

## **1SFSE1: INTRODUCTION TO EARTHQUAKE AND RETROFITTING OF STRUCTURES**

Interior of earth, Engineering geology of earthquakes, plate tectonics, Seismicity of the world, tectonic features of India, Faults, Propagation of earthquake waves, Quantification of earthquake (magnitude, energy, intensity of earthquake), Measurements of earthquake (Accelerograph, Accelerogram recording), Determination of magnitude, Epicenter distance, focal depth, etc. Ground motion and their characteristics, Factors affecting ground motions, Guidelines for achieving efficient seismic resistant planning, selection of sites, importance of architectural features in earthquake resistant buildings, continuity of construction, Projection & suspended parts, special construction features like separation of adjoining structure, Crumble section, Stair case etc, Twisting of building, seismic effects on structures, inertia forces, horizontal & vertical shaking.

Non-Engineered structures: Behavior of masonry structure during earthquake, bands & reinforcement in masonry building, openings in wall, importance of flexible structures.

Concept of earthquake Resistant design, design philosophy, four virtues of EQRD: Stiffness, Strength, ductility and Configurations.

Principles of Repairs and Retrofitting, Terminology in Repairs, Restoration, Strengthening and Rehabilitation, Criteria for Repairs, Restoration and Retrofitting; Repair Materials; In-situ testing methods for RC and masonry structures; Seismic Hazard Evaluation; Techniques of repair and retrofitting of masonry buildings; Seismic evaluation of RC building-Demand capacity method, Pushover analysis and performance based approach; Techniques of Repair and Retrofitting in RC buildings; Retrofitting of buildings by seismic base isolation and supplemental damping; One case study in retrofitting.

### **Reference Books:**

1. Wakabayashi M.; Design of Earthquake Resistant Buildings, McGraw Hill Books Company; 1986
2. Okamoto, S.; Introduction to Earthquake Engineering; University of Tokyo press; 2nd Edition; 1984
3. Kramer, S.L.; Geotechnical Earthquake Engineering; Prentice Hall; New Jersey; 1996
4. Bolt, B.A.; Earthquakes; W. H. Freeman & Company; NY; 1988
5. Amita Sinhal, Understanding Earthquake Disasters, Tata Mcraw-Hill Publishing Company Ltd.
- 6 P. N. Agrawal, Engineering Seismology ,Oxford & IBH Publishing Co Pvt .Ltd
7. Pankaj Agrawal & Manish Shrikhande, Earthquake Resistant Design of Structures, Prentice Hall India.
8. Duggal S. K., Earthquake Resistant Design of Structures, Oxford University Press 2007

## **1SFSE2: THEORY OF ELASTICITY AND ELASTIC STABILITY**

3D-cartesian: Elastic structure subjected to loads, body forces, surface forces, components of displacement, strain and stress at a point of 3D structure, Generalised Hooke's law, isotropic, orthotropic material, stresses in terms of strains and vice-versa, stress equilibrium equations, boundary conditions, strain-displacement relations, principal stresses and principal planes, elastic constants.

2D-cartesian: Plane stress and plane strain conditions, stress-strain relations, strain displacement relations, strain-compatibility condition, stress-compatibility condition, bi-harmonic equilibrium equation, Airy stress function, principal stresses and strains. Saint Venant principle, solution of simple problems in tension, bending, torsion, plate with small circular hole under tension.

Concept of stability, stable, unstable and neutral equilibrium, energy criteria, method of stability analysis.

Elastic buckling of columns, buckling of continuous beams, buckling of frames, neutral equilibrium method, matrix approach, moment distribution method.

Buckling of thin rectangular plates.

### **Reference Books:**

1. Timoshenko S. P., Theory of Elasticity, Tata McGraw Hill.
2. Timoshenko S. P. and Gere J. N., Theory of Elastic stability Tata McGraw Hill.
3. Alexander Chajes, Principle of Structural Stability.

## **1SFSE3: MATRIX METHODS OF STRUCTURAL ANALYSIS**

Flexibility method(structural approach), flexibility coefficients, generalized flexibility coefficients, static degree of indeterminacy, basic determinate structure, redundant, alternate choices of redundant and corresponding primary structures, matrix formulation, hand solution of simple problem on truss, beams, frames, grids up to three unknown.

