INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–501** Course Title: **Theory of Vibration**

2. Contact Hours: L: **03** T: **01** P: **2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS 20 PRS 20 MTE 20 ETE 4 0 PRE 0 0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To provide the basic framework for studying time-dependent response of mechanical systems to external excitations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Vibrations and the nature of time dependent phenomena, inertia, dynamic equilibrium and mathematical models of physical systems; Energy storing and dissipation mechanisms.	3
2.	Dynamics of Single Degree of Freedom Systems, undamped and damped, free and forced vibrations; Steady-state and transient response, impulse response.	10
3.	Harmonic response and applications to vibration isolation; theory of seismic pickups: Seismometers, accelerometers.	4
4.	Convolution integral and solution of equation of motion; Numerical methods for solution of linear and non-linear equations of motion; response/shock spectra; Fourier transforms and analysis in frequency domain.	6
5.	Dynamics of Multi-Degree of Freedom Systems**,** Lagrange's equations; equations of motion for MDOF systems; Algebraic eigenvalue problem and free vibration analysis; Undamped and damped normal modes; Mode superposition method for dynamic analysis of linear systems; Mode-truncation and correction for the missing mass.	12
6	Dynamics of Continuous Systems**,** Hamilton's principle; Axial and transverse vibrations of beams, torsional vibrations of shafts; Normal modes; Free and forced vibration analysis by mode superposition; Vibrations of elastic half-space.	4
7	Approximate Methods for Vibration Analysis**,** Rayleigh quotient, rayleigh-ritz method.	3
	Total	**42**

List of Experiments:

1. Vibration transducers and elementary data processing.
2. Free vibration characteristics of structural systems-natural frequency and damping ratio.
3. Harmonic forced vibration response of structural models and frequency response functions.
4. Dynamic vibration absorber.
5. Prototype testing and system identification.

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Warburton, G. B., "The Dynamic Behaviour of Structures", 2nd edition, Pergamon Press.	1976
2.	Clough, R. W. and Penzien., J., "Dynamics of Structures", 2nd edition, Mc-Graw Hill Book Company.	1993
3.	Humar, J. L., "Dynamics of Structures", 2nd edition, Taylor & Francis.	2002
4.	Chopra, A. K., "Dynamics of Structures", 3rd edition, PHI Learning.	2006
5.	Craig, R. R., Jr. and Kurdila, A., "Fundamentals of Structural Dynamics", 2nd edition, John Wiley & Sons.	2006
6.	Villaverde, R., "Fundamental Concepts of Earthquake Engineering", Taylor & Francis.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–502** Course Title: **VIBRATIONS OF ELASTIC MEDIA**
2. Contact Hours: L: **03** T: **01** P: **2/2**
3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0
4. Relative Weight : CWS **25** PRS **00** MTE **25** ETE **5 0** PRE **0 0**
5. Credits: **04** 6. Semester: Autumn 7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course: To provide the basic framework for studying time-dependent response of mechanical systems to external excitations.
10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Vibrations and the Nature of Time Dependent Phenomena**: Inertia, dynamic equilibrium and mathematical models of physical systems, energy storing and dissipation mechanisms.	2
2.	**Dynamics of Single Degree of Freedom Systems:** Undamped and damped, free and forced vibrations, steady-state and transient response, impulse response; Vibration isolations.	9
3.	**Convolution Integral and Solution of Equation of Motion**: Numerical methods for solution of linear and non-linear equations of motion; response/shock spectra, Fourier transforms and analysis in frequency domain.	6
4.	**Dynamics of Multi-Degree of Freedom Systems**: Lagrange's equations, equations of motion for mdof systems, algebraic eigenvalue problem and free vibration analysis, undamped and damped normal modes, mode superposition method for dynamic analysis of linear systems, mode-truncation and correction for the missing mass.	9
5.	**Probability Theory and Stochastic Processes:** Random variables, functions of random variables, correlation, stationary and ergodic random processes, power spectrum, extreme value statistics, first passage problem, peak value statistics.	8
6.	**Response of SDoF and MDoF Systems to Random Excitations:** Time domain characterization, frequency domain analysis, estimation of maximum response, normal mode theory.	8
	Total	**42**

11. List of Experiments:
    1. Vibration transducers and elementary data processing.
    2. Free vibration characteristic of structural systems-natural frequency and damping ratio.
    3. Harmonic forced vibration response of structural models and frequency response functions.
    4. Dynamic vibration absorber.
    5. Prototype testing and system identification.
12. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publishers	Year of Publication/Reprint
1.	Warburton, G.B., "The Dynamic Behaviour of Structures", 2nd edition Pergamon Press,.	1976
2.	Clough ,R.W. and Penzien J., "Dynamics of Structures", 2nd edition, Mc-Graw Hill Book Company.	1993
3.	Chopra, A.K., "Dynamics of Structures", 3rd edition, PHI Learning Pvt. Ltd.	2006
4.	Craig, R.R. Jr. and Kurdila, A., " Fundamentals of Structural Dynamics", 2nd edition, John Wiley & Sons.	2006
5.	Nigam N.C., Introduction to Random Vibrations, MIT Press.	1983
6.	Wirsching, P.H., Paez, T.L. and Ortz, H., "Random Vibration", Dover Publications	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN–503** Course Title: **Engineering Seismology**

2. Contact Hours: L: **03** T : **01** P : **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight: **CWS 15 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring** 7.Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the relevant principles and prevalent practices in Engineering Seismology from Earthquake Engineering viewpoint.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Scope of seismology; Definitions of important terms; Causes of earthquakes and their classifications; Earthquake effects on ground and structures.	4
2.	**Plate Tectonics and Seismicity:** Plate tectonics- continental drift, types and characteristics of various plate margins; Earthquake catalogue and seismicity of the earth; Major earthquakes in the world; Important Indian earthquakes.	6
3.	**Wave Propagation and Internal Structure of Earth:** Theory of elasticity; Wave equation; Body and surface waves; Laws of reflection, refraction, attenuation, diffraction and dispersion; Local site effects; Seismic phases; Ray parameter; Travel time curves; Internal structure of earth; Reference models.	8
4.	**Earthquake Size:** Earthquake intensity scales and isoseismal map; Earthquake magnitude scales, energy, acceleration, frequency magnitude relations and return period.	4
5.	**Instrumentation:** Earthquake recordings – principles and theory of seismograph; Various kinds of seismographs; Analog and digital recording, WWSSN, GDSM; Real time warning system; International monitoring system (IMS); Local seismological networks, strong motion networks and their engineering importance.	6
6.	**Data Processing and Analysis**: Processing, analysis and interpretation of seismograms; Estimation of earthquake parameters, source parameters and fault plane solutions.	4
7.	**Seismic Hazard Assessment:** Definitions- seismic hazard, disaster and risk; Probabilistic and deterministic approach; Earthquake occurrence models; Seismotectonic modeling and type of sources; Estimation of maximum magnitude, maximum credible earthquake, design basis earthquake; Frequency magnitude relationship; Poissonian and Non Poissonian models; Ground motion prediction equations; Uncertainties in seismic hazard assessment and their quantification; Return periods and strong motion exceedance rates; Site-specific design earthquake parameters; Case studies.	10

	Total	**42**

List of Experiments:

1. Installation and operation of seismograph to record ground motion.
2. Calibration of seismograph to compute its response.
3. Background noise survey for selection of site.
4. Interpretation of seismograms and estimation of source parameters.

11. Suggested Books:

S. No.	**Name of Authors / Books / Publishers**	**Year of Publication/Reprint**
1.	Bullen, K.E. and Bolt, B.A., "An introduction to the Theory of Seismology", Fourth Edition, Cambridge University Press, Cambridge.	1985
2.	Kulhanek, O., "Anatomy of Seismograms", Elsevier Science Publication.	1990
3.	Lay Thorne and Wallance Terry C., "Modern global seismology", Academic press.	1995
4.	William Lowrie, "Fundamentals of Geophysics", Cambridge, Univ. Press.	1997
5.	Kramer, S.L., "Geotechnical Earthquake Engineering", Second Indian reprint, Pearson Education.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–504** Course Title: **Finite Element Method**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** 0

4. Relative Weight : **CWS** **25** **PRS** **00** **M TE** **25** **ETE** **50** **PRE** **00**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To provide a framework for developing computational models for solving engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Mathematical Modeling:** Differential equations; Boundary conditions; Method of weighted residuals; Variational principles and approximate solutions; Convergence of approximate solutions; Concept of finite element method as extension of method of weighted residuals to piecewise continuous approximation; Rules of domain discretization; Discretization errors.	5
2.	**Finite Elements of One Dimension:** Continuity requirement; Truss/rod/shaft, beam bending; Locking in shear deformable beam elements and solution; Modeling of framed structures; Skewed boundary conditions; constraint equations; Rules for monotonic convergence of the finite element solution.	7
3.	**Finite Elements of Two/Three Dimensions:** Equations of 3-D elasticity; Plane stress, plane strain and axi-symmetric idealizations; Triangular and rectangular elements; Interpolation functions; Degree of complete polynomial; Pascal's triangle; Evaluation of domain and surface integrals; Tetrahedral and brick elements; Incompatible modes; Patch test.	10
4.	**Mapped Elements:** Parametric distortions and finite elements; Numerical integration; Full reduced and selective integration; Constraint counting techniques; Modeling of unbounded domains.	10
5.	**Plates and Shells:** Finite elements for plates and shells; Shear and membrane locking and solution; Semi-analytical procedure for axi-symmetric shells.	4
6.	**Time Dimension:** Consistent mass matrix; Lumping procedures; Algebraic eigenvalue problem; Time-marching schemes; Adequacy of the finite element mesh.	3
7.	**Error Analysis:** Posteriori error estimation procedures; Adaptive finite element analysis – *h*, *p* and *r* adaptivity; Super-convergent patch recovery.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Zienkiewicz, O.C. and Morgan, K. "Finite Elements and Approximation", John Wiley & Sons.	1983
2.	Reddy, J.N. " Finite Element Method", 2nd edition, McGraw-Hill Book Company.	1993
3.	Bathe, K. J., "Finite Element Procedures", 2nd edition, PHI Learning.	1994
4.	Dow, J.O., "A Unified Approach to the Finite Element Method and Error Analysis Procedures", Elsevier Publications.	1999
5.	Cook, R.D., Malkus, D., Plesha, M. and Witt, J. "Concepts and Applications of Finite Element Method", 4th edition, John Wiley & Sons.	2004
6.	Akin, J.E. "Finite Element Analysis with Error Estimators", Elsevier Publications.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN–511** Course Title: **Earthquake Resistant Design of Masonry Structures**

2. Contact Hours: L: **03** T: **01** P**: 00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 00 M TE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide insight into relevant theories, simulation techniques and principles of earthquake resistant design and construction for various types of masonry structures and to introduce various code provisions.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Behaviour of Masonry Structures During Past Earthquakes:** Common modes of failure, effect of unit shapes and mortar type, effect of roof and floor systems; Common deficiencies.	4
2.	**Material Properties:** Masonry units- stones, brick and concrete blocks, hollow and solid units; Manufacturing process; Mortar, grout and reinforcement; Various tests and standards.	5
3.	**Masonry Under Compression**: Prism strength, Failure mechanism, types of construction and bonds; Eccentric loading; Slenderness – effective length and effective height, effect of openings; Code provisions.	5
4.	**Masonry Under Lateral Loads:** In-plane and out-of-plane loads, bending parallel and perpendicular to bed joints; Shear and flexure behaviour of piers; Test and standards; Analysis of perforated shear walls, lateral force distribution for flexible and rigid diaphragms; Arching action; Combined axial and bending actions.	10
5.	**Earthquake Resistant Measures:** Analysis for earthquake forces, role of floor and roof diaphragm; Concept and design of bands, bandages, splints and ties; Reinforced masonry; Vertical reinforcement at corners and jambs; Measures in random-rubble masonry; Confined masonry; Code provisions.	5
6.	**Masonry Infills:** Effect of masonry infills on seismic behaviour of framed buildings; Failure modes; Simulation of infills – FEM and equivalent strut; Safety of infills in in-plane action – shear, compression and buckling; Out-of-plane action, arching; Code provisions.	5
7.	**Retrofitting of Masonry Building:** Techniques of repair and retrofitting of masonry buildings; IS: 13935-1993 provision for retrofitting.	3

