and Shells, McGraw Hill, 1975.
4. Kumar, A., Stability of Structures, Allied Publishers Limited, 1998.
5. Iyengar, N.G.R., Structural Stability of Columns and Plates, East West Press, 1986.
6. Simitses, G.J., Introduction to the elastic stability of structures, Prentice Hall Inc., New Jersey, 1976.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Identify structures or structural elements where stability analysis is very relevant.
2. Perform stability analysis of beam-columns and design them.
3. Carryout stability analysis of bars/columns and simple frames and determine safe load.
4. Perform stability analysis of thin walled sections, beams undergoing lateral buckling, plated and shell structure.

CE6421 ADVANCED DESIGN OF FOUNDATIONS

L	T	P	C
3	0	0	3

Pre-requisite: Nil

Total hours: 42 hours

<u>Course Objectives:</u>

1. To get familiarised with soil structure interaction problems.
2. To understand the behaviour, analysis and design of pile foundations.
3. To understand the behaviour and analysis of machine foundations.
4. To design machine foundation as per latest BIS codes.

Module 1: (10 Hours)

Soil -Structure Interaction

Introduction to Soil -Structure interaction problems -Contact pressure distribution – factors influencing Contact pressure distribution beneath rigid and flexible footings – concentrically and eccentrically loaded cases – contact pressure distribution beneath rafts - Modulus of sub grade reaction – Determination of modulus of sub grade reaction – Factors influencing modulus of subgrade reaction

Module 2: (10 Hours)

Pile Foundations

Introduction – Estimation of pile capacity by static and dynamic formulae – Wave equation method of analysis of pile resistance – Load -Transfer method of estimating pile capacity – Settlement of single pile – Elastic methods. Laterally loaded piles – Modulus of sub grade reaction method – ultimate lateral resistance of piles. Pile Groups – Consideration regarding spacing – Efficiency of pile groups – Stresses on underlying soil strata – Approximate analysis of pile groups –Settlement of pile groups Pile caps –Pile load tests – Negative skin friction.

Module 3: (11 Hours)

Introduction to Machine Foundations

Introduction -nature of dynamic loads -stress conditions on soil elements under earthquake loading -dynamic loads imposed by simple crank mechanism -type of machine foundations special considerations for design of machine foundations – Criteria for a satisfactory machine foundation -permissible amplitude of vibration for different type of machines -methods of analysis of machine foundations -methods based on linear elastic weightless springs methods based on linear theory of elasticity (elastic half space theory) -degrees of freedom of a block foundation –definition of soil spring constants -nature of damping -geometric and internal damping -determination of soil constants – methods of determination of soil constants in laboratory and field based on IS code provisions.

Module 4: (11 Hours)

Design of Machine Foundations

Vertical, sliding, rocking and yawing vibrations of a block foundation -simultaneous rocking, sliding and vertical vibrations of a block foundation -foundation of reciprocating machines - design criteria -calculation of induced forces and moments -multi-cylinder engines -numerical example (IS code method).

Foundations subjected to impact loads - design criteria - analysis of vertical vibrations computation of dynamic forces - design of hammer foundations (IS code method) - vibration isolation – active and passive isolation - transmissibility -methods of isolation in machine foundations.

References

1 Lambe and Whitman, “Soil Mechanics”, Wiley Eastern., 1976.
2 Das B.M., “Advanced Soil Mechanics”, Mc. Graw-Hill, NY, 1985.
3 Winterkorn H.F. and Fang H.Y. Ed., “Foundation Engineering Hand Book”, Van-Nostrand Reinhold, 1975.
4 Bowles J.E., “Foundation Analysis and Design” (4Ed.), Mc.Graw –Hill, NY, 1996
5 Poulose H.G. and Davis E.H., “Pile foundation Analysis and Design”, John-Wiley & Sons, NY, 1980.
6 Leonards G. Ed., “Foundation Engineering”, Mc.Graw-Hill,NY, 1962.
7 Bowles J.E., “Analytical and Computer Methods in Engineering“ Mc.Graw-Hill,NY,1974.
8 Alexander Major, “Dynamics in Soil Engineering”, Akadémiai Kiadóa, Budapest, 1980.