Stiffness method(structural approach), stiffness coefficient, generalized stiffness coefficients, kinematic degree of indeterminacy, unknown joint displacements for various structures, joint equilibrium equations, hand solution for simple problems of beams, frames, trusses up to three unknowns.

Stiffness method(member approach), general strategy, member and structure coordinate system, force-displacement relations in member coordinates, member stiffness matrix, transformation of displacements and forces from member to structure coordinates and vice-versa, stiffness matrix referred to structure coordinate system, joint equilibrium equations using assembly procedure, large structures, boundary conditions. Application to beams, plane and space trusses, plane and space frames and grids. Programming aspects, flow charts, solution of equations, member end forces, free body diagram of members

Memory problems, in-core solution techniques, assembly of stiffness matrix in full form, half band form and sky line storage, half band width, column height, diagonal address.

Data preparation for solution of structures by stiffness method(member approach), alternatives for data preparation, displacement codes, joint-displacement and element displacement code relations.

### **Reference Books:**

1. Pandit G.S. and Gupta S.P., Structural Analysis A matrix approach, Tata Mc Graw Hill, New Delhi 1986
2. Gere J.M. and W.Weaver, Analysis of framed Structures, D.Van Nostrand com. Inc.,Affiliated East West Press, 1965
3. Meghre A.S. and Deshmukh S.K., Matrix Methods of Structural Analysis, Charotar Publishing, Anand, India 2003.

#### **1SFSE4: STRUCTURAL DYNAMICS**

Sources of vibration, types of excitations, Spring action and damping; Degrees of freedom; Application of Newton's laws, D'Alembert's principle, Single degree of freedom systems; Mathematical model of physical systems; free vibrations, damped free vibrations, critical damping, and response, periodic loading expressed in harmonics, dynamic load factor.

Single degree freedom system, response to impulsive loading, rectangular, triangular pulses, Duhamel Integral. Response to general dynamic loading, Numerical schemes such as Wilson-Theta, Newmark-Beta, constant linear acceleration & time domain and frequency domain analysis.

Multi-degree freedom system, stiffness and flexibility approaches, Lumped-mass matrix, free vibrations fundamental Frequencies and mode shapes, orthogonality of, response to dynamic loading, Formulations of equations of motion, mode superposition method, modal matrix, numerical scheme of iteration method.

Vibration of Continuous Systems: Free vibrations of Continuous systems-axial and transverse vibration of bars / beams. Response of continuous systems to dynamic loads. Rayleigh-Ritz method.

Structural response to earthquake, Response spectrum design earth quake, IS code provisions for multistory frames

#### **Reference Books:**

- 1 Chopra, A. K.; Dynamics of Structures; Prentice Hall; 1995
- 2 Clough, R.W.; & Penzin, J.; Dynamics of Structures; McGraw Hill; 1993
- 3 Humar J. L.; Dynamics of Structures; Prentice Hall; 1990
- 4 Mario, Paz; Structural Dynamics; CBS Publ.; N-Delhi; 1995
- 5 Timoshenko, S.; Advanced Dynamics; McGraw Hill Book Co; NY; 1948
- 6 Meirovitch L.; Elements of Vibration Analysis; 2<sup>nd</sup> Edition; McGraw Hill International Edition; Singapore; 1986
- 7 Biggs, J.M.; Introduction to Structural Dynamics; McGraw Hill; NY; 1964

#### **1SFSE5: EARTHQUAKE RESISTANT DESIGN OF REINFORCED CONCRETE STRUCTURES**

Review of Limit State Design of RC members. Confinement of concrete  
Philosophy of earthquake resistant design, Ductility, Redundancy & Over strength, Damping, Supplemental Damping, Base Isolation, Codal Provisions. Seismic behaviour of concrete,

Beams (Flexural, Shear and torsion)

Uni-axial and biaxial Beam-column (Axial, shear and moments)

Building frames, frame-shear wall buildings, Braced Buildings, Preliminary sizing and Mathematical modeling of buildings with different structural systems with and without diaphragms,

Earthquake, wind and other (i.e. blast, snow) load calculations along with dead load and live loads and their combinations.

Special aspects in Multi-storied buildings: Effect of torsion, flexible first story, P-delta effect, effect of soil-structure interaction on building response, drift limitation.

