Curriculum and Syllabi

M.Tech Degree Programme

STRUCTURAL ENGINEERING

(with effect from Academic Year 2006-2007)

Approved by DCC on 05/04/06 in its 28th meeting as item 28.2

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

CALICUT

Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Proposed Curriculum for M.Tech Programme in CIVIL ENGINEERING—STRUCTURAL ENGINEERING (CEA)

S1

	Code	Title	L/T	P/S	C
1	CEA601	Theory of Elasticity	3	0	3
2	CEA602	Structural Dynamics	3	0	3
3	CEA603	Advanced Theory and Design of Concrete Structures	3	0	3
4	CEA691	Computational Lab	0	3	2
5	CEA692	Stress Analysis Lab	1	2	2
6	****	Elective	3	0	3
7	****	Elective	3	0	3
8	****	Elective	3	0	3

Total credits = 13 (Core)+9 or 6 (Electives)

S2

	Code	Title	L/T	P/S	C
1	CEA611	Finite Element Method	3	0	3
2	CEA612	Theory of Plates and Shells	3	0	3
3	CEA613	Advanced Metal Structures	3	0	3
4	CEA693	Structural Engineering Design Studio	1	2	2
5	CEA697	Seminar	0	2	1
6	****	Elective	3	0	3
7	****	Elective	3	0	3
8	****	Elective	3	0	3

Total credits = 12 (Core)+9 or 6 (Electives)

S3

	Code	Title	L/T	P/S	C
1	CEA798	Project			8
2	****	Elective	3	0	3
3	****	Elective	3	0	3

Total credits = 8 (Core)+ 0 to 6 (Electives)

S4

	Code	Title	L/T	P/S	C
1	CEA799	Project			12

Total credits = 12 (Core)

Stipulations:

1. A minimum of 63 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 credit) during summer term is optional

List of Electives (CEA)

S1 or S3

CEA621	Structural Optimisation
CEA622	Modelling, Simulation and Computer Application
CEA623	Earthquake Analysis and Design of Structures
CEA624	Analytical Dynamics
CEA625	Bridge Engineering
CEA626	Construction Project Management
CEA627	Forensic Engineering and Rehabilitation of Structures
CEA628	Multibody Dynamics and Applications
CEA629	Tall Structures
CEA630	Structural Health Monitoring
CEA631	Structural Reliability
CEB623	Geographic Information System and Applications
CEC602	Stochastic Processes in Structural Mechanics
CED621	Advanced Design of Foundation
CEA701	Advanced Finite Element Analysis
CEA702	Advanced Theory of Shells
CEA703	Theory of Plasticity
* Any other subject offered in the Institute with approval from the Programme Coordinator/Faculty Advisor	

S2

CEA651	Concrete Shells and Folded Plates
CEA652	Random Vibrations
CEA653	Engineering Fracture Mechanics
CEA654	Advanced Prestressed Concrete Design
CEA655	Design of Plated Structures and Shells
CEA656	Mechanics of Composite Structures
CEC613	Stability of Structures
* Any other subject offered in the Institute with approval from the Programme Coordinator/Faculty Advisor	

CEA601 THEORY OF ELASTICITY

L	T	P	Cr
3	0	0	3

Prerequisite: - Nil

Module 1 (12hrs)

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.

Module 2 (12hrs)

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.

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.

Module 3 (12hrs)

Stress and strain problems in three dimensions: Principal stresses, principal strains, three-dimensional problems.

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.

Module 4 (10hrs)

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.

References

1. Timoshenko, S.P. and Goodier, J.N., *Theory of Elasticity*, Mc Graw Hill, Singapore, 1982.
2. Leipholz, H., *Theory of Elasticity*, Noordhoff International Publishing, Layden, 1974.
3. Sokolnikoff, I.S., *Mathematical Theory of Elasticity*, Tata Mc Graw Hill, India, 1974.
4. Xu, Z., *Applied Elasticity*, Wiley Eastern Ltd, India, 1992.
5. Srinath, L.S., *Advanced Mechanics of Solids*, Second Edition, Tata McGraw Hill, India, 2003.
6. Ameen, M., *Computational Elasticity—Theory of Elasticity, Finite and Boundary Element Methods*, Narosa Publishing House, 2004.

CEA602 STRUCTURAL DYNAMICS

L	T	P	Cr
3	0	0	3

Prerequisite: - Nil

Module 1 (12hrs)

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 (12hrs)

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 (12hrs)

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 (9hrs)

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.

CEA603 ADVANCED THEORY AND DESIGN OF CONCRETE STRUCTURES

Prerequisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (12hrs)

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 (12hrs)

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 (10hrs)

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 (11hrs)

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.

CEA691 COMPUTATIONAL LABORATORY

Pre-requisite: -Nil

L	T	P	Cr
1	0	2	2

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.

CEA692 STRESS ANALYSIS LABORATORY

Pre-requisite: -Nil

L	T	P	Cr
1	0	2	2

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.