8.	**Advance Concepts:** Strength and ductility; Nonlinear pushover analysis; Performance based design; Vulnerability and fragility analysis.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Drysdale, R. G., Hamid, A. H. and Baker, L. R., "Masonry Structure: Behaviour and Design", Prentice Hall, Englewood Cliffs.	1994
2.	Schneider, R.R. and Dickey, W. L., "Reinforced Masonry Design", 3rd Ed, Prentice Hall.	1994
3.	Paulay, T. and Priestley, M. J. N., "Seismic Design of Reinforced Concrete and masonry Buildings", John Wiley & Sons.	1995
4.	Amrhein, J. E., "Reinforced Masonry Engineering Handbook," Masonry Institute of America, CRC Press.	1998
5.	Hendry, A. W., "Structural Masonry", Macmillan Press Ltd.	1998
6.	"Prestandard and Commentry For The Seismic Rehabilitation of Buildings," FEMA 356, Federal Emergency Management Agency, Washington, D.C.9	2000
7.	Tomazevic, M., "Earthquake Resistant Design of Masonry Buildings", Imperial Colleges Press.	2000
8.	Donald Anderson and Svetlana Brzev, "Seismic Design Guide for Masonry Buildings," Canadian Concrete Masonry Producers Association.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–512** Course Title: **Advanced Earthquake Resistant Design of Structures**
2. Contact Hours: L: **03** T: **0** P: **0**
3. Examination Duration (Hrs.): **Theory 3** **Practical 0**
4. Relative Weight : **CWS 25 PRS 00 M TE 25 ETE 50 PRE 00**
5. Credits: **3** 6. Semester: **Spring** **7.** Subject Area: **PEC**
8. Pre-requisite: **EQ-501 or equivalent**
9. Objective: The course deals with special provisions and requirements of structures for their safety against earthquake forces.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Concepts of Earthquake Resistant Design**: Force based vs. displacement based design, performance based design, seismic input characteristics and their effect on seismic design, comparative study of different national codes.	4
2.	**Modelling and Analysis of Structures for Displacement Based Design**: Back-bone curve, Idealized component models, estimation and modelling of stiffness, strength and ductility of RC, steel and masonry structures, nonlinear static and dynamic analyses.	10
3.	**Direct Displacement Based Design**: Structure performance objectives, performance levels and limit states; P-Delta effects; Torsion; Capacity design for direct displacement based design.	10
4.	**Performance Based Design:** Structural and non-structural performance, quantification of performance, performance evaluation of structures, services and equipment.	6
5.	**Overhead Water Tanks:** Modelling and analysis of overhead water tanks, hydrostatic and hydrodynamic effects, earthquake resistant provisions.	6
6.	**Cooling Towers :** Seismic behaviour and besign of cooling towers, chimneys and silos; Seismic analysis and design of hyperbolic cooling towers, axisymmetric bodies subjected to non-axisymmetric loads, analysis and design of short and tall stacks & chimney structures, foundation compliance, codal provisions.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Paulay, T. and Priestley, M.J.N. "Seismic Design of Reinforced Concrete and Masonry Buildings," John Wiley & Sons.	1992
2.	M.J.N. Priestley, F. Seible, and G.M. Calvi, "Seismic Design and retrofit of Bridges," John Wiley & Sons.	1996
3.	Skinner, R., Robinson ,W.H., McVerry ,G.H., "An Introduction to Seismic Isolation", John Wiley and Sons.	1996
4.	George G. Penelis and Andreas J. Kappos, "Earthquake Resistant Concrete Structures," E & FN Spon.	1997
5.	FEMA-356, "Prestandard and Commentary for the Seismic Rehabilitation of Buildings," Federal Emergency management Agency.	2000
6.	FEMA-450, "NEHRP Recommended provisions for Seismic Regulations for New Buildings and Other Structures," Federal Emergency management Agency.	2003
7.	Priestley, M.J.N., Calvi, G.M. and Kowalsky, M.J., "Displacement-Based Seismic Design of Structures," IUSS Press.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–513** Course Title: **Numerical Methods for Dynamic Systems**

2. Contact Hours: L: **03** T: **00** P: **0**

3. Examination Duration (Hrs.): Theory **3** Practical **0**

4. Relative Weight : **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course provides the conceptual basis of analysis of dynamic systems with emphasis on computer implementation.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Elementary concepts of vector spaces, subspaces; Column and row space of a matrix; Range, null space, and rank of a matrix, ortho-normal bases, vector and matrix norms, testing for convergence, errors in floating point arithmetic.	6
2.	Computer implementation of matrix and vector operations, operation counting, structures of matrices and their storage, block algorithms, vector processing and parallel processing.	6
3.	Computational aspects of elimination and in-situ factorisation methods for solution of large system of equations for dynamic problems; Implementation details for band and/or skyline solvers.	9
4.	Problems associated with choice and implementation of solution techniques; Eigen solution of large problems arising in dynamic systems.	9
5.	Application of Interpolation and extrapolation, numerical differentiation and quadrature methods	4
6.	Response evaluation by the Integration of ordinary differential equations with emphasis on accuracy and stability considerations, integration of stiff ordinary differential equations, concepts of *A*-stability and stiff-stability.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Pariett, B. N., "The Symmetric Eigenvalue Problem" Prentice-Hall.	1980
2.	George, A. and Liu J.W.H., "Computer Solution of Large Sparse Positive Definite Systems", Prentice Hall.	1981
3.	Hager, W. W., "Applied Numerical Linear Algebra", Prentice-Hall.	1988
4.	W. H., Teukolsky S. A., Vetterling W.T. and Flannery B.P., "Numerical Recipes – The Art of Scientific Computing," Second Edition, Cambridge University Press.	1992
5.	Clough, R. W. and Penzien J., "Dynamics of Structures," Second Edition, McGraw-Hill.	1993
6.	Golub, G. H. and Van Loan C.F., "Matrix Computations," Third Edition, The Johns Hopkins University Press.	1996
7.	Bathe, K.J., "Finite Element Procedures", Prentice Hall.	1996
8.	Hughes, T.J. R., "The Finite Element Method - Linear Static and Dynamic Finite Element Analysis," Dover Publications.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–514** Course Title: **Seismic Evaluation and Retrofitting of Structures**

2. Contact Hours: L: 03 T**:** 01 P: 00

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart the knowledge for improve with the performance of buildings not designed as per seismic codes of practice.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Terminology; Basic principles of seismic evaluation and retrofitting.	2
2.	**Qualitative Methods of Seismic Evaluation**: Rapid visual screening procedure (RVSP) and simplified evaluation of buildings; Visual inspection method and non-destructive testing (NDT) method.	8
3.	**Quantitative Methods of Seismic Evaluation**: Performance based method using nonlinear static push-over analysis (NSP) and non linear dynamic method of analysis (NDP); Estimation of seismic capacity (strength and ductility).	8
4.	**Local and Global Methods of Seismic Retrofitting of RC Buildings**: System completion; Strengthening of existing components; RC, Steel and FRP Jacketing; Addition of new components – frames, shear walls and braced frames; Introduction to supplemental energy dissipation and base isolation.	8
5.	**Re-evaluation of Buildings with Retrofitting Elements**: Linear and Non-linear modelling; Modelling of soil and foundations.	4
6.	**Seismic Repair and Retrofitting of Earthquake Damaged RC Buildings**: Schemes of temporary shuttering damages; Methods of repair and retrofitting.	3
7.	**Seismic Evaluation and Retrofitting of RC Bridges:** Seismic evaluation and retrofitting techniques for reinforced concrete bridges – columns/piers, cap beams, cap beam-column joint, footing.	3
8.	**Seismic Safety of Equipments and Accessories:** Retrofitting solutions against sliding and overturning of equipments and accessories.	2
9.	**Case Studies in Seismic Retrofitting:** Case studies RC buildings, masonry buildings, bridges, water tanks and gravity dams.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	"Seismic Evaluation and retrofit of concrete building – Vol. I & II", Applied Technology Council, California, ATC 40.	1996
2.	M.J.N., Seible, F. and Calvi, G.M "Seismic Design and Retrofit of Bridges", John-Wiley & Sons.	1996
3.	Penelis, George G., and Kappos, Andreas J., "Earthquake Resistant Concrete Structures", E & FN Spon.	1997
4.	"Rapid Visual Screening of Buildings for Potential Seismic Hazards", Federal Emergency Management Agency, Building Seismic Safety Council, Washington, D.C., FEMA 154/155.	2002
5.	"Evaluating the Seismic Resistance of Existing Building" ATC -14 project, Applied Technology Council, California.	2002
6.	"Seismic Evaluation of Existing Building" ASCE/SEI 31-03.	2003
7.	"Seismic Rehabilitation of Existing Buildings" ASCE & SEI.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–515** Course Title: **Mechanics of Deformable Media**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the theories related to elasticity, plasticity and visco-elasticity and their applications to engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Theory:** Concept of continuum, vector and tensor analysis.	7
2.	**Elasticity:** Generalized Hook's Law and Stress Strain Relationship for Isotropic Elastic Material, stress tensor and transformation, equilibrium condition; Compatibility, simple state of stress, strain displacement relation, strain tensors and its transformation, impartibility condition, constitutive relation, energy principles, problems of linear elasticity - basic equation, boundary value problems, solution of basic equation and equation of plane problems, St. Venant's Principle, Energy theorems.	10
3.	**Plasticity:** Plastic solid, loading and unloading conditions, isotropic stress theory, deformation theory, yield functions, work hardening and flow rules.	10
4.	**Visco-elasticity:** Visco-elastic material, stress strain relation, various models, creep and relaxation, compliance and modulus of mechanical models, Navier's equation.	5
5.	**Visco-plasticity:** Viscoplastic medium, Basic relation and equation of viscoplastic flow; Creeping plastic medium, Basic relation; Equations of creeping plastic flow.	5
6.	**Fracture Mechanics:** Stress and displacements fields in the vicinity of Cracks; Stable and unstable crack growth; Integral variational principle in Crack Theory; Basic characteristic of a cracked body.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Fung, Y.C. "Fundamentals of Continuum Mechanics", Prentice Hall, Englewood Cliffs.	1965
2.	Spencer, A.J.M. "Continuum Mechanics", Longman Group.	1980
3.	Truessdell, C. "The Elements of Continuum Mechanics", Springer-Verlag, Berlin.	1985
4.	Karasudhi, P. "Fundamentals of Solid Mechanics", Kluwer Academic.	1991
5.	Khan A.S. and Huang S. "Continuum Theory of Plasticity", John Wiley & Sons.	1995
6.	Shames, I.H. and Cozzarelli, F.A., "Elastic and Inelastic Stress Analysis, Taylor and Francis.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–519** Course Title: **Dynamic Soil-Structure Interaction**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8**.** Pre-requisite: **NIL**

9. Objective: To provide basic background on dynamic soil-structure interaction.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Objectives and practical significance and importance of soil-structure interaction (SSI); Fixed base structure, structures on soft ground; Modeling of unbounded media.	2
2.	**Fundamentals of Soil-Structure Interaction**: Direct and substructure methods of analysis; Equation of motion for flexible and rigid base; Kinematic interaction, inertial interaction and effect of embedment.	4
3.	**Modeling of Structure:** Temporal and spatial variation of external loads (including seismic loads); Continuous models, discrete models (lumped mass) and finite element models.	2
4.	**Wave Propagation for SSI:** Waves in semi-infinite medium – one, two and three-dimensional wave propagation; Dynamic stiffness matrix for out-of-plane and in-plane motion.	4
5.	**Free-Field Response of Site:** Control point and control motion for seismic analysis; Dispersion and attenuation of waves; Half-space, single layer on half-space; Parametric studies.	4
6.	**Modeling of Boundaries:** Elementary, local, consistent and transmitting boundaries.	4
7.	**Modeling of Soil:** Green's influence functions, boundary-element method, finite element model; Dynamic stiffness coefficients for different types of foundations – surface foundation, embedded foundation, shallow (strip) foundation and deep (piles) foundations.	4
8.	**Soil Structure Interaction in Time Domain:** Direct method; Substructure method (using dynamic stiffness and Green's functions of soil); Hybrid frequency-time domain approach.	6
9.	**Nonlinear Analysis:** Material nonlinearity of soil (including plasticity and strain hardening), geometrical nonlinearity (slip and separation of foundation with soil); Nonlinear structure with linear soil considering both soil and structure nonlinearity.	4