Analysis and Design of multi-storied buildings with masonry infill,

#### **Reference Books:**

1. Paulay T. and Prestiley M.J.N.; Seismic design of R C & Masonry Buildings; John Willey & Sons; 2<sup>nd</sup> Edition; 1999
2. Booth, E.; Concrete Structures in Earthquake Regions; Longman Higher Education; 1994
3. Raynolds C.E.; Reinforced Concrete Design Handbook; 9<sup>th</sup> Edition; Rupa & Company; Calcutta; 1981
4. Raynolds, C.E.; Basic Reinforced Concrete Design; Vol.-II; Conc. Publications Ltd.; 1962
5. Fintel M.; Handbook of Concrete Engineering; 2<sup>nd</sup> Edition; CBS Publishers, Delhi; 1986
6. Park and Paulay; Reinforced Concrete Structures, John Wiley and Sons
7. Duggal S. K., Earthquake Resistant Design of Structures, Oxford University Press 2007

#### **1SFSE6: EARTHQUAKE RESISTANT DESIGN OF REINFORCED CONCRETE STRUCTURES: STUDIO**

Complete Design calculations and Drawings to be developed for a multi-storied building based on the above syllabus.

#### **1SFSE7: COMPUTER AIDED ANALYSIS & DESIGN OF STRUCTURES: STUDIO**

- Introduction to Computer systems and facilities. Operating systems, Software, Software development processes.

-Introduction to software packages like STAADPRO, STRUDS, SAP-2000, Etab and ANSYS

## 2SFSE1: FINITE ELEMENT METHOD

Continuum structure, discretisation, nodes and elements, minimum potential energy theorem, relation to Rayleigh- Ritz method

Interpolation, shape functions, one dimensional Lagrangian and first order Hermitian functions, Natural or local coordinate, Two dimensional shape functions, Lagrangian and Serendipity shapes, Area and volume coordinates.

Two dimensional plane stress and plane strain analysis, constant strain triangle, linear strain triangle, rectangle, stiffness matrix, nodal load matrix due to body forces.

Isoparametric elements, plane stress/strain analysis, coordinate and derivative transformation, formulations for four and eight noded element, extrapolation of stress, Gauss integration, locations and weightages of Gauss points.

Three dimensional stress analysis using eight and twenty noded isoparametric hexahedron, four noded tetrahedron.

Ring type element for analysis of axisymmetric solids subjected to axisymmetric loads only

Thin plate bending element,  $C^1$  continuity, 12 d.o.f. ACM element, 16 d.o.f. Bogner Fox element.

Thin shallow shells, cylindrical shell, axisymmetrical shell subjected to axisymmetric loads only, Conical frustum element.

Plate bending elements for Mindlin plates,  $C^0$  continuity, four eight and nine noded isoparametric element, nodal loads due to transverse load on element.

Convergence, different types of convergence trends, condition for convergence, geometric isoparametry, continuity of displacement and derivatives along element edge.

Programming aspects, geometry, connectivity, code number, alternate data types, half band, data preparation, flow chart, typical subroutines for assembly, shape functions, stiffness matrix solution of equation.

### Reference Books:

1. O. C. Zienkiewing and R. L. Taylor, The finite element method, Vol.1 and 2, Mc Graw Hills.
2. C.S.Krishnamoorthy, Finite Element Analysis, Theory and Programming., Tata Mc Graw Hills 1994
3. R. D. Cook, Concept and application of finite element analysis, John Willey and Sons.
4. Bathe and Wilson, Numerical Methods of Structural analysis
5. E.Hinton and D.R.J. Owen, Finite Element programming, Academic press
6. A.D. Belegunda and T.R.Chandrupatla, Finite element method in engineering, pretile Hall

## **2SFSE2: ADVANCED DESIGN OF STEEL STRUCTURES**

Introduction to Allowable Stress Design, Plastic design, Limit state Design  
Loadings as per IRC, IS (IS: 800-2007, IS: 875 part 1-V, IS: 1893) applicable to various steel structures.

Welded and riveted connections.

Design of Beams, Beam-column, Plate Girders.

Industrial Buildings including crane girders.

Design of Foot Bridge and Introduction to Composite structures.

