Department of Civil Engineering

Curriculum and Syllabi for M. Tech. in Geotechnical Engineering

With effect from 2019 entry batch

PO Statements:

PO-1: Ability to independently carry out research / investigation and development work to solve practical problems.

PO-2: Ability to write and present a substantial technical report/document.

PO-3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of theprogram. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO-4: Students will gain knowledge and skill in integrating Geotechnical engineering concepts across multipledisciplines.

PO-5: Students will demonstrate skills to use modern engineering tools, software and equipment to analyze andsolve geotechnical problems.

PO-6: Students will be motivated for higher study and lifelong learning maintaining work ethics throughout their career.

Course Structure

Semester I

S. N.	Code	Subject	L	T	P	Credit
1	CE 5101	Advanced Soil Mechanics	3	0	0	3
2	CE 5102	Advanced Foundation Engineering	3	1	0	4
3	CE 5103	Theoretical Geomechanics	3	0	0	3
4	CE 5104	Advanced Geotechnical Engineering Laboratory	0	0	3	2
5	CE xxxx	**Elective - I**	3	0	0	3
6	CE xxxx	**Elective - II**	3	0	0	3
		Total contact hours/ Credits	**15**	**1**	**3**	**18**

Semester II

S. N.	Code	Subject	L	T	P	Credit
1	CE 5111	Dynamics of Soils and Foundations	3	0	0	3
2	CE 5112	Stability of Slopes	3	1	0	4
3	CE 5313	Finite Element Methods	3	0	0	3
4	CE 5113	Seminar	0	0	3	2
5	CE xxxx	**Elective - III**	3	0	0	3
6	CE xxxx	**Elective - IV**	3	0	0	3
		Total contact hours/ Credits	**15**	**1**	**3**	**18**

Semester III

S. N.	Code	Subject	L	T	P	Credit
1	CE 6198	Project Phase I	0	0	0	6
			Total Credit			**6**

Semester IV

S. N.	Code	Subject	L	T	P	Credit
1	CE 6199	Project Phase II	0	0	0	8
			Total Credit			**8**

Elective – I

S. N.	Code	Subject	L	T	P	Credit
1	CE 5131	Ground Improvement Techniques	3	0	0	3
2	CE 5132	Rock Mechanics	3	0	0	3
3	CE 5241	Seismic Microzonation	3	0	0	3

Elective – II

S. N.	Code	Subject	L	T	P	Credit
1	CE 5141	Geotechnical Earthquake Engineering	3	0	0	3
2	CE 5142	Soil-Foundation Interaction	3	0	0	3

Elective-III

S. N.	Code	Subject	L	T	P	Credit
1	CE 5151	Geosynthetics and Reinforced Earth	3	0	0	3
2	CE 5152	Offshore Geotechniques	3	0	0	3
3	CE 5153	Earthquake Resistant Design of Foundations	3	0	0	3

Elective-IV

S. N.	Code	Subject	L	T	P	Credit
1	CE 5161	Probability Methods in Civil Engineering	3	0	0	3
2	CE 5162	Earth Retaining Structures	3	0	0	3
3	CE 5163	Geoenvironmental Engineering	3	0	0	3
4	CE 5562	Optimization Methods in Engineering Design	3	0	0	3

DETAILED SYLLABI

Semester - I

CODE	Advanced Soil Mechanics	L	T	P	C
CE 5101	M.Tech. (Geotechnical Engineering), 1st Sem (Core)	3	0	0	3

Introduction to Soil Mechanics
Formation of soil, Identification and classification of soil, Soil weight volume relationship, Indexproperties of soils.

Surface Tension and Capillary phenomenon
Measurement of capillary rise in soil, Soil moisture, Soil –water potential, Buckingham's concept, Component potential, Measurement of soil-water potential, Tentiometer, Pressure-plate apparatus.

Permeability of Soil
Permeability, Darcy's law, Kozeny- Carmans's equation, Theories of wells, flow nets and theirproperties.

Seepage Analysis
Seepage, Quick sand & critical hydraulic condition, Flow net in dams, Flow net by relaxation method,Seepage forces, Uplift, Piping phenomenon, Problems, Effective and Pore water pressures.

Compressibility and Consolidation
Compressibility and Consolidation, I-D & 3-D consolidation problems, Settlement of soil due toconsolidation.

Shear Strength of Soil
Principal Stresses, Mohr – Coulomb Failure Criteria, Stress-Strain behaviour of granular soil, Criticalvoid ratio, Shear strength of cohesive soil, Direct Shear Test, Triaxial Test, Unconfined Compressive strength test, Vane Shear test, Stress paths, and Yield Surfaces in three dimension.

Text/Reference Books:

1. Advanced Soil Mechanics by B. M. Das
2. Soil Mechanics by R. F. Craig
3. An introduction to the Mechanics of soils and Foundations by J. H. Atkinson
4. Soil Mechanics in Engineering Practice by K. Terzaghi and R. B. Peck
5. Soil Mechanics by T. W. Lambe and R. V. Whitman

Course Outcomes: At the end of the course, student will be able to:

- CO- 1 develop a clear knowledge on soil formation, soil classification, structure of soil particles, index properties of soil and clay mineralogy.
- CO- 2 develop a clear knowledge about Surface Tension and Capillary phenomenon
- CO- 3 understand and solve problems related to Permeability of soil and Seepage flow
- CO- 4 develop in depth understanding of problems related to compressibility and consolidation
- CO- 5 develop in depth knowledge about shear strength characteristics of soil

CODE	Advanced Foundation Engineering	L	T	P	C
CE 5102	M.Tech. (Geotechnical Engineering), 1stSem (Core)	3	1	0	4

Shallow foundations

Design considerations- factors of safety (including limit state), allowable settlements, location and depth of foundations. Bearing capacity theories (Terzaghi, Meyerhof, Brinch Hansen, Vesic's method& IS code method of analysis), layered soils, choice of shear strength parameters, bearing capacity from N-values, static cone tests, plate load tests. Total and differential settlement, stress distribution, consolidation settlement in clays (with correction factors), immediate settlement. Settlement in sands from N-values, elastic solutions static cone tests, plate load tests. Design of shallow foundations, combined footings, strap foundation, mat foundations including floating raft.

Pile foundations

Types of piles, construction methods, axial capacity and design of single pile & group of piles, dynamicformulae, static formula, soil mechanics approach. Skin friction and end bearing in sands and clays. Single and multiple under reamed pile. Negative skin friction, piles subjected to uplift load (includingunder reamed piles), pile load tests, pile integrity tests settlement of single piles and group. Influence of pile cap, influence of pile driving in sand, pull out capacity, laterally loaded piles.

Well foundations

Different types, components, construction methods, design methods (Terzaghi, IS and IRC approaches), check for stability, base pressure, side pressure and deflection.

Retaining walls

Types (types of flexible and rigid earth retention systems: counter fort, gravity, diaphragm walls, sheetpile walls, soldier piles and lagging). Support systems for flexible retaining walls (struts, anchoring), construction methods, stability calculations, design of flexible and rigid retaining walls.

Sheet pile walls

Cantilever and anchored sheet pile walls.

Text/Reference Books:

1. Basic and Applied Soil Mechanics by Gopal Ranjan & A. S. R. Rao
2. Foundation Analysis and Design by J. E. Bowles
3. Pile Foundations in Engineering Practice by Prakash and Sharma
4. Design of Foundation Systems- Principles and Practices by N. P. Kurian
5. Principles of Foundation Engineering by Braja M. Das
6. Foundation Design and Construction by M. J. Tomlinson
7. Advanced Foundation Engineering by V. N. S. Murthy.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 analyse given soil condition to decide suitability of a particular foundation.

CO- 2 design shallow foundations for structures.

CO- 3 design deep foundations for structures.

CO- 4 design retaining walls.

CODE	Theoretical Geomechanics	L	T	P	C
CE 5103	M.Tech. (Geotechnical Engineering), 1stSem (Core)	3	0	0	3

Stress and strain

Introduction, soil mechanics and continuum mechanics, deformation and strain, strain compatibility, forces and tractions, concept of stress, principal stresses and strains, invariants, Mohr circles, effective stress principles, equilibrium, determination of displacements, conditions of compatibility, principle of superposition, problems and solutions.

Elastic behaviour of soil

Role of constitutive modelling, importance of laboratory testing with relation to constitutive modelling,the Winkler model, elastic continuum models, two-parameter elastic models, elastic-plastic and time-dependent behaviour of soil masses, practical applications.

Plastic behaviour of soil

Yield: Introduction, principal stress space, yield surfaces of metals, the Coulomb yield criterion, modification to Coulomb's criterion, the Cambridge models, Two-dimensional yield loci, example.

Plastic flow: Introduction, normality, associated flow rules, non-associated flow rules, a complete stress-strain relationship, example.

Collapse load theorems: Lower bound theorem, upper bound theorem, discontinuities of stress and deformation, examples.

Slip line: Two-dimensional stress state, slip line, frictional materials, effect of gravity, examples.Work hardening theorems: Work hardening for metals, hardening soil, soft soil.

Critical state soil mechanics

Critical state concept, drained and undrained triaxial tests, critical state line, critical state line for sand,effect of dilation, Camclay and critical state concept, consolidation.

Text/Reference Books:

1. Advanced Mechanics of Solids by L. S. Srinath
2. Theory of Elasticity by Timoshenko and Goodier
3. The Mechanics of Soils by Atkinson and Bransby
4. Elasticity and Geomechanics by Davis and Selvadurai
5. Plasticity and Geomechanics by Davis and Selvadurai
6. Critical State Soil Mechanics by Schofield and Wroth
7. Fundamentals of Fracture Mechanics by Kundu
8. Elastic Analysis of Soil-Foundation Interaction by A. P. S. Selvadurai
9. Dynamics of Structure and Foundation by Chowdhury and Dasgupta

Course Outcomes: At the end of the course, students will be able to:

CO- 1 analyse stress and strain states in a soil mass.

CO- 2 apply appropriate constitutive model to simulate behaviour of soil.

CO- 3 design ground engineering problems using geomechnics concepts.

CO- 4 solve geomechanics problems related to soil behaviour.

CODE	Advanced Geotechnical Engineering Laboratory	L	T	P	C
CE 5104	M.Tech. (Geotechnical Engineering), 1st Sem (Core)	0	0	3	2

1. Standard Penetration Test
2. Cone Penetration Test
3. Resonant Column Testing
4. Dynamic Triaxial
5. Seismic Refraction
6. Block Vibration Test
7. Relative Density
8. Determination of properties of Geosynthetics

Text/Reference Books:

1. Bureau of Indian Standard Codes
2. American Society for Testing and Materials Codes
3. Principles of Testing Soils, Rocks and Concrete by Nagaraj
4. Soil Testing Manual by Robert W. Day
5. Interpreting Soil Test Results by Hazelton and Murphy

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand the basic principle of different laboratory tests on soil and their applicability in the field.

CO- 2 analyse merits and demerits of every laboratory test.

CO- 3 apply results of experiment to interpret soil condition.

ELECTIVE – I

CODE	Ground Improvement Techniques	L	T	P	C
CE 5131	M.Tech. (Geotechnical Engineering), 1st Sem (Elective I)	3	0	0	3

Introduction
Need for Ground Improvement, Classification and Methods of ground modification techniques,Economic considerations, Emerging trends in ground Improvement.

Mechanical modification
Soil-Mixing. Shallow surface compaction: Types of compaction equipment and their suitability for different type of soils, specification and quality control. Deep compaction: Dynamic compaction, Vibro-compaction, Vibro-replacement, Compaction piles, Blasting. Stone column.

Hydraulic modification
Ground Improvement by drainage, Dewatering methods. Design of dewatering systems, Preloading, Vertical drains, vacuum consolidation, Electro-kinetic dewatering, design and construction methods.

Soil stabilization
Cement stabilization, lime stabilization, lime pile and column, bitumen stabilization, chemical stabilization, mechanical stabilization.

Grouting
Permeation grouting, compaction grouting, jet grouting, different varieties of grout materials,grouting under difficult conditions.

Soil reinforcement
Geosynthetic materials and application in road, slope, embankment etc., design of reinforced earthwalls.

In-situ soil treatment methods
Soil nailing, micro-piles, design methods, construction techniques.

Text/Reference Books:

1. Ground Improvement Techniques by Purushothama Raj
2. Engineering Treatment of Soils by F. G. Bell
3. Engineering Principles of Ground Modification by Manfired R. Hausmann
4. Soil Improvement and Ground Modification Methods by Peter G. Nicholson
5. Designing with Geosynthetics by Koerner
6. Principles of Grouting by Shah and Shroft
7. Foundation Engineering by J. Bowles

Course Outcomes: At the end of the course, student will be able to:

CO- 1	justify the requirement of ground improvement for a civil engineering project.
CO- 2	analyse the ground condition to decide suitability of a ground improvementtechnique.
CO- 3	apply appropriate ground improvement technique.
CO- 4	design the implementation process of ground improvement techniques.

CODE	Rock Mechanics	L	T	P	C
CE 5132	M.Tech. (Geotechnical Engineering), 1st Sem (Elective I)	3	0	0	3

Engineering properties of rock masses, subsurface investigations in rock deposits, field and laboratorytesting of rocks.

Stress- deformation characteristics of rock masses under heavy loads, flow of water through rock masses, failure theories, shear strength of rock under high pressure, friction in rocks, time dependent properties of rock masses.

Stability of rock slopes, idealized rock system, anisotropic rock system, deep cuts, deep boreholes, stability of boulder fills and embankments, lateral pressure on retaining structures for high hill slopes.

Bearing capacity of rock masses, opening in rocks, lined and unlined tunnels, pressure tunnels and tunnels for other purposes.

Text/Reference Books:

1. A text book of Geology by P. K. Mukerjee

2. Rock Mechanics for Underground Mining by B. H. G. Brady and E. T.

Brown3.Rock Characterisation, Testing and Monitoring by E. T. Brown

4.Stresses in Rockby G. Herget

5. Underground Excavation in Rock by E. Hoek, and E. T.Brown

6. Introduction to Rock Mechanics by R. E. Goodman

7. Engineering Rock Mass Classification by Z. T. Bieniawski

8. Rock Mechanics Principles by D. F. Coates

9.Fundamentals of Rock Mechanics by J. C. Jaeger and N. G. W.

Cook10.Foundations on Rock by D. C. Wyllie

11. Comprehensive Rock Mechanics by J.A. Hudson et al.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 interpret behaviour of rock.

CO- 2 analyse real life problems in hilly areas with exposed rock.

CO- 3 design rock system in hilly areas.

ELECTIVE – II

CODE	Geotechnical Earthquake Engineering	L	T	P	C
CE 5141	M.Tech. (Geotechnical Engineering), 1stSem (Elective II)	3	0	0	3

Introduction

Scope and objective, Nature and types of earthquake loading, Importance of Geotechnical EarthquakeEngineering.

Seismology and earthquakes

Basic Seismology, Earthquake, List of major earthquakes, Causes of earthquakes, Sources of earthquake data, Elastic rebound Theory, Faults, Plate tectonics, Seismograph and Seismogram, Prediction of Earthquakes, Protection against earthquake damage, Origin of universe, Layers of Earth,Theory of Continental Drift, Hazards due to Earthquakes.

Strong ground motion

Size of Earthquake: Magnitude and Intensity of Earthquake, Modified Mercalli Intensity Scale, Measuring of Earthquake, Earthquake Magnitude- Local (Richter) magnitude, surface wave magnitude, Moment magnitude, Seismic energy, Correlations. Spectral Parameters: Peak Acceleration, Peak Velocity, Peak Displacement, Frequency, Content and duration, Spatial Variability of Ground Motion, Attenuation Relationships, Fourier Amplitude Spectra, Arias Intensity.

Seismic Hazard Analysis

Magnitude Indicators, Segmentation, Deterministic Seismic Hazard Analysis (DSHA), Probabilistic Seismic Hazard Analysis (PSHA), Earthquake Source Characterization, Gutenberg-Richter recurrencelaw, Predictive relationships, temporal uncertainty, Probability computations, Seismic Hazard Curve,Logic tree methods.

Wave propagation

Waves in unbound media; Waves in semi-infinite media; Waves in layered media, Seismic Travel Time Curve, Three Circle Method for locating an Earthquake's Epicentre.

Dynamic soil properties

Stiffness, damping and plasticity parameters of soil and their determination (laboratory testing, intrusive and non-intrusive in-situ testing), Correlations of different soil parameters.

Ground response analysis

One dimensional ground response analysis, Two-dimensional ground response analysis, soil-structureinteraction.

Local site effects and design ground motions

Effects of local site conditions on ground motions, design parameters, development of ground motiontime histories.

Liquefaction

Basic concept, flow liquefaction, cyclic mobility, liquefaction susceptibility, effects.

Seismic slope stability analysis

Static slope stability analysis, seismic slope stability analysis, earthquake induced landslides.

Seismic Design of retaining wall

Types of retaining walls, static pressure, dynamic response, seismic pressures, seismic displacement.

Soil improvement techniques for remediation of seismic hazards

Densification, reinforcement, grouting, drainage.

Text/Reference Books:

1. Geotechnical Earthquake Engineering by S. L. Kramer

2. Soil Plasticity: Theory and Implementations by W.F. Chen and G.Y. Baladi

3. Foundation Vibration Analysis using Simple Physical Models by J. P. Wolf

Course Outcomes: At the end of the course, students will be able to:

- CO- 1 solve problems relating to origin of earthquakes and response of structures to earthquake vibrations.
- CO- 2 solve problems relating to hazard analysis.
- CO- 3 assess properties of soil effected by seismic wave propagation
- CO- 4 solve problems relating to the effect of ground shaking on stability of slopes, stability of retaining wall, stability of footings etc.
- CO- 5 apply earthquake mitigation theories on stability of structures.

CODE	Soil-Foundation Interaction	L	T	P	C
CE 5142	M.Tech. (Geotechnical Engineering), 1stSem (Elective II)	3	0	0	3

Introduction

Soil-foundation interaction problems, Soil behaviour, Foundation behaviour, Interface behaviour, Scope of soil-foundation interaction analysis, soil response models, Elastic continuum, Two-parameterelastic models, Elastic-plastic behaviour, Time-dependent behaviour.

Beams on elastic foundation

Infinite beam, Isotropic elastic half space, Analysis of beams of finite length, Classification of finite beams in relation to their stiffness.

Plates on elastic medium

Infinite plate, Winkler, Two parameters, Isotropic elastic medium, Thin and thick plates, Analysis of finite plates, rectangular and circular plates, Numerical analysis of finite plates, simple solutions.

Elastic analysis of piles

Elastic analysis of single pile, Theoretical solutions for settlement and load distribution, Analysis of pile group, Interaction analysis, Load distribution in groups with rigid cap.

Laterally loaded piles

Load deflection prediction for laterally loaded piles, subgrade reaction and elastic analysis, Interactionanalysis, and pile raft system, solutions through influence charts.

Dynamic Soil- Foundation Interaction

Introduction to soil and elasto-dynamics, Halfspace elasto-dynamic solution, Soil dynamics and earthquake, Waves induced by underground blast, Geotechnical analysis of machine foundations, Vibration of embedded footings.

Text/Reference Books:

1. Foundation Analysis and Design by J.E. Bowles

2. Fundamentals of Soil Dynamics by B. M. Das

6. Dynamics of Bases and Foundations by D. D. Barkan

4. Beams on Elastic Foundation by Hetenyi

3. Pile Foundations in Engineering Practice by S. Prakash and H. D. Sharma

4. Elastic Analysis of Soil-Foundation Interaction by A. P. S. Selvadurai

5. Dynamics of Structure and Foundation by Chowdhury and Dasgupta

Course Outcomes: At the end of the course, student will be able to:

CO- 1	Evaluate the soil stiffness and damping ratio.
CO- 2	Analyse the cases when to consider or neglect the soil-structure interaction effects.
CO-3	Analyse the structure with soil-structure interaction effects by lumped mass model.

SEMESTER - II

CODE	Dynamics of Soils and Foundations	L	T	P	C
CE 5111	M.Tech. (Geotechnical Engineering), 2nd Sem (Core)	3	0	0	3

Introduction: Importance of soil dynamics; Nature and types of dynamic loading; Static and dynamic system; Dynamic properties of geo-materials.

Vibration theory: Vibration of elementary systems; Degrees of freedom (SDOF and MDOF systems); Equation of motion for SDOF system; Types of vibrations; Transient vibration; Analysis of earthquake and blast load; Undamped and damped free vibrations; Critical damping; Decay of motion;

Undamped and damped forced vibration; Constant force and rotating mass oscillators; Dynamic magnification factor; Transmissibility ratio; Vibration isolation; Vibration measuringinstruments.

Dynamic soil properties: Stresses in soil element; Determination of dynamic soil properties; Field tests; Laboratory tests; Model tests; Stress-strain behaviour of cyclically loaded soils; Estimation of shear modulus; Modulus reduction curve; Damping ratio.

Liquefaction: Types and estimation of liquefaction; Effect of liquefaction, Simplified procedure for liquefaction estimation; Factor of safety; Cyclic stress ratio; Cyclic resistance ratio.

Machine foundations: Types of machines; Basic design criteria; Methods of analysis; Mass- Spring-Dashpot model; Elastic-Half-Space theory; Types of foundations; Modes of vibrations;Vertical, sliding, to rsional and rocking modes of oscillations; Design guidelines as per codes;Typical design problems.

Interaction of soils and foundations under dynamic loading: Dynamic earth pressures; Force and displacement based analysis; Pseudo-static and Pseudo- dynamic analysis; Guidelines of various design codes; Dynamic analyses of various geotechnical structures using MSD model.

Text/Reference Books:

1	Soil Dynamics	Sahmsher Prakash	Mc Graw-Hill
2	Principles of Soil Dynamics	B. M. Das	Thomas Press (I) Ltd
3	Foundation Analysis and Design	J.E. Bowles	Mc Graw-Hill
4	Dynamics of Bases and Foundations	D. D. Barkan	Mc Graw-Hill
5	Soil Dynamics and Machine Foundations	Swami Saran	Galgotia Pub. Pvt Ltd
6	Dynamics of Structure and Foundation	Chowdhury and Dasgupta	

Course Outcomes: At the end of the course, student will be able to:

CO- 1 develop basic knowledge about theory of vibration and dynamic behavior of soil.
CO- 2 analyze different types of vibration isolation system and vibration measuring instruments.
CO- 3 identify liquefaction susceptibility of a site and estimate the factor of safety against liquefaction.
CO- 4 analyze and design the suitable foundation system for different structures subjected to different types of dynamic loading.
CO- 5 analyze earth pressure under dynamic conditions and dynamic analyses of various geotechnical structures using MSD model.