10.	**Engineering Applications of Dynamic Soil-Structure Interaction:** Low-rise residential buildings, multistory buildings, bridges, dams, nuclear power plants, offshore structures, soil-pile-structure interactions.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1	Wolf, J. P., "Dynamic Soil-Structure Interaction", Prentice-Hall.	1985
2.	Cakmak, A.S. – Editor, "Soil-Structure Interaction", Developments in Geotechnical Engineering 43, Elsevier and Computational Mechanics Publications.	1987
3.	Wolf, J.P., "Soil-Structure Interaction in the Time-Domain", Prentice-Hall.	1988
4.	Wolf, J.P. and Song C. "Finite Element Modelling of Unbounded Media", John Wiley & Sons.	1996
5.	Kramer, S.L., "Geotechnical-Earthquake Engineering", Pearson Education.	1996
6.	Hall, W.S. and Oliveto G., "Boundary Element Method for Soil-Structure Interaction", Kluwer Academic Publishers.	2003
7.	Chen, Wai-Fah and Duan Lian, "Bridge Engineering (Seismic Design)", CRC Press.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–521** Course Title: **Geotechnical Earthquake Engineering**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 0 0 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Autumn** **7.** Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To provide fundamental knowledge of soil-dynamics and seismic behavior of soils.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Background and lessons learnt from damages in past earthquakes.	1
2.	**Wave Propagation:** Waves in semi-infinite media – one, two and three dimensional wave propagation; Attenuation of stress waves – material and radiation damping; Dispersion, waves in a layered medium.	2
3.	**Dynamic Soil Properties:** Stress & strain conditions, concept of stress path; Measurement of seismic response of soil at low and high strain, using laboratory tests; Cyclic triaxial, cyclic direct simple shear, resonant column, shaking table, centrifuge and using field tests - standard penetration test, plate load test, block vibration test, SASW/MASW tests, cross bore hole; Evaluation of damping and elastic coefficients; Stress-strain behavior of cyclically loaded soils; Effect of strain level on the dynamic soil properties; Equivalent linear and cyclic nonlinear models; Static and dynamic characteristics of soils.	10
4.	**Ground Response Analysis:** Introduction, one, two and three dimensional analyses; Equivalent and nonlinear finite element approaches; Introduction to soil-structure interaction.	4
5.	**Liquefaction:** Introduction, pore pressure, liquefaction related phenomena – flow liquefaction and cyclic mobility, factors affecting liquefaction, liquefaction of cohesionless soils and sensitive clays, liquefaction susceptibility; State Criteria –CVR line, SSL, FLS; Evaluation of liquefaction potential: characterization of earthquake loading and liquefaction resistance, cyclic stress ratio, Seed and Idriss method; Effects of liquefaction.	10
6.	**Earth Pressure**: Active and passive earth pressures; Terzaghi's passive wedge theory, numerical methods, earth pressure measurements.; Seismic design of retaining walls: types, modes of failures, static pressure, seismic response (including M-O Method), seismic displacement, design considerations.	6

7.	**Seismic Slope Stability:** Types of earthquake induced landslides; Evaluation of slope stability – stability analysis with dynamic loading, friction circle method, effective and total stress methods of analysis, factor of safety, yield acceleration, damage potential, displacement analysis, effect of saturated and submerged conditions, FEM analysis of slope stability.	4
8.	**Ground Improvement Techniques:** Densification, reinforcement, and grouting and mixing, drainage; Reinforced earth: application of reinforced earth under static and dynamic loads, determination of properties of reinforcements, composite materials, reinforced earth drains and other applications.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Prakash, S., "Soil Dynamics", McGraw Hill Book Company.	1981
2.	Ranjan, G. and Rao A.S.R., "Basic and Applied Soil Mechanics", New Age Int. Ltd.	2000
3.	Kameshwara, Rao, N.S.V, "Dynamic Soil Tests & Applications", Wheeler Publications.	2000
4.	Day Robert, W., "Geotechnical Earthquake Engineering Handbook", McGraw-Hill.	2001
5.	Kramer, S.L., "Geotechnical-Earthquake Engineering", Pearson Education – Indian Low Price Edition.	2004
6.	Saran, S. "Soil Dynamics & Machine Foundation", Galgotia Publication.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–522** Course Title: **Seismic Microzonation**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To deal with all aspects of seismic microzonation, including basic principles and prevailing practices, surveys and techniques.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Seismic microzonation and its objectives, historical developments; Seismic microzonation exploration, investigation and data interpretation.	4
2.	**Use of GIS and GPS in Microzonation:** Type of surveys, map scales; GIS-components, vector and raster data; GIS-techniques, methodology software; Use of GIS in microzonation; GPS, mapping using GPS & GIS.	7
3.	**Seismic Waves and Local Site Effects:** Body and surface waves; Factors affecting ground motion characteristics; Local site effects basic physical concept, impedance contrast, resonance, basement topography, attenuation, trapping; Basin-edge, topography, ridge, valley, slope; Lateral discontinuity.	7
4.	**Geophysical Methods for Determination of Soil Properties:** Seismic methods; Well logging; Steady state Rayleigh method; Spectral analysis of surface waves-SASW and MASW methods; Ground penetrating radar, bedrock profiling.	7
5.	**Quantification of Site Effects:** Experimental methods; Microearthquake-standard spectral ratio method & horizontal to vertical spectral ratio method; Microtremors -absolute spectra, SSR method & H/V ratio; Empirical relations; Analytical method; 1D ground response of layered medium	6
6.	**Site-specific Ground Motion Estimation:** Empirical Green's function; Numerical methods; Basic concept, recent developments; Domain method, boundary method & hybrid method; Effects of nonlinearity on ground motion.	4
7.	**Seismic Microzonation:** PSHA and DSHA; Seismic microzonation of mega cities, scales used in seismic microzonation; Recent developments and case studies.	5
8.	**Computer Programs:** Computer programs to estimate seismic ground motion knowing the seismic response at given point using linear and non-linear properties of layered medium; Seismic hazard assessment; H/V ratio method.	2
	Total	**42**

List of Experiments:

1. Locating sites using GPS survey.
2. Preparation of various types of maps using GIS technique.
3. Determination of S-wave velocity and thickness of soil layers using MASW method.
4. Bed rock and soil amplification determination using H/V ratio method.

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Dobrin, M.B. and Savit, C.H., "Introduction to Geophysical Prospecting", Fourth Edition, McGraw Hill Book Company.	1988
2.	Leon Reiter, "Earthquake Hazard Analysis", Columbia University Press".	1990
3.	Antoni Roca and Carlos Oliveria, "Earthquake Microzoning" , Birkhauser Verlag.	2002
4.	Konency, G., "Geoinformation, Remote Sensing, Photogrammetry and Geographic Information System", Taylor and Francis.	2003
5.	Kramer, S.L., "Geotechnical Earthquake Engineering", Second Indian reprint, Pearson Education.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–524** Course Title: **Earthquake Resistant Design of Foundations**

2. Contact Hours: L: **03** T: **00** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 0 0 MTE 25 ETE 5 0 PRE 0 0**

5. Credits: **3** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course covers various types of soil investigations, soil parameters, foundations, and codes of practice and design considerations for seismic resistant design of foundations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: General requirements, types of shallow and deep foundations and their use; Performance of various types of foundations during past earthquakes.	3
2.	**Design Seismic Data**: Design seismic coefficients for various foundation soil systems, provisions of IS code and their limitations; Influence of local geology, depth & properties of soil cover on seismic coefficient and response spectra; Ground response magnification by wave propagation, predominant period of ground vibrations, approximate check for occurrence of resonance of structure foundation system, factors to be considered in foundation design.	6
3.	**Shallow Foundations:** IS code for foundation design, allowable differential & total settlements, allowable bearing pressures, increase in permissible stress under earthquake type of loading; Transient loads, examples of transient loads, methods of analysis, experimental investigations, critical review of the state of art; Combined footings, raft foundation, modulus of subgrade reaction, Winkler model, beam on elastic foundation, soil line method.	10
4.	**Pile Foundations:** Bearing capacity of piles, dynamic pile formulae, group action, influence of pile cap; Laterally loaded piles, elastic analysis; Reese and Matlock approach, fixity of pile heads, dimensionless factors; Pile with dynamic loads, soil-pile analysis with spring-mass & FEM idealisation, slip elements, IS code of practice for design of pile foundations.	10
5.	**Well Foundations & Caissons:** Types; casting, floating and sinking of caissons; Well sinking scour depth, depth & bearing capacity of wells, static forces considered in stability of wells; Pseudo-static analysis with earthquake induced loads, displacement dependent earth pressures for wells; Lateral load resistance of well foundation; IRC, IS and Indian Railway Codes, their limitations; Dynamic analysis of wells, discretisation of soil-well, scour around wells in analysis.	7

6.	**Bearing Capacity under Transient & Earthquake Type Loads:** Types of dynamic loads; Footing requirements to account for settlements and earthquake induced forces; Pseudo-Static analysis of footings with eccentric & inclined loads; Foundations of framed structures with isolated footings; Moments on connecting beams & columns due to differential settlements.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Prakash, S., "Soil Dynamics", McGraw Hill Book Company.	1981
2.	Bowles, J.E., "Foundation Analysis and Design", McGraw Hill International Editions.	1997
3.	Ranjan, G. and Rao, A.S.R., "Basic and Applied Soil Mechanics", New Age Int.	2004
4.	Kramer, S.L., "Geotechnical Earthquake Engineering", Second Indian reprint, Pearson Education.	2004
5.	Kuriyan, N.P., "Design of Foundations System: Principles and Practice", Narosa Publishing House.	2005
6.	Saran, S., "Soil Dynamics & Machine Foundation", Galgotia Publication.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–525** Course Title: **Seismic Hazard Assessment**

2. Contact Hours: L: **03** T: **01** P: 0

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight : **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course is designed to provide the necessary conceptual and analytical background for seismic hazard assessment.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Seismic hazard and risk, definition of seismic hazard, types of magnitudes, MCE, DBE, SSE, OBE, MPE, site specific design earthquake parameters.	4
2.	**Earthquake Catalogues**: Existing important earthquake catalogues, historical and instrumental seismicity, magnitude homogenisation, regression methods, orthogonal regression analysis, declustering and completeness models, minimum magnitude of completeness.	5
3.	**Ground Motion Prediction Equations:** Strong motion attenuation relationships, dependent and independent parameters, PGA and spectral accelerations, elastic and inelastic response spectra, displacement spectra, periods of interest.	6
4.	**Earthquake Recurrence Models:** Statistical properties of an earthquake sequence, foreshocks and aftershocks, asperity and barrier models, size distribution of earthquakes, temporal and spatial distributions, Gutenberg-Richter relationship, migration of seismicity.	4
5.	**Temporal Distribution of Earthquakes**: Poissonian model, time dependent Poisson process, characteristic earthquake model, periodicity, conditional probabilities, Gamma distribution, Weibul distribution, Gaussian distribution, log normal distribution, Markov and semi-Markov models, Gumbel distributions and mixed Gumble distribution; Time and slip predictable earthquake models; Use of ANN models.	10
6.	**Seismic Hazard Assessment**: Deterministic and probabilistic seismic hazard assessment, seismotectonic modelling; Line, point and volume sources, random seismicity method, seismotectonic province method, geological slip rate method, Zoneless seismic hazard estimation, spatial and size uncertainties, prediction of strong ground motion, mean annual rates of exceedance and their engineering aspects, uniform seismic hazard spectra, desegregation.	6