Analysis and Design of Multistory building subjected to Seismic and Wind forces

### **Reference Books:**

1. Owens, G.W. & Knowles, P.R.; Steel Designers Manual; Blackwell; 1994
2. Gaylords E.H. & Gaylords, C. N.; Design of Steel Structures; McGraw Hill Publ.1998
3. Steel Design Manual; ELBS and Granada Publishers; London
4. Johnson, R.P.; Composite Structures of Steel and Concrete; Volume-I; Granado Publishing Ltd.; London; 1975
5. Salmon and Johnson; Steel Structures – Design and Behaviour, Harper and Collins Publishers.
6. Subramanian N., Design of Steel Structures, Oxford University Press 2008
7. IS 800-2007, BIS
8. Duggal S.K., Limit State Design of Steel Structures, Tata McGraw Hill Education Private Limited.
9. Bavikatti S.S., Design of Steel Structures By Limit State Method As Per IS:800-2007, I.K. International Publishing House Pvt. Ltd.
10. Subramanian N., Steel Structures Design and Practice, Oxford University Press 2008

## **2SFSE3: THEORY OF PLATES AND SHELLS**

Governing differential equations of thin rectangular Plates with various boundary conditions and loadings.

Introduction, Moment of curvature relation in pure bending, metrical bending of circular plates (Lateral loaded, uniformly loaded with clamped)

Laterally loaded rectangular plates, Differential equation of the deflection surface (Lagrange's equation), Boundary conditions, simply supported plates under sinusoidal loading, Navier's solution.

Finite differential method, differential equation to bent surface of anisotropic plate, Application to grid.

General shell geometry, classifications, stress resultants, equilibrium equation, Membrane theory for family of shells (Parabolic, Quaternary, Cycloid, Circular, hyperbolic).

Classical bending theories of cylindrical shells with and without edge beams, Finster Walder Theory, Schorer's Theory

Approximate analysis & design of cylindrical shells.

### **Reference Books:**

1. Timoshenko, S. P. & Kriegar, W.; Theory of Plates & Shells; McGraw Hill; NY; 1970
2. Szilard, R.; Theory and Analysis of Plates; Prentice Hall; 1974

3. Novozhilov, V.V.; Thin Shells; Noordho of Groningen; 1964
4. Ramaswamy G. S., Design of Concrete Shells; Krieger Publication Co.; 1984
5. Chandrasekhar K.; Theory of Plates; University Press India Ltd.; Hyderabad; 1<sup>st</sup> Edition; 2001

#### **2SFSE4: DESIGN OF PRESTRESSED CONCRETE STRUCTURES**

1. Introduction to pre-stressing, Analysis for pre-stress, Load balancing.
2. Partial pre-stressing, Grouting of beams, fire resistance of beams, special problems like stress corrosion, fatigue under dynamic loading etc.
3. Basic design for flexure (Type I structures), Introduction to Limit state method.
4. Limit state of collapse: Shear, Bond, deflection & cracking in pre-stressed concrete member
5. Comprehensive design of a rectangular and/or a T-section by limit state method.
6. Design of Poles, Piles and Sleepers by limit state method.
7. Design and analysis of pre-stressed concrete pipes and circular tank.
8. Analysis and design of end block by I. S. code method.
9. Comprehensive design of post-tensioned girders by limit state method.
10. Analysis and design of continuous beams up to two spans linear transformation, concordant cable.
11. Analysis and design of portal frame, single storey and single bay.

#### **Reference Books:**

1. Krishna Raju, N.; Prestressed Concrete Structures; TMH; Delhi; 1981
2. Lin, T.Y. and Burns, N.H.; Design of Prestressed Concrete Structures; 3<sup>rd</sup> Edition; John Wiley & Sons; NY; 1981
3. Ashok Jain, R. C. C. Design
4. Edward Nhawy, Basics of Prestressed Concrete
5. Latest relevant BIS codes

#### **2SFSE5: Elective: (1) SUBSTRUCTURES AND FOUNDATION DESIGN**

Analysis and design of Piers, Abutments and Retaining walls.

Shallow foundations: Individual and combined footings for axial and bending loads (Uniaxial and biaxial), Loss of contacts.

Rafts, Annular Footings, Rigid and flexible foundations, Beams and slabs on elastic foundations.

Deep Foundations: Piles and Wells foundations.

Design of Machine Foundations.