CODE	Stability of Slopes	L	T	P	C
CE 5112	M.Tech. (Geotechnical Engineering), 2nd Sem (Core)	3	1	0	4

Slopes: Introduction, types of slope, factors affecting stability, types of slope movement andlandslides, geology and slopes.

Stability conditions of analysis: Performance indicators, global and local factors of safety, reliability index, probability of failure and reliability, end-of-construction stability, long-term stability, rapid drawdown, partial consolidation and staged construction, other loading conditions, case study.

Limit equilibrium procedures: Factors of safety, equilibrium conditions, procedures of slices,shear strength parameters, pore water pressure representation, simple methods of analysis, slope stability charts, use of spreadsheet, application of software, examples.

Reinforced slopes and embankments: Types of reinforcement, reinforcement forces, allowable reinforcement forces and factors of safety, reinforced slopes on firm foundation, embankment on weak foundations.

Seismic slope stability: Analysis procedures, pseudo-static analysis, determination of peak acceleration, displacement of slopes, post-earthquake stability analysis.

Rainfall-induced slope stability: Estimation of infiltration, seepage analysis, pore-water pressure profiles, stability analysis based on infiltration profile, controlling factors for rainfall-induced landslides.

Text/Reference Books:

Sl	Name of the Book	Authors	Publishers
1	Soil Strength and Slope Stability	Duncan, Wright and Brandon	
2	Geotechnical Slope Analysis	Chowdhury, Flentje and Bhattacharya	
3	Slope Stability Analysis by the Limit Equilibrium Method	Huang	
4	Principles and Practice of Ground Improvement	Han	
5	Geotechnical Earthquake Engineering	Kramer	
6	Rainfall-Induced Soil Slope Failure	Zhang, Li, Zhang and Zhu	

Course Outcomes: At the end of the course, student will be able to:

CO- 1 analyse possible causes behind the instability of soil slopes.

CO- 2 apply appropriate method to determine performance indictor of soil slope.

CO- 3 design soil slopes with reinforcement to enhance stability.

CO- 4 design the soil slope to be stable during earthquake and rainfall.

CODE	Finite Element Methods	L	T	P	C
CE 5313	M.Tech. (Geotechnical Engineering), 2nd Sem (Core)	3	0	0	3

Brief history: Introduction to matrix notation, Introduction to Matlab, General steps of the finite element method, Applications. Basic concepts of engineering analysis and introduction to the finite element method. Solution of discrete system mathematical models-steady state problem, propagation problem, eigen value problem. Solution of Continuous-system mathematical models
– differential formulation, variational formulations, weighted residual methods, Finite difference differential and energy methods.

Introduction to stiffness method: Solution of discrete system mathematical models-steady state problem, propagation problem, eigen value problem. Solution of Continuous-system mathematicalmodels – differential formulation, variational formulations, weighted residual methods, Finite difference differential and energy methods.

Introduction to stiffness method: Definition of stiffness matrix, derivation of stiffness matrix of aspring, assembly of stiffness matrices, boundary conditions, Potential energy approach.

Introduction to truss problems: Derivation of stiffness matrix of a truss element in local coordinates and global coordinates, Formulation of force equation, Solution of a plane truss, solution in Matlab, ANSYS.

Solution of beam and frame problems: Beam stiffness, distributed load, examples, Two dimensional arbitrarily oriented beam element, Rigid plane frame, examples, solution in Matlab, ANSYS.

Plane stress and plane strain problems: Basic concepts, derivation of linear strain triangular element, examples, rectangular plane stress element, isoparametric formulations, numerical integration, stiffness matrix and stress matrix by Gaussian quadrature, higher order shape functions, solution in Matlab, ANSYS.

Axisymmetric problems: Derivation of stiffness matrix, axisymmetric pressure vessels, applications.

Three dimensional stress analysis: Three dimensional stress and strain, tetrahedral element, isoparametric formulation, examples.

Plate bending elements: Basic concepts, derivation of plate bending element stiffness matrix, examples.

Heat transfer problems: Derivation of basic differential equation, one dimensional problem, twodimensional problem.

Fluid flow problems: Derivation of basic differential equation, one dimensional problem, twodimensional problem.

Structural dynamics: Dynamics of spring-mass system, eignevalue and eigenvector problems,solution in Matlab, ANSYS.

Text/Reference Books:

1	A First Course in The Finite Element Method	Daryl L. Logan and Martin Logan	Cengage Learning, Inc
2	An Introduction to the Finite Element Method	J. N. Reddy	Mc Graw Hill

3	Concept and Application of Finite Element Analysis	R.D. Cook, D. S. Malkus and M. E. Plesha	John Wiley
4	The Finite Element Method – Linear Static and Dynamic Finite Element Analysis	T.J. R. Hughes	Dover Publications
5	Finite Element Procedures	K. J. Bathe	Oxford University
6	Finite Element Methods	K. J. Bathe and E. L.Wilson	
7	Finite Element Methods in Engineering	O. C. Zeinkiewicz	Elsevier

Course Outcomes: At the end of the course, student will be able to:

CO- 1 Apply the knowledge to discretize any continuum body into finite elements.

CO- 2 Apply the knowledge for determining stress and strain at a given nodal point of a structure.

CO- 3 Obtain deformed shape of a structure under static and dynamic conditions.

CO- 4 Apply the knowledge to critically assess the working principle of any structural analysis software.

CO- 5 Apply the knowledge to solve non-structural problems.

CODE	Seminar	L	T	P	C
CE 5113	M.Tech. (Geotechnical Engineering), 2nd Sem (Core)	**0**	**0**	**3**	**2**

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand the importance of presentation and improve confidence for oral delivery.CO- 2 explore the updated literature in the interested area or topic and interaction thereon. CO- 3 demonstrate scope and problem statement on specific theme.

ELECTIVE - III

CODE	Geosynthetics and Reinforced Earth	L	T	P	C
CE 5151	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective III)	3	0	0	3

Introduction: History, ancient and modern structures. Type of geosynthetics - geotextiles, geogrids, geonets, geocells, geo-composites, manufacturing methods. Functions of geosynthetics and application areas. Reinforcement action – mechanism of reinforced soil through Mohrcircle analysis, facings. Factors affecting the performance and behavior of reinforced soil.

Testing methods for geosynthetics: Techniques for testing of different index properties, strength properties, Apparent Opening Size, In-plane and cross-plane permeability tests, assessment of construction induced damage, extrapolation of long term strength properties from short term tests.

Reinforced earth walls: Behaviour of Reinforced earth walls, basis of wall design, the Coulomb force method, the Rankine force methods, internal and external stability condition,Construction methods of reinforced retaining walls.

Application in foundations: Binquet and Lee's approach for analysis of foundations with reinforcement layers.

Reinforced soil slopes: Different slope stability analysis methods like planar wedge method, bi-linear wedge method, circular slip methods. Erosion control on slopes using geosynthetics.

Use of geosynthetics in embankment: Basal reinforcement for construction on soft clay soils.Analysis and design concepts.

Applications of geosynthetics for drainage and filtration: Different filtration requirements, filtration in different types of soils and criteria for selection of geotextiles, estimation of flow of water in retaining walls, pavements, etc. and selection of geosynthetics.

Application of geosynthetics in pavement: Geosynthetics used in unpaved road-function, mechanism, benefit, design- by Giroud-Noiray
approach, Paved road - reflection cracking and control using geosynthetics. Use of geosynthetics in raiway lines.

Construction of landfills using geosynthetics: Different components of modern landfills, collection techniques for leachate, application of different geosynthetics like geonets, geotextiles for drainage in landfills, use of geomembranes and Geosynthetic Clay Liner (GCL) as barriers.

Text/Reference Books:

Sl	Name of the Book	Authors
1	Earth Pressure and Earth Retaining Structures	C. R. I. Clayton, J. Milititsky and R. I. Woods
2	Reinforced Earth	T. Ingold
3	Earth Reinforcement and Soil Structures	C. J. F. P. Jones
4	Designing with Geosynthetics	R. M. Koerner

5	An Introduction to Soil Reinforcement and Geosynthetics	G.L SivakumarBabu
6	Reinforced Soil and its Engineering Applications	Swami Saran

Course Outcomes: At the end of the course, student will be able to:

CO- 1	select appropriate geosynthetic as per requirement.
CO- 2	apply geosynthetics in different civil engineering project.
CO- 3	design earthen structures with geosynthetic reinforcements.
CO- 4	design pavement with geosynthetics.

CODE	Offshore Geotechniques	L	T	P	C
CE 5152	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective III)	3	0	0	3

Introduction: Site Survey and In-Situ Testing: Boring and sampling in marine deposits.

Laboratory Determination of Soil Properties: Morphology and genesis of marine sediments.

Shallow Foundations and Dead weight Anchors: Design Considerations, DesignMethodology and Procedure.

Pile Foundations and Anchors: Pile Descriptions, Design Procedures for Simple Piles in SoilSeafloors; Breakout of Objects from the seafloors.

Text/Reference Books:

Sl	Name of the Book	Authors	Publishers
1	Offshore Geotechnical Engineering	Mark Randolph and Susan Gourvenec	
2	Offshore Geotechnical Engineering: Principles and practice	E.T.R. Dean	
3	Pile Foundation Analysis and Design	Poulos and Davis	
4	Pile design and construction practice	M. J. Tomlinson	
5	Deep water Foundations and Pipeline Geomechanics	William O. McCarron	
6	Construction of marine and offshore structures	Ben C Gerwick, jr	
7	Foundation Engineering Handbook	Hsai-Yang Fang	

Course Outcomes: At the end of the course, student will be able to:

CO- 1 analyse offshore soil sample data.
CO- 2 apply knowledge of soil exploration in offshore foundation design.
CO- 3 design shallow foundation for offshore structures.
CO- 4 design pile foundation for offshore structures.

CODE	Earthquake Resistant Design of Foundations	L	T	P	C
CE 5153	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective III)	3	0	0	3

Introduction: General requirements; types of dynamic loads; types of shallow and deep foundations and their use; performance of various types of foundations during past earthquakes.

Shallow Foundations: Safe bearing capacity under earthquake loads, differential & total settlements. Modulus of subgrade reaction, Winkler model, beam on elastic foundation. Dynamic Bearing Capacity under Transient and Earthquake Loads; requirements to account for settlements due to earthquake induced forces; Pseudo-Static analysis of foundation with eccentric & inclined loads. Effect of horizontal load and moment. Dynamic analysis of shallow foundations for various modes of vibrations.

Pile Foundations: Laterally loaded piles, elastic analysis; Reese and Matlock approach; Soil-pile analysis with spring-mass & FEM idealization, elements for slip and separation, soil-pile interaction, IS code of practice for design of pile foundations, piles through liquefiable soils.

Well Foundations & Caissons: Pseudo-static analysis with earthquake induced loads, Lateral load resistance of well foundation; Terzaghi's approach; IRC, IS and Indian Railway Codes.

SSI for Deep Foundations: Soil-Structure Interaction, Modelling of Unbounded Soil Media for Dynamic Loads, Free Field Motion, Kinematic Interaction and Inertial Interaction.

Books and references:

1. Soil Dynamics by S. Prakash, McGraw-Hill Company, New York.
2. Geo technical-Earthquake Engineering by S. L. Kramer, Pearson Education Pvt. Ltd., Singapore.
3. Foundation Analysis and Design by J. E. Bowles, McGraw Hill International Editions, Singapore.
4. Pile foundation: Analysis and Design by Poulos and Davis
5. Soil Dynamics & Machine Foundation by Swami Saran, Galgotia Pub. Pvt. Ltd, New Delhi.
6. Geotechnical Earthquake Engineering Handbook by Robert W. Day, McGraw Hill

Course outcome:

CO1: analyze and solve problems on shallow foundations subjected to dynamic loads

CO2: analyze the effect of dynamic loads on pile foundations and solve related problems

CO3: evaluate the stability of well foundations subjected to the earthquake loads

CO4: evaluate the effect of soil-pile interaction under earthquake loads

ELECTIVE - IV

CODE	Probability Methods in Civil Engineering	L	T	P	C
CE 5161	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective IV)	3	0	0	3

Introduction: Role of probability and statistics in civil engineering.

Random events: Definition of basic random events; Application of set theory in definition ofcomposite event operations. Probability of events and definition of probability axioms; Solution of real life examples from civil engineering.

Random variables: Definition of random variables – discrete and continuous; Probability definitions – PMF, PDF, CDF; Moments and expectations.

Functions of random, variables: Definitions of probability distributions of functions of single and multiple random variables– exact methods and approximate methods; Moments and expectations of functions–direct and indirect methods.

Probability distributions Discrete distributions – binomial distribution, Poisson's distribution; Continuous distribution– exponential distribution, gamma distribution; Central limit theorem; Normal and lognormal distributions; Extreme value distributions.

Random samples and statics: Examples on various civil engineering problems.

Sampling distributions: Chi-square distribution, t- distribution, F distribution.

Parameter estimation: Point estimation, confidence interval estimation.

Hypothesis testing: Tests of hypotheses on the mean and variance.

Text/Reference Books:

Sl	Name of the Book	Authors	Publishers
1	Probability Concepts in Engineering: Emphasis on Applications in Civil and Environmental Engineering	Ang, A. H. S., and Tang, W. H.	
2	Probability and Statistics for Engineers	Ravichandran, J.	
3	Applied Statistics for Civil and Environmental Engineers	Kottegoda and Rosso	
4	A First Course on Probability	Ross, S.	

Course Outcomes: At the end of the course, student will be able to:

- CO- 1 understand probabilistic distribution of geotechnical variables.
- CO- 2 analyse geotechnical problems using probabilistic perspectives.
- CO- 3 apply probabilistic methods to geotechnical problems.
- CO- 4 solve geotechnical problems using statistical methods.

CODE	Earth Retaining Structures	L	T	P	C
CE 5162	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective IV)	3	0	0	3

Introduction: Earth pressure; basic concepts; active, passive and at rest earth pressures; Rankine'sand Coulomb's earth pressure theories; earth pressure models; graphical methods and their interpretations, earthquake effects

Types of earth retaining structures: Classifications, rigid and flexible retaining structures, stabilityanalysis, design specifications and pressure distribution variations, selection of wall.

Gravity walls: Mass concrete gravity walls, gabions, crib walling, masonry walls, reinforced concrete cantilever walls, counterfort walls, buttressed walls. Preliminary and detailed design. Internal and external stability.

Embedded walls: Sheet-pile walls, bored pile walls, diaphragm walls, jet grouted walls. Preliminary and detailed design. Stability check.

Composite walls and other supporting systems: Cofferdams, reinforced soil structures, anchoredearth, support using ground anchors, soil nailing. Preliminary and detailed design. Internal and external stability.

Braced Excavations: Arching in soils, pressure distribution insoil, bottom heave, braced walls and their design.

Sl	Name of the Book	Authors	Publishers
1	Earth Pressure and Earth-Retaining Structures	Chris R.I. Clayton, Rick I. Woods, Andrew J. Bond, Jarbas Milititsky	
2	Foundations and Earth Retaining Structures	Muni Budhu	
3	Foundation Analysis and Design	J. E. Bowles	
4	Principles of Foundation Engineering	B. M. Das	
5	Principles and Practice of Ground Improvement	Han	
6	Geotechnical Earthquake Engineering	Kramer	

Course Outcomes: At the end of the course, student will be able to:

CO- 1	calculate earth pressure on various earth retaining structures.
CO- 2	analyse earth pressure condition to select suitable earth retaining structure.
CO- 3	design relevant earth retaining structure for given soil condition.

CODE	Geoenvironmental Engineering	L	T	P	C
CE 5163	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective IV)	3	0	0	3

Sources and effects of subsurface contamination; physical, chemical and biological characteristics of solid wastes; soil-waste interaction; contaminant transport; laboratory and field evaluation of permeability; factors affecting permeability; waste disposal on land.

Types of landfill; silting criteria; waste containment principles; types of barrier materials; planning anddesign aspects relating to waste disposal in landfills, ash ponds, tiling ponds and rocks.

Environmental monitoring around landfills; detection, control and remediation of subsurface contamination; engineering properties and geotechnical reuse of demolition waste dumps; regulations,case studies.

Sl	Name of the Book	Authors	Publishers
1	Geotechnical Practice for Waste Disposal	D. E. Daniel Jarbas Milititsky	
2	Clay Barrier Systems for Waste Disposal Facilities	Rowe, Quigley and Booker	
3	Geotechnical and Geoenvironmental Engineering Handbook	R.K. Rowe	
4	Geoenvironmental Engineering–Principles and Applications	Reddi and Inyang	
5	Design, Construction and Monitoring of Landfills	A. Bagchi	
6	Waste Containment Systems, Waste Stabilization and Landfills: Design and Evaluation	Sharma and Lewis	

Course Outcomes: At the end of the course, student will be able to:

CO- 1 analyse soil-waste interaction.

CO- 2 apply containment principles to detect level of contamination.

CO- 3 design appropriate barrier to control contamination.

CODE	Optimization Methods in Engineering Design	L	T	P	C
CE 5562	M.Tech. (Geotechnical Engineering), 2nd Sem (Elective IV)	3	0	0	3

Introduction to optimization: definitions, classification, overview of topicsIntroduction to numerical linear algebra

Single variable optimization algorithms – optimality criteria, bracketing methods, region elimination methods, point estimation methods, gradient based methods, root finding using optimization techniques.

Multivariable optimization algorithms – optimality criteria, direct search methods, gradient based methods.

Constrained optimization algorithms – Kuhn-Tucker conditions, transformation methods, direct searchmethods.

Specialised algorithms – integer programming, Geometric programming

Introduction to Genetic algorithms, particle swam optimization, fire-fly algorithms and others.

Sl	Name of the Book	Authors	Publishers
1	Engineering Optimization: Theory and Practice	Singiresu S. Rao, Wiley.	
2	Optimization for Engineering Design: Algorithms and Examples	Kalyanmay Deb, PHI.	
3	Engineering Optimization - Methods and Applications	A. Ravindran, G.V. Reiklaitis and M. Rangsdell.	

Course Outcomes: At the end of the course, student will be able to:

CO- 1 To enable the graduates to understand the concept of optimization, design and develop analytical skills.

CO- 2 To enable graduates, apply optimization concept to different civil engineering problems.

CO- 3 The graduates will be able to summarize the Linear, Non-linear and Geometric Programming.

NATIONAL INSTITUTE OF TECHNOLOGY SILCHAR

Department of Civil Engineering

Curriculum and Syllabi for M. Tech. in Structural Dynamics and Earthquake Engineering

With effect from 2019 entry batch

PO Statements:

PO-1: To expose the students to vibration theory and problems, earthquake hazards, earthquake engineeringprinciples, and earthquake disaster management.

PO-2: To impart training to graduate students to the latest earthquake resistant design philosophies, codal designand design philosophies beyond the code, so that the students can independently tackle earthquake engineeringproblems and they can handle the earthquake hazard mitigation projects.

PO-3: To expose the graduate students to current national and international scenario on earthquake engineeringand to motivate them in interdisciplinary involvement in earthquake related problems.

PO-4: To orient the graduate students to high value research on Structural Dynamics and earthquake Engineering so that they get impetus to pursue lifelong learning.

Course Structure

Semester I

Sl. No	Code	Subject	L	T	P	Credit
1	CE 5201	Theory of Vibration	3	1	0	4
2	CE 5202	Engineering Seismology	3	0	0	3
3	CE 5203	Matrix Methods for Dynamical Systems	3	0	0	3
4	CE 5204	Dynamics Lab	0	0	3	2
5	CE xxxx	Elective - I	3	0	0	3
6	CE xxxx	Elective - II	3	0	0	3
		Total contact hours/ Credits	**15**	**1**	**3**	**18**

Semester II

Sl. No.	Code	Subject	L	T	P	C
1	CE 5211	Earthquake Resistant Design of Structures	3	0	0	3
2	CE 5212	Seismic Hazard, Vulnerability and Risk Analysis and Retrofitting	3	0	0	3
3	CE 5213	Dynamics of Plates, Shells and Arches	3	1	0	4
4	CE 5214	Seminar	0	0	3	2
5	CE xxxx	Elective - III	3	0	0	3
6	CE xxxx	Elective - IV	3	0	0	3
		Total contact hours/ Credits	**15**	**1**	**3**	**18**

Semester III

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 6298	Project Phase I	0	0	0	6
			Total Credit			**6**

Semester IV

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 6299	Project Phase II	-	-	-	8
		Total contact hours/ Credits	**-**	**-**	**-**	**8**

Elective - I

Sl. No.	Code	Subject name	L	T	P	Credit
1	CE 5141	Geotechnical Earthquake Engineering	3	0	0	3
2	CE 5331	Theory of Stability of Structures	3	0	0	3

Elective – II

Sl. No.	Code	Subject name	L	T	P	Credit
1	CE 5241	Seismic Microzonation	3	0	0	3
2	CE 5242	Numerical Methods for Dynamical Systems	3	0	0	3

Elective - III

Sl. No.	Code	Subject name	L	T	P	Credit
1	CE 5251	Performance-Based Seismic Design of Structures	3	0	0	3

2	CE 5352	Advanced Bridge Engineering	3	0	0	3
3	CE 5562	Optimization methods in Engineering Design	3	0	0	3
4	CE 5313	Finite Element Methods	3	0	0	3

Elective – IV

Sl. No.	Code	Subject name	L	T	P	Credit
1	CE 5261	Random Vibration	3	0	0	3
2	CE 5262	Structural Response Control for Seismic Protection	3	0	0	3
3	CE 5111	Dynamics of Soils and Foundations	3	0	0	3
4	CE 5153	Earthquake Resistant Design of Foundations				

DETAILED SYLLABI

Semester - I

CODE	Theory of Vibration	L	T	P	C
CE 5201	M. Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Core)	3	1	0	4

Sources of vibration, types of excitations; spring action and damping: Degrees of freedom; Applicationof Newton's laws, D'Alembert's Principle.

Single degree of freedom system: Mathematical model of physical systems; Free vibrations of undamped and viscously damped systems; Coulomb damping material and radiation damping. Logarithmic decrement and its applications.