7.	**Uncertainties and their Treatments**: Aleatory and epistemic uncertainties, uncertainties at different stages of PSHA, quantification and classification of uncertainties, logic tree approaches, Monte Carlo simulations, COV maps.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Reiter, L., "Earthquake Hazard Analysis: Issues and Insights", Columbia University Press.	1990
2.	Taylor, J.R. "An introduction to Error Analysis", 2nd edition, University Science Books.	1997
3.	Chernick, M. R., "Bootstrap methods: A practitioner's guide, in Wiley Series in Probability and Statistics," W. A. Shewhart (Editor), John Wiley and Sons.	1999
4.	"Seismotectonic Atlas of India and its Environs," Geological Survey of India.	2000
5.	McGuire, R.K., "Seismic Hazard and Risk Analysis", Monograph MNO-10, Earthquake Engineering Research Institute.	2004
6.	Draper, N.R. and Smith, H., "Applied regression analysis", John Wiley & Sons (Asia).	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–531** Course Title: **SEISMOLOGICAL MODELLING AND SIMULATION**
2. Contact Hours: L: **03** T: **01** P: **00**
3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0
4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**
5. Credits: **0 4** 6. Semester: Autumn 7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course: To provide basic knowledge about simulation and modelling of strong ground motion.
10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** Definition of important terms; Scope of seismology and engineering seismology; Causes of earthquakes; Earthquake effects on ground and structures; Earthquake magnitude and intensity scales, energy.	5
2.	**Seismic Wave Propagation:** Wave equation, laws of reflection, refraction, attenuation, diffraction and dispersion.	7
3.	**Strong Ground Motion Characteristics:** Amplitude, frequency, duration and intensity; Correlation between ground motion parameters and earthquake magnitude; Source and path effects on ground motion characteristics.	8
4.	**Strong Motion Synthetics:** Concepts of strong motion synthetics; Numerical modelling of realistic fault rupture processes, kinematic dislocation models, 3-D modelling of spontaneous fault rupture processes; Stochastic simulation; Far field and near field radiation, attenuation mechanism; Aki's law of scaling, energy release, types and proportions; Fault surface integral techniques, source parameterization of finite faults.	10
5.	**Strong Ground Motion Processing:** Introduction and basic theory, properties of digital system, sampling theorem and aliasing; Discrete Fourier transform, inverse transform; Characterisation of digital filters, low pass and high pass filters; Interpolation and decimation of digital data; Correlation and power spectrum estimation; Instrument correction and restitution of ground motion.	06
6.	**Engineering Applications:** Displacement, velocity and acceleration response spectra, deconvolution, response spectrum based time histories, selection of strong ground motion for earthquake engineering applications.	06
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publishers	Year of Publication/Reprint
1.	Bolt, B. A., "Seismic Strong Motion Synthetics", Academic Press.	1990
2.	Stein, S. and Wysession, M., "An Introduction to Seismology, Earthquake and Earth Structures", Black Well Publications.	2003
3.	Villaverde, R., "Fundamental Concepts of Earthquake Engineering", Taylor & Francis.	2008
4.	Oppenheim, A.V. and Schafer, R.W., "Discrete Time Signal Processing", Prentice Hall.	2009
5.	Akkar, S., Gulkan, P. and Eck, T. van, "Earthquake Data in Engineering Seismology - Predictive Models, Data Management and Networks", Springer.	2011
6.	Fichtner, A., "Full Seismic Waveform Modelling and Inversion", Springer.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–532** Course Title: **VULNERABILITY AND RISK ANALYSIS**
2. Contact Hours: L: **03** T: **01** P: **00**
3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0
4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**
5. Credits: **0 4** 6. Semester: Autumn 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective of Course: The course introduces various methods and approaches of vulnerability and risk estimation.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Concepts and Components of Seismic Risk**: Hazard, vulnerability, exposure and risk; Estimation of risk from components.	4
2.	**Modelling and Analysis of Structures**: Introduction to matrix and finite element procedures, modelling of buildings and bridges.	8
3.	**Seismic Vulnerability of Buildings and Lifelines:** Empirical, analytical, experimental and hybrid approaches, building typology, intensity scales, use of intensity scales for estimating seismic vulnerability, capacity spectrum method, HAZUS methodology, displacement based approach.	8
4.	**Assessment of Exposure**: Building stock inventory, sources of available information, census data, application of satellite imageries, stratified random sample survey, applications of GIS.	6
5.	**Risk Estimation**: Convolution of hazard, vulnerability and exposure to quantify risk, loss ratios, indoor and outdoor casualty rates; Case studies of different projects- RADIUS, HAZUS, PAGER, GEM, EU-RISK.	6
6.	**Post Earthquake Damage Studies**: Earthquake damage surveys, questionnaires and data to be collected, handling and processing of data, classification of damage, estimation of fragility from damage data.	5
7.	**Risk Communication:** Role of planners, architects, engineers, banks and insurers; Rating of damage assessment, disaster impact analysis.	5
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publishers	Year of Publication/Reprint
1.	Krammer, S. L., “Geotechnical Earthquake Engineering”, Pearson Education.	1996
2.	Reiter, L. “Earthquake Hazard Analysis, Issues and Insights”, Columbia University Press.	2001
3.	Coburn, A. and Spence R., “Earthquake Protection”, John Wiley and Sons, Ltd.	2002
4.	McGuire, Robin K., “Seismic Hazard and Risk Analysis”, Earthquake Engineering Research Institute.	2004
5.	“HAZUS-MH, MR1 & MR2 Technical Manual”, FEMA, Federal Emergency Management Agency, Washington, D.C.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–533** Course Title: **Seismotectonics**

2. Contact Hours: **L: 03** **T: 01** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25** **PRS 0 0** **MTE 25** **ETE 50** **PRE 0 0**

5. Credits: **4** 6. Semester: **Both** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course provides knowledge regarding the relationship between occurrence of earthquakes and tectonic processes, characteristics of seismic sources and assessing their seismic potential.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definition, geological and seismological data required to study seismotectonics; An overview of seismicity and tectonics of the earth's crust and upper mantle.	03
2.	**Seismotectonics of Plate Boundaries:** Seismotectonics of divergent, transform and convergent plate boundaries.	06
3.	**Seismotectonics and Mountain Building Processes:** Seismicity and mountain building; Seismotectonic models of the Himalaya; Seismicity and tectonics of Tibetan plateau and surrounding region.	06
4.	**Seismotectonic Sources:** Geological, geophysical and other criteria used to identify faults; Definition of active fault and capable fault; Geological and seismological attributes of active fault; Characteristics of seismotectonic structures and seismotectonic provinces; Importance of stress data for the demarcation of seismotectonic provinces.	08
5.	**Characteristics and Delineation of Seismic Sources for Seismic Hazard Analysis:** Geological and seismological criteria used for source identification and source geometry; Buried or Blind sources; Modeling of fault segments in hazard analysis.	05
6.	**Maximum Earthquake:** Different types of maximum earthquakes; The physical basis for maximum earthquake; Concept of characteristic earthquake; Different methods (e.g., methods based on dimension of fault rupture and historic seismicity) to estimate maximum earthquake.	06
7.	**Estimation of Earthquake Recurrence Rate:** Different types of recurrence models (e.g., exponential recurrence model and characteristic earthquake model); Methods to treat earthquake catalogues. Importance of paleoseismology for estimating the recurrence rate of large earthquakes; Computation of fault slip-rate.	04

8.	**Seismotectonics of Indian Subcontinent:** Seismotectoinc source zones of Peninsular India and Himalayan region; Different types of seismic zoning maps (e.g., deterministic and probabilistic maps) of Indian subcontinent and their engineering significance.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Reiter, Leon, "Earthquake Hazard Analysis: Issues and Insights", Columbia University Press.	1990
2.	Coppersmith, Kevin J., "Seismic Source Characterization for Engineering Seismic Hazard Analysis," Proceedings of forth ICSZ, Stanford, California, PP 3-60.	1991
3.	Thorne and Wallace, T.C., "Modern Global Seismology," Lay, Academic Press.	1995
4.	Stein, Seth and Wysession, M., "An Introduction to Seismology, Earthquake, and Earth Structure," Blackwell Publishing.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–534** Course Title: **ADVANCED SEISMIC MICROZONATION**
2. Contact Hours: L: **03** T: **01** P: **00**
3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0
4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**
5. Credits: **0 4** 6. Semester: Both 7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course: To provide advanced knowledge on seismic microzonation, procedures and methodologies and deliverables.
10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Basic Concepts**: Seismic microzonation; Basic steps, data requirements, scales, general methodology; Site characterization and quantification; Seismic zonation map of India; Socio-economic aspects of seismic microzonation, factors affecting seismic microzonation, seismic microzonation of mega cities.	6
2.	**Procedures and Methodologies:** Multidisciplinary input data, geological, geotechnical, geomorphological and geophysical data; Seismic hazard assessment, site characterization and its response, ground shaking effects and liquefaction, integration of hazards.	8
3.	**Site Response Analysis:** Experimental, analytical and numerical methods, empirical relations; Effects of topography, ground water and bedrock; Ground response analysis using SHAKE-program; Determination of in-situ shear-wave velocity and Q-factor; Site amplification and its relation to surficial geologic condition; Engineering uses of strong motion data in seismic microzonation.	12
4.	**Seismic Microzonation Deliverables:** Amplification maps, fundamental frequency map, **s**urface iso acceleration maps for different time periods and return periods, probability of exceedance of strong ground motion; Liquefaction potential maps; Landslide hazard zonation maps; Thematic maps with various primary and secondary effects of earthquakes; Earthquake engineering perspective and limitations.	12
5.	**Case Studies:** Mega cities; Delhi, Guwahati, Bangalore, Dehradun, Istanbul, Mexico city.	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publishers	Year of Publication/Reprint
1.	Kramer, S. L., "Geotechnical Earthquake Engineering", Pearson Education.	1996
2.	Reiter, L., "Earthquake Hazard Analysis, Issues and Insights", Columbia University Press.	2001
3.	Ansal, A., "Recent Advances in Earthquake Geotechnical Engineering and Microzonation", Springer.	2006
4.	"Geotechnical/Geophysical Investigations for Seismic Microzonation Studies of Urban Centres in India-Technical Report", NDMA, New Delhi.	2011
5.	Nath, S.K., "Seismic Microzonation Handbook", MoES, Govt. of India.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: DEPARTMENT OF EARTHQUAKE ENGINEERING

1. **Subject Code: EQN–535** **Course Title: SEISMIC DISASTER MITIGATION AND MANAGEMENT**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0