#### **Reference Books:**

1. Hetenyi M.; Beam on Elastic foundation; University of Michigan Press; 1946
2. Bowles, J. E.; Foundation Analysis & Design; McGraw Hill; 5<sup>th</sup> Edition; 1996

3. Swami Saran; Soil Dynamics and Machine Foundations, Galgotia Publications (P) Ltd, New Delhi, 1999
4. Srinivasulu P, Vaidyanathan C V ; Handbook of Machine Foundation
5. Kurian N P; Modern Foundations – Introduction to advanced Techniques

**2SFSE5: Elective: (2) EARTHQUAKE RESISTANT DESIGN OF BRIDGES AND DAMS**

Bridges:

Performance in past earthquakes, Types of bridge superstructure and introduction to their design, sub-structure, bearings, IRC / IRS Bridge loadings and other codal recommendations, Performance of Bridges in past earthquakes.

Seismic design philosophy for Bridges, State of art Modeling of bridges, Seismic Design of Substructures, Capacity design of substructures and ductile detailing, Seismic design of well and pile foundations

Dams:

Performance of concrete and masonry gravity dams, seismic design considerations, dynamic analysis of dams. Dam-foundation-reservoir interaction, bending, shear and finite element method of analysis.

**Reference Books:**

- 1 Chen W.F. and Duan L., Bridge engineering Handbook; CRC Press; 1999
- 2 Fintel, M.; Handbook of Concrete Engineering; 2<sup>nd</sup> Edition; CBS Publishers Delhi; 1986

**2SFSE5: Elective: (3) EXPERIMENTAL STRESS ANALYSIS**

Photo elasticity: stress analysis by photo elasticity, light, polarization of light, Polariscopes, plane polariscopes, circular polariscopes, fringes, optics of polariscopes, stress-optic law, isoclinics and isochromatics.

2D-photoelasticity, compensators and compensation technique, separation of principal stresses, analytical and experimental methods, typical model studies.

3D techniques, stress freezing, scattered light technique.

Stress analysis by strain measurement, mechanical, optical, acoustical strain gauges, strain gradients.

Electrical resistant strain gauges, various types, mounting of gauges, Rosette and rosette analysis, gauge factor, Wheatstone bridge, temperature compensation. Strain recording instruments, bridge configuration, and sensitivity,

Model analysis, direct and indirect methods, prototype and model similarities, dimensional analysis, influence lines, beams and other deformer.

Brittle coating method

Refringent coating method

Moiré fringe method

**Reference Books:**

1. Dally And Rally, Experimental Stress Analysis, Mcgraw Hill.
2. M-Frocht, Photoelasticity, John Wiley
3. Bungy S., Testing Of Concrete In Structure, Surrey University Press.

**2SFSE5: Elective: (4) DESIGN OF ENVIRONMENTAL STRUCTURE**

1. Analysis and design of cylindrical shaped E.S.R, supported peripherally & internally making the tank floor a solid continuous slab system, Analysis and design of staging.
2. Design of underground water tanks, swimming pools, Jacks well
3. Design of Water Treatment Plant units, aeration tank, Clari-floculator, flash mixers.
4. Design of water sumps, filters, Design of digestion tank.

**Reference Books:**

1. Paulay T. & Park R.; Reinforced Concrete structures; John Willey & Sons
2. Krishna Raju N., Advanced R.C.C. Design, Tata McGraw Hill, New Delhi
3. Reynolds C.E.; Reinforced Concrete Design Handbook; 9<sup>th</sup> Edition; Rupa & Company; Calcutta; 1981
4. Punmia B. C., R. C. C. Design, Laxmi publications
5. Datta N. P., Waste Water Treatment, Oxford & IBH Publication

**2SFSE6 ADVANCED DESIGN OF STEEL STRUCTURES: STUDIO**

Complete Design calculations and Drawings to be developed for the following structures based on syllabus For the relevant theory subject (2SFSE2)

1. Design of a steel bridge
2. Design of an Industrial shed

**2SFSE7 DESIGN OF PRESTRESSED CONCRETE STRUCTURES: STUDIO**

Complete Design calculations and Drawings to be developed for the following structures based on syllabus For the relevant theory subject (2SFSE4)

1. Comprehensive design of a pre-tensioned Pole
2. Comprehensive design of a post-tensioned Girder
3. Field visit report

**3SFSE1 & 4SFSE1 SEMINAR AND DISSERTATION**

A Dissertation on Recent Trends in Structural Engineering to be submitted.

Marks shall be based on Seminar, dissertation. and Viva-Voce on dissertation.