Response of viscously damped SDOF systems to harmonic excitations. Non-periodic excitation – Duhamel's integral. Vibration isolation-Vibration arrest trench, Force transmissibility and base motion; Principle of vibration measuring instruments; Equivalent viscous damping.

Numerical evaluation of dynamic response of linear and non-linear

systems.Frequency domain analysis.

Multiple degree of Freedom systems: Vibrations of undamped 2 DOF systems; Response of 2 DOF toharmonic excitation, mode superposition, vibration absorber.

Lagranges equations and their application to lumped parameter models of MDOF. Free vibrations of MDOF systems, methods of solving eigenvalue problems; iteration methods.

Dynamic response of MDOF systems – mode superposition method.

Vibrations of Continuous systems: Free vibrations of continuous systems-axial transverse vibrations of beams. Numerical schemes for obtaining frequencies and mode shapes, vibration of elastic half space (Richart and Hall idealization).

Response of beams to harmonic excitation.

Earthquake Response of Systems: Response of SDOF and MDOF systems to earthquake excitation. Response spectra; Fourier spectra.

Text Books/References:

1. Chopra, A. K., Dynamics of structures, Prentice Hall.

2. Clough, R. W. and Penzien, J., Dynamics of structures, Mc Graw Hill.

3. Humar, J. L., Dynamics of Structures, Prentice-Hall.

4. Paz, M., Structural dynamics: theory and computation, CBS Publishers & Distributor, Delhi.

5. Timoshenko, S. P., and Young, D. H., Advanced dynamics, McGraw Hill

7. Biggs, J. M., and Testa, B, Introduction to structural dynamics.

8. Craig, R. R. and Kurdila, A. J., Fundamentals of structural dynamics, John Wiley & Sons.

9. Filiatrault, A., Elements of earthquake engineering and structural dynamics, Presses interPolytechnique.

10. Buchholdt, H. A., Structural dynamics for engineers. Thomas Telford.

11. Paultre, P., Dynamics of structures, Wiley India.

12. T. K. Datta, Seismic Analysis of Structures, John Wiley & Sons (Asia).

Course Outcomes: At the end of the course, students will be able to:

CO-1 gather the understanding of the principles of vibrations.

CO-2 analyse SDOF and MDOF systems under dynamic loading and obtain the response of the systems.

CO-3 apply the knowledge of theory of vibration in solving real life dynamic problems.

CO-4 apply creative thinking in dynamics and acquire inspiration for life-long learning.

CODE	Engineering Seismology	L	T	P	C
CE 5202	M. Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Core)	3	0	0	3

Propagation of earthquake Waves, Body & surface waves, laws of reflection, refraction and attenuation, travel times curves, internal structure of earth

Seismicity of earth, major earthquakes in the world, important Indian Earthquakes, earthquakecatalogs, plate tectonics, causes of earthquakes

Magnitude, energy, intensity, acceleration, return period, frequency, Ground motion characteristics

Earthquake recording instruments, seismographs, different modes of recording analogue, digital, micro earthquake, teleseismic, local, strong motion, band width and their engineering implications

Processing, analysis and interpretation of earthquake data, determination of magnitude, epicentral distance, focal depth, focal mechanism, seismic hazard and risk, seismic zoning

Introduction to prediction

Design earthquake parameters

Text Books/References:

1. Richter,C.F. Elementary Seismology, Eurasia Publishing House (Pvt) LTD, New Delhi
2. Agrawal, P.N., Engineering Seismology, Oxford& IBH Publishing Co. Pvt. Ltd, New Delhi
3. Aki,K and Richard, P.G. Quantitative seismology, Theory and Methods, Vol. I and II, W.H.Freeman & Co.
4. Lee, W.H.K and Stewart, SW. Principles and applications of microearthquake networks, 1981,Academic Press Inc.
5. Kulhanek, O. Anatomy of seismograms,1990, Elsevier Science Publications.
6. Rikitake,T.,1976 Earthquake Prediction, Elsevier Science, Amsterdam
7. Oldham,1989 Report on Great Earthquake of 12th June 1897, Memoir Geological Survey ofIndia,V29
8. Latest Codes of IS-1893-part-I 2016

Course Outcomes: At the end of the course, students will be able to:

CO-1: gain a thorough, and critical understanding of advanced seismology and causes of earthquakes

CO-2: gain a detailed understanding of seismic hazard and a detailed understanding of wave equationsand their solutions. Students will be able to use, interpret and evaluate.

CO-3: assess the design basis ground motion parameters and its application in earthquake engineeringfor disaster mitigation.

CODE	Matrix Methods for Dynamical Systems	L	T	P	C
CE 5203	M. Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Core)	3	0	0	3

General Matrix Static Analysis: Rod Structures, Beam Structures, Truss and Frame, Structural Connections, Equivalent Loads, Elastic Supports, Loads and Reactions, Sub-structuring, Matrix Stability Analysis of Truss, Beams, Frames,

Dynamics of Elastic Systems

Linear Elastic Structures, Harmonic Motion and Vibration, Complex Notation, Damping, Forced Response

Vibration of Rods and Beams

Rod, Beam, Spectral Analysis of Beams, Exact Dynamic Stiffness Matrix, Approximate Dynamic Stiffness Matrix, Matrix form of Dynamic Problems.

Matrix Modal Analysis of Frames

Dynamic Stiffness for Space Frames, Modal Matrix, Transformation of Principal Coordinates, Forced Damped Motion, Modal Model, Dynamic Structural Testing, Structural Modification

Structural Dynamics Principles

Elements of Analytical Dynamics, Hamilton's Principle, Approximate Structural Theories, Lagrange's Equation, Ritz Method, Discrete Systems, Rayleigh Quotient

Matrix Computer Methods

Computers and Data Storage, Structural Analysis Program, Node Renumbering, Solving Simultaneous Equations, Solving Eigen Value Problems, Finite Differences, Direct Integration Methods, Wilson (1973) Method for Nonlinear Dynamic Analysis of Complex Structures, Newmark's Method, Jacobi Method, Subspace Iteration, Selecting Dynamic Solver, Finite Element Method

Text Books/References:

1. James F. Doyle (1991) Static and Dynamic Analysis of Structure with Emphasis on Mechanicsand Computer Matrix Methods, Kluwer Academic Publishers, Springer Science + Business Media Dordrecht
2. Madhu B. Kanchi (1993), Matrix Methods of Structural Analysis, Wiley
3. A. K. Mukherjee, P. K. Som (1985), Computer Methods of Structures, Khanna Publishers
4. A. K. Chopra (2007), Dynamics of Structures, Pearson
5. V.K. ManickhaSelvam (1992), Advanced Structural Dynamics, Dhanpat Rai & Sons
6. F. Y. Cheng (2001), Matrix Analysis of Structural Dynamics: Applications and EarthquakeEngineering, Marcel Dekker, Taylor and Francis

Course Outcomes: At the end of the course, students will be able to:

CO-1 gather the understanding on matrix methods in dynamical systems.

CO-2 develop understanding using computer programming on different methods for solving the problems on dynamical systems.

CO-3 extend the analysis skill for different dynamical structural components like beams, frames androds etc.

CODE	Dynamics Laboratory	L	T	P	C
CE 5204	M. Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Core)	0	0	3	2

Soil Dynamics: Seismic refraction survey, Cyclic triaxial test

Structural Dynamics: Modal Testing, Dynamic properties estimation of a structures, Shake table testing, Software (SAP2000, STADPRO & ANSYS) for Structural Dynamics and Earthquake Engineering

Course outcomes: At the end of the course, students will be

able to:CO- 1 conduct seismic refraction survey on geological

structures.
CO- 2 conduct cyclic triaxial test to understand liquefaction potential of saturated soil.
CO- 3 conduct modal testing of and shall be able to estimate dynamic properties of structures.CO- 4 get exposure about different structural dynamics software.

ELECTIVE - I

CODE	Geotechnical Earthquake Engineering	L	T	P	C
CE 5141	M. Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Elective -I)	3	0	0	3

Introduction

Scope and objective, Nature and types of earthquake loading, Importance of Geotechnical Earthquake Engineering.

Seismology and earthquakes

Basic Seismology, Earthquake, List of major earthquakes, Causes of earthquakes, Sources of earthquake data, Elastic rebound Theory, Faults, Plate tectonics, Seismograph and Seismogram, Prediction of Earthquakes, Protection against earthquake damage, Origin of universe, Layers of Earth,Theory of Continental Drift, Hazards due to Earthquakes.

Strong ground motion

Size of Earthquake: Magnitude and Intensity of Earthquake, Modified Mercalli Intensity Scale, Measuring of Earthquake, Earthquake Magnitude- Local (Richter) magnitude, surface wave magnitude, Moment magnitude, Seismic energy, Correlations. Spectral Parameters: Peak Acceleration, Peak Velocity, Peak Displacement, Frequency, Content and duration, Spatial Variability of Ground Motion, Attenuation Relationships, Fourier Amplitude Spectra, Arias Intensity.

Seismic Hazard Analysis

Magnitude Indicators, Segmentation, Deterministic Seismic Hazard Analysis (DSHA), Probabilistic Seismic Hazard Analysis (PSHA), Earthquake Source Characterization, Gutenberg-Richter recurrencelaw, Predictive relationships, temporal uncertainty, Probability computations, Seismic Hazard Curve,Logic tree methods.

Wave propagation

Waves in unbound media; Waves in semi-infinite media; Waves in layered media, Seismic Travel Time Curve, Three Circle Method for locating an Earthquake's Epicentre.

Dynamic soil properties

Stiffness, damping and plasticity parameters of soil and their determination (laboratory testing, intrusive and non-intrusive in-situ testing), Correlations of different soil parameters.

Ground response analysis

One dimensional ground response analysis, Two-dimensional ground response analysis, soil-structureinteraction.

Local site effects and design ground motions

Effects of local site conditions on ground motions, design parameters, development of ground motiontime histories.

Liquefaction

Basic concept, flow liquefaction, cyclic mobility, liquefaction susceptibility, effects.

Seismic slope stability analysis

Static slope stability analysis, seismic slope stability analysis, earthquake induced landslides.

Seismic Design of retaining wall

Types of retaining walls, static pressure, dynamic response, seismic pressures, seismic displacement.

Soil improvement techniques for remediation of seismic hazards

Densification, reinforcement, grouting, drainage.

Text Books/References:

1. Geotechnical Earthquake Engineering by S. L. Kramer
2. Soil Plasticity: Theory and Implementations by W.F. Chen and G.Y. Baladi
3. Foundation Vibration Analysis using Simple Physical Models by J. P. Wolf

Course Outcomes: At the end of the course, students will be able to:

CO-1 solve problems relating to origin of earthquakes and response of structures to earthquakevibrations.

CO-2 solve problems relating to hazard analysis.

CO-3 assess properties of soil effected by seismic wave propagation

CO-4 solve problems relating to the effect of ground shaking on stability of slopes, stability ofretaining wall, stability of footings etc.

CO-5 apply earthquake mitigation theories on stability of structures.

CODE	Theory of Stability of Structures	L	T	P	C
CE 5331	M.Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Elective-I)	3	0	0	3

Basic Concepts: Concept of stability, Structural instability and bifurcation, Basic approaches to stability analysis.

Discrete Systems: Law of minimum potential energy, Concept of dynamics and energy criteria; Stability of single and multi-degrees of freedom systems, large deflection analysis.

Columns: Governing differential equation and boundary conditions; End-restrained columns; Effect of imperfection; Eccentrically loaded columns; Large deflection solution of elastic columns.

Beam-Columns and Frames: Behavior of beam-columns; continuous columns and beam-columns, single-storey frames, frames with sway and no-sway, buckling analysis using stiffness and flexibility method.

Approximate Methods: Solution of boundary value problems; Rayleigh-Ritz Method; Method of weighted residuals; Eigenvalue problems; Numerical solution of elastically supported columns.

Stability of Plates: Governing differential equation for rectangular plates, Thin plates with all edges simply supported, plates with other boundary conditions, Plates under uniform and sinusoidal loading conditions; buckling under in-plane shear, post buckling analysis.

Buckling: Buckling snap through and post-buckling; Inelastic buckling; Torsional buckling, torsional-flexural buckling, lateral-torsional buckling of symmetric cross-sections.

Text Books/References:

1. W. F. Chen and E. M. Lui (1987), Structural Stability: Theory and implementation, Prentice-Hall.
2. T. V. Galambos and A. E. Surovek (2008), Structural Stability of Steel: Concepts and applications for structural engineers, Wiley.
3. S. P. Timoshenko and J. M. Gere (1961), Theory of Elastic Stability, McGraw-Hill.
4. J.M.T. Thompson and G.W. Hunt (1973), A general theory of elastic stability, Wiley
5. Z.P. Bazant and L. Cedolin (1991), Stability of structures, Dover

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand the concept of structural stability and nonlinear structural behavior.CO- 2 determine and interpret the buckling loads for simple columns and frames.

CO- 3 analyze basic structural components and systems that are susceptible to instability. CO- 4 design and evaluate advanced numerical techniques to bucking analysis of structures.

ELECTIVE – II

CODE	Seismic Microzonation	L	T	P	C
CE 5241	M. Tech. (Structural Dynamics and Earthquake Engineering) First Semester (Elective -II)	3	0	0	3

Introduction: Importance of seismic microzonation, historical development, seismic microzonation of mega cities; Seismic zoning of India; Factors affecting seismicmicrozonation; Ground shaking effects, liquefaction and landslides; Major steps involved in seismic microzonation, probabilistic and deterministic approaches in evaluating ground motions

Seismic wave: Surface and body waves, their reflection and refraction, diffraction and attenuation, geophysical and geotechnical methods, spectral analysis of surface wave (SASW & MASW) methods; Determination of P-wave and S-wave velocities

Site characterization: Influence of local geology and nature of soil deposits on the responseof ground, earthquake induced permanent displacements and their influence on life-line structures, buildings, dams and other structures; material and geometric damping;consideration on inelastic properties of layers on seismic ground response

SCI & Surface topography effects: Site-city-interaction (SCI) effects, basic concept, basin shape and size, building type; 2D and 3D topography effects, ridge, valley and slope variation.

Assessment of local site effects: Empirical relationships, Micro-earthquake records, standard spectral ratio method, horizontal to vertical spectral ratio method; Noise records, absolute spectra, H/V ratio method; Numerical and analytical methods.

Seismic microzonation deliverables: Amplification maps**;** Liquefaction potential maps; Hazard maps; Thematic maps with various primary and secondary effects of earthquakes; Earthquake engineering perspective and limitations.**Case Studies:** Delhi, Kolkata, Guwahati, Bangalore, Dehradun, Mexico city, etc.

Text Books/References:

1. Dobrin, M.B. and Savit, C.H., "Introduction to Geophysical Prospecting", McGraw-Hill
2. Kramer, S. L., “Geotechnical Earthquake Engineering”, Pearson Education.
3. Kausel, E. and Manolis, G., "Advances in earthquake engineering-wave motion in earthquake engineering, WIT press.
4. Ansal, A., “Recent Advances in Earthquake Geotechnical Engineering and Microzonation”, Springer.
5. Villaverde, R., “Fundamental Concepts of Earthquake Engineering”, Taylor & Francis.
6. “Geotechnical/Geophysical Investigations for Seismic Microzonation Studies of Urban Centres in India-Technical Report”, NMDA, New Delhi.

Course Outcomes: At the end of the course, students will be able to:

CO-1: gain the basic knowledge about seismic waves, effects of topography on seismic waves, localsite effects, etc.
CO- 2: quantify different earthquake hazards and its effects (e.g. site effects, liquefaction, landslidesetc).
CO-3: gain knowledge on seismic microzonation, procedures and methodologies.
CO-4: get introduced to case studies which will further help to correlate the theory learnt with realcase scenarios.

CODE	Numerical Methods for Dynamical Systems	L	T	P	C
CE 5242	M. Tech. (Structural Dynamics and Earthquake Engineering), First Semester (Elective -II)	3	0	0	3

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.

Systems of Linear Equations- Solving Linear Systems, Problem Transformations, Triangular Linear Systems, Elementary Elimination Matrices, LU Factorization, Implementation of LU Factorization, Complexity of Solving Linear Systems, Iterative methods- Jacobi iteration, Gauss Seidel iteration

Non Linear systems- Newton Raphson iterations for 1D nonlinear equation, Newton Iterations, QuasiNewton iterations. Programs.

Properties of Eigenvalues and Eigenvectors, Diagonalization and Numerical techniques to compute eigenvalues - Vector Iteration, QR algorithm, Jacobi Method, Programs

Numerical Integration and Differentiation

Integration-Existence, Uniqueness, and Conditioning, Numerical Quadrature, Newton-CotesQuadrature, Gaussian Quadrature, Composite Quadrature, Adaptive Quadrature

Differentiation-Finite Difference Approximations, Automatic Differentiation, RichardsonExtrapolation

Partial differential equations; Elliptic, parabolic and hyperbolic PDEs.

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-stabilityand stiff-stability

Text Books/References:

1. J. B. Scarborough, Numerical Mathematical Analysis, Oxford & IBH Publishing Co. Pvt. Ltd., 2000.

2. K. K. Jain, S. R. K Iyengar and R. K. Jain, Numerical Methods - Problem and Solutions, Wiley IndiaPvt. Ltd, 2001.

3. R.W. Hamming, Numerical Methods for Scientist and Engineers, McGraw Hill, 1998.

4. J. H. Mathews and K.D. Fink, Numerical Methods using MATLAB, Pearson Education, 2004.

Course Outcomes: At the end of the course, students will be able to:

CO-1 formulate structural dynamics problems using numerical methods applied to structural system.

CO-2 carry out numerical simulations of many structural dynamics and earthquake engineering problems.

CO-3 relate different aspects of the structural dynamics and earthquake engineering aspects in orderto have a global picture of the behavior of a given problem.

CO-4 develop programming to solve particular problems in structural dynamics systems.

Semester II

CODE	Earthquake Resistant Design of Structures	L	T	P	C
CE 5211	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Core)	3	0	0	3

Introduction: Origin of earthquakes, magnitude, intensity, ground motions, sensors, strong motion characteristics.

Concepts of earthquake resistant design of R.C. buildings: Earthquake and vibration effects on structure, identification of seismic damages in buildings, effect of structural irregularities on the performance of buildings during earthquakes and seismic resistant building architecture.

Seismic analysis and modeling of R.C. buildings**:** Codal procedure for design of lateral loads, infill walls, seismic analysis of R.C. building as per IS: 1893 – 2000 (Part 1).

Earthquake resistant design of buildings and other structures: Ductility considerations, E.R.D. of R.C.building, design of load bearing buildings, design of shear wall, design of liquid storage tanks, retainingwall, chimney and industrial structures.

Text Books/References:

Sl	Name of the Book	Authors
1	Seismic Design of Reinforced Concrete and Masonry Building	T. Paulay and M.J.N. Priestly, John Wiley & Sons
2	Masonry and Timber structures including earthquake Resistant Design	AnandS.Arya
3	Earthquake –Resistant Design of Masonry Building	MihaTomazevic
4	Earthquake Tips – Learning Earthquake Design and Construction	C. V. R. Murty

Course Outcomes: At the end of the course, student will be able to:

CO- 1 correlate information from various engineering and scientific discipline to understand complex behaviour of RC buildings and other structures subjected to seismic forces and various design principles

CO- 2 design RC buildings and other structures in accordance with the provisions of Indian and International building codes

CO- 3 use performance based design framework and nonlinear analysis techniques

CODE	Seismic Hazard, Vulnerability and Risk Analysis and Retrofitting	L	T	P	C
CE 5212	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Core)	**3**	**0**	**0**	**3**

Introduction: Components of seismic risk-Hazard, Exposure, Vulnerability; difference between risk and hazard; probabilistic and deterministic seismic hazard approaches; earthquake sources; estimation of maximum magnitude; maximum credible earthquake; design basis earthquake.

Seismicity Data and Treatment: Seismicity catalogues; spatial coverage; temporal coverage; completeness in size and time; cut off magnitude; foreshocks and aftershocks; declustering of data; homogenization of catalogue; estimation of maximum probable magnitude; Gutenberg Richter frequency magnitude distribution; return period; Poissonian model, time dependent Poisson process.

Ground Motion Prediction Equations: Strong motion attenuation relationships; PGA and spectral accelerations, response spectra, displacement spectra.

Deterministic and Probabilistic Seismic Hazard Analysis: Deterministic and probabilistic seismic hazard methods; Types of earthquake sources-point, line and areal sources; geological slip rate method; deaggregation; logic tree; hazard estimation at the bedrock level; probability of exceedance and return periods in earthquake engineering.

Seismic Vulnerability of Buildings and Lifelines: Empirical, analytical, experimental and hybrid approaches; building typology; intensity scales, use of intensity scales for estimating seismic vulnerability; HAZUS methodology

Risk Estimation and Post Earthquake Damage Studies: Convolution of hazard, vulnerability and exposure to quantify risk; loss ratios, indoor and outdoor casualty rates; Earthquake damage surveys, questionnaires and data to be collected, handling and processing of data, classification of damage, estimation of fragility from damage data

Text Books/References:

1. Geotechnical Earthquake Engineering. Kramer, S. L., Pearson Education
2. Earthquake Hazard Analysis, Issues and Insights. Reiter, L. Columbia University Press
3. Seismic Hazard and Risk Analysis. McGuire, Robin K Earthquake Engineering Research Institute

Course Outcomes: At the end of the course, students will be able to:

CO- 1 acquire knowledge and ability to exposure to development, declustering, homogenization ofearthquake catalogues.

CO-2 acquire knowledge and ability to performance of deterministic and probabilistic seismic hazardanalysis.

CO- 3 acquire knowledge and ability to introduction to various methods and approaches of vulnerability assessment.

CO- 4 acquire knowledge and ability to introduction to various methods and approaches of riskassessment.