4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**

5. Credits: **0 4** 6. Semester: Both 7. Subject Area: **PEC**

8. Pre-requisite:

9. Objective of Course: The course introduces various aspects of disaster mitigation and management.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to Seismic Hazard:** Definitions, uncertainties in hazard, vulnerability and risk, seismic hazard estimation and mapping, effect of local site conditions, processing and integration of data (such as tectonics, geology, remote sensing, various geophysical anomalies, soil characteristics, economic development).	8
2.	**Earthquake Damages:** Grades of damages, direct and indirect damages, damage to structures, structure types, quantitative analysis, lessons learnt from past earthquakes.	4
3.	**Seismic Vulnerability and Risk:** Seismic vulnerability assessment – various methodologies, building typology survey, empirical and analytical methods, estimation of life loss, direct and indirect economic losses, shelter needs.	8
4.	**Disaster Mitigation:** Do's and don't about disaster, warning and evacuation, damage survey for designing aid package and detailed survey for reconstruction, repair and retrofitting, post disaster surveys, survey proformas; Long term measures- disaster resistant construction, codal practices, retrofitting cost-benefit analysis.	10
5.	**Post Disaster Issues:** Post disaster reconstruction and recovery for sustainable development, issues and policies.	6
6.	**Disaster Management Act :** Disaster management policy; Techno legal aspect, techno-legal and techno-financial work; Model town and country planning legislation, land use zoning regulations, development control regulations and building bye-laws; Registration, qualification and duties of professionals, disaster response policy.	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors /Books/ Publishers	Year of Publication
1.	Andrew, C. and Spence, R., "Earthquake Protection", John-Wiley & Sons.	2002
2.	Carter, W.N., "Disaster Management: A Disaster Manager's Handbook", Manila, ADB.	2006
3.	Sinvhal, A., "Understanding Earthquake Disaster", McGraw Hill.	2011
4.	"Geotechnical/Geophysical Investigations for Seismic Microzonation Studies of Urban Centres in India-Technical Report", NDMA, New Delhi.	2011
5.	Nath, S.K., "Seismic Microzonation Handbook", MoES, Govt. of India.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–536** Course Title: **GROUND FAILURE HAZARD**
2. Contact Hours: L: **03** T: **01** P: **00**
3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0
4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**
5. Credits: **0 4** 6. Semester: Both 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: The objective of the course is to impart knowledge of ground failure due to earthquakes and related phenomena.
10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** Background of geotechnical seismic hazards including ground shaking and liquefaction, geotechnical damages and problems encountered during earthquakes; Deterministic and probabilistic seismic hazard assessment.	5
2.	**Behaviour of Soil for Dynamic Loads:** Geotechnical methods, cyclic triaxial, resonant column, shaking table, SPT, CPT, cyclic plate load test, block vibration test; Geophysical methods, surface wave analysis, up hole and down hole tests, dynamic soil coefficients and assessment, effect of strain level on dynamic soil properties including nonlinear soil models.	6
3.	**Soil-Structure Interaction:** Concepts, ground amplification analyses; Finite element nonlinear analysis, kinematic and inertial interactions, effects of SSI.	6
4.	**Liquefaction Hazard:** Damages due to liquefaction in past earthquakes, excess pore pressure due to shaking, liquefaction susceptibility of cohesionless soils and sensitive clays; Liquefaction potential assessment: characterization of earthquake loading and liquefaction resistance using different approaches; Remedial measure for liquefaction.	8
5.	**Local Site Effects:** Effects of local site condition on ground motion, development of site specific design parameters, development of ground motion time histories.	4
6.	**Earth Retaining Structures:** Types of earth pressures, numerical methods, pseudostatic methods; Retaining walls: types, failure modes, static pressure, seismic response.	4
7.	**Seismic Stability of Slopes and Embankments:** Case histories of earthquake induced landslides; Slope stability using pseudostatic limit equilibrium analysis, seismic coefficients, stability analysis with dynamic loading, damage potential, displacement analysis, dynamic analysis of slope stability; Seismic behavior of slopes and embankments; Possible counter measures for large ground movements including design of retaining walls for seismic forces.	9
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books/Publishers	Year of Publication/Reprint
1.	Ranjan, G. and Rao, A.S.R., “Basic and Applied Soil Mechanics”, New Age Int. Ltd., New Delhi.	2000
2.	Kameshwara Rao, N.S.V., “Dynamic Soil Tests & Applications”, Wheeler Publications, New Delhi,	2000
3.	Day Robert W., “Geotechnical Earthquake Engineering Handbook”, McGraw-Hill, New York.	2001
4.	Kramer, S.L., “Geotechnical Earthquake Engineering”, Pearson Education-Indian Low Price Edition, Delhi.	2004
5.	Saran, S., “Soil Dynamics and Machine Foundation”, Galgotia Pub. Pvt. Ltd., New Delhi.	2006
6.	Towhata Ikou, “Geotechnical Earthquake Engineering”, Springer-Verlag, Berlin Heidelberg,	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: DEPARTMENT OF EARTHQUAKE ENGINEERING

1. Subject Code: **EQN–537** Course Title: **EARTHQUAKE PRECURSORS AND EARLY WARNING SYSTEMS**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0

4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**

5. Credits: **0 4** 6. Semester: Both 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective of Course: The course describes present knowledge base of earthquake precursors and details of earthquake early warning systems.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction**: Precursor definition, scope and its relation with earthquake prediction, forecast and warning.	2
2.	**Earthquake Precursors**: Types of precursors- seismological, geological and geophysical; Fault creep, foregoing seismic activity, vertical crustal deformation, electrical resistivity, tectonomagnetic effects; radon emanation, ground water changes, electrokinetic effects, seismic wave anomalies, migration of seismic activity, precursory swarms, seismic quiescence, thermal anomaly, multiple precursor observations; Other general precursors, biological precursors, environmental changes, animal behaviour.	6
3.	**Analysis of Earthquake Precursors**: Identification of precursors, precursors' relation to main event, physical phenomenon associated with precursors, IASPEI procedure for the evaluation of earthquake precursors, experimental observation of precursor and evaluation, case studies.	5
4.	**Earthquake Precursor Models:** Dilatancy models, premonitory fault creep model, propagating deformation front model, static stress changes (CFS) and accelerating moment release (AMR); Seismic gaps for large and great earthquakes, linear migration of large earthquakes; Indian earthquake precursors monitoring program, other countries' earthquake prediction programs.	8
5.	**Earthquake Early Warning (EEW) Systems:** Concept of EEW systems, onsite EEW, regional EEW, description of some EEW systems operating in different countries, advantages and problems of EEW systems, engineering aspects of EEW.	3
6.	**Requirements of EEW System:** Instrumentation, selection of locations, density of network, specifications, blind zone, data transmission, various options for data transmission, central processing unit, protocol for issue of warning.	8
7.	**Algorithms for EEW System:** Algorithms for picking onset of earthquake record, real-time location of earthquakes, characteristics of first few seconds of recorded strong ground motion data and their relationship with magnitude, τp - Pd method for estimating magnitude, cumulative average velocity (CAV) and other attributes for estimating magnitude for EEW, ANN approach for estimating magnitude, flow chart and logic tree for issue of warning, development and testing of EEW algorithms.	10
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors /Books/ Publishers	Year of Publication
1.	Rikitake, T., "Earthquake Prediction", Elsevier, Amsterdam	1976
2.	Zongjin, M., Zhengxiang, F., Yingzhen, Z., Chengmin, W., Guomin, Z. and Defu, L., "Earthquake Prediction", Seismological Press Beijing and Springer-Verlag.	1990
3.	Jochen Zschau and Andreas, N. Kiippers, "Early Warning Systems for Natural Disaster Reduction", Springer	2003
4.	Sen, P. and Das, N. K. (Eds.), "Geochemical Precursors for Earthquakes", Macmillan India Ltd.	2007
5.	Gasparini, P., Manfredi, G. and Zschau, J. (Eds.), "Earthquake Early Warning Systems", Springer.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–538** Course Title: **GEOINFORMATICS**

2. Contact Hours: L: **03** T: **01** P: 0

3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0

4. Relative Weight : CWS **2 5** PRS **0** MTE **25** ETE **50** PRE **0 0**

5. Credits: **0 4** 6. Semester: Both 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective of Course: The course is designed to provide basic knowledge about mapping and geoinformatics need in earthquake engineering.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** Earthquakes, characteristics and distribution, tectonic features of the earth, geotectonic divisions of Indian continent, geologic hazards perception.	3
2.	**Earthquakes in Different Geological Set Ups:** Geological structures and deformation pattern, inter and intra – continent set up, convergent zones, divergent margins, trenches, thrusts and faults. Earthquake implication of structural discontinuities, impact of neo-tectonic activity.	8
3.	**Mapping:** Coordinate and coordinate systems; geographical and map projection system, 2D and 3D data transformation, types of maps, scales, mapsheet numbering systems and uses, types of maps, introduction to topographical and geological maps, thematical maps, geological sections, data processing, analysis and presentation techniques.	8
4.	**Remote Sensing in Earthquake Geology:** Basic concepts of satellite imaging of ground, types of satellite data in identifying the tectonic features, recognising characteristics of earthquake deformation features, SAR interferometry for earthquake deformation studies; Application of GPS for mapping.	12
5.	**GIS:** Basic GIS concepts, vector and raster data understanding, database creation for geological, tectonic and earthquake themes, GIS data integration and analysis techniques; Tectonic hazard assessment using GIS, geospatial data modelling, geographic information systems, hardware and software components, data transformation, processing and analysis models, overlay, network and proximity analysis, data visualization tools and models.	11
	Total	**42**

11. List of Experiments:
(i) Demonstration of GIS Software
(ii) Scanning and digitization of thematic maps.
(iii) Registration and Georeferencing.
(iv) Database creation and management.
(v) Processing of pre and post earthquake satellite images.
(vi) Collection of data using GPS and mapping.
(vii) Use of SAR interferometry for surface displacement measurement.

12. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publishers	Year of Publication/Reprint
1.	Lillesand, T.M., "Remote Sensing and Image Interpretation", John Wiley and Sons.	1979
2.	Burrough, P.A., "Principles of Geographic Information Systems for Land Resources Assessment", Oxford University Press.	1986
3.	Ramsay, J.G. and Huber, M.I., "The Technique of Modern Structural Geology", Vol 2: Folds and Fracture. Academic Press, London.	1987
4.	Goodman, R.E., "Engineering Geology", Wiley, New York.	1993
5.	Moores, E.M., and Twiss, R.J., "Tectonics", W.H. Freeman and Company, New York	1995
6.	Yeats, R.S., Sieh, K. and Allen, C.R., "Geology of Earthquakes", Oxford Univ. Press, New York	1997
7.	Gupta, R.P., "Remote Sensing Geology", Springer-Verlag Press, Berlin	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **DEPARTMENT OF EARTHQUAKE ENGINEERING**

1. Subject Code: **EQN–539** Course Title: **GROUND SHAKING HAZARD**
2. Contact Hours: L: **03** T: **00** P: 00
3. Examination Duration (Hrs.): Theory 0 3 Practical 0 0
4. Relative Weight : CWS **2 5** PRS **0 0** MTE **2 5** ETE **5 0** PRE **0 0**
5. Credits: **0 3** 6. Semester: Spring 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: The basis objective of the course is to provide knowledge for estimation of ground shaking hazard.
10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** Seismic hazard definition, probabilistic and deterministic approaches, earthquake occurrence models, seismotectonic modeling, earthquake sources, estimation of maximum credible earthquake, design basis earthquake, maximum probable earthquake.	4
2.	**Seismicity Data and Treatment:** Seismicity catalogues, spatial coverage, temporal coverage, completeness in size and time, cut off magnitude, earthquake swarm, foreshocks and aftershocks, declustering of data, homogenization of catalogue, bivariate orthogonal regression, estimation of maximum probable magnitude, types of earthquake sources-point, line and areal sources, random seismicity method, seismotectonic providence method, geological slip rate method..	11
3.	**Frequency Magnitude Distribution:** Gutenberg Richter frequency magnitude distribution, ground motion prediction equations, uncertainties in seismic hazard assessment and their quantification return period and strong motion exceedance rates.	5
4.	**Earthquake Occurrence Modelling:** Poissonian model, non-Poissonian models; Normal, Weibull, Gamma distributions, extreme value statistics- Gumbel I, II and III type distributions, Markov and semi-Markov chains.	8
5.	**Site-specific Ground Motion Prediction:** Empirical Green's function; Numerical methods, basic concepts and recent developments, domain, boundary and hybrid methods, effects of nonlinearity on ground motion.	8
6.	**Deterministic and Probabilistic Seismic Hazard Analysis:** Deterministic and Probabilistic Seismic Hazard methods, compilation of data, epistemic and aleatory uncertainty estimation, attenuation relationship, deaggregation, logic tree, hazard estimation at the bedrock level, various types of iso acceleration maps and return periods, probability of exceedance and return periods in earthquake engineering.	**6**
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publishers	Year of Publication/Reprint
1.	Kramer, S.L., "Geotechnical Earthquake Engineering", Pearson Education.	1996
2.	Reiter, L., "Earthquake Hazard Analysis, Issues and Insights:, Columbia University Press.	2001
3.	Stein, S. and Wysession, M., "An Introduction to Seismology, Earthquake and Earth Structures", Black Well Publications.	2003
4.	McGuire, Robin K., "Seismic Hazard and Risk Analysis", Earthquake Engineering Research Institute.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN-546** Course Title: **Instrumentation and Model Testing Techniques**

2. Contact Hours: L: **3** T: **1** P: **0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **EQ-501 or equivalent**

9. Objective: The course introduces basic principles and applications of seismic instrumentation and also imparts knowledge on model studies for experimental validation in dynamic environment.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Introduction of Motion Measurement**: Devices for relative motion measurement, requirements of ground motion measurement; Requirements for Instrumentation of structures.	2
2.	**Seismic Sensors**: Description of seismic sensors, Equation of motion, acceleration, velocity and displacement sensors, seismographs, strong motion accelerographs, SRRs; Characteristics and calibration of sensors, seismic instrumentation networks.	8
3.	**Sampling and Recording:** Conditioning of analog signal, sampling theorem, anti-aliasing filter, AD Conversion, parameters for configuration of data acquisition system, laboratory demonstration of a typical data acquisition system.	6
4	**Processing of Recorded Data:** Causes and characteristics of noise, transducer correction in frequency domain and time domain; Basics of digital filters, examples of some typical low pass and high pass filters, Filter implementation in time domain and in frequency domain.	6
5.	**Characteristics of Recorded Data** Determination of response spectra, determination of Fourier spectra, shape of spectra and its relation with site condition, algorithms for development of spectrum compatible time history.	4
6.	**Real Time Engineering Seismology**: Development of shake maps using strong ground motion data, ground motion parameters for early warning systems, description and case studies of some existing early warning systems in different parts of world.	4
7.	**Model Analysis:** Similitude, true model, dead load effect, adequate model, distorted models, model material.	4
8.	**Dynamic Model Testing:** Details of shake tables, issues in design of structural models, model material and fabrication of models, simulation of shake table excitation, data acquisition, interpretation and prediction of response of prototype.	6