CEA611 FINITE ELEMENT METHOD

Prerequisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (10hrs)

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 (12hrs)

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 (12hrs)

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 (11hrs)

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.

CEA612 THEORY OF PLATES AND SHELLS

Prerequisite: - Theory of Elasticity

L	T	P	Cr
3	0	0	3

Module 1 (8hrs)

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 (8hrs)

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 (17hrs)

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 (12hrs)

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.

CEA613 ADVANCED METAL STRUCTURES

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (11hrs)
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 (12hrs)
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 (10hrs)
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 (12hrs)
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.

CEA693 STRUCTURAL ENGINEERING DESIGN STUDIO

L	T	P	Cr
1	0	2	2

Pre-requisite: - Nil

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.

CEA697 SEMINAR

L	T	P	Cr
0	0	2	1

Prerequisite: -Nil

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.

CEA621 STRUCTURAL OPTIMISATION

L	T	P	Cr
3	0	0	3

Pre-requisite: - Nil

Module 1 (12hrs)

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 (12hrs)

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 (11hrs)

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 (10hrs)

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.

CEA622 MODELLING, SIMULATION AND COMPUTER APPLICATION

Prerequisite: -Nil.

L	T	P	Cr
3	0	0	3

Module 1 (11hrs)

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 (12hrs)

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 (10hrs)

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 (12hrs)

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.

CE A 623 EARTHQUAKE ANALYSIS AND DESIGN OF STRUCTURES

Pre-requisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (11hrs)

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

Module 2 (14hrs)

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 (10hrs)

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

Module 4 (10hrs)

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

CEA624 ANALYTICAL DYNAMICS

Pre- requisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (12hrs)

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 (9hrs)

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

Module 3 (1hrs)

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 (12hrs)

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.

CE A 625 BRIDGE ENGINEERING

L	T	P	Cr
3	0	0	3

Pre-requisite: -Nil

Module 1 (12hrs)

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 (15hrs)

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 (12hrs)

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

Module 4 (6hrs)

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.

CEA626 CONSTRUCTION PROJECT MANAGEMENT

L	T	P	Cr
3	0	0	3

Prerequisite :-Nil

Module 1 (10hrs)

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 (12hrs)

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 (12hrs)

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 (11 hrs)

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

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

CEA627 FORENSIC ENGINEERING AND REHABILITATION OF STRUCTURES

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (10hrs)

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 (12hrs)

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 (11hrs)

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 (12hrs)

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.

CEA 628 MULTI BODY DYNAMICS AND APPLICATIONS

L	T	P	Cr
3	0	0	3

Prerequisite: - Nil

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 (12 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 (12 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 (12 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

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

CEA629 TALL STRUCTURES

L	T	P	Cr
3	0	0	3

Prerequisite: -Nil.

Module 1 (10hrs)

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

Module 2 (11 hrs)

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 (15hrs)

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 hrs)

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

CEA630 STRUCTURAL HEALTH MONITORING

L	T	P	Cr
3	0	0	3

Prerequisite: - Nil

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 (12 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 (12 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 (12 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.

CEA631 STRUCTURAL RELIABILITY

Pre-requisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (9hrs)

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 (10hrs)

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 (13hrs)

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 (13hrs)

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.

CEB623 GEOGRAPHIC INFORMATION SYSTEMS AND APPLICATIONS

Prerequisite:- Nil

L	T	P	Cr
2	1	0	3

Module 1 (11hrs)

Introduction:- Definitions of GIS – Components of GIS – Geographic data presentation: maps – mapping process – coordinate systems – transformations – map projection – geo referencing - data acquisition.

Module 2 (12hrs)

Geographic Data Representation, Storage, Quality and Standards:- Storage - Digital representation of data – Data structures and database management systems – Raster data representation – Vector data representation – Concepts and definitions of data quality – Components of data quality – Assessment of data quality – Managing data errors – Geographic data standards.

Module 3 (12hrs)

GIS Data Processing, Analysis and Modeling:- Raster based GIS data processing – Vector based GIS data processing – Queries – Spatial analysis – Descriptive statistics – Spatial autocorrelation – Quadrant counts and nearest neighbor analysis – Network analysis – Surface modeling – DTM.

Module 4 (10hrs)

GIS Applications:- (in one of the following areas)
Applications of GIS in Environment monitoring – Natural hazard management – Natural resources management urban planning – utility management – Land information – Business development

References

1. Lo, C.P. & Yeung A.K.W., *Concepts and Techniques of Geographic Information Systems*, Prentice Hall of India, New Delhi, 2002.
2. Anji Reddy, M., *Remote Sensing and Geographical Information Systems*, B.S.Publications, Hyderabad, 2001.
3. Burrough, P.A., *Principles of Geographical Information Systems*, Oxford Publication, 1998.
4. Clarke, K., *Getting Started with Geographic Information Systems*, Prentice Hall, New Jersy, 2001.
5. DeMers, M.N., *Fundamentals of Geographic Information Systems*, John Wiley & Sons, New York, 2000.
6. *Geo Information Systems – Applications of GIS and Related Spatial Information Technologies*, ASTER Publication Co., Chestern (England), 1992
7. Jeffrey, S. & John E., *Geographical Information System – An Introduction*, Prentice-Hall, 1990
8. Marble, D.F., Galkhs HW & Pequest, *Basic Readings in Geographic Information Systems*, Sped System Ltd., New York, 1984.