CODE	Dynamics of Plates, Shells and Arches	L	T	P	C
CE 5213	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Core)	**3**	**1**	**0**	**4**

Plates: Membrane Theory of Plates; Bending of Plates – Analytical solutions for Rectangular and Circular Plates with different edge restraints; Introduction to Composites; Classical Laminate Plate Theory; First Order Shear Deformation Theory; Finite Element formulation

Free vibration analysis; Pates subjected to Transient and time-varying LoadsModelling and

Analysis of Plate structures using ANSYS

Advanced Topics – Folded plates; Introduction to Vibration Control of Plates

Shells**:** Basic Equations of Differential Geometry; Types of Shells; Membrane theory and solutions forshells with regular geometry; bending theory of Cylindrical Shells; Finite Element formulation

Free Vibration of Shells – Analytical formulation, Forced Vibration Analysis of ShellsModelling

and Analysis of Shell problems using ANSYS

Arches: Free Vibration of Arches: Fundamentals; Eigenvalues and Eigenfunctions of Arches withfinite DOF; Circular Arches – Lamb's Differential Equation, Demidovich's Solution, Parabolic Arch
– Rabinovich's Method

Transient and Steady-state Vibration of Arches

Text Books/References:

1	Theory of Plates and Shells	SP Timoshenko and K Woinowsky-Krieger
2	Vibration Analysis of Plates by the Superposition Method	DJ Gorman
3	Free Vibration Analysis of Rectangular Plates	DJ Gorman
4	Finite Element Software for Plates and Shells	E Hinton and DRJ Owen
5	An Introduction to the Mathematical Theory of Vibrations of Elastic Plates	RD Mindlin Edited by J Yang
6	Mechanics of Composite Materials and Structures	M Mukhopadhyay
7	Thin Shells: Theory and Problems	J Ramachandran

Course Outcomes: After the completion of the course, students will be able to

CO- 1 analyse an isotropic plate subjected to static and dynamic loads,

CO- 2 define laminated composites and analyse a laminated composite plate structure based ondifferent plate theories,

CO- 3 formulate the dynamic problems involving the finite element formulation of the platestructure,

CO- 4 analyse different types of shell structures analytically and using numerical methods,

CO- 5 compute the frequency and mode-shapes of circular and parabolic arches and also analysearches subjected to time-varying loads,

CO- 6 model and analyse plate and shell structures using ANSYS software.

CODE	Seminar	L	T	P	C
CE 5214	M.Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Core)	0	0	3	2

Course Outcomes: After the completion of the course, students will be able to

CO- 1 effectively prepare materials for presentation on technical world.CO- 2 enhance the skill of communication.
CO-3 get exposure to some topic generally outside the curriculum.

ELECTIVE – III

CODE	Performance-Based Seismic Design of Structures	L	T	P	C
CE 5251	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective III)	**3**	**0**	**0**	**3**

Force-based method of design *vs*. Performance-based method of design, Historical development. Limitations of Force-based method of design. Limitations of IS 1893 (Part 1)-2016. Moment-curvaturerelationship. Strength- Stiffness relationship. Types of strengths - Expected strength, characteristic strength, extreme strength.

Definition of Maximum earthquake and Design Basis Earthquake. Spectrum Compatible Ground Motions. Review of Response Spectrum Method of Design. Displacement Spectra.

The concept of Capacity Design. Capacity design applied to buildings and other structures.

Performance levels – Immediate Occupancy Level, Life Safety Level, Collapse Prevention Level. Theconcept of Operational Level Buildings. Multi-objective design.

Drift in buildings and design for drift. Design for desired performance objectives.

Displacement-based design philosophy. Direct Displacement-based design methods. Unified Performance-based design method. Application to Frame Buildings, Frame-Shear wall buildings and other structures. Effect of infill.

Base Isolation and added damping, Application in Bridges.

Text Books/References:

Sl	Name of the Book	Authors
1	Displacement-Based Seismic Design of Structures	M.J.N. Priestley, G.M. Calvi and M.J. Kowalasky
2	Seismic Design of Frame-Wall Buildings	T.J. Sullivan, M.J.N. Priestley, G.M. Calvi
3	Seismic Design of Reinforced Concrete and Masonry Structures	T. Paulay and M.J.N. Priestley
4	Reinforced Concrete Structures	Park and Paulay
5	Seismic Evaluation and Retrofit of Concrete Buildings	ATC-40

Course outcomes: After the completion of the course, students will be able to

CO- 1 get familiarized with limitation of force-based codal method of design and the need for cement-based design.

CO- 2 learn design with target criteria under given hazard level.

CO- 3 learn design incorporating drift and performance level for frame buildings, frame-wall buildingsand other structures.

CO- 4 gets motivation for higher studies in displacement-based design and get impetus for lifelong learning.

CODE	Advanced Bridge Engineering	L	T	P	C
CE 5352	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective III)	3	0	0	3

Introduction, historical review, engineering and aesthetic requirements in bridge design.

Introduction to bridge codes. Economic evaluation of a bridge project. Site investigation and planning,Scour - factors affecting and evaluation.

Bridge foundations - open, pile, well and caisson. Piers, abutments and approach structures; Superstructure - analysis and design of right, skew and curved slabs.

Girder bridges - types, load distribution, design. Orthotropic plate analysis of bridge decks. Introduction to long span bridges - cantilever, arch, cable stayed and suspension bridges.

Text Books/References:

Sl	Name of the Book	Authors	Publishers
1	Essentials of Bridge Engineering	D. J. Victor	
2	Design of Bridges	N. Krishna Raju	
3	Concrete Bridge Practice: Analysis, Design and Economics	V. K. Raina	
4	Dynamics of Railway Bridges	L. Fryba	
5	A Text Book of Bridge Engineering	K.S. Rakshit	
6	Construction & Practice in Bridge Engineering	S. Ponnaswamy	

Course Outcomes: After the completion of the course, students will be able to

CO- 1 use structural codes and standards to model dead, live, snow, wind, and earthquake loads in the design of both super and Sub structures.

CO- 2 determine the various structural parameters namely Moments, Shear Stress and mode shapes of continuous system, natural frequency using classical methods.

CO- 3 solve statically indeterminate structures namely Super Structures, Sub structures, Pile cap, PierShaft, Well cap and Well foundation etc.

CO- 4 use modern structural analysis software such as MIDAS, SAP.

CODE	Optimization Methods in Engineering Design	L	T	P	C
CE 5562	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective III)	**3**	**0**	**0**	**3**

Introduction to optimization: definitions, classification, overview of

topicsIntroduction to numerical linear algebra

Single variable optimization algorithms – optimality criteria, bracketing methods, region elimination methods, point estimation methods, gradient based methods, root finding using optimization techniques.

Multivariable optimization algorithms – optimality criteria, direct search methods, gradient based methods.

Constrained optimization algorithms – Kuhn-Tucker conditions, transformation methods, direct searchmethods.

Specialised algorithms – integer programming, Geometric programming

Introduction to Genetic algorithms, particle swam optimization, fire-fly algorithms and others.

Text/Reference Books:

1. Engineering Optimization: Theory and Practice, Singiresu S. Rao, Willey
2. Optimization of Engineering Design: Algorithms and Examples, Kalyanmay Deb, PHI.
3. Engineering Optimization-Methods and Applications, A. Ravindran, G.V. Reiklaitis and M. Rangsdell, Wiley.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand the basic concept and overview of optimization.

CO- 2 compare various existing optimization tools and algorithms particularly for problems in structural dynamics.

CO- 3 formulate the problem and apply specific optimization tools/techniques related to the problem.

CODE	Finite Element Methods	L	T	P	C
CE 5313	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective III)	**3**	**0**	**0**	**3**

Introduction to finite element model: Brief history, Introduction to matrix notation, Introduction to Matlab, General steps of the finite element method, Applications.

Some basic concepts of engineering analysis and introduction to the finite element method:

Solution of discrete system mathematical models- steady state problem, propagation problem, eigenvalue problem.

Solution of Continuous-system mathematical models – differential formulation, variational formulations, weighted residual methods, Finite difference differential and energy methods.

Introduction to stiffness method: Definition of stiffness matrix, derivation of stiffness matrix of a spring, assembly of stiffness matrices, boundary conditions, Potential energy approach.

Introduction to truss problems: Derivation of stiffness matrix of a truss element in local coordinates and global coordinates, Formulation of force equation, Solution of a plane truss, solution in Matlab, ANSYS.

Solution of beam and frame problems: Beam stiffness, distributed load, examples,Two dimensional arbitrarily oriented beam element, Rigid plane frame, examples, solution in Matlab, ANSYS.

Plane stress and plane strain problems: Basic concepts, derivation of linear strain triangular element, examples, rectangular plane stress element, isoparametric formulations, numerical integration, stiffness matrix and stress matrix by Gaussian quadrature, higher order shape functions, solution in Matlab, ANSYS.

Axisymmetric problems: Derivation of stiffness matrix, axisymmetric pressure vessels, applications.

Three dimensional stress analysis: Three dimensional stress and strain, tetrahedral element, isoparametric formulation, examples.

Plate bending elements: Basic concepts, derivation of plate bending element stiffness matrix,examples.

Heat transfer problems: Derivation of basic differential equation, one dimensional problem, two dimensional problem.

Fluid flow problems: Derivation of basic differential equation, one dimensional problem, twodimensional problem

Structural dynamics: Dynamic of spring-mass system, eigenvalue and eigenvector problems, Solutionin MATLAB, ANSYS

Text Books/References:

Sl	Name of the Book	Authors
1	A First Course in The Finite Element Method	Daryl L. Logan and Martin Logan
2	An Introduction to the Finite Element Method	J. N. Reddy
3	Concept and Application of Finite Element Analysis	R.D. Cook, D. S. Malkus and M.E. Plesha

4	The Finite Element Method – Linear Static and Dynamic Finite Element Analysis	T. J. R. Hughes
5	Finite Element Procedures	K. J. Bathe
6	Finite Element Methods	K. J. Bathe and E. L. Wilson
7	Finite Element Methods in Engineering	O. C. Zeinkiewicz

Course Outcomes: At the end of the course, student will be able to:

CO- 1 apply the knowledge to discretize any continuum body into finite elements.

CO- 2 apply the knowledge for determining stress and strain at a given nodal point of a structure.

CO- 3 obtain deformed shape of a structure under static and dynamic conditions.

CO- 4 apply the knowledge to critically assess the working principle of any structural analysis software.

CO- 5 apply the knowledge to solve non-structural problems.

ELECTIVE- IV

CODE	Random Vibration	L	T	P	C
CE 5261	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective IV)	3	0	0	3

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.

Stochastic process, counting process, random walk, Marcov chain, Gaussain process, filtered point process, marcov process and non-stationary Gaussian process. Stochastic continuity and differentiation, integral, time average, erodicity, correlation and power spectrum. Threshold crossing,peak, envelope distribution and first passage problem.Random vibration system,s, single degree and multi-degree of freedom system, contneous system andnonlinear system-equivalent linearization and Gaussian closure technique.

Text Books/References:

Sl	Name of the Book	Authors	Publishers
1	Probabilistic theory of structural dynamics	Lin,Y.K (1967)	McGraw Hill, NY
2	Probabilistic structural dynamics advanced theory and application	Lin,Y.K. and G.Q Cal. (1995)	McGraw Hill, NY
3	Introduction to random vibration	Nigam, N.C. (1983)	MIT Press
4	Random Vibration	Wirsching, P.H.Paez, T.L. and H. Ortiza	John Wiley & Sons, NY

Course Outcomes: After the completion of the course, students will be able to

CO-1 gather the understanding of the principles of vibrations along with uncertainty.

CO-2 analyse SDOF and MDOF systems under dynamic loading and obtain the response of the systems.

CO-3 apply the knowledge of theory of vibration in solving real life dynamic problems.

CO-4 apply creative thinking in dynamics and acquire inspiration for lifelong learning.

CODE	Structural Response Control for Seismic Protection	L	T	P	C
CE 5262	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective IV)	3	0	0	3

Introduction to response control of structure, Historical development of structural response control systems and base isolation techniques, Methods of structural response control.

Vibration Control by Structural Design: Damping Models and Measures, Origin of Structural Damping, Damping-Stress Relationship, Selection Criteria for Linear Hysteretic Materials, CombinedFatigue-Strength Damping Criteria, Design for Enhanced Material Damping

Isolation System: 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

Isolation Devices: Laminated rubber bearing, lead rubber bearing, high damping rubber bearing, friction pendulum system; Modelling of isolation bearings; Design process for multilayered elastomeric bearings and buckling behaviour of elastomeric bearings.

Energy Dissipation Devices: General requirements, Implementation of energy dissipation devices, tuned mass dampers, tuned liquid dampers, Shape memory alloy dampers, Modelling, linear and nonlinear procedures, Application to buildings.

Active Vibration Control under seismic condition: Introduction to Closed Loop Control, Classical Control System, Piezoelectric Sensors and Actuators, Vibration Control of Flexible Beam, Energy Harvesting System

Text Books/References:

Sl	Name of the Book	Authors
1	An introduction to seismic isolation	IR Hkinner, WH Robinson & KH Mcberry
2	Earthquake resistant design with rubber	JM Kelly
3	Mechanical Vibrations	J.P Den Hartog
4	Seismic analysis of structures	T. K. Datta
5	Passive and active structural vibration control in civil engineering	T. T Soong, & M. C. Costantinou
6	Vibration control of active structure: An introduction	A. Preumont

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand concepts and theory of seismic response control of structure.

CO- 2 learn the numerical formulation for different vibration control techniques.

CODE	Dynamics of Soils and Foundations	L	T	P	C
CE 5111	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective IV)	3	0	0	3

Introduction: Importance of soil dynamics; Nature and types of dynamic loading; Static and dynamic system; Dynamic properties of geo-materials.

Vibration theory: Vibration of elementary systems; Degrees of freedom (SDOF and MDOF systems); Equationof motion for SDOF system; Types of vibrations; Transient vibration; Analysis of earthquake and blast load; Undamped and damped free vibrations; Critical damping; Decay of motion;

Undamped and damped forced vibration; Constant force and rotating mass oscillators; Dynamic magnificationfactor; Transmissibility ratio; Vibration isolation; Vibration measuring instruments.

Dynamic soil properties: Stresses in soil element; Determination of dynamic soil properties; Field tests; Laboratory tests; Model tests; Stress-strain behaviour of cyclically loaded soils; Estimation of shear modulus; Modulus reduction curve; Damping ratio.

Liquefaction: Types and estimation of liquefaction; Effect of liquefaction, Simplified procedure for liquefactionestimation; Factor of safety; Cyclic stress ratio; Cyclic resistance ratio.

Machine foundations: Types of machines; Basic design criteria; Methods of analysis; Mass-Spring-Dashpot model; Elastic-Half-Space theory; Types of foundations; Modes of vibrations; Vertical, sliding, torsional and rocking modes of oscillations; Design guidelines as per codes; Typical design problems.

Interaction of soils and foundations under dynamic loading: Dynamic earth pressures; Force and displacement based analysis; Pseudo-static and Pseudo- dynamic analysis; Guidelines of various design codes; Dynamic analyses of various geotechnical structures using MSD model.

Text Books/References:

Sl	Name of the Book	Authors
1	Soil Dynamics	Sahmsher Prakash
2	Fundamentals of Soil Dynamics	B. M. Das
3	Foundation Analysis and Design	J.E. Bowles
4	Dynamics of Bases and Foundations	D. D. Barkan
5	Soil Dynamics and Machine Foundations	Swami Saran
6	Dynamics of Structure and Foundation	Chowdhury and Dasgupta

Course Outcomes: At the end of the course, student will be able to:

CO- 1 develop basic knowledge about theory of vibration and dynamic behavior of soil.

CO- 2 analyze different types of vibration isolation system and vibration measuring instruments.

CO- 3 identify liquefaction susceptibility of a site and estimate the factor of safety against liquefaction.

CO- 4 analyze and design the suitable foundation system for different structures subjected to different types of dynamic loading.

CO- 5 analyze earth pressure under dynamic conditions and dynamic analyses of various geotechnical structures using MSD model.

CODE	Earthquake Resistant Design of Foundations	L	T	P	C
CE 5153	M. Tech. (Structural Dynamics and Earthquake Engineering), Second Semester (Elective IV)	3	0	0	3

Introduction: General requirements; types of dynamic loads; types of shallow and deep foundations and their use; performance of various types of foundations during past earthquakes.

Shallow Foundations: Safe bearing capacity under earthquake loads, differential & total settlements. Modulus of subgrade reaction, Winkler model, beam on elastic foundation. Dynamic Bearing Capacity under Transient and Earthquake Loads; requirements to account for settlements due to earthquake induced forces; Pseudo-Static analysis of foundation with eccentric & inclined loads. Effect of horizontal load and moment. Dynamic analysis of shallow foundations for various modes of vibrations.

Pile Foundations: Laterally loaded piles, elastic analysis; Reese and Matlock approach; Soil-pile analysis with spring-mass & FEM idealization, elements for slip and separation, soil-pile interaction, IS code of practice for design of pile foundations, piles through liquefiable soils.

Well Foundations & Caissons: Pseudo-static analysis with earthquake induced loads, Lateral load resistance of well foundation; Terzaghi's approach; IRC, IS and Indian Railway Codes.

SSI for Deep Foundations: Soil-Structure Interaction, Modelling of Unbounded Soil Media for Dynamic Loads, Free Field Motion, Kinematic Interaction and Inertial Interaction.

Books and references:

1. Soil Dynamics by S. Prakash, McGraw-Hill Company, New York.
2. Geo technical-Earthquake Engineering by S. L. Kramer, Pearson Education Pvt. Ltd., Singapore.
3. Foundation Analysis and Design by J. E. Bowles, McGraw Hill International Editions, Singapore.
4. Pile foundation: Analysis and Design by Poulos and Davis
5. Soil Dynamics & Machine Foundation by Swami Saran, Galgotia Pub. Pvt. Ltd, New Delhi.
6. Geotechnical Earthquake Engineering Handbook by Robert W. Day, McGraw Hill

Course outcome:

CO1: analyze and solve problems on shallow foundations subjected to dynamic loads

CO2: analyze the effect of dynamic loads on pile foundations and solve related problems

CO3: evaluate the stability of well foundations subjected to the earthquake loads

CO4: evaluate the effect of soil-pile interaction under earthquake loads

Department of Civil Engineering

Curriculum and Syllabi for M. Tech. in Structural Engineering (SE)

With effect from 2019 entry batch

PO Statements:

PO-1: An ability to independently carry out research / investigation and development work to solve practical problems.

PO-2: An ability to write and present a substantial technical report/document.

PO-3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements inthe appropriate bachelor program.

PO-4: Program graduates will gain knowledge and skill in integrating Structural engineering conceptsacross multiple disciplines.

PO-5: Program graduates will develop understanding on project in Structural Engineering with ethicalvalue towards social, environmental and economic development / sustainability.

PO-6: Graduates will develop interest to pursue higher studies and lifelong learning.

Course Structure

Semester I

S. N.	Code	Subject	L	T	P	Credits
1.	CE 5301	Structural Dynamics	3	1	0	4
2.	CE 5302	Continuum Mechanics	3	0	0	3
3.	CE 5303	Advanced Structural Analysis	3	0	0	3
4.	CE 5304	Structural and Concrete Lab	0	0	3	2
5.	CE xxxx	Elective I	3	0	0	3
6.	CE xxxx	Elective II	3	0	0	3
		Total contact hours/credits	**15**	**1**	**3**	**18**

Semester II

S. N.	Code	Subject	L	T	P	Credits
1.	CE 5311	Advanced Concrete Design	3	1	0	4
2.	CE 5312	Advanced Steel Design	3	0	0	3
3.	CE 5313	Finite Element Methods	3	0	0	3
4.	CE 5314	Seminar	0	0	3	2
5.	CE xxxx	Elective III	3	0	0	3
6.	CE xxxx	Elective IV	3	0	0	3
		Total contact hours/credits	**15**	**1**	**3**	**18**

Semester III

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 6398	Project Phase I	0	0	0	6
			Total Credit			**6**

Semester IV

Sl. No.	Code	Subject	L	T	P	Credits
1	CE 6399	Project Phase II	-	-	-	8
		Total contact hours/Credits	-	-	-	**8**

Elective I

S. N.	Code	Subject	L	T	P	Credits
1.	CE-5331	Theory of Stability of Structures	3	0	0	3
2.	CE-5332	Numerical Methods in Structural Engineering	3	0	0	3
3.	CE-5333	Reliability Analysis of Structures	3	0	0	3

Elective II

S. N.	Code	Subject	L	T	P	Credits
1.	CE-5341	Theory of Plates and Shells	3	0	0	3
2.	CE-5342	Construction Management	3	0	0	3
3.	CE-5343	Design of Masonry Structures	3	0	0	3
4.	CE-5344	Advanced Concrete Technology	3	0	0	3

Elective III

S. N.	Code	Subjects	L	T	P	Credits
1.	CE-5351	Structural Optimization	3	0	0	3
2.	CE-5352	Advanced Bridge Engineering	3	0	0	3
3.	CE-5211	Earthquake Resistant Design of Structures	3	0	0	3
4.	CE-5212	Seismic Hazard, Vulnerability and Risk Analysis and Retrofitting	3	0	0	3

Elective IV

S. N.	Code	Subject	L	T	P	Credits
1.	CE-5361	Composite Materials and Structures	3	0	0	3
2.	CE-5362	Design of Pre-Stressed Concrete Structures	3	0	0	3
3.	CE-5363	Modal Analysis Theory and Testing	3	0	0	3
4.	CE-5364	Vibration Control Techniques	3	0	0	3
5.	CE-5365	Structural Health Monitoring	3	0	0	3

DETAILED SYLLABI

Semester - I

CODE	Structural Dynamics	L	T	P	C
CE 5301	M.Tech. (Structural Engineering), 1stSem (Core)	3	1	0	4

Sources of Structural vibrations; Meaning and types of excitations; spring action, spring in series and parallel. D'Alembert's Principle.

Free vibrations of undamped and viscously damped SDOF systems; logarithmic decrement and its applications; Coulomb damping, material damping and radiation damping.

Response to harmonic excitations – Duhamel's integral. Vibration isolation-and vibration absorption, Force transmissibility and base motion; Equivalent viscous damping and structural damping.

MDOF systems: Vibrations of undamped 2 DOF systems; Free vibrations of MDOF systems, methods of solving eigenvalue problems; Characteristic equation method and other methods.

Modal analyses of MDOF systems: mode superposition method.

Vibrations of Continuous systems: Free vibrations of continuous systems-axial transverse vibrations of beams. Numerical schemes for obtaining frequencies and mode shapes.

Concept of Response spectrum and its applications.

Nonlinear Systems: material and geometric nonlinearity; Seismic Response of Nonlinear Systems: Earthquake analysis of multi-storey building frames – time step analysis.