9.	**Case Studies:** Case studies of seismic testing of models of buildings and dams.	2
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Harry, G. Harris and Gajanan M. Sabnis, "Structural Modeling and Experimental Techniques", CRC Press.	1999
2.	Samuel, D. Stearns, "Digital Signal Processing with Examples in MATLAB", Prentice Hall.	2003
3.	Havskov, J., Gerardo Alguacil, "Instrumentation in Earthquake Seismology", Springer Verlag.	2004
4.	Agarwal, Pankaj and Shrikhande, Manish, "Earthquake Resistant Design of Structures", PHI Learning Pvt. Ltd, Eastern Economy Edition.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–548** Course Title: **Discrete Time Signal Processing**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course is designed to cover the elements of discrete time signal processing and the application of relevant techniques in processing earthquake records.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Signal Processing:** Basic Theory and Introduction, types of signals; Properties of digital system (time invariance, causality, linearity).	4
2.	**Data Analysis:** Z - transform, sampling theorem, antialiasing filter, discrete Fourier Transform, Fast Fourier Transform; Inverse Transform**.**	6
3.	**Digital Filters:** Characterisation of digital filters (non recursive and recursive filters), properties of some commonly used analog filters for low pass, high pass and band pass operation.	8
4.	**Realization of Filters:** Transformation for realisation of digital filters from transfer functions of analog filters (matched Z-transform, bilinear transform etc.), some commonly used non recursive filter windows.	9
5.	**Convolution:** Convolution theorem, unit impulse response and transfer function, convolution in time domain and in frequency domain; Interpolation and decimation of digital data; Correlation and Power Spectrum Estimation; Application in processing of earthquake records.	8
6.	**Processing and Applications:** Interpolation and decimation, Correlation and power spectral estimation, processing procedure of earthquake ground motion data.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Soisson, E.H., "Instrumentation in Industry". John Wiley & Sons.	1975
2.	Rabiner, L.R. and Gold B "Theory and Application of Digital Signal Processing". NJ: Prentice-Hall.	1975
3.	Lam H.Y.F , "Analog and Digital Filters-Design and Realization" , Prentice Hall.	1979
4.	Oppenheim, A.V. and Schafer, R.W, "Discrete Time Signal Processing". Prentice Hall.	1989
5.	Antoniou, A, "Digital Filters-Analysis, Design and Applications". McGraw-Hill Science/Engineering/Math.	2000
6.	Proakis, J.G. and Manolakis, D.G "Digital Signal Processing". Prentice Hall.	1996
7.	Steven W. Smith "The Scientist and Engineer's Guide to Digital Signal Processing California Technical Publishing.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–551** Course Title: **Random Vibrations**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **2 5** **PRS** **0 0** **MTE** **2 5** **ETE** **5 0** **PRE** **0 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **EQ-501 or equivalent**

9. Objective: This course covers the basic principles of random variables and stochastic processes and applications to the response of systems subjected to random vibrations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Theory:** Meaning and axiom of probability, events, random variables, discrete and continuous distribution, some examples; Functions of random variables, expectations, characteristic functions; Orthogonality principles, sequence of random variables.	10
2.	**Stochastic Processes:** Counting process, random walk, Markov chain, Gaussian process, filtered point process, Markov process and non-stationary Gaussian process; Stochastic continuity and differentiation, integral, time average, ergodicity; Correlation and power spectrum; Threshold crossing, peak, envelope distribution and first passage problem.	12
3.	**Response of Linear Systems to Random Vibrations:** Linear response of single and multiple-degree of freedom systems subjected to random inputs; Linear response of continuous systems.	10
4.	**Response of Non linear Systems to Random Vibrations:** Response of nonlinear systems to random inputs; Equivalent linearization and Gaussian closure technique.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Nigam, N. C., "Introduction to Random Vibration", MIT Press.	1983
2.	Preumont Andre, "Random Vibration and Spectral Analysis", Kluwer Academic Publishers.	1994
3.	Lin, Y. K., "Probabilistic Structural Dynamics Advanced Theory and Applications", McGraw Hill.	1995
4.	Cho T. W. S., "Nonlinear Random Vibration", Taylor and Francis.	2000
5.	Lalanne, C., "Random Vibration", CRC Press.	2002
6.	Wirsching, P. H, Paez, T. L. and Ortiz, H., "Random Vibration", Dover Publications.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–552** Course Title: **Reliability Based Design**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** 0

4. Relative Weight : **CWS** **2 5** **PRS** 0 0 **MTE** **2 5** **ETE** **5 0** **PRE** **0 0**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide a framework for ascertaining safety margins associated with structural design procedures.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Nature of Structural Design and Safety:** Evolution of design codes; Hazards, risks and economy of structural design.	2
2.	**Uncertainty Modeling:** Probability theory, random variables, probability distributions, moments, extreme value statistics, utility and descriptive statistics; Fuzzy set theory.	10
3.	**Bayesian Decision Theory:** A priori and posteriori probability; Bayes strategy and computation.	3
4.	**Statistical Inference:** Model estimation, hypothesis testing, confidence intervals and significance testing.	3
5.	**Stochastic Models for Material Strengths:** Classic strength models - ideal brittle material, idea plastic material, fibre bundle; Fatigue - damage accumulation laws, cycle counting, damage statistics; Bogdanoff's cumulative damage model.	5
6.	**Stochastic Models for Loads:** Gust wind loads, wave loads, earthquake loads, traffic load and live load modeling; Stochastic theory of load combinations.	4
7.	**Reliability Methods:** Multiple safety factor formats; Characteristic values; Reliability index and system reliability; code calibrations.	15
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Ang , A.H., S. and Tang, W.H.. "Probability Concepts in Engineering Planning and Design", Vol. I & II., John Wiley & Sons.	1975
2.	Blockley , D.I.. "The Nature of Structural Design and Safety", Ellis Horwood.	1980
3.	Augusti, G., Baratta, A. and Casciati, F., "Probabilistic Methods in Structural Engineering", Chapman & Hall.	1984
4.	Chernoff, H. and Moses, L.E., "Elementary Decision Theory", Dover Publications.	1986
5.	Elishakoff, I.., "Probabilistic Theory of Structures", 2nd edition, Dover Publications.	1999
6.	Ditlevson, O. and Madsen, H.O., "Structural Reliability Methods, Department of Mechanical Engineering".	2002
7.	Madsen, H.O., Krenk, S. and N.C. "Lind. Methods of Structural Safety", Dover Publications.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–558** Course Title: **Advanced Structural Dynamics**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **2 5** **PRS** **0 0** **MTE** **2 5** **ETE** **5 0** **PRE** **0 0**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **EQ-501 Theory of vibration or equivalent**

9. Objective: The objective of the course is to impart advance structural dynamics in particular reference to earthquake problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Nonlinear Systems**: Common types of nonlinearity, material and geometric nonlinearity, cubic stiffness, bilinear stiffness and damping, piecewise linear stiffness, nonlinear damping, coulomb friction, systems with finite deflection.	4
2.	**Dynamics of Nonlinear Systems:** Concept of nonlinear vibration; State space models, phase portraits, jump phenomenon, strange attractors and chaos parametric or self-excited oscillations; Approximate solution methods-perturbation techniques, equivalent linearization.	10
3.	**Seismic Response of Nonlinear Systems:** Inelastic earthquake analysis of multi-storey building frames, Pushover Analysis, Concepts of ductility and inelastic response spectrum, ductility in a multi-storey structure.	8
4.	**Stability of Dynamic Systems:** Concepts of stability of motion, Liapunov's criterion, Routh-Hurwitz criterion, Nyquist stability criterion; Stability of nonlinear and time varying systems.	10
5.	**Inverse Problems in Vibrations:** Review of linear algebra concepts; System identification as an inverse problem; Discrete time approach, linear discrete time models, model validity, system identification using neural networks; Continuous time approach, system identification using genetic algorithms; Updating finite element models using vibration records.	10
	Total number of lectures	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Dordrecht, The Netherlands, Friswell , "Finite Element Model Updating In Structural Dynamics", Kiuwer Academic Publisher.	1995
2.	Japanese Society of Civil Engineers, Dynamic Analysis and Earthquake Resistant Design, Volume 2: Methods of dynamic Analysis, Oxford & IBH Publishing Company.	2000
3.	Graham, M.L. Gladwell, "Inverse Problems in Vibration", Springer Verlag.	2004
4.	Wei-Chau Xie, Dynamic Stability of Structures, Cambridge University Press.	2006
5.	T. K. Datta, Seismic Analysis of Structures, John Wiley & Sons (Asia).	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN–560** Course Title: **Earthquake Resistant Design of Bridges and Concrete Dams**

2. Contact Hours: L: 03 T: **01** P: 00

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **EQ-501 or equivalent**

9. Objective: This course provides an insight into earthquake resistant design of RC bridges and concrete gravity dams**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Performance of RC Bridges in Past Earthquakes**: Types of failures and lessons learnt; Terminology related to bridges.	3
2.	**General Concept and Seismic Design Principles**: Earthquake loading and analysis; Forced based design and displacement based design including the concept of performance based design.	4
3.	**Conceptual Design of Bridges**: Constraints, bent configuration; Superstructure pier connection, superstructure-abutment connection; Foundation systems.	4
4.	**Mathematical Modelling of RC Bridges**: Modelling of super structure, substructure and bearings; Modelling of foundations; Concept of non-linear modelling of bridge components.	4
5.	**Seismic Analysis of RC Bridges**: Seismic coefficient method of analysis; Response spectrum analysis, time history method, push-over analysis.	4
6	**Seismic Design Codes of RC Bridges:** Seismic design provision based on Indian codes (IRC-6, IS 1893); Major international codes (ASTHO, CALTRANS, EURO, NZ and JSCE).	5
7.	**Seismic Design of RC Bridges:** Capacity based design of piers; Design and ductile detailing of piers; Joints, footings and pile caps; Movement design, unseating prevention systems, bearing; Design using isolation and energy dissipation devices.	7
8.	**Seismic design of Gravity Dams:** Performance of concrete gravity dam in past earthquakes; Types of loading and its consideration, issues in dam; Traditional methods of analysis; Consideration of dam-reservoir, dam- foundation, and dam-reservoir-foundation interaction effects; Modelling aspects of concrete gravity dam in seismic analysis including foundation and reservoir interaction aspects; Issues and modelling aspects in non-linear analysis.	11
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	"Earthquake Engineering for Concrete Dams: and Research Needs" National Academy Press.	1990
2.	Seible F., Calvi G.M "Seismic Design and Retrofit of Bridges", John Wiley and Sons.	1996
3.	"Design specifications of Highway Bridges", Part V. Seismic Design, PWRI.	1998
4.	Mark Yashinsky and Karshenas, M.J. "Fundamentals of Seismic Protection for Bridges", Earthquake Engineering Research Institute.	2003
5.	Allan Willians "Seismic Design of Building & Bridges", Oxford University Press.	2003
6.	Robin Fell, Patrick Macgregor, David Stapleton Graeme Bell, "Geotechnical Engineering of Dams" A.A. Balkeme Publishers.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN–562** Course Title: **Dynamics of Plates, Shells and Arches**