CEC602 STOCHASTIC PROCESSES IN STRUCTURAL MECHANICS

L	T	P	Cr
3	0	0	3

Pre-requisite :- Nil

Module 1 (10hrs)

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 (9hrs)

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 (13hrs)

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 (13hrs)

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. Jack R. Benjamin & C. Allin Cornell., *Probability, Statistics and Decision for Engineers,* McGraw-Hill.
3. Papoulis, A., *Probability, Random Variables and Stochastic Processes*, McGraw Hill, 1991.
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.
8. Bendat & Piesol., *Random Data Analysis and Measurement Procedure*, John Wiley,1991.
9. Meirovitch, L., *Elements of Vibration Analysis*, McGraw Hill, 1986.
10. Ray W Clough & Joseph Penzien,. *Dynamics of Structures*, McGraw Hill, 1993.

CED621 ADVANCED DESIGN OF FOUNDATIONS

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (8 hrs)

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 (12 hrs)

Pile Foundation: - 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(14 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* (4^{th} Ed.), 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
8. Shamsher Prakash, *Soil Dynamics*, McGraw Hill
9. Alexander Major, *Dynamics in Soil Engineering*
10. Sreenivasalu & Varadarajan, *Handbook of Machine Foundations*, Tata McGraw Hill
11. IS 2974 - Part I and II, *Design Considerations for Machine Foundations*
12. IS 5249: *Method of Test for Determination of Dynamic Properties of Soils.*

CEA701 ADVANCED FINITE ELEMENT ANALYSIS

L	T	P	Cr
3	0	0	3

Prerequisite: A basic course on **Finite Element Analysis**

Module 1 (12 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 (12 hours)

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 (12 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.

CEA702 ADVANCED THEORY OF SHELLS

L	T	P	Cr
3	0	0	3

Prerequisite**:** *A course on* **Theory of Elasticity**

Module 1 (10hrs)

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 (9hrs)

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

Module 3 (10hrs)

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

Module 4 (10hrs)

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.

CEA703 THEORY OF PLASTICITY

L	T	P	Cr
3	0	0	3

Pre-requisite: *A course on* **Theory of Elasticity**

Module 1 (12hrs)

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 (13hrs)

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 (11hrs)

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 (9hrs)

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.

CEA651 CONCRETE SHELLS AND FOLDED PLATES

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (11hrs)

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 (10hrs)

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

Module 3 (12hrs)

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

Module 4 (12hrs)

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.

CEA652 RANDOM VIBRATIONS

Pre-requisite***:*** **Stochastic Processes in Structural Mechanics**

L	T	P	Cr
3	0	0	3

Module 1 (9hrs)

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 (13hrs)

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 (12hrs)

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 (11hrs)

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.

CEA653 ENGINEERING FRACTURE MECHANICS

Prerequisite: A course on **Theory of Elasticity**

L	T	P	Cr
3	0	0	3

Module (11hrs)

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 (12hrs)

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 (10hrs)

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 (10hrs)

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.

Text Book: Ewalds, H.L. & Wanhill, R.J.H., Fracture Mechanics – Edward Arnold Edition

References

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

CEA654 ADVANCED PRESTRESSED CONCRETE DESIGN

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (**12hrs)**

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 (12hrs)

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

Module 3 (6hrs)

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 (15hrs)

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.

CEA655 DESIGN OF PLATED STRUCTURES AND SHELLS

L	T	P	Cr
3	0	0	3

Prerequisite: -Nil

Module 1 (12 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 (12 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 (12 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.

CEA656 MECHANICS OF COMPOSITE STRUCTURES

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (12hrs)

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 (10hrs)

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

Module 3 (12hrs)

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

Module 4 (11hrs)

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.

CEC613 STABILITY OF STRUCTURES

Prerequisite: -Nil

L	T	P	Cr
3	0	0	3

Module 1 (11hrs)

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 (13hrs)

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 (11hrs)

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 (10hrs)

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.
2. Chajes, A., *Principles of Structural Stability Theory*, Prentice Hall Inc., Englewood Cliffs, New Jersey.
3. Brush, D.O., and Almorth, B.O., *Buckling of Bars, Plates and Shells*, McGraw Hill.
4. Kumar, A., *Stability of Structures*, Allied Publishers Limited.
5. Iyengar, N.G.R., Structural Stability of Columns and Plates, East West Press.