Dynamic origin of Earthquake code provisions.

Texts/References:

1. Chopra, A. K, Dynamics of structures,Prentice Hall of India.
2. Clough, R. W., &Penzien, J., Dynamics of structures, McGraw Hill.
3. Humar, J. L., Dynamics of Structures, Prentice-Hall.
4. Paz, M., Structural dynamics: theory and computation, CBS Publishers, Delhi.
5. Timoshenko, S. P., & Young, D. H., Advanced dynamics. McGraw Hill
6. Meirovitch, L., Elements of vibration analysis, McGraw-Hill.
7. Biggs, J. M., &Testa, B., Introduction to structural dynamics.
8. Craig, R. R., &Kurdila, A. J., Fundamentals of structural dynamics, John Wiley & Sons.
9. Filiatrault, A., Elements of earthquake engineering and structural dynamics, Presses interPolytechnique.
10. Buchholdt, H. A., Structural dynamics for engineers, Thomas Telford.
11. Paultre, P., Dynamics of structures, John Wiley & Sons.
12. T. K. Datta, Seismic Analysis of Structures, John Wiley & Sons (Asia)

Course Outcomes: At the end of the course, student will be able to:CO-1 understand the effect of vibration on structures.
CO-2 analyze SDOF and MDOF structures under various dynamic loadings and obtain the responses.CO-3 understand the effect of nonlinearity in structural response.
CO- 4 conceptualize the importance of structural dynamics in design code provisions.

CODE	Continuum Mechanics	L	T	P	C
CE 5302	M.Tech. (Structural Engineering), 1st Sem (Core)	3	0	0	3

Force and deformation: Body force, surface traction, point force, conservation of linear momentum, conservation of angular momentum, Saint-Venant principle

Stress at a point: Cauchy stress, equilibrium of stresses, symmetry of stress tensor, transformationof stress tensor, hydrostatic stress and deviatoric components of stress tensor, Principal stress and principal plane

Strain at a point: Displacement at a point (Lagrangian approach and Eulerian approach), deformation gradient, various types of strain measurement, Green Lagrange strain tensor, compatibility conditions, transformation of strain tensor

Energy of deformation: Kinetic energy of solid body, first law of thermodynamics, strain energy,strain energy density function, energy conjugate pairs (Stress tensor/Strain tensor)

Constitutive modelling: Different types of material behaviour, effect of loading-rate / temperature / cyclic-loading on material behaviour, hyperelastic material, material symmetry, evaluation of engineering elastic constants of isotropic and orthotropic linear elastic material

Boundary value problem: Introduction to boundary value problem in linear elasticity, displacement formulation (Navier equations), force formulation.

Rod/Bar:description of deformation in rod/bar, stress resultants for rod/bar, equilibrium equation of rod/bar in terms of stress resultant, formulation for extension ofrod/bar

Bending of beam: Euler-Bernoulli's beam theory, Timoshenko's beam theory, evaluation of stressresultants for bending, equilibrium equations, Zhuravskii shear stress, bending of arbitrary cross- section, stress resultants and equilibrium equations in biaxial bending, shear centre

Torsion of shaft: Engineering theory of torsion of circular shaft/bar, evaluation of stress resultant and equilibrium equations, torsion of non-circular prismatic shaft/bar, warping, stress resultant and equilibrium equations in torsion of non-circular section, torsion of elliptic prismatic bar, torsion ofthin-walled shaft/bar.

Plane stress and plain strain: Introduction to the plane stress and the plain strain problemsin linearelasticity,evaluation of constitutive relationship for the plane stress problem for isotropic and orthotropic materials, evaluation of constitutive relationship for the plane strain problem for isotropic and orthotropic materials, compatibility equations

Energy methods in solid mechanics: Castigliano's theorem, principle of stationary total potential,principle of virtual work (virtual displacement), principle of virtual work (virtual force) and unit load method, Hamilton's principle.

Failure criteria: Yield criteria for ideally plastic material, Von Mises yield criteria, Tresca yield criteria, Mohr-coulomb yield criteria, Drucker-Prager yield criteria

Introduction to nonlinear problems in mechanics: Introduction to various problems in solid mechanics based on material nonlinearity, geometric nonlinearity and boundary nonlinearity

Texts/References:

1. Y.C. Fung, Foundations of Solid Mechanics, Prentice Hall.
2. I.S. Sokolnikoff, Mathematical Theory of Elasticity, Prentice Hall.

3. C.T. Wang, Applied Elasticity, McGraw-Hill Book Company.
4. J.N. Reddy, Principles of Continuum Mechanics, Cambridge University Press, 2010.
5. S.P. Timoshenko, J.N. Goodier, Theory of Elasticity, 3rd Edition, McGraw Hill Publishing Co.1970.
6. L.S. Srinath, Advanced Mechanics of Solids, 2nd Ed., TMH Publishing Co. Ltd., New Delhi,2003.
7. D. S. Chandrasekharaiah, L. Debnath, Continuum Mechanics, Academic Press, 1994.
8. A.K. Singh, Mechanics of Solids, PHI publication, 2007

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand the fundamental theories of continuum mechanics like: Force and deformation, Stress at a point, Strain at a point, Constitutive modeling, Plane stress and plain strain, Energyof deformation.

CO- 2 develop the understanding of applying fundamental theories of continuum mechanics in termsof: Boundary value problem, axial deformation of bar, Bending of beam, Torsion of circular and non-circular bar.

CO- 3 understand the principles of energy methods in solid mechanics.CO- 4 develop the understanding on Failure criteria.

CO- 5 understand various nonlinear problems in mechanics.

CODE	Advanced Structural Analysis	L	T	P	C
CE 5303	M.Tech. (Structural Engineering), 1st Sem (Core)	3	0	0	3

Introduction of Matrix Method of Structural Analysis: Static and kinematics indeterminacy of structures; Fundamentals of Flexibility and Stiffness method; Basic examples of application of Flexibility and Stiffness Method.

Direct Stiffness Matrix Method: Derivation of local stiffness matrices for prismatic and non-prismatic members, transformation matrices and global stiffness matrices, assembling, compatibility equation. Application of Matrix Displacement Method to plane truss, space truss, beams, grids, plane frames and space frames subjected to various loadings including effects of temperature change and support displacements, Applications of software in structural analysis.

Introduction to Finite Element Method: Introduction to principles of Finite Element Method and its application using two/three nodded bar element, beam element, three/four nodded plane elements.

Special Structure: Beam on elastic foundation.

Introduction to nonlinear structural analysis: Material and geometric nonlinear problems, incremental and iterative procedures, Convergence criteria, P-Δ effect, buckling of frames.

Text Books/References:

1. Weaver, W. and Gere J., Matrix Analysis of Framed Structures, CBS Publishers & Distributors,Delhi.
2. Kenneth M. Leet, Chia-Ming Uang, Fundamentals of Structural Analysis, McGraw-Hill BookCompany.
3. Nicholas Willems and W.M. Lucas, Structural Analysis for Engineers, McGraw Hill Ltd.
4. Weaver, Jr. and James M. Gere, Matrix Analysis of Framed Structures, Van Nostran Reinhold /CBS.
5. Harry H. West and Louis F. Geschwinder, Fundamentals of Structural Analysis, , John Wiley andSons.
6. R.R. Craig, Matrix Analysis of Structures, Cole Publishing Company.
7. McGuire, H.G. and Ziemian, R.D., Matrix Structural Analysis, John Wiley.
8. Wang, C.K., Intermediate Structural Analysis, McGraw-Hill.
9. Ghali, A. and Neville, A.., Structural Analysis, E & FN Spon, Taylor Francis.
10. Leet, K.M. and Uang C., Fundamentals of Structural Analysis, Tata McGraw Hiil.
11. Hibbler R.C., Structural Analysis, Pearson Education, Asia.
12. Rajasekharan, S. and Sankarasubramanian, G., Computationsl Structural Mechanics, PHI, NewDelhi.
13. Robert D. Cook, David S. Malkus, Michael E. Plesha, Robert J. Witt, Concepts and Applicationsof Finite Element Analysis, John Wiley & Sons.
14. P SESHU, TEXTBOOK OF FINITE ELEMENT ANALYSIS, PHI.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 develop the comprehensive understanding on matrix methods of structural analysis.
CO- 2 develop the understanding on fundamental principles of Finite Element Method.
CO- 3 extend the analysis skill for special structure.
CO- 4 develop the understanding on non-linear analysis of structures.
CO- 5 do structural analysis using computer software.

CODE	Structural and Concrete Lab	L	T	P	C
CE 5304	M.Tech. (Structural Engineering), 1st Sem (Core)	0	0	3	2

Basic Tests on cement, basic tests on
aggregatesEvaluation of Young's Modulus
of Concrete
Evaluation of modulus of rupture through prism test and split tensile
test.Normal Concrete Mix Design & casting elements
High Strength Concrete Mix Design & casting elements for strength
studies Self-Compacting Concrete Mix Design & casting elements for
strength studiesGeopolymer Concrete Mix Design & casting elements for
strength studies Non-Destructive testing of concrete
Determining strength of concrete elements after retrofitting with new concrete
materials.Flexural fatigue test on RC Beam member
Cyclic loading test on beam – column joint.

Text Books/References:

1. Neville, A.M., Properties of Concrete, *The English Language ook Society and PitmanPublishing.*
2. Raju, N. Krishna, Design of Concrete Mixes, *CBS Publishers and Distributor, Delhi*.
3. Santhakumar, A.R., Concrete Technology, *Oxford University Press*.
4. Neville AM. And Brooks J.J., Concrete Technology, *Addison Wesley*.
5. A.I.Laskar, Concrete Technology Practices ,*Alpha Science Intl Ltd, India*

Course Outcomes: At the end of the course, student will be
able to:CO- 1 conduct Quality Control tests on concrete making
materials.
CO- 2 conduct Quality Control tests on fresh & hardened
concrete.CO- 3 design and test concrete mixes with different
codes.
CO- 4 conduct Non-destructive tests on concrete.

ELECTIVE - I

CODE	Theory of Stability of Structures	L	T	P	C
CE 5331	M.Tech. (Structural Engineering), 1stSem (Elective-I)	3	0	0	3

Basic Concepts: Concept of stability, Structural instability and bifurcation, Basic approaches to stability analysis.

Discrete Systems: Law of minimum potential energy, Concept of dynamics and energy criteria; Stability of single and multi-degrees of freedom systems, large deflection analysis.

Columns: Governing differential equation and boundary conditions; End-restrained columns; Effect of imperfection; Eccentrically loaded columns; Large deflection solution of elastic columns.

Beam-Columns and Frames: Behavior of beam-columns; continuous columns and beam-columns, single-storey frames, frames with sway and no-sway, buckling analysis using stiffness and flexibility method.

Approximate Methods: Solution of boundary value problems; Rayleigh-Ritz Method; Method of weighted residuals; Eigenvalue problems; Numerical solution of elastically supported columns.

Stability of Plates: Governing differential equation for rectangular plates, Thin plates with all edges simply supported, plates with other boundary conditions, Plates under uniform and sinusoidal loading conditions; buckling under in-plane shear, post buckling analysis.

Buckling: Buckling snap through and post-buckling; Inelastic buckling; Torsional buckling, torsional-flexural buckling, lateral-torsional buckling of symmetric cross-sections.

Text Books/References:

6. W. F. Chen and E. M. Lui (1987), Structural Stability: Theory and implementation, Prentice-Hall.
7. T. V. Galambos and A. E. Surovek (2008), Structural Stability of Steel: Concepts and applications for structural engineers, Wiley.
8. S. P. Timoshenko and J. M. Gere (1961), Theory of Elastic Stability, McGraw-Hill.
9. J.M.T. Thompson and G.W. Hunt (1973), A general theory of elastic stability, Wiley
10. Z.P. Bazant and L. Cedolin (1991), Stability of structures, Dover

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand the concept of structural stability and nonlinear structural behavior.CO- 2 determine and interpret the buckling loads for simple columns and frames.
CO- 3 analyze basic structural components and systems that are susceptible to instability. CO- 4 design and evaluate advanced numerical techniques to bucking analysis of structures.

CODE	Numerical Methods in Structural Engineering	L	T	P	C
CE 5332	M.Tech. (Structural Engineering), 1st Sem (Elective-I)	3	0	0	3

Introduction to Numerical Methods, error in numerical solutions, Order of accuracy

Direct Solution of Linear systems- Gauss elimination, Gauss Jordan elimination, Pivoting, inaccuracies due to pivoting, Factorization, Cholesky decomposition, Diagonal dominance, condition number, ill conditioned matrices, singularity and singular value decomposition. Banded matrices, storage schemes for banded matrices, skyline solver.

Iterative solution of Linear systems- Jacobi iteration, Gauss Seidel iteration, Convergence criteria. Programs

Direct Solution of Non Linear systems- Newton Raphson iterations to find roots of a 1D nonlinear equation, Newton Iterations, Quasi Newton iterations.Programs.

Properties of Eigenvalues and Eigenvectors, Diagonalization and Numerical techniques to compute eigenvalues - Vector Iteration, QR algorithm, Jacobi Method. Programs

Numerical integration- Introduction, Newton – Cotes formulas, Adaptive Integration, Gaussian quadrature

Numerical differentiation- Equally Spaced Data, Taylor Series Approach, Difference Formula, Error Estimation, Programs

Partial differential equations; Elliptic, parabolic and hyperbolic PDEs.

Numerical Solution of Boundary Value Problems - Finite Difference Method, Explicit and Implicit Approaches; Method of Weighted Residuals, Galerkin’s Method.

Text Books/References:

1. J. B. Scarborough, Numerical Mathematical Analysis, Oxford & IBH Publishing Co. Pvt.
2. Ltd., 2000.
3. K. K. Jain, S. R. K Iyengar and R. K. Jain, Numerical Methods - Problem and Solutions,
4. Wiley India Pvt. Ltd, 2001.
5. R.W. Hamming, Numerical Methods for Scientist and Engineers, McGraw Hill, 1998.
6. J. H. Mathews and K.D. Fink, Numerical Methods using MATLAB, Pearson

Education,7. 2004.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 formulate structural problems using numerical methods applied to tural system.CO- 2 carry out numerical simulations of many structural engineering problems.

CO- 3 relate different aspects of the structural engineering aspects in order to have a global picture ofthe behavior of a given problem.

CO- 4 develop program for solve particular problems in structural systems.

CODE	Reliability Analysis of Structures	L	T	P	C
CE 5333	M.Tech. (Structural Engineering), 1stSem (Elective-I)	3	0	0	3

Introduction: Overview, Objectives of this course, Deterministic vs. Probabilistic Models, Uncertainties in Engineering Systems

Probability Theory: Sample Space and Random Events, Random Variables and their Functions, Set Theory, Axioms of Probability, Conditional Probability, Total Probability Theorem, Bayes' Theorem, Bayesian Inference

Basic Structural Reliability Methods: Concept of Safety, Failure Surface and Limit State Function, Component Reliability, Probability of Failure and Reliability Index, First Order Second Moment Methods (FOSM), Advanced First Order Second Moment Methods (AFOSM)

Probabilistic Simulation Methods: Monte Carlo Methods, Generation of Random Numbers, Variance Reduction Techniques, Stratified and Latin Hypercube Sampling, Importance Sampling, 2K+1 Point Estimate Method

Advanced Reliability Methods: Second Order Reliability Method, Response Surface Method, Adaptive Sampling Method, Sensitivity Analysis, Random Process, Time-varying Reliability

Reliability-Based Design: Development of Design Codes, Load and Resistance Factor Design, Target Safety Levels, Calibration of Safety Factors

Structural System Reliability: Components and Systems, Series, Parallel and Hybrid Systems, System Reliability Bounds, Systems with Correlated Components, Reliability of systems for Normal and Non-Normal Random Variables, System Reliability Computation: Probabilistic Graphical Models, Bayesian Networks

Concepts of Structural Risk Analysis: Basic Definition of Risk, Relation between Reliability and Risk, Application of Reliability and Risk Principles to Structural Engineering Field

Computational Lab Component: Software/Programming Language, Coding in MATLAB/Python

Text Books/References:

1. Ang, A. H-S., Tang, W. H. (2007). *Probability Concepts in Engineering*. Second Edition. JohnWiley & Sons, Inc.
2. Nowak, A. S., Collins, K. R. (2013). *Reliability of Structures*. Second Edition. CRC Press.
3. Haldar, A., Mahadevan, S. (2000). *Probability, Reliability and Statistical Methods in EngineeringDesign*. Second Edition. John Wiley & Sons, Inc.
4. Ranganathan, R. (2006). *Structural Reliability: Analysis and Design*. Second Edition. Jaico Publishing House, India.
5. Melchers, R. E. (2002). *Structural Reliability Analysis and Predictions*. Second Edition. JohnWiley & Sons, Inc.
6. Pratap, R. (2010). *Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers*. South Asia Edition. Oxford University Press.
7. Martelli, A., Ravenscroft, A., Holden, S. (2017). *Python in a Nutshell*. Third Edition. O'ReillyMedia.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 review, understand, define and express safety, reliability & risk for structural engineering problems

CO- 2 interpret algorithm and implement computer codes for probabilistic simulations and basic and advanced structural reliability methods

CO- 3 analyze the reliability of structural components and systems

CO- 4 design/evaluate practical reliability and risk problems for structural engineering systems

ELECTIVE - II

CODE	Theory of Plates and Shells	L	T	P	C
CE 5341	M.Tech. (Structural Engineering), 1stSem (Elective-II)	3	0	0	3

Introduction to Elastic Plates: Review of Concepts of Elasticity, Classical Plate Theory: Basic Assumptions, Formulations, Boundary Conditions, Governing Equations

Bending of Plates: Pure Bending, Plates with Various Loadings and Boundary Conditions, Navier's Solution for Rectangular Plates, Levy's Solution

Solutions by Numerical Methods: Potential Energy Minimization, Energy Principles and Rayleigh-Ritz Methods, Numerical Integration Method, Finite Element Analysis of Plates

Refined Plate Theories: Large Deflections of Plates, Plates with Shear Deformation, Higher Order Plate Bending Theory, Thermal Stresses in Plates

Introduction to Elastic Shells: Basics of Differential Geometry, Space Curves, Surfaces, Theory ofSurfaces, Coordinates Systems

Thin Elastic Shell Analysis: Different Shell Forms, Basic Assumptions, Strain-Displacement Relations, Love Shell Theory, Axisymmetric Shells And Cylindrical Shells, Membrane Theory of Shells, Solution of Cylindrical Shells.

Text Books/References:

1. Timoshenko, S. P. and Krieger, S. W., "Theory of Plates and Shells", McGrawHill.
2. Szilard, R.,"Theory and Analysis of Plates: Classical and Numerical Methods",Prentice Hall, New York.
3. Gould, P. L., "Analysis of Shells and Plates", Springer-Verlag
4. Bairagi, N. K., "Shell Analysis", Khanna Publishers, New Delhi.
5. Timishenko, S.P. and Goodier, J. N., "Theory of Elasticity", McGraw-Hill.

Course Outcomes: At the end of the course, student will be

able to:CO- 1 understand the action of plates and shells in

structures

CO- 2 articulate plate/shell problems and determine the component
responses CO- 3 analyze plate and shell structures using analytical and
numerical methods
CO- 4 evaluate the elastic plate/shell theories and design structural engineering systems

CODE	Construction Management	L	T	P	C
CE 5342	M.Tech. (Structural Engineering), 1st Sem (Elective-II)	3	0	0	3

Introduction: Phase of project, project management and its relevance, stake holders of a project,structure of project organization, management levels, and traits of a project manager.

Construction Planning: Introduction, activities involved types of project plan, work breakdownstructure. Planning terminologies, Critical path method, forward and backward pass, PERT, Ladder network, Precedence network, Line of balance.

Project scheduling and resource leveling: Introduction, Resource allocation and leveling for unlimited resources, Resource allocation for limited resources, Multi resource allocation, Optimalscheduling.

Contracts Estimation and Bidding Strategy: Introduction, Determination of bid price, Biddingmodels such as EPC, Turnkey etc.

Project Monitoring and Control: Introduction, Project updating, Cost control.

Construction Management: Construction Equipment and Management, Construction Account Management, Construction Material management, Construction Quality Management, Construction Safety Management, Computer Application In Construction Management,Workforce Motivation And Human Factors In Construction Management, Plant Management, Project Communication

Text Books/References:

1. Callahan, M. T., Quackenbush, D. G., and Rowings, J. E., Construction Project Scheduling,McGraw-Hill, New York, 1992.
2. Cleland, D. I. and Ireland, L. R., Project Management: Strategic Design and Implementation 4thEdition, McGraw-Hill, New York, 2002.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 prepare work break down plan and estimate resources requirements.
CO- 2 solve problems of resource allocation and levelling using network diagrams.
CO- 3 plan and develop management solutions to construction projects.
CO- 4 understand the principles of project management, resource management and inventory.

CODE	Design of Masonry Structures	L	T	P	C
CE 5343	M.Tech. (Structural Engineering), 1st Sem (Elective-II)	3	0	0	3

Earthen building: Typical damage and collapse of earthen building, material properties, recommendation for seismic areas, Seismic strengthening and desirable features.
Stone building: Typical damage and failure of stone building, structure properties, general construction aspects, general recommendations for seismic areas.
Material Properties, Masonry units: clay and concrete blocks, Mortar, grout and reinforcement,Bonding patterns, shrinkage and differential movements.
Masonry in compression, Prism strength, Eccentric loading, Kem distance.
Masonry under lateral loads, in-plane and out-of-plane loads, Analysis of perforated shear walls, Lateral force distribution for flexible and rigid diaphragms.
Behavior of masonry members, Shear and flexure, Combined bending and axial loads, ReinforcedVs. unreinforced masonry, Cyclic loading, Ductility of masonry shear walls for seismic design, Infill masonry.
Structural design of masonry, working and Ultimate strength design, in-plane and out-of-plane design criteria for infills, connecting elements and ties, Consideration of seismic loads, Codal provisions.
Evaluation and existing structures, In-situ and non-destructive tests for masonry properties. Repairand strengthening of existing masonry structure for seismic loads.
Construction practices and new materials.