2. Contact Hours: L: **03** T: **01** P**: 00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course provides knowledge on the theories and solution techniques, both classical and contemporary, to study the dynamic behaviour of plates, shells and arches.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Plates:** Small deflection theory of thin plates, analysis of rectangular plates under static vertical loads; Navier and Lavy solution for rectangular plates, free vibration of rectangular and circular plates, effects of transverse and rotatory inertia, finite difference method for rectangular plates, introduction to large deflection theory of thin plates, analysis of orthotropic, anisotropic and laminated plates.	10
2.	**Shells:** Membrane solution of shells of revolution under axisymmetric and nonsymmetric static loads; Analysis and design of shell roofs and vertical and lateral loads, beam theory and DKJ theory, free vibration of cylindrical shell roofs.	10
3.	**Arches:** Free vibration of curved members in their own plane, partial differential equation of motion for thin curved member, closed form expressions of natural frequencies and mode shapes for hinged and fixed circular arches, influence coefficient method, out of plane vibration of arches, earthquake effects on arches.	10
4.	**Finite Element Simulation of Plates and Shells:** Finite elements for plates, mindlin plate elements, discrete Kirchoff element, shell elements, flat shell elements, axisymmetric shell elements, arch elements, straight and curved arch elements; Mindlin arch elements.	12
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Timoshenko, S.P. and Winowski-Krieger, S., "Theory Of Plates And Shells", McGraw-Hill.	1965
2.	Szilard, R., "Theory And Analysis of Plates", Prentice-Hall.	1974
3.	Ramaswamy, G.S., "Design Of Concrete Shell Roofs", Tata-McGraw Hill.	1978
4.	Calladine, C., "Theory of Shell Structures", Cambridge University Press.	1983
5.	Cook, R.D., Malkus, David S. and Plesha Michael E., "Concepts and Applications of Finite Element Analysis," Third Edition, John Wiley & Sons.	1989
6.	Ugural, A. C., "Stresses in Plates and Shells", 2nd ed., McGraw-Hill.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN–563** Course Title: **Earthquake Resistant Design of Structures**

2. Contact Hours: L: **03** T: **01** P**: 00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5 PRS 0 0 M TE 25 ETE 5 0 PRE 0 0**

5. Credits: **4** 6. Semester: **Autumn** **7.** Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: This course will provide insight into design of structures to withstand earthquake forces and related seismic safety issues**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts:** Seismic performance of structures and structural components during earthquakes; Ground motion parameters; Response spectrum, design spectrum.	5
2.	**Seismic Design Philosophy:** Concept of strength, overstrength and ductility, Concept of equal displacement and equal energy principles, capacity design; seismic design consideration in buildings with irregularities.	7
3.	**Seismic Analysis of Buildings:** Equivalent static analysis, response spectrum analysis, mode superposition method; Time history analysis; Modelling concept of reinforced concrete building.	10
4.	**Seismic Design of Building Components:** Seismic resistant properties of reinforced concrete; Seismic behaviour and design of linear reinforced concrete elements; Seismic behavior of planar reinforced concrete elements, codal provisions.	10
5.	**Seismic Provisions for Structural Steel Buildings:** Materials, connections, joints and fasters; Columns, ordinary, intermediate and special moment resisting frame; Concentrically and eccentrically braced frames.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Pauley, T. and Priestley, M.J.N "Seismic Design of Reinforced Concrete and Masonry Buildings", John-Wiley & Sons.	1992
2.	Drysdale, R.G. Hamid, A. H. and Baker, L.R "Masonry Structure: Behaviour and Design", Prentice Hall, Englewood Cliffs.	1994
3.	Schneider, R.R. and Dickey, W.L. "Reinforced Masonry Design", 3nd Ed., Prentice Hall.	1994
4.	Edmund Booth, "Concrete Structure in earthquake regions – Design & Analysis" Longman Scientific & Technical.	1994
5.	"Seismic Evaluation and retrofit of concrete building – Vol. I & II", Applied Technology Council, California, ATC 40.	1996
6.	Penelis, George G., and Kappos, Andreas J., "Earthquake Resistant Concrete Structures", E & F. N., Spon.	1997
7.	"Building Seismic Safety Council", Federal Emergency Management Agency, Washington, D.C, FEMA 356, 2000, FEMA 440 / ATC 55, 2005, FEMA 310.	1998
8.	Amrhein, J. E. "Reinforced Masonry Engineering Handbook", Masonry Institute of America, CRC Press.	1998
9.	Allan Willians, "Seismic Design of Building & Bridges", Oxford University Press.	2003
10.	Robert E. Englekirk "Seismic Design of Reinforced and Precast Concrete Buildings", John Wiley & Sons.	2003
11.	Steven L. Krammer "Geotechnical Earthquake Engineering", Low Priced Edition, First Indian Reprint, Prentice-Hall International Series in Civil Engineering and Engineering Mechanics, Pearson Education.	2003
12.	Edmund Booth and David Key, "Earthquake Design Practice for Buildings", Tomas Telford publishing, Thomas Telford , London.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN–566** Course Title: **Structural Response Control for Seismic Protection**

2. Contact Hours: L: **03** T: **01** P**: 00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **EQ-501 or equivalent**

9. Objective: To provide insight into the concepts and theories of devices used to control seismic response of structures for their seismic protection and to introduce techniques to simulate the seismic response of structures using control devices.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Structural Control:** Historical development of structural control and base isolation, active control, passive control, hybrid control, semi active control; Application to new and existing buildings.	5
2.	**Theory of Vibration Isolation:** Principle of base isolation; Theory of vibration isolation; Components of base isolation; Advantages and limitations; General Design Criteria; Linear and Nonlinear procedures of isolation design; Application of theory to multiple degree of freedom system.	10
3.	**Isolation Devices:** Laminated rubber bearing, lead rubber bearing, high damping rubber bearing, PTFE sliding bearing, friction pendulum system and sleeved pile system; Modelling of isolation bearings; Design process for multi-layered elastomeric bearings and buckling behaviour of elastomeric bearings; Isolation system testing.	10
4.	**Energy Dissipation Devices:** General requirements; Implementation of energy dissipation devices; Metallic yield dampers, friction dampers, viscoelastic dampers, tuned mass dampers, tuned liquid dampers; Shape memory alloy dampers; Modelling, linear and nonlinear procedures; Detailed system requirements; Application to multistorey buildings; Testing of energy dissipation devices.	17
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Skinner, R., Robinson , W.H., Mc Verry, G. H., "An Introduction to Seismic Isolation", John Wiley and Sons.	1996
2.	Pristley, M.J.N., Seible, F., Calvi, G.M. "Seismic Design and Retrofit of Bridges", John Wiley and Sons.	1996
3.	James, M., Kelly, "Earthquake - Resistant Design with Rubber", Springer Verlag .	1997
4.	"Prestandard and Commentary for The Seismic Rehabilitation of Buildings," FEMA 356, Federal Emergency Management Agency.	2000
5.	Kelly, Trevor E. "Base Isolation of Structures – design Guidelines," Holmes Consulting Group.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–571** Course Title: **Ground Improvement Techniques**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 0 0 MTE 25 ETE 50 PRE 0 0**

5. Credits: **4** 6. Semester: **Both** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course describes various ground improvement techniques to mitigate the effects of earthquakes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Objective, history and development; Classifications of techniques; Advantage and limitations of various techniques.	2
2.	**Densification using Vibration Techniques:** Vibro Compaction:- blasting, vibratory probe, vibratory compactors; Vibro-displacement compaction:- displacement piles, vibro flotation, sand compaction piles, stone columns, heavy tamping.	8
3.	**Geosythetics:** Types, Geotextiles, Geomembranes, Geonets, Geocomposites; Manufacturing, Functions and Applications; Modeling for Dynamic analysis.	6
4.	**Reinforcement Techniques:** Reinforced earth; engineering applications, strength characteristics; Improvement in bearing capacity and settlement characteristic; Randomly distributed fiber reinforced soil: strength characteristics, improvement in bearing capacity and reduction in settlement; Soil nailing; Analysis and design of steep open cuts.	12
5.	**Drainage Methods:** Introduction, Ground water and seepage control, methods of dewatering system including design steps, various types of drains with their design.	6
6.	**Precompression:** Introduction, compressibility of soils & consolidation, preloading and surcharge fills, monitoring of compression, dynamic consolidation, consolidation by electro-osmosis	4
7.	**Grouting and Injection:** Introduction; Aspects of grouting; Grouting procedure; Applications.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Rao, G.V. and Raju, G.V.S.S., "Engineering with Geosynthetics", Tata McGraw-Hill Publishing Company.	1990
2.	Koerner, R.M., "Designing with Geosynthetics", Prentice-Hall.	1990
3.	Shukla, S.K., "Geosynthetics and their Applications", Thomas Telford.	2002
4.	Kramer, S.L, "Geotechnical-Earthquake Engineering", Pearson Education – Indian Low Price Edition.	2004
5.	Purushothama, R.P., "Ground Improvement Techniques", Laxmi Publications.	2005
6.	Saran, S., "Reinforced Soil and its Engineering Applications", IK International.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–572** Course Title: **Machine Foundation**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course provides an insight into different types of machine foundations and their design to withstand for various types of loads in accordance with the prevalent codes of practice.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Various types of machine foundations; Permissible amplitudes of vibrations, factors affecting the resonant frequency and amplitudes of vibrations; Estimation of damping and plastic coefficients.	4
2.	**Foundations under Reciprocating Machine:** Resonant frequency of the block foundations; Weightless spring and weighted spring method, elastic half space method, miscellaneous methods; Behaviour and design of block foundations, permissible amplitudes.	12
3.	**Hammer Foundations:** Hammer foundations, classification, natural frequencies and amplitudes of foundation vibrations; Design principles, permissible amplitudes.	6
4.	**Framed Foundations:** Framed foundations, their advantage for high-speed machines; Permissible amplitudes, design principles.	6
5.	**Vibration Isolation and Screening:** Methods of decreasing vibrations on existing foundations; Isolation of vibrations; Screening of vibrations.	5
6.	**IS Code of Practice:** Critical review of IS code provisions for design of machine foundations.	4
7.	**Structural Design:** General principles of design; Construction aspects; Case studies on failures of machine foundations.	5
	Total	**42**

List of Experiments:

1 Horizontal and Vertical Block Vibration Tests for determination of c_u and c_τ.
2. Shear Velocity Profile using Cross-Bore Test.
3. Liquefaction Resistance of Soil using Cyclic Triaxial Test Apparatus.
4. Wave Propagation Tests for Dynamic Soil Properties.

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Barkan, D.D., "Dynamics of Bases and Foundation", McGraw Hill Book Company.	1962
2.	Richart, F.E., Jr., Hall, J.R., Jr. and Woods, R.D., "Vibrations of Soils and Foundations", Prentice Hall.	1962
3.	Srinivasu, P. and Vaidyanathan, C. V., "Hand Book of Machine Foundations", Tata McGraw Hill.	1976
4.	Prakash S., "Soil Dynamics", McGraw Hill Book Company.	1981
5.	Saran S., "Soil Dynamics & Machine Foundation", Galgotia Publication.	2006
6.	Bhatia K.G., "Foundation for Industrial Machines – A Handbook for Practicing Engineers", D-CAD Publishers.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–576** Course Title: **Seismic Slope Stability: Earth Dams and Retaining Walls**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **00** **MTE** **25** **ETE** **50** **PRE** **0 0**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: It deals with the issues pertaining to earth dams and retaining walls and their analysis using classical and contemporary approaches.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Earth Dams:** Performance of earth and rockfill dams in past earthquakes; Homogenous and non-homogenous dams, general features, zoned dams, influence of inclined and vertical core; Dams with upstream impervious linings, composite dams, slope protection measures; Seepage in earth and rockfill dams, estimation of pore pressure by flow net, standard analytical solutions for seepage problems, piping and liquefaction, foundation problems.	6
2.	**Stability Analysis of Earth Dams:** Effective and total stress methods of analysis; Analysis by Fellinius, Spencer and Bishop methods; Pseudo-static analysis by Friction-circle, Fellinius and Bishop's methods, factor of safety, yield accelerations and damage potential under saturated and submerged conditions; Displacement analysis by Newmark and Makdisi-Seed methods.	9
3.	**FEM for Earth Dams:** Application of FEM, dam-foundation interaction; Identification of zones of hydraulic fractures and cracks; Nonlinear analysis, tangent stiffness, secant stiffness methods and no-tension analysis.	7
4.	**Earth Pressures Under Static and Dynamic Conditions:** History; State of stress in semi-infinite medium with level/sloping surface; Rankine and Coulomb's theories; Critical wall friction, its choice and design curves for its determination; Method of slices to obtain earth pressures; Terzaghi's general wedge theory for passive pressure; Velocity field method; Method of characteristics.	4
5.	**Mononobe-Okabe theory;** Rehban's and Culman's methods and their extension to dynamic case; Dimensionless earth pressure factors; Structural surcharges; Pressures induced by soil compaction.	2
6.	**Displacement Analysis of Soil-Wall System:** Displacement dependent earth pressures and failure of walls; Types of movements and shape of failure surfaces; Arching action its influence on earth pressures; Consideration of movement of structures in static/dynamic pressures; Factor of safety.	6