9 Sreenivasalu & Varadarajan, “Handbook of Machine Foundations”, Tata McGraw Hill, 1976.
10 IS 2974 -Part I and II, “Design Considerations for Machine Foundations”
11 IS 5249: “Method of Test for Determination of Dynamic Properties of Soils”

Assessment Methods:

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

Course Outcomes:

The student will be able to

1. Determine the contact pressure distribution under a footing and determine the modulus of sub-grade reaction of given soil.
2. Analyse and design a pile foundation under varied design situations.
3. Model and analyse a machine foundation and determine its response.
4. Design a machine foundation subject to different dynamic loading, as per latest BIS code.

CE6302 STOCHASTIC PROCESSES IN STRUCTURAL MECHANICS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 42 hours

Course Objectives:

1. To highlight importance of probabilistic analysis and stochastic dynamic analysis of structures.
2. To familiarize the stake holders with the basic probability concepts and basic theory of stochastic processes.
3. To acquire knowledge of various mathematical theories associated with stochastic processes which are essential for the stochastic dynamic analysis of structure and for finding important design properties of the stochastic processes.
4. To introduce different models of stochastic processes representing various physical phenomena that occurs in nature.

Module 1 (10 hours)

Basic Probability Concepts:- Sample space and events, probability measure, mathematics of probability.
Random variables: Probability distribution of a random variable, multiple random variables, main descriptors of a random variable – moments, expectation, covariance, correlation, conditional mean and variance. Functions of Random variables, expectation of a function of a random variable

Module 2 (8 hours)

Common Probabilistic Models:- Models from simple discrete random trails, models from random occurrences, models from limiting cases, other commonly used distributions, multivariate Models.

Derived probability distributions and distributions of functions.

Module 3 (12 hours)

Basic Theory of Stochastic Processes: Introduction, statistics of stochastic processes, stationary, ergodic and non stationary processes, auto and cross correlation and co variance function, stochastic calculus and mean square limit, conditions for continuity, differentiability, integrability of a random process, spectral decomposition of a random process, power spectral density function, narrow band and broad band random process, Wiener-Khintchine equation

Module 4 (12 hours)

Some important random processes: Normal processes, Poisson processes, Markov processes.
Properties of Random Processes: Level crossing peaks, fractional occupation time, envelopes, first-passage time, maximum value of a random process in a time interval.
Some models of random processes in nature: Earthquake, wind, atmosphere turbulence, random runways, road roughness, jet noise, ocean wave turbulence

References

1. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. I Basic Principles, John Wiley & Sons, 1975.
2. J.R. Benjamin & C.A. Cornell., Probability, Statistics and Decision for Engineers, McGraw-Hill, 1970.
3. Papoulis, A., Probability, Random Variables and Stochastic Processes, McGraw Hill, 2002.
4. Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA, 1983.
5. Loren D Lutes & Shahram Sarkani., Stochastic Analysis of Structural and Mechanical Vibrations, Prentice Hall, NJ, 1997.
6. J Solnes, Stochastic Processes & Random Vibration, Theory and Practice, John Wiley, 1997
7. Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill, 1995.
8. Bendat & Piesol., Random Data Analysis and Measurement Procedure, John Wiley,1991.
9. Meirovitch, L., Elements of Vibration Analysis, McGraw Hill, 1986.
10. R.W Clough & J. Penzien,. Dynamics of Structures, McGraw Hill, 1993.

<u>Assessment Methods:</u>

Continuous Assessment : 50 Marks
(Test 1: 15/20; Test 2: 25/20; Assignments/Tutorials etc: 10)
End Semester Examination : 50 Marks

<u>Course Outcomes:</u>

The student will be able to

1. Distinguish deterministic and random variables associated with structural analysis and response.
2. Quantify the randomness or uncertainties in the variables associated with structural analysis and response.
3. Model different physical phenomena by appropriate stochastic processes.
4. Apply the various mathematical theories associated with stochastic processes representing various natural phenomena to find important properties that are useful at design stage.