Text Books/References:

1. Drysdale, R.G. Hamid, A.H. and Baker, L.R., Masonry Structure: Behavior Design, *Prentice Hall.*
2. Hendry A.W., Structural Masonry, *Macmillan International*.
3. Hendry A.W., Sinha B.P. and Davis S.R., Design of Masonry Structures, *E & FN Spon, Madras*.
4. Paulay, T. and Priestley, M.J.N., Seismic Design of Reinforced Concrete and Masonry Building,*John Wiley and sons.*
5. Wakabayshi, M., Design of Earthquake resistant Buildings, *McGraw Hill*

Course Outcomes: At the end of the course, student will be able to:

CO- 1 learn about properties of masonry and behaviour of masonry structures, earthen structures.CO- 2 identify the types of failures of masonry structures.
CO- 3 analyze and design masonry structures.CO- 4 evaluate existing masonry structures.

CODE	Advanced Concrete Technology	L	T	P	C
CE 5344	M.Tech. (Structural Engineering), 1st Sem (Elective-II)	3	0	0	3

Concrete Science
Standards – specifications – Ingredients - cement and its types – Coarse Aggregate – Fine Aggregate.
Chemical admixtures - Mineral admixtures - Polymer concrete -
Mix design - Mix Design by IS:10262-2019 - Mix Design by ACI :312 - Other methods of mixdesign.

Concrete Types
Normal Vibrated Concrete - High volume fly ash concrete - High strength concrete - Reactivepowder concrete & Oil well concrete - Ready mix concrete, pervious concrete.
Fiber Reinforced Concrete – FRP in concrete - Self compacting concrete – Bacterial Concrete - Selfcuring concrete - Geopolymer Concrete.

Durability and fire hazards in concrete
Deterioration of concrete - Factors effecting the durability - Sulphate attack - Acid attackAlkali Aggregate reaction – Carbonation - Abrasion
Freezing and Thawing - Corrosion of Rebar - Rapid Chloride penetration test

Use of waste materials in concrete
Waste from industry - Recycled aggregates -
SustainabilityGreen concrete - Eco-Friendly Concrete

Non Destruct Test (NDT)
Rebound Hammer Test - Ultrasonic pulse velocity test - Core Extraction for Compressive StrengthTest - Windsor Probe System – pull out resistance test – pull off test.

Under Water Concrete
Tremie Method - Concrete in Cold weather - Concrete in Hot weather - miscellaneous topics

Text Books/References:

1. Concrete Materials, Properties, Specification and Testing by S. Popovics, Standard Publishers,India
2. Properties of Concrete by A.M. Neville, ELBS Ed.
3. Waste Materials in Concrete Manufacture by Satish Chandra, Indian Standard Publishers
4. Nondestructive Testing in Concrete by Bungey, Surrey University Press, London.

Course Outcomes: At the end of the course, student will be

able to:CO- 1 understand the advanced concrete terminology.
CO- 2 understand the mixed design of concrete, high strength of concrete requirements for advanced concrete.
CO- 3 understand the use of plasticizers, effect of water cement ratio and super plasticizers Used inthe construction works.

SEMESTER - II

CODE	Advanced Concrete Design	L	T	P	C
CE 5311	M.Tech. (Structural Engineering), 2ndSem (Core)	3	1	0	4

Behaviour of concrete under various states of stresses. Shrinkage and creep.
Design philosophies: Ultimate load design, working stress design, limit state design.
Design of RC skeletal members under flexure, shear, torsion and combination, bi-axial bending.
Design of Compression members. P-M and P-M1-M2 interaction. Shear-moment-torsion interaction.Serviceability limit states - estimation of deflection and crack-width in RC members.
Capacity design concept.
Yield line analysis of
slabs.
Ductility, effect of confinement. Beam column joints: detailing for ductility.
Design of deep beams, shear walls, coupled-shear wall, ribbed slabs, corbels and pile caps, folded plates, silos, chimneys, water tanks.
Outlines of Pre-stressed concrete.

Text Books/References:

1. Hsu, T.T.C., and Mo, Unified Theory of Concrete Structures, Wiley Ltd.
2. Pillai, S. U., Menon, D., Reinforced Concrete Design, Tata McGraw-Hill.
3. Krishna Raju, N., Structural Design and Drawing: Reinforced Concrete and Steel, Universities Press(India) Pvt. Ltd.
4. James, K. K. and Gregor, J. G. M., Reinforced Concrete Mechanics and Design, Pearson.
5. Reynolds, C. E., Basic Reinforced Concrete Design: Elementary (Vol. 1). Concrete Publications.
6. Arthur, H. N., Design of Concrete Structures, John-Wiley.
7. Park, R. and Paulay, T., Reinforced Concrete Structures, John-Wiley.
8. Paulay, T. and Priestley, M.J.N., Seismic Design of Reinforced Concrete and Masonry Buildings,John Wiley & Sons Inc., NY.
9. IS:456-2016, BIS
10. IS:13920 (Ductile Detailing), BIS
11. SP 16 (Design Aid), BIS
12. SP 34 (Detailing), BIS.
13. SP 24 (Explanation of IS: 456), BIS.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 acquire knowledge and ability to understand behaviour of concrete structures and methods of reinforce concrete design
CO- 2 acquire knowledge and ability to design and detail various types of RC structures
CO- 3 acquire knowledge and ability to understand techniques and method of communicating engineering design to industry.
CO- 4 acquire knowledge and ability to get motivation for research and lifelong learning.

CODE	Advanced Steel Design	L	T	P	C
CE 5312	M.Tech. (Structural Engineering), 2nd Sem (Core)	3	0	0	3

Properties of steel: mechanical properties, hysteresis, ductility.
Hot-Rolled Sections: compact, semi-compact and plastic sections, slenderness ratio, residual stresses. Revisiting Design of Tension Members, Compression Members, Flexural Members, beam-column, column-foundation, splices.
Design for inelastic bending–curvature, plastic moments, design criteria - stability, strength, drift.
Stability criteria: stability of beams - local buckling of compression flange and web, lateral-torsionalbuckling,
Column theories, Stability of columns - slenderness ratio of columns, local buckling of flanges and web, bracing of column about weak axis, method of design - allowable stress design, plastic design, load and resistance factor design, P-M and other interactions.
Strength Criteria: beams – flexure, shear, torsion. Moment magnification factor, effective length, bi- axial bending, joint panel zones.
Drift criteria: P-Δ effect, deformation-based design.
Design of plate girders. Plastic analysis. Industrial buildings, Gantry girder.

Text Books/References:

1. *Steel Structures*: *Design and Practice* By N. Subramanian, Oxford Publishers.
2. *Steel Structures*: Design and Behavior, Charles G. Salmon, John E. *Johnson.*
3. *Design of steel Structures, Gaylod and Gaylord.*
4. *Structural Stability, Chen and Lui,* PTR Prentice Hall,
5. Structural Stability Of Steel: Concepts And Applications For Structural Engineers, Theodore V.Galambos Andrea E. Surovek, John Wiley & Sons, Inc.
6. *Theory of Elastic Stability, SP Timoshenko, McGraw Hill.*

Course Outcomes: At the end of the course, student will be able to:

CO- 1 identify the behaviour of steel structures based on its usage and functionality.CO- 2 design real life steel structures of various types.

CO- 3 carry out research in understanding the behaviour of steel structuresCO- 4 be motivated to higher studies, research and lifelong learning.

CODE	Finite Element Methods	L	T	P	C
CE 5313	M.Tech. (Structural Engineering), 2nd Sem (Core)	3	0	0	3

Introduction to Finite Element Method (FEM); Finite element formulations based on: Variational methods, Galerkin method, Virtual displacement; Fundamentals of discretization and shape functions;Isoparametric formulation; Analysis of truss using FEM; Analysis of frame using FEM;

Plane stress and plane strain problem;Axisymmetric problems;

Three dimensional FEM formulation; Introduction to application of FEM for plates and shells; Introduction to application of FEM for heat-transfer and fluid-flow problem;

Error analysis, convergence and mesh refinement;FEM for structural dynamics;

Eigen analysis;

Computer implementation of FEM algorithms.

Text Books/References:

1. R.D. Cook, D.S. Malkus and M.E. Plesha, Concepts and Applications of Finite Element Analysis,John Wiley & Sons, 2002.
2. J.N. Reddy, An Introduction to the Finite Element Method, Tata McGraw Hill, 2003.
3. S.S. Rao, Finite Element Method in Engineering, Butterworth Heinemann, 1999.
4. O.C. Zienkiewicz, R.L. Taylor and J.Z. Zhu, Finite Element Method Its Basis and Fundamentals,Elsevier, 2005.
5. K.J. Bathe, Finite Element Procedures, Prentice Hall of India Pvt. Ltd., 2002.
6. T.J.R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis,Dover Publications, 2000.
7. T.R. Chandrupatla and A.D. Belegundu, Introduction to Finite Elements in Engineering, PrenticeHall, 2003.
8. P. Seshu, Textbook of Finite Element Analysis, PHI Learning Pvt. Ltd., 2003.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 be familiar to the historical background and interdisciplinary applicability of FEM.

CO- 2 understand various frameworks for finite element formulation (based on: variational methods, Galerkin and other weighted residual methods, principle of virtual work) and realize the finite element discretization.

CO- 3 develop understanding on FEM (formulations as well as methodology) for analysis of various types of structure/solid.

CO- 4 understand the formulation of FEM for structural dynamics. CO- 5 be aware of computer implementations of FEM-algorithms.

CODE	Seminar	L	T	P	C
CE 5314	M.Tech. (Structural Engineering), 2ndSem (Core)	0	0	3	2

Course Outcomes: At the end of the course, student will be able to:

CO- 1 effectively prepare materials for presentation on technical world.CO- 2 enhance the skill of communication.
CO- 3 get exposure to some topic generally outside the curriculum.

ELECTIVE – III

CODE	Structural Optimization	L	T	P	C
CE 5351	M.Tech. (Structural Engineering), 2nd Sem (Elective-III)	3	0	0	3

Introduction
Motivation (why this course?), How real-life structural optimization problems are formulated and implemented efficiently?
Basic concepts with computer programming
Elements of optimization problem formulation (design variables, objective function, constraints, variable bounds), Examples, classification of optimization algorithms: advantages and limitations; Review of MATLAB/Python scientific programming languages; Overview of computer programs/toolbox to solve optimization problem numerically
Mathematical programming
Single variable optimization problems: optimality criteria, Algorithms and implementations for: bracketing methods, region elimination methods, point elimination methods, gradient-based methods, polynomial approximation,
Multi-variable optimization problems: optimality criteria, unidirectional search, direct search methods, gradient-based methods (steepest descent, conjugate gradient, variable metric method), Illustrative examples
Constrained optimization algorithms
Optimality criteria: differential calculus, gradient and Hessian of multi-variable functions, Kuhn-Tucker conditions, Lagrange multiplier, Sensitivity analysis, Penalty function methods, Multiplier methods, Linear programming: Simplex method, Primal-dual problems, Quadratic programming , Applications
Heuristic optimization algorithms
Basic concepts, classification, Genetic algorithm: basic principles, algorithm and computer implementation, Swarm intelligence, Simulated annealing
Practical applications in structural engineering
General steps to practical optimization problem formulation and implementation, Structural optimization: review of -- differential and variational calculus, finite element method; optimality conditions, gradient computations, Structural analysis and design, shape/size/topology optimization, Test problems: Truss/frame structures, continuum structures, composite structures, fast re-analysis techniques, surrogate models
Structural optimization under uncertainty
Special topics: Reliability-based design optimization, robust design optimization, risk-based optimization, applications

Text Books/References:

1. Optimization for Engineering Design: Algorithms and Examples. Second Edition. Deb, K.
2. Engineering Optimization: Theory and Practices. Fourth Edition Rao, S. S
3. Elements of Structural Optimization. Third Revised and Expanded Edition Haftka, R. T., Gurdal,Z
4. Numerical Optimization Techniques for Engineering Design. Third Edition Vanderplaats, G. N.
5. Numerical Optimization Nocedal, J., Wright, S. J.
6. Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers. Pratap, R.
7. Python in a Nutshell. Third Edition Martelli, A., Ravenscroft, A., Holden, S

Course Outcomes: At the end of the course, student will be able to:

CO- 1 review, understand, define/express engineering optimization problems.
CO- 2 interpret algorithms for unconstrained/constrained structural optimization problems.CO- 3 implement computer codes for linear/nonliner mathematical programming.
CO- 4 understand working principles of metaheuristic optimization techniques.
CO- 5 learn formulation/execution of practical structural design optimization problems.

CODE	Advanced Bridge Engineering	L	T	P	C
CE 5352	M.Tech. (Structural Engineering), 2nd Sem (Elective-III)	3	0	0	3

Introduction, historical review, engineering and aesthetic requirements in bridge design. Introduction to bridge codes. Economic evaluation of a bridge project. Site investigation and planning, Scour - factors affecting and evaluation. Bridge foundations - open, pile, well and caisson. Piers, abutments and approach structures; Superstructure - analysis and design of right, skew and curved slabs. Girder bridges - types, load distribution, design. Orthotropic plate analysis of bridge decks. Introduction to long span bridges - cantilever, arch, cable stayed and suspension bridges.

Text/References Books:

1. D. J. Victor, Essentials of Bridge Engineering, Oxford and IBH, 1980.
2. N. Krishna Raju, Design of Bridges, Oxford and IBH, 1988.
3. V. K. Raina, Concrete Bridge Practice: Analysis, Design and Economics, Tata McGraw Hill, 2002.
4. L. Fryba, Dynamics of Railway Bridges, Thomas Telford, 1996.
5. K.S. Rakshit, A Text Book of Bridge Engineering, Oxford and IBH Publishing Co.
6. S. Ponnaswamy, Design, Construction & Practice in Bridge Engineering, Tata McGraw HillPublishing Co. Ltd.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 use structural codes and standards to model dead, live, snow, wind, and earthquake loads inthe design of both super and Sub structures.

CO- 2 determine the various structural parameters namely Moments, Shear Stress and mode shapesof continuous system, natural frequency using classical methods.

CO- 3 solve statically indeterminate structures namely Super Structures, Sub structures, Pile cap, PierShaft, Well cap and Well foundation etc.

CO- 4 use modern structural analysis software such as MIDAS, SAP.

CODE	Earthquake Resistant Design of Structures	L	T	P	C
CE 5211	M.Tech. (Structural Engineering), 2ndSem (Elective-III)	3	0	0	3

Introduction**:** Origin of earthquakes, magnitude, intensity, ground motions, sensors, strong motion characteristics.
Concepts of earthquake resistant design of R.C. buildings: Earthquake and vibration effects on structure, identification of seismic damages in buildings, effect of structural irregularities on the performance of buildings during earthquakes and seismic resistant building architecture.
Seismic analysis and modeling of R.C. buildings: Codal procedure for design of lateral loads, infill walls, seismic analysis of R.C. building as per IS: 1893 – 2000 (Part 1).
Earthquake resistant design of buildings and other structures**:** Ductility considerations, E.R.D. of R.C. building, design of load bearing buildings, design of shear wall, design of liquid storage tanks,retaining wall, chimney and industrial structures.

Text Books/References:

1. Earthquake Resistant Design of structures, S. K. Duggal.
2. Earthquake Resistant Design of structures, PankajAgarwal and Manish Shrikhande.
3. Seismic Design of Reinforced Concrete and Masonry Building, T. Paulay and M.J.N. Priestly.
4. Masonry and Timber structures including earthquake Resistant Design, AnandS.Arya.
5. Earthquake –Resistant Design of Masonry Building, CVR Murty.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 acquire knowledge and ability to correlate information from various engineering and scientificdiscipline to understand complex behaviour of RC buildings and other structures subjected to seismic forces and various design principles

CO- 2 acquire knowledge and ability to design RC buildings and other structures in accordance with the provisions of Indian and International building codes

CO- 3 acquire knowledge and ability to use performance based design framework and nonlinear analysis techniques

CODE	Seismic Hazard, Vulnerability and Risk Analysis and Retrofitting	L	T	P	C
CE 5212	M.Tech. (Structural Engineering), 2nd Sem (Elective-III)	3	0	0	3

Introduction: Components of seismic risk-Hazard, Exposure, Vulnerability; difference between risk and hazard; probabilistic and deterministic seismic hazard approaches; earthquake sources; estimation of maximum magnitude; maximum credible earthquake; design basis earthquake.

Seismicity Data and Treatment: Seismicity catalogues; spatial coverage; temporal coverage; completeness in size and time; cut off magnitude; foreshocks and aftershocks; declustering of data;homogenization of catalogue; estimation of maximum probable magnitude; Gutenberg Richter frequency magnitude distribution; return period; Poissonian model, time dependent Poisson process.

Ground Motion Prediction Equations: Strong motion attenuation relationships; PGA and spectral accelerations, response spectra, displacement spectra.

Deterministic and Probabilistic Seismic Hazard Analysis: Deterministic and probabilistic seismic hazard methods; Types of earthquake sources-point, line and areal sources; geological slip rate method; deaggregation; logic tree; hazard estimation at the bedrock level; probability of exceedanceand return periods in earthquake engineering.

Seismic Vulnerability of Buildings and Lifelines: Empirical, analytical, experimental and hybrid approaches; building typology; intensity scales, use of intensity scales for estimating seismic vulnerability; HAZUS methodology

Risk Estimation and Post Earthquake Damage Studies: Convolution of hazard, vulnerability and exposure to quantify risk; loss ratios, indoor and outdoor casualty rates; Earthquake damage surveys, questionnaires and data to be collected, handling and processing of data, classification of damage, estimation of fragility from damage data

Text Books/References:

4. Geotechnical Earthquake Engineering. Kramer, S. L., Pearson Education
5. Earthquake Hazard Analysis, Issues and Insights. Reiter, L. Columbia University Press
6. Seismic Hazard and Risk Analysis. McGuire, Robin K Earthquake Engineering Research Institute

Course Outcomes: At the end of the course, student will be able to:

CO-1 acquire knowledge and ability to exposure to development, declustering, homogenization of earthquake catalogues.

CO- 2 acquire knowledge and ability to performance of deterministic and probabilistic seismic hazard analysis.

CO- 3 acquire knowledge and ability to introduction to various methods and approaches of vulnerability assessment.

CO- 4 acquire knowledge and ability to introduction to various methods and approaches of risk assessment.

ELECTIVE - IV

CODE	Composite Materials and Structures	L	T	P	C
CE 5361	M.Tech. (Structural Engineering), 2nd Sem (Elective-IV)	3	0	0	3

Introduction: Definitions, Constituent materials, Types of fibres and matrices, Fabrication processes/ Manufacturing methods, Advantages and Drawbacks of composites, Overview of the field of applications.
Micromechanics: Geometrical aspects, Volume and weight fractions, Longitudinal strength and stiffness, Transverse modulus, In-plane shear modulus, Introduction to mechanical testing of composites.
Macromechanical Analysis of Laminated Composites: Stress-Strain relationship of a lamina, Transformation of stress and strain, Engineering constants, Laminates, Types (Symmetric and Anti- symmetric laminates, Quasi-Isotropic laminate, etc.), Elastic Moduli, Strain-displacement relationship,Stress-strain relations, Laminate stiffness, Compliance matrix.

Analysis of Laminated Plates: Introduction to various plate theories, Classical Laminate Plate Theory,First Order Shear Deformation Theory, Introduction to Higher Order Shear Deformation Theory, Staticanalysis and free vibration analysis.
Introduction to advanced topics: Finite element analysis of composite structures, Hygrothermal effects, Introduction to failure theories, Modelling and analysis of composite structure using ANSYS

Text Books/References:

1. Mechanics of Fibrous Composites, C.T. Herakovich, John Wiley & Sons, Inc. New York, 1998.
2. Mechanics of Composite Materials and Structures, M. Mukhopadhyay, University Press, 2004.
3. Mechanics of Composite Materials, R.M. Jones, Technomic Publication.
4. Mechanical Testing of Advanced Fibre Composites, J.M. Hodgkinson, Woodhead PublishingLimited, Cambridge, 2000.
5. ASTM standards.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 describe a composite material and understand its advantages and drawbacks over other conventional structural materials. They will be able to understand the manufacturing process ofa composite material by using different constituent materials based on their mechanical properties.

CO- 2 derive the stress-strain relationship of a unidirectional lamina and subsequently transform themfrom its local axes to the global axes system to form the relationship for the laminates.

CO- 3 understand the characteristics of different component in the laminate stiffness matrix.CO- 4 analyse a laminated composite plate structure based on different plate theories.

CO- 5 formulate the static and dynamic problems involving the finite element formulation of the composite structure.

CO- 6 analyse a composite structure under static, dynamic, thermal loads using ANSYS software.

CODE	Design of Pre-stressed Concrete Structure	L	T	P	C
CE 5362	M.Tech. (Structural Engineering), 2nd Sem (Elective-IV)	3	0	0	3

Introduction – concept of Pre-stressing – Advantages of Pre-stressing – Materials for pre-stressedconcrete.
Different Pre-stressing System – Analysis of pre-stress and bending stresses various losses of pre-stress – Deflection of pre-stressed concrete member.
Flexural and shear strength of pre-stressed concrete members- Transfer of pre-stress in pre-tensioned members
Anchorage zone stresses in post tensioned members- Limit state design criteria for Pre-stressedconcrete members
Design of pre-stressed concrete sections – Design of pretension and post tensioned Flexural memberstatically indeterminate Pre-stressed Structures
Pre-stressed concrete pipes and tanks- Pre-stressed concrete slabs and grid floors
Pre-stressed concrete poles, pipes, sleepers, pressure vessels and pavements – Pre-stressed concreteBridges.

Text Books/References:

1. Lin, T.Y. and Burns, N.H., Design of Pre-stressed Concrete Structures.
2. Krishna Raju, Design of Pre-stressed Concrete Structures, PHI.
3. Rajagopalan, N., Design of Pre-stressed Concrete Structures, Narosa Pub. House.
4. Nawy, E.G., Pre-stressed Concrete, Prentice Hall Int.
5. Libby, J.R., Modern Pre-stressed Concrete, Von Nostrand R Co.,
6. IS: 1343- Code of Practice for Pre-stressed Concrete.

Course Outcomes: At the end of the course, student will be able to:CO- 1 understand the basic aspects of pre-stressed concrete

CO- 2 identify and interpret the appropriate relevant industry design codes.
CO- 3 get familiar with professional and contemporary issues in the analysis and design of pre-stressed concrete members.
CO- 4 get familiar with professional and ethical issues and the importance of lifelong learning in structural engineering.