7.	**Design of Retaining Walls:** Types of walls; Earth pressures for gravity/counter-fort walls; Structural design of wall and its foundation; Stability of wall-soil system; Slip circle analysis; Anchored retaining structures.	5
8.	**Computer Applications:** Software to evaluate static/dynamic earth pressures; Pressure distribution, stability of retaining structures and critical wall friction.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Prakash, S., "Soil Dynamics", McGraw Hill Book Company.	1981
2.	Duncan, J.M., "State-of-the-art: static stability and deformation analysis," in R.B. Seed and R.W. Boulanger, Eds., Proc. Specialty Conf. on Stability and Performance of Slopes & Embankments, II, ASCE, Vol. I, pp. 222-266.	1992
3.	Bharat Singh & R.S. Varshney , "Embankment Dam Engineering", Nem Chand & Brothers.	2004
4.	Kramer, S.L., "Geotechnical-Earthquake Engineering", Pearson Education – Indian Low Price Edition.	2004
5.	Saran, S., "Soil Dynamics & Machine Foundation", Galgotia Publication.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–577** Course Title: **Constitutive Modelling in Soil Dynamics**

2. Contact Hours: L: **03** T: **01** P: **00**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0 0** **MTE** **25** **ETE** **50** **PRE** **0 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The objective of the course is to appraise the governing constitutive laws and applicable models for soil as a medium**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Stress-Strain Laws of Soils:** Stress and strain invariants, linear and bilinear elastic laws; K-G model, nonlinear elastic models (hyperbolic models), elasto-plastic and elasto-viscoplastic models; Basic concepts of plasticity, yield function, flow rules-dilatancy, strain hardening and softening laws.	9
2.	**Mohr-Coulomb and Tresca Models:** Yield functions, derivation of constitutive matrix; Formulation suitable for finite element analysis.	5
3.	**Critical State Models:** Yield function, hardening law, soil parameters; Drucker-Prager Model, HiSS models and their performance.	6
4.	**Bounding Surface Models:** Multi-surface model, Dafalias two surface model; Kinematic hardening laws, soil parameters.	5
5.	**Basic Formulation of Soil in Finite Element Analysis:** Static and quasi static problems; Drained, undrained analysis and their discretisation in finite element procedure; Consolidation transient and its discretisation statement; Drained and undrained dynamic analysis.	8
6.	**Two Phase Formulation:** Two phase formulation of saturated soil; Finite element discretisation of saturated soil; Transient response of saturated soil, consolidation, liquefaction.	9
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Chen, W.F., Baladi G.Y., "Soil Plasticity: Theory and Implementation", Elsevier.	1985
2.	Wolf, J.P, "Soil-Structure Interaction in the Time Domain", Prentice Hall.	1988
3.	Kolymbs, D., "Constitutive Modelling of Granular Materials", Springer.	2000
4.	Desai, C. S., "Mechanics of materials and interfaces: the disturbed state concept", CRC Press.	2001
5.	Kramer, S.L., "Geotechnical-Earthquake Engineering", Pearson Education – Indian Low Price Edition.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–584** Course Title: **Engineering Applications of Geophysical Techniques**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5 PRS 0 0 MTE 25 ETE 50 PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge on various geophysical techniques for engineering applications related to site investigations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Basic concepts and objectives of geophysical techniques-gravity, magnetic, electrical and well logging; need of Geophysics in Earthquake Engineering.	5
2.	**Seismic method**: Seismic refraction method, time-distance relations for horizontal layers, dipping layer and linearly increasing velocity with depth, elevation and weathering time corrections, limitations of seismic refraction method; Seismic reflection method, Time-distance relation for horizontal and dipping layers, static and dynamic time corrections, simple interpretation techniques.	4
3.	**Gravity Method**: Earth gravitational field, gravimeters, gravity field measurements, gravity field reduction and interpretation, gravity effects of subsurface bodies of simple shapes.	3
4.	**Magnetic Method**: Earth magnetic field, magnetism of rocks and minerals, magnetometers, field operations, local magnetic anomaly, magnetic effects of buried magnetic bodies and interpretation.	3
5.	**Electrical Method**: Electrical properties of rocks, resistivity method, electrode arrangements, soundings and profiling, data acquisition, analysis and interpretation.	3
6.	**Well logging:** General aspects of well logging; Resistivity methods; SP-logging, Density logging, acoustic logging.	2
7.	**Delineation of Subsurface Parameters:** Seismic velocity, density, modulus of elasticity, water saturation, saline contamination, porosity, permeability.	5
8.	**Site Investigations:** Seismic potential, induced seismicity, water mining blast, lineament mapping, depth and topography of bedrock, water table, water leakage, fault, dike, landfill sites.	6
9.	**Identification of Subsurface Structures:** Archaeological sites, weak zones, cavities and voids, tunnelling, underground excavation.	5

10.	**Case histories:** Case studies of geophysical methods for engineering applications.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Dobrin, M. B. and C. H. Savit, "Introduction to Geophysical Prospecting", Fourth Edition, McGraw Hill.	1988
2.	Telford, W.M., Geldart, L.P. and Sheriff, R.E., "Applied Geophysics", Second edition, Cambridge Univ. Press.	1990
3.	William Lowrie, "Fundamentals of Geophysics", Cambridge Univ. Press.	1997
4.	Reynolds, John M., "An Introduction to Applied and Environmental Geophysics", John Wiley & Sons.	1997
5.	Darling, T. "Well Logging and Formation Evaluation" Gulf Professional Publishing.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code: **EQN–590** Course Title: **Strong Motion Seismology**

2. Contact Hours: L: **03** T: **01** P: **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 2 5** **PRS 0 0** **MTE 2 5** **ETE 5 0** **PRE 0 0**

5. Credits: **4** 6. Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course provides insight into the characteristics and parameters of strong ground motion (SGM), measurement of SGM, interpretation of accelerogram, strong motion attenuation relations and theoretical models for estimation of SGM.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definitions, basic concepts and historical development in the field of Strong Motion Seismology (SMS); Characteristics of Strong Ground Motion (SGM); SGM parameters based on amplitude, frequency content and duration of shaking.	4
2.	**Physics of the SGM Earthquake Source:** Representation theorems; Source effect in the near-field and far-field; Aki's scaling law of seismic spectrum, Brune's model and finite source models.	5
3.	**Measurement of SGM:** Principle and theory of accelerometer, forced balanced accelerometer, seismoscope and structural response recorder; Construction and working of analog and digital accelerographs; Seismic alarm/circuit tripping and control devices.	5
4.	**Processing and Interpretation of Accelerogram:** Digitization of accelerogram, digitization errors and filtering to control these errors; transducer correction; Routine processing and double integration of accelerogram; Computation of frequency spectra and response spectra.	6
5.	**Factors Affecting SGM:** Asperity, Barrier and Stochastic ω-square models to explain the high frequency SGM; Effect of radiation pattern, fault type and directivity on SGM; Various type of scaling laws, differences in the scaling laws of interplate and intraplate earthquakes; Modification of SGM due to propagation path effects such as geometrical spreading, scattering and attenuation; Basin response and site effects including nonlinearity.	6
6.	**Strong Motion Instrument Arrays:** Principles of site selection for favorable array locations; Source mechanism and wave propagation arrays; Various types of local effects arrays to study site effects; Operation and maintenance of strong motion arrays; Indian strong motion program.	6

7.	**Strong Motion Attenuation Models:** General form of attenuation model relating specific SGM parameter to seismological parameters; Description of various earthquake source parameters (e.g., size, focal mechanism, stress drop) and strong motion parameters that enter into regression; Hanging wall and footwall effects; Various types of source to site distances; Different classifications of local site conditions, site classifications based on shear wave velocity (e.g.,30-meter velocity and effective velocity); Effect of site location and tectonic environment on SGM; Analysis and interpretation of random errors.	6
8.	**Theoretical Models for Estimation of SGM:** Stochastic models, synthetic Green's function and empirical Green's function models to predict SGM.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Iwan, W.D, Proceedings of the International Workshop on Strong-Motion Earthquake Instrument Arrays held at Honolulu, Hawaii, May 2-5, 1978.	1978
2.	Hudson, D.E., "Reading and Interpreting Strong Motion Accelerogram," Earthquake Engineering Research Institute.	1979
3.	Aki, K. and Richard, P. G., "Quantitative Seismology, Theory and Methods", Vol. I and II, W. H. Freeman & Company.	1980
4.	Bolt, B. A., "Seismic Strong Motion Synthetics", Academic Press.	1987
5.	Kramer, S.L., "Geotechnical Earthquake Engineering", Prentice Hall.	1996
6.	Lee, W.H.K., Kanamori, H., Jennings, P.C., and Kisslinger, C. "International Hank Book of Earthquake and Engineering Seismology," (Part B), Academic Press.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Earthquake Engineering**

1. Subject Code**: EQN-598** Course Title: **Principles of Seismology**

2. Contact Hours: L: **03** T : **01** P : **0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **4** 6. Semester: **Spring/Autumn** 7.Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the principles of seismology to engineers.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Importance of science of earthquakes for engineers; Impact of historical and recent earthquake hazards on the built environment, including lifelines and infrastructure; Relevant seismological glossary; Classification of earthquakes.	4
2.	**Causes of Tectonic Earthquakes:** Internal structure of the earth; Faults, folds, thrusts, shear zones and lineaments; Plate margins – creative, destructive, and conservative; Triple Junction; Characteristics of earthquakes at various margins; Causes of plate motion; Anthropogenic seismicity.	8
3.	**Seismicity:** Global seismicity belts – Circum Pacific, Alpine Himalayan, mid oceanic ridges; Earthquakes and major topographic features in oceans and continents – ridge, trench, rift, mountain ranges; Major global and Indian earthquake disasters – inter and intra plate earthquakes.	6
4.	**Ground Motion:** Principles of elasticity; Equations and laws governing seismic wave propagation; Characteristics of ground motion - duration, frequency and amplitude; Factors affecting characteristics of ground motion – source, path, site; Attenuation relationships; Relation between characteristics of ground motion and damage to civil structures.	8
5.	**Earthquake recording**, **parameters and Quantification:** Seismic recording; Estimation of earthquake parameters – epicenter, focal depth, origin time, magnitude; Intensity mapping based on earthquake effects on ground, seismic response of built environment and human perception; Seismic zoning.	8
6.	**Engineering Applications**: Estimation of design earthquake parameters - deterministic and probabilistic approach; Estimation of vulnerability and risk – case studies; Preparedness and planning for seismic risk reduction, Estimation of depth of bedrock for large civil structures using seismic refraction method; Seismological considerations for safety of pipelines, tunnels, cavities, archeological monuments, etc.	8
	Total	**42**

List of Experiments:

1. Familiarization with the instruments in seismological observatory
2. Interpretation of seismograms
3. Estimation of epicenter of earthquake using circle method
4. Estimation of magnitude of earthquake
5. Estimation of origin time and focal depth of an earthquake
6. Preparation of isoseismal maps
7. Fault plane solutions

11. Suggested Books:

S. No.	**Name of Authors / Books / Publishers**	**Year of Publication/Reprint**
1.	Agarwal, P. and Shrikhande, M., "Earthquake Resistant Design of Structures", Prentice Hall of India, New Delhi.	2006
2.	Bullen, K.E. and Bolt, B.A., "An introduction to the Theory of Seismology", Fourth Edition, Cambridge University Press, Cambridge.	1985
3.	McGuire, R.K., "Seismic Hazard and Risk Analysis", Monograph MNO-10, Earthquake Engineering Research Institute.	2004
4.	Reiter, L., "Earthquake Hazard Analysis: Issues and Insights", Columbia University Press.	1990
5.	Richter, C. F., "Elementary Seismology", W. H. Freeman and Co., San Francisco. Indian Edition.	1969
6.	Sinvhal, A., "Understanding Earthquake Disasters", Tata McGraw Hill, New Delhi.	2010