CODE	Modal Analysis Theory and Testing	L	T	P	C
CE 5363	M.Tech. (Structural Engineering), 2nd Sem (Elective-IV)	3	0	0	3

Overview of modal analysis
Theoretical basis for SDoF system, Theoretical basis for undamped MDoF system, Theoretical basisfor damped MDoF system, Frequency response function (FRF) measurement
Single-input Single-output (SISO) modal analysis methods, Single-input multi-output (SIMO) modal analysis methods
Multi-input multi-output (MIMO) modal analysis techniques
Introduction to Operational Modal Analysis, Experimental demonstration on modal testing

Text Books/References:

1. D.J. Ewins, Modal Testing: Theory, Practice and Application, John Wiley & Sons, 2009.
2. Jimin He, Zhi-Fang Fu, Modal Analysis, Butterworth-Heinemann, Elsevier, 2001.
3. N.M.M. Maia (Editor), J.M.M.S. Silva (Editor), Theoretical and Experimental Modal Analysis,John Wiley & Sons, 1997.
4. Rune Brincker, Carlos E. Ventura, Introduction to Operational Modal Analysis, John Wiley &Sons, 2015.

Course Outcomes: At the end of the course, student will be able to:CO- 1 realize the requirement of Modal testing of structures.

CO- 2 develop understanding on the theoretical basis for SDoF system, undamped MDoF system and damped MDoF system.
CO- 3 understand the measurement methodologies of frequency response function (FRF).
CO- 4 be familiar with modal analysis techniques in various setup: Single-input Single-output (SISO),single-input multi-output (SIMO) and multi-input multi-output (MIMO).
CO- 5 be familiar with the fundamentals of operational modal analysis (OMA).
CO- 6 develop understanding on experimental modal testing.

CODE	Vibration Control Techniques	L	T	P	C
CE 5364	M.Tech. (Structural Engineering), 2nd Sem (Elective-IV)	3	0	0	3

Introduction to vibration Control, Historical development of structural vibration control systems and base isolation techniques, Methods of Vibration Control.
Vibration Control by Structural Design: Damping Models and Measures, Origin of Structural Damping, Damping-Stress Relationship, Selection Criteria for Linear Hysteretic Materials, Combined Fatigue-Strength Damping Criteria, Design for Enhanced Material Damping.
Vibration Isolation System: Principle of base isolation; Theory of vibration isolation; Componentsof base isolation; Advantages and limitations; General Design Criteria; Linear and Nonlinear procedures of isolation design.
Isolation Devices: Laminated rubber bearing, lead rubber bearing, high damping rubber bearing, friction pendulum system; Modelling of isolation bearings; Design process for multilayered elastomeric bearings and buckling behaviour of elastomeric bearings.
Dynamic Vibration Absorbers:Introduction, Dynamic Vibration Neutralizers, Self-tuned PendulumNeutralizer, Optimum Design of Damped Absorbers, tuned mass dampers, tuned liquid dampers; Shape memory alloy dampers; Modelling, Applications of DVA.
Active Vibration Control:Introduction to Closed Loop Control, Classical Control System, Piezoelectric Sensors and Actuators, Vibration Control of Flexible Beam, Energy Harvesting System.

Text Books/References:

1. IR Hkinner, WH Robinson & KH Mcberry. An introduction to seismic isolation. John Wileypublication, 1993.
2. JM Kelly. Earthquake resistant design with rubber. Springer publication 1993.
3. J.P Den Hartog, Mechanical Vibrations, McGraw Hill Publication 1956
4. T. K. Datta, Seismic analysis of structures. John Wiley & Sons. 2010
5. T. T Soong, & M. C. Costantinou, Passive and active structural vibration control in civil engineering (Vol. 345). Springer. 2014
6. Preumont. Vibration control of active structure: An introduction. Kulwer publication 1997.

Course Outcomes: At the end of the course, student will be able to:CO- 1 understand concepts and theory of dynamic response control.
CO- 2 learn the numerical formulation for different vibration control techniques.CO- 3 apply these techniques for vibration control of various structures.

CODE	Structural Health Monitoring	L	T	P	C
CE 5365	M.Tech. (Structural Engineering), 2^{nd} Sem (Elective-IV)	3	0	0	3

Introduction to Structural Health Monitoring, Historical Overview
Introduction to Various Structural Damage Detection Techniques, Various Sensing Technologies for Structural Health Monitoring
Data Acquisition, Communication and Data Management
Vibration-Based Damage Detection Techniques, Principles of Modal Testing
Damage Detection Using Finite Element Model Updating, Structural Health Monitoring UsingMachine Learning Techniques, Structural Health Monitoring For Large Structures

Text Books/References:

1. Daniel Balageas Claus-Peter Fritzen Alfredo Güemes, Structural Health Monitoring, John Wiley& Sons Ltd, 2006.
2. Hua-Peng Chen Yi-Qing Ni, Structural Health Monitoring of Large Civil Engineering Structures,John Wiley & Sons Ltd, 2018.
3. Charles R. Farrar, Keith Worden, Structural Health Monitoring: A Machine Learning Perspective,John Wiley & Sons Ltd, 2012

Course Outcomes: At the end of the course, student will be able

to:CO- 1 realize the requirement of Structural Health Monitoring.
CO- 2 be familiar with various structural damage detection techniques.
CO- 3 develop understanding on various sensing technologies, data acquisition, data communication and data management.
CO- 4 develop understanding (along with problem solving skills) on: vibration-based damage detectiontechniques, principles of modal testing, damage detection using finite element model updating,structural health monitoring using machine learning techniques.
CO- 5 aware of various problems and solutions in structural health monitoring of large civil structures.

Department of Civil Engineering
Curriculum and Syllabi for M.Tech. in Transportation Engineering
With effect from 2019 entry batch

PO Statements:

PO-1: An ability to independently carry out research/investigation and developmental work to solve practical problems in transportation engineering area.

PO-2: An ability to write and present a substantial technical report/document.

PO-3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the problem. The mastery should be at a level higher than the requirements inthe appropriate bachelor program.

PO-4: Graduates of the program will develop the confidence to solve the state- of –art problems in keyareas of transportation engineering.

PO-5: Graduate will have the ability to work independently/ in a team with high ethical values towardssocial, environmental and economic issues.

Semester- I

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 5401	Urban Transportation System Planning	3	0	0	3
2	CE 5402	Pavement Materials	3	0	0	3
3	CE 5403	Traffic Engineering	3	1	0	4
4	CE 5404	Transportation Engineering Lab	0	0	3	2
5	CE xxxx	Elective – I	3	0	0	3
6	CE xxxx	Elective - II	3	0	0	3
		Total contact hours/Credit	**15**	**1**	**3**	**18**

Semester - II

Sl. No	Code	Subject	L	T	P	Credit
1	CE 5411	Analysis and Design of Pavements	3	1	0	4
2	CE 5412	Mass Transportation System	3	0	0	3
3	CE 5413	Geometric Design of Transportation Facilities	3	0	0	3
4	CE 5414	Seminar	0	0	3	2
5	CE xxxx	Elective III	3	0	0	3
6	CE xxxx	Elective IV	3	0	0	3
		Total contact hours/Credit	**15**	**1**	**3**	**18**

Semester–III

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 6498	Project Phase I	-	-	-	6
					Total credits	**6**

Semester–IV

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 6499	Project Phase II	-	-	-	8
					Total credits	**8**

Elective-I

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 5431	Hill Roads	3	0	0	3
2	CE 5432	Advanced Highway Materials	3	0	0	3
3	CE 5344	Advanced Concrete Technology	3	0	0	3

Elective –II

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 5141	Geotechnical Earthquake Engineering	3	0	0	3
2	CE 5131	Ground Improvement Techniques	3	0	0	3
3	CE 5441	Design and Construction of Rural Roads	3	0	0	3

Elective- III

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 5352	Advanced Bridge Engineering	3	0	0	3
2	CE 5451	Airport Planning and Design	3	0	0	3
3	CE 5151	Geosynthetics and Reinforced Earth	3	0	0	3

Elective- IV

Sl. No.	Code	Subject	L	T	P	Credit
1	CE 5562	Optimization Methods in Engineering Design	3	0	0	3
2	CE 5161	Probability Methods in Civil Engineering	3	0	0	3
3	CE 5461	Intelligent Transportation System	3	0	0	3
4	CE 5462	Traffic Safety	3	0	0	3

DETAILED SYLLABI

Semester - I

CODE	**Urban Transportation System Planning**	**L**	**T**	**P**	**C**
CE 5401	M.Tech. (Transportation Engineering), 1st Sem (Core)	**3**	**0**	**0**	**3**

Urban Transportation Planning Process, Urban Travel and Transportation Systems Characteristics, Travel Demands Forecasting - trip generation, trip distribution, modal split and trip assignment, Transport Behaviour of Individuals and Households, Land use/ Transportation systems, Introduction to Urban Freight Transportation and Urban Mass Transportation Systems.

Text/References Books:

1. J. de D. Ortuzar and L.G. Willumsen, Modelling Transport, John Wiley and Sons, 2001.
2. C.J. Khisty and B.K. Lall, Transportation Engineering – An Introduction, Prentice Hall of IndiaPvt. Ltd., 2002.
3. C.S. Papacostas and P.D. Prevedouros, Transportation Engineering and Planning, Prentice Hall ofIndia Pvt. Ltd., 2001.
4. P. Chakroborty and A. Das, Principles of Transportation Engineering, Prentice Hall of India Pvt.Ltd., 2003.
5. B.G. Hutchinson, Principles of Urban Transport Systems Planning, McGraw-Hill Book Co., NewYork, 1974.
6. L.R. Kadiyali, Traffic Engineering and Transport Planning, Khanna Publishers, New Delhi, 2000.
7. G. E. Gray and L. A. Hoel, Public Transportation, Prentice Hall, New Jersey, 1992.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand the concept of urban transportation system and their

characteristicsCO- 2 understand and analyse the process of urban travel demand

forecasting.

CO- 3 understand the relationship between transportation and land use.

CODE	Pavement Materials	L	T	P	C
CE 5402	M.Tech. (Transportation Engineering), 1st Sem (Core)	**3**	**0**	**0**	**3**

Road Materials - classification, properties of subgrade and road aggregates; design of aggregate gradation. Bituminous road binders -bitumen, emulsions, cut backs and modified binders. Rheology ofbituminous binders, modified binders, Mix design - Marshall method and Superpave procedure. Designof emulsified mixes, Visco-elastic and fatigue properties of bituminous mixtures, resilient modulus ofpavement materials. Requirements of paving concrete, design of mixes for recycling of bituminous and concrete pavement surfaces. Soil stabilization techniques.

Text/References Books:

1. P.H. Wright, Highway Engineering, John Wiley & Sons, 1996.
2. S.K. Khanna and C.E.G. Justo, Highway Material Testing, New Chand & Bros., 1999.
3. G.N. Durhan, W.A. Marr, and W.L. DeGroff, Resilient Modulus Testing for Pavement Components, ASTM International, U.S.A., 2003.
4. G. Correia, Flexible Pavements, A. A. Balkema Publishers, 1996.
5. S.E. Zoorob, A.C. Collop, and S.F. Brown, Performance of Bituminous and Hydraulic Materialsin Pavements, A. A. Balkema Publishers, 2002.
6. R.N. Hunter, Bituminous Mixtures in Road Construction, Thomas Telford Services Ltd., 1995.
7. MOST, Specifications for Road and Bridge Work (4th Revision), Ministry of Road Transport andHighways, 2001.
8. ASTM, Annual Book of ASTM Standards – Section IV, Vol. 04.03, ASTM International, 2002.
9. D. Croney, and P. Croney, Design and Performance of Road Pavements, McGraw-Hill, 1998.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 apply the concept of different road materials and its evaluation.

CO- 2 understand and analyse the materials characterisation and their

importance.CO- 3 impart knowledge of materials design and its quality

aspects.

CODE	Traffic Engineering	L	T	P	C
CE 5403	M.Tech. (Transportation Engineering), 1st Sem (Core)	**3**	**1**	**0**	**4**

Vehicle Characteristics, Human Factors and Driver behaviour, Traffic control mechanism. Traffic studies- volume, speed and delay studies, elements of traffic flow theory. Characteristics of uninterrupted traffic, Capacity and LOS of Uninterrupted facilities, Characteristics of interrupted traffic, Traffic characteristics at Un-signalised intersections, Design of Signalized intersections, Capacity and LOS of Signalized intersections, Signal control and signal coordination.

Text/References Books:

1. Roger P. Roess, William R. McShane & Elena S. Prassas, Traffic Engineering, Prentice-Hall, 1990.
2. Pignataro L. J., Traffic Engineering – Theory and Practice, Prentice Hall, 1973.
3. Khisty and B. K. Lall, Transportation Engineering: An Introduction, Prentice- Hall India, 2003.
4. Wohl M. and Martin B. V., Traffic System Analysis, McGraw-Hill Book Company, 1967.
5. P. Chakroborty and A. Das, Principles of Transportation Engineering, Prentice Hall of India Pvt.Ltd., 2003.
6. L. R. Kadiyali, Traffic Engineering and Transportation Planning, Khanna Publishers, 2000.
7. D. May, Traffic Flow Fundamentals, Prentice–Hall, 1990.
8. C.S. Papacostas, Transportation Engineering and Planning, Prentice-Hall India, 2001.Highway Capacity Manual (HCM), Transportation Research Board, USA, 2000.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 study fundamental characteristics of traffic stream and Drivers'

behaviour.CO- 2 understand different types of traffic control systems.

CO- 3 design traffic signal system at intersections.

CO- 4 estimate capacity and Level of Service foruninterrupted and interrupted flow facilities.

CODE	Transportation Engineering Laboratory	L	T	P	C
CE 5404	M.Tech. (Transportation Engineering), 1st Sem (Core)	**0**	**0**	**3**	**2**

Tests on bitumen, emulsion, cutback, soil and aggregates, aggregate blending, viscosity of binders. Viscoelastic properties of bituminous mixtures and bituminous mix design. Speed, headway and traveltime studies on highways. Parking surveys, Traffic data collection and analysis.

Text/References Books:

1. MOST, Specifications for Road and Bridge Work (4th Revision), Ministry of Road Transport andHighways, 2001.
2. S.K. Khanna and C.E.G. Justo, Highway Material Testing, New Chand & Bros., 1999.
3. C.A.O' Flaherty, Highways – The Location, Design, Construction, & Maintenance of Pavements,Butterworth Heinemann, 2002.
4. R. N. Hunter, Bituminous Mixtures in Road Construction, Thomas Telford Services Ltd., 1995.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand and perform the various tests on road

material.CO- 2 understand and analyse the mix design

aspects.

CO- 3 study macroscopic and microscopic parameters of traffic.

ELECTIVE-I

CODE	Hill Roads	L	T	P	C
CE 5431	M.Tech. (Transportation Engineering), 1st Sem (Elective- I)	**3**	**0**	**0**	**3**

Introduction to hill road, classification of terrains, features and planning of hill roads, development ofhill roads in India. Alignment of hill roads, Geometrics of hill roads pavement formation, camber, sight distance, horizontal curves, vertical curves, hair pin bends. Construction of hill roads-formation works, rock cutting, retaining walls. Drainage systems on hill roads-components drainage system, road-side drains, cross drainage structures, sub-surface drainage. Maintenance of hill roads. Landslide-type of landslides, factors causing landslides, remedial measures of hill roads.

Text/References Books:

1. Khanna, S.K., Justo, C.E.G. and Veeraragavan, A: Highway Engineering. Nem Chand & BrosPublisher, Civil Lines, Roorkee, India.
2. Ahuja, T.D.: Highway Engineering. Standard Book House Publisher, 1705-A, NaiSarak, Delhi,India.
3. Hill Road Manual, IRC: SP 48-1998.
4. Guidelines for the design of flexible pavements for low volume rural roads, IRC: SP: 72-2007

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand various features of Hill roads

CO- 2 learn the alignment and geometric design of Hill

roadsCO- 3 study the Hill road drainage system

CO- 4 learn the maintenance of Hill roads

CODE	Advanced Highway Materials	L	T	P	C
CE 5432	M.Tech. (Transportation Engineering), 1st Sem (Elective- I)	3	0	0	3

Aggregate: Nature and properties – aggregate requirements – types and processing – aggregates for pavement base – aggregate for bituminous mixture – aggregate for Portland Cement Concrete – lightweight aggregate – tests on aggregate – specification.

Bituminous Materials: conventional and modified binders – production – types and grade – physical and chemical properties and uses – types of asphalt pavement construction – principles of bituminouspavement construction – tests on bituminous materials. Bituminous Mix design – modified mixtures –temperature susceptibility and performance.

Cement /concrete based materials: Cement – properties – PCC mix design and properties – modified PCC – Mix Design – Behaviour – Performance – Tests on Cement and Concrete mixes. High Performance Concrete – low shrinkage – increased strength.

Composites, Plastics and Geosynthetics: Plastics and polymerization process – properties – durabilityand chemical composition – Reinforced Polymer Composites – Geosynthetics – Dry PowderedPolymers – Enzymes. Reclaimed / Recycled Waste Products: Reclaimed Materials – waste products in civil engineering applications – effect of waste products on materials, structure and properties – selfhealing and smart materials – locally available materials.

Text/References Books:

1. P. T. Sherwood, Alternative Materials in Road Construction, Thomas Telford Publication,London,1997.
2. RRL, DSIR, Soil Mechanics for Road Engineers, HMSO, London, 1995
3. Koerner, R. M. Designing with Geosynthetics, Prentice Hall, Englewood Cliffs, New Jersey,U.S.A.
4. Shan Somayaji, Civil Engineering Materials, second edition, Prentice Hall Inc., 2001.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 Understand the behaviour and characteristics materials used for differenttypes of

pavement.CO- 2 Understand the utilization of waste and recycled materials in pavement

construction.

CO- 3 Application of new pavement

materials. CO- 4 Understand the principles

of mix design.

CODE	Advanced Concrete Technology	L	T	P	C
CE 5344	M.Tech. (Transportation Engineering), 1st Sem (Elective –I)	**3**	**0**	**0**	**3**

Concrete science, standards and specifications. Chemical admixtures, mineral admixtures, polymer concrete, high volume fly ash concrete, high strength concrete, self-compacting concrete, reactive powder concrete, mass concrete, roller compacted concrete, oil well concrete. Durability and fire hazards in concrete, use of waste materials in concrete, NDT.

Text/References Books:

1. S. Popovics, Concrete Materials, Properties, Specification and testing, Standard Publishers,India.
2. A.M. Neville, Properties of Concrete, ELBS Ed.
3. S. Chandra, Waste Material in Concrete Manufacture, Indian Standard Publishers.
4. Bungey, Non Destructive Testing in Concrete, Surrey University Press, Lndon.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understanding of advanced concrete terminology.

CO- 2 understanding of the mixed design of concrete, high strength of concrete requirements foradvanced concrete.

CO- 3 understanding to use plasticizers, effect of water cement ratio and super plasticizers used inthe construction works.

ELECTIVE –II

CODE	Geotechnical Earthquake Engineering	L	T	P	C
CE 5141	M.Tech. (Transportation Engineering), 1st Sem (Elective- II)	**3**	**0**	**0**	**3**

Introduction, Seismic risks and seismic hazards, cause and strength of earthquake, social and economical consequences, theory of dynamics and seismic response, the nature and attenuation of ground motion. Determination of site characteristics, local geology and soil condition, site investigation and soil tests. Determination of design earthquake response spectra and accelerogrames as design earthquake, criteria for earthquake resistant design. Site response to earthquake, liquefactionof saturated cohesionless soils, seismic response of soil structure system, shallow foundation, pile foundation, foundation in liquefiable ground. A seismic design of earth retaining structures.

Text/References Books:

1. C.L. Kramer, Geotechnical Earthquake Engineering, Prentice Hall, New Jersey, 1996.
2. W.F. Chen and G.Y. Baladi, Soil Plasticity: Theory and Implementations, Elsevier Amsterdam,1985.
3. J.P. Wolf, Foundation Vibration Analysis using Simple Physical Modes, PTR Prentice Hall Inc.,Eaglewood Cliffs, New Jersey, 1994.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 Solve problems relating to origin of earths and response of structures to earthquake vibrations.CO- 2 Solve problems relating to hazard analysis.

CO- 3 Assess properties of soil effected by seismic wave propagation.

CO- 4 Solve problems relating to the effect of ground shaking on stability of slopes.CO- 5 Apply earthquake mitigation theories on stability of structures.

CODE	Ground Improvement Techniques	L	T	P	C
CE 5131	M.Tech. (Transportation Engineering), 1st Sem (Elective –II)	**3**	**0**	**0**	**3**

Introduction, Economic considerations, Consolidation by preloading and sand drains; strengthening bygranular columns, Stone columns; lime columns; Compaction by vibrofloatation, blasting and dynamic consolidation; Improvement of deep strata of fine soils by vacuum dewatering, electroosmosis, groundfreezing and thermal stabilization; Grouting techniques and principles. Reinforced earth and applications of geosynthetics; retaining walls, slopes, roads, erosion. Ground anchors and soil nailing;Problems and case histories

Text/References Books:

1. Bowels, J. E., Foundation Analysis and Design, McGraw-Hill International Edition, Singapore,1997.
2. Moseley, M. P., Ground Improvement, Blackie Academic & Professional, Boca Raton, Florida,USA, 1993.
3. Hausmann, M. R., Engineering Principles of Ground Modification, McGraw-Hill InternationalEditions, 1990.
4. Yonekura, R., Terashi, M. and Shibazaki, M. (Ed), Grouting and Deep Mixing, A.A. Balkema,Rotterdam, The Netherlands, 1966.
5. Xanthakos, P. P., Abramson, L. W. and Bruce, D. A., Ground Control and Improvement, JohnWiley & Sons, New York, USA, 1994.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 learn the various methods of Ground Improvement Techniques.

CO- 2 understand the changes in behaviour of soil due to application of various ground improvement techniques.

CO- 3 apply the ground improvement methods in solving the problems associated with poor soils.

CODE	Design and Construction of Rural Roads	L	T	P	C
CE 5441	M.Tech. (Transportation Engineering), 1st Sem (Elective – II)	**3**	**0**	**0**	**3**

Introduction about Rural Roads and Planning and Alignment: Importance of Rural roads, Classification of rural roads, Terrain classification, Socio-economic impact of rural roads. Data base for master plan, Concept of network planning, Rural Roads plan, Road alignment, Governing factors for route selection, Factors controlling alignment, Special considerations while aligning hill roads, Surveys, Detailed project report, Environmental issues.

Geometric Design and Road Materials: Introduction, Design speed, Basic principles of geometric design, Elements, Horizontal and vertical alignment, Alignment compatibility, Lateral and vertical clearances. General, Soil and material surveys, Soil as road construction material, Aggregates for pavement courses, Materials for bituminous construction, Materials for semi-rigid and rigid pavement,Materials for special pavements Climatic suitability of concrete materials

Pavement Design, Specifications and Construction of Rural Roads: Introduction, Design parameters, Pavement components, Design of flexible pavement, Design of semi-rigid pavement, Design of rigid pavement, Drainage and Shoulders. General, Selection of construction materials and methodology, Earthwork, Sub-base, Base course, Bituminous constructions, Semi-rigid pavement construction, Concrete pavements, Equipment required for different operations.

Use of Waste Materials in Rural Road Construction and Quality Control Tests & Maintenance: Introduction, Significance of green roads, Fly ash for road construction, Iron & steel and copper slags, recycled concrete aggregate, other waste materials. General, Pre-requisite, Specifications and codes ofpractice, Quality control tests during construction. Distresses/defects in pavements, Types of maintenance, Classification of maintenance activities, Maintenance norms of maintenance cost.

Text/References Books:

1. IRC: SP 20-2002 “Rural Roads Manual”.
2. Guidelines for the design of flexible pavements for low volume rural roads, IRC: SP: 72-2007
3. Geometric design standards for Rural (Non-Urban) Highways, IRC: 73-1980.
4. Guidelines for quality systems for road construction, IRC: SP: 57-2000.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 obtain a basic knowledge of rural road network and it influences on socio-economic conditionof rural area.

CO- 2 learn basic principles of geometric design and the material used for rural road. CO- 3 understanding the planning, alignment and design consideration for rural roads. CO- 4 learning construction, quality control, and maintenance measures for rural roads.

Semester- II

CODE	Analysis and Design of Pavements	L	T	P	C
CE 5411	M.Tech. (Transportation Engineering), 2nd Sem (Core)	**3**	**1**	**0**	**4**

Philosophy of design of flexible and rigid pavements, analysis of pavements using different analyticalmethods, selection of pavement design input parameters - traffic loading and volume, material characterization, drainage, failure criteria, reliability, design of flexible and rigid pavements using different methods, comparison of different pavement design approaches, design of overlays and drainage system.

Text/References Books:

1. Yang H. Huang, Pavement Analysis and Design, Pearson Prentice Hall, 2004.
2. Yoder and Witzech, Pavement Design, McGraw-Hill, 1982.
3. Sharma and Sharma, Principles and Practice of Highway Engg., Asia Publishing House, 1980.
4. Teng, Functional Designing of Pavements, McGraw- Hill, 1980.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand basic concepts of pavement structures and their structural behaviors.CO- 2 learn different techniques for analysis of pavement structures.
CO- 3 impart knowledge of pavement design considerations and their performance evaluation.CO- 4 apply probabilistic evaluation of pavement performance.

CODE	Mass Transportation System	L	T	P	C
CE 5412	M.Tech. (Transportation Engineering), 2nd Sem (Core)	**3**	**0**	**0**	**3**

Urban Passenger Transport Modes & Classifications, System Performance, Capacity and Quality of Service, Planning Issues, Route Determination, Network Design, Service Policy and Schedule development, Scheduling: trip generation, blocking, runcutting and rostering, Priority Measures and their Implementations, Improvements in Mass Transportation System - Issues and Challenges, DemandModeling, Development of Generalized Cost, RP & SP Data and Analysis Techniques, Case Studies.

Text/References Books::

1. VuchicVukan R., Urban Transit: Operations, Planning and Economics, Prentice Hall, 2005.
2. Gray G. E., and Hoel L. A., Public Transportation, Prentice Hall, 1992.
3. Tyler N., Accessibility and the Bus System – Concepts and Practice, Thomas Telford, 2002.
4. Tiwari G., Urban Transport for Growing Cities – High Capacity Bus System, MacMillan IndiaLtd., 2002.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand the various urban transit modes and their characteristics in the realm of urbantransportation system.
CO- 2 understand and estimate the capacity and quality of mass transit system.CO- 3 understand the concept of route determination and scheduling.
CO- 4 understand the specific mode of mass transit systems through case studies.

CODE	Geometric Design of Transportation Facilities	L	T	P	C
CE 5413	M.Tech. (Transportation Engineering), 2nd Sem (Core)	**3**	**0**	**0**	**3**

Geometric design provisions for various transportation facilities as per AASHTO, IRC and other guidelines. Discussion of controls governing geometric design, Route layout and selection, Elements of design - sight distances, horizontal alignment, transition curves, super elevation and side friction. Vertical alignment: - grades, crest and sag curves. Highway cross-sectional elements and their designfor rural highways, urban streets and hill roads. At-grade Inter-sections - sight distance consideration and principles of design, channelization, mini round-abouts, layout of round-abouts, Inter-changes: major and minor interchanges, entrance and exit ramps, acceleration and deceleration lanes, Bicycle and Pedestrian Facility Design; Parking Layout and Design; Terminal Layout and Design.

Text/References Books:

1. M. Rogers, Highway Engineering, Blackwell Publishing, 2003.
2. P. H. Wright, Highway Engineering, John Wiley & Sons, 1996.
3. C. H. Oglesby, and R. G. Hicks, Highway Engineering, John Wiley & Sons, 1982.
4. R. L. Brockenbrough, and K. J. Boedecker, Highway Engineering, McGraw-Hill, 1996.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand basic concepts of road structures and use of related codes in design provisions.CO- 2 learn different techniques for analysis and design of highway geometric elements.

CO- 3 understand and design of various highway facilities.

CODE	Seminar	L	T	P	C
CE 5414	M.Tech. (Transportation Engineering), 2nd Sem (Core)	**0**	**0**	**3**	**2**

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand the importance of presentation and improve confidence for oral delivery.CO- 2 explore the updated literature in the interested area or topic and interaction thereon. CO- 3 demonstrate scope and problem statement on specific theme.

ELECTIVE-III

CODE	Advanced Bridge Engineering	L	T	P	C
CE 5352	M.Tech. (Transportation Engineering), 2nd Sem (Elective –III)	3	0	0	3

Introduction, historical review, engineering and aesthetic requirements in bridge design. Introduction to bridge codes. Economic evaluation of a bridge project. Site investigation and planning, Scour - factors affecting and evaluation. Bridge foundations - open, pile, well and caisson. Piers, abutments and approach structures; Superstructure - analysis and design of right, skew and curved slabs. Girder bridges - types, load distribution, design. Orthotropic plate analysis of bridge decks. Introduction to long span bridges - cantilever, arch, cable stayed and suspension bridges.

Text/References Books:

7. D. J. Victor, Essentials of Bridge Engineering, Oxford and IBH, 1980.
8. N. Krishna Raju, Design of Bridges, Oxford and IBH, 1988.
9. V. K. Raina, Concrete Bridge Practice: Analysis, Design and Economics, Tata McGraw Hill, 2002.
10. L. Fryba, Dynamics of Railway Bridges, Thomas Telford, 1996.
11. K.S. Rakshit, A Text Book of Bridge Engineering, Oxford and IBH Publishing Co.
12. S. Ponnaswamy, Design, Construction & Practice in Bridge Engineering, Tata McGraw HillPublishing Co. Ltd.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 ability to use structural codes and standards to model dead, live, snow, wind, and earthquakeloads in the design of both super and Sub structures.

CO- 2 ability to determine the various structural parameters namely Moments, Shear Stress andmode shapes of continuous system, natural frequency using classical methods.

CO- 3 ability to solve statically indeterminate structures namely Super Structures, Sub structures Pilecap, Pier Shaft, Well cap and Well foundation etc.

CO- 4 ability to use modern structural analysis software such as MIDAS, SAP.

CODE	Airport Planning and Design	L	T	P	C
CE 5451	M.Tech. (Transportation Engineering), 2nd Sem (Elective – III)	**3**	**0**	**0**	**3**

Aircraft characteristics; planning and site selection; obstruction criteria; air traffic control; runways: orientation, length, geometric standards, capacity, configuration; runway lighting and markings;taxiway and runway pavement design; taxiway: geometric standards, fillets, high speed exit taxiway; apron-gate area and circulation; terminal building - functional areas and facilities; visual aids; drainage;heliports.

Text/References Books:

1. S.K. Khanna and M.G. Arora, Airport Planning and Design, Nem Chand & Bros., 1999.
2. Yang H. Huang, Pavement Analysis and Design, Pearson Prentice Hall, 2004.
3. Yoder and Witzech, Pavement Design, McGraw-Hill, 1982.
4. Horonjeff, R., McKelvey, F. X., Sproule, W.J. and Young, S.B., Planning and design ofAirport engineering.,Fifth edition, McGraw Hill, New Delhi, India,2010.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand different components of aircrafts. CO- 2 study various principles of Air traffic control.

CO- 3 understand the geometric designs of runway, taxiway, apron, hanger, heliports.CO- 4 learn the planning of different functional units of airport terminal building.

CODE	Geosynthetics and Reinforced Earth	L	T	P	C
CE 5151	M.Tech. (Transportation Engineering), 2nd Sem (Elective III)	3	0	0	3

Introduction -History, ancient and modern structures. Type of geosynthetics - geotextiles, geogrids, geonets, geocells, geo-composites, manufacturing methods. Functions of geosynthetics and applicationareas. Reinforcement action – mechanism of reinforced soil through Mohr circle analysis, facings. Factors affecting the performance and behaviour of reinforced soil.

Testing methods for Geosynthetics -Techniques for testing of different index properties, strength properties, Apparent Opening Size, In-plane and cross-plane permeability tests, assessment of construction induced damage, extrapolation of long term strength properties from short term tests.

Reinforced earth walls - Behaviour of Reinforced earth walls, basis of wall design, the Coulomb force method, the Rankine force methods, internal and external stability condition, Construction methods of reinforced retaining walls.

Application in foundations - Binquet and Lee's approach for analysis of foundations with reinforcement layers.

Reinforced soil slopes - Different slope stability analysis methods like planar wedge method, bi-linear wedge method, circular slip methods. Erosion control on slopes using geosynthetics.

Use of geosynthetics in embankment - Basal reinforcement for construction on soft clay soils. Analysis and design concepts.

Applications of geosynthetics for drainage and filtration - Different filtration requirements, filtration in different types of soils and criteria for selection of geotextiles, estimation of flow of waterin retaining walls, pavements, etc. and selection of geosynthetics.

Application of geosynthetics in pavement - Geosynthetics used in unpaved road-function, mechanism, benefit, design- by Giroud-Noiray approach, Paved road - reflection cracking and controlusing geosynthetics. Use of geosynthetics in raiway lines.

Construction of landfills using geosynthetics - Different components of modern landfills, collectiontechniques for leachate, application of different geosynthetics like geonets, geotextiles for drainage inlandfills, use of geomembranes and Geosynthetic Clay Liner (GCL) as barriers.

Text/References Books:

1. Earth Pressure and Earth Retaining Structures by C. R. I. Clayton, J. Milititsky and Woods
2. Reinforced Earth by T. Ingold
3. Earth Reinforcement and Soil Structures by C. J. F. P. Jones
4. Designing with Geosynthetics by R. M. Koerner
5. An Introduction to Soil Reinforcement and Geosynthetics by G.L SivakumarBabu
6. Reinforced Soil and its Engineering Applications by Swami

Course Outcomes: At the end of the course, students will be able to:

CO- 1 select appropriate geosynthetic as per requirement.
CO- 2 apply geosynthetics in different civil engineering project. CO- 3 design earthen structures with geosynthetic reinforcement.CO- 4 design pavement with geosynthetics.

ELECTIVE-IV

CODE	Optimization Methods in Engineering Design	L	T	P	C
CE 5562	M.Tech. (Transportation Engineering), 2nd Sem (Elective –IV)	**3**	**0**	**0**	**3**

Introduction to optimization – definitions, classification, overview of topics. Introduction to linear algebra. Single variable optimization algorithms - optimality criteria, bracketing methods, region elimination methods, point estimation methods, gradient based methods. Root finding using optimization techniques. Multivariable optimization algorithms – optimality criteria, direct search methods, gradient search methods. Constrained optimization algorithms – Kuhn – Tucker conditions,algorithms for solving nonlinear optimization problems, LPP. Introduction to genetic algorithms.

Text/References Books:

1. K. Deb., Optimization for Engineering Design: Algorithms and Examples, Prentice-Hall of IndiaPvt. Ltd., New Delhi, 1998.
2. J. S. Arora, Introduction to Optimum Design, McGraw Hill International Edition, 1989.
3. R. T. Hafta and Z. Gurdal., Elements of Structural Optimization, Third Revised and ExpandedEdition, Kluwer Academic Publishers, 1996.
4. D.G. Luenberger, Introduction to Linear and Non Linear Programming, Addison Wesley.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 enable the graduates to understand the concept of optimization, design and develop analyticalskills.

CO- 2 enable graduates, apply optimization concept to different civil engineering

problems.CO- 3 summarize the Linear, Non-linear and Geometric Programming.

CODE	Probability Methods in Civil Engineering	L	T	P	C
CE 5161	M.Tech. (Transportation Engineering), 2nd Sem (Elective – IV)	**3**	**0**	**0**	**3**

Introduction- Role of probability and statistics in civil engineering.

Random events- Definition of basic random events; Application of set theory in definition of composite event operations. Probability of events and definition of probability axioms; Solution of reallife examples from civil engineering.

Random variables - Definition of random variables – discrete and continuous; Probability definitions – PMF, PDF, CDF; Moments and expectations.

Functions of random variables- Definitions of probability distributions of functions of single and multiple random variables - exact methods and approximate methods; Moments and expectations of functions – direct and indirect methods.

Probability distributions Discrete distributions - binomial distribution, Poisson's distribution; Continuous distribution – exponential distribution, gamma distribution; Central limit theorem; Normaland lognormal distributions; Extreme value distributions.

Random samples and statistics - Examples on various civil engineering problems.

Sampling distributions - Chi-square distribution, t- distribution, F distribution.

Parameter estimation - Point estimation, confidence interval estimation.

Hypothesis testing - Tests of hypotheses on the mean and variance.

Text/References Books:

1. Probability Concepts in Engineering: Emphasis on Applications in Civil and EnvironmentalEngineering by Ang, A. H. S., and Tang, W. H.
2. Probability and Statistics for Engineers by Ravichandran, J.
3. Applied Statistics for Civil and Environmental Engineers by Kottegoda and Rosso
4. A First Course on Probability by Ross, S.

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understand probabilistic distribution of geotechnical variables. CO- 2 analyse geotechnical problems using probabilistic perspectives.CO- 3 apply probabilistic methods to geotechnical problems.
CO- 4 solve geotechnical problems using statistical methods.

CODE	Intelligent Transportation System	L	T	P	C
CE 5461	M.Tech. (Transportation Engineering), 2nd Sem (Elective IV)	3	0	0	3

Introduction to Intelligent Transportation Systems (ITS) – Definition of ITS and Identification of ITS Objectives, Historical Background, Benefits of ITS - ITS Data collection techniques – Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), Geographic InformationSystems (GIS), video data collection.

Telecommunications in ITS – Importance of telecommunications in the ITS system, Information Management, Traffic Management Centres (TMC). Vehicle – Road side communication – Vehicle Positioning System

ITS functional areas – Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), Commercial Vehicle Operations (CVO), Advanced Vehicle Control Systems (AVCS), Advanced Public Transportation Systems (APTS), Advanced Rural TransportationSystems (ARTS).

ITS User Needs and Services – Travel and Traffic management, Public Transportation Management, Electronic Payment, Commercial Vehicle Operations, Emergency Management, Advanced Vehicle safety systems, Information Management.

Automated Highway Systems - Vehicles in Platoons – Integration of Automated Highway Systems. ITS Programs in the World – Overview of ITS implementations in developed countries, ITS in developing countries.

Text/References Books:

1. ITS Hand Book 2000: Recommendations for World Road Association (PIARC) by Kan PaulChen, John Miles.
2. Sussman, J. M., Perspective on ITS, Artech House Publishers, 2005.
3. National ITS Architecture Documentation, US Department of Transportation, 2007 (CD-ROM).

Course Outcomes: At the end of the course, students will be able to:

CO- 1 understanding the basic features of intelligent transport system and its

application.CO- 2 understand the control system and communication technologies in

ITS.

CO- 3 understanding the concept of transportation management and automated highway system.

CODE	Traffic Safety	L	T	P	C
CE 5462	M.Tech. (Transportation Engineering), 2nd Sem (Elective IV)	3	0	0	3

Module 1: Crash Data Collection and Interpretation
Various approaches for collecting crash data; Black spot analysis; Crash frequency and severity; Interpretation of crash statistics; Application of stochastic mechanisms in the prediction of future crash rate; Fatality rate and its influencing factors.

Module 2: Traffic Safety Analysis and Surrogate Measures
Conflict and its types; Conflict weights; Conflict potential and its estimation; Strategies to control conflict potential; Vehicle-pedestrian interaction; Pedestrian crossing time and its components; Measurement of gap and lag; Gap acceptance behavior; Critical gap; Raff's method; Post-Encroachment Time (PET); Time to Collision (TTC); Yaw rate.

Module 3: Road Safety Audit
Different stages of road safety audit; Salient features and principles for safe road design; IRC specifications- Safety considerations for intersections, horizontal and vertical curves; Curb parking Provisions; Estimation of Safe Parking Distance (SPD).

Module 4: Crash Prevention
Strategies of accident prevention; Traffic Calming and its benefits; Traffic calming measures; Crash prevention measures for intersection, pedestrians and bicyclists; Injury control; Post-injury management.

Books/References:

1. Tiwari, G. and Mohan, D. (2016) "Transport Planning & Traffic Safety". CRC Press Taylor & Francis Group
2. Shiner, D. (2017) "Traffic Safety and Human Behaviour". Emerald Publishing Limited.
3. Indian Roads Congress. (2010) "IRC SP:88-2010: Manual on Road Safety Audit", New Delhi India
4. Yannis, G. and Cohen, S. (2016) "Traffic Safety". ISTE Ltd and John Wiley & Sons, Inc.

Course Outcomes: At the end of the course, students will be able to:

CO-1: to understand how to identify a potential crash location and interpret the crash data for the futuristic crash prediction
CO-2: to analyze a traffic safety situation using the state-of-the-art surrogate measures
CO-3: to conduct a safety audit for any given roadway stretch
CO-4: to understand different counter-measures to prevent crashes at different roadway facilities

Department of Civil Engineering

Curriculum and Syllabi for M. Tech. in Water Resources Engineering

With effect from 2019 entry batch

PO Statements:

PO-1: An ability to independently carry out research / investigation and development work to solve practical problems.

PO-2: An ability to write and present a substantial technical report/document.

PO-3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO-4: Program graduates will gain knowledge and skill in integrating Water resources engineering concepts across multiple disciplines.

PO-5: Program graduates will develop understanding on project in Water resources engineering withethical value towards social, environmental and economic development / sustainability.

PO-6: Graduates will develop interest to pursue higher studies and lifelong learning

Course Structure

Semester I

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 5501	Applied Hydrology	3	0	0	3
2	CE 5502	Advanced Hydraulics	3	0	0	3
3	CE 5503	Unsteady Open Channel Flow	3	0	0	3
4	CE 5504	Computational Methods in Water Resources Engineering	2	2	0	4
5	CE 5505	Water Resources Engineering Lab	0	0	3	2
6	CE xxxx	Elective – I	3	0	0	3
		Total contact hours/ Credits	**14**	**2**	**3**	**18**

Semester II

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE-5511	Advanced Groundwater Hydrology	3	0	0	3
2	CE 5512	Hydraulic Structures and Hydropower Engineering	3	1	0	4
4	CE 5513	Seminar	0	0	3	2
	CE xxxx	Elective – II	3	0	0	3
5	CE xxxx	Elective – III	3	0	0	3
6	CE xxxx	Elective – IV	3	0	0	3
Total contact hours/ Credits			**15**	**1**	**3**	**18**

Semester III

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 6598	Project Phase I	-	-	-	6
Total contact hours/ Credits			**-**	**-**	**-**	**6**

Semester IV

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 6599	Project Phase II	-	-	-	8
Total contact hours/ Credits			**-**	**-**	**-**	**8**

Elective-I

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 5531	Application of Remote Sensing and GIS in Water Resources Engineering	3	0	0	3
2	CE 5532	Watershed Management	3	0	0	3
3	CE 5533	Flood Control and Drainage Engineering	3	0	0	3

Elective-II

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 5541	Fluvial Hydraulics	3	0	0	3
2	CE 5542	Coastal Engineering and Coastal Zone Management	3	0	0	3

Elective-III

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 5551	Water Resources Planning and Management	3	0	0	3
2	CE 5552	Computational Fluid Dynamics	3	0	0	3

Elective-IV

Sl. No.	Subject Code	Subject	L	T	P	Credit
1	CE 5561	Introduction of Soft Computing Technique in Engineering	3	0	0	3
2	CE 5562	Optimization Methods in Engineering Design	3	0	0	3

DETAILED SYLLABI

Semester- I

CODE	Applied Hydrology	L	T	P	C
CE-5501	M.Tech. (Water Resources Engineering), 1st Sem (Core)	3	0	0	3

Physical processes in hydrology; hydrologic cycle, systems concept, hydrologic model classification; Reynold's Transport Theorem (RTT), continuity, momentum, and energyequations.

Soil moisture, porosity, saturated and unsaturated flow; Richards' equation, infiltration models;Horton's, Philip's, and Green Ampt methods, parameter estimation, ponding time concepts

Effective Rainfall, Runoff, Direct Runoff Hydrograph, Hydrograph Analysis, unit hydrograph theory and its applications; Hortonian and saturation overland flow; SCS method, overland and channel flow modeling, time area concepts, and stream networks.

Application of statistical methods in hydrology; Frequency analysis, flood routing

models<u>Text/Reference books:</u>

1. Chow, V.T., Maidment, D.R. and Mays, L.W. (2010*),"Applied Hydrology*", TataMcGraw Hill Edition
2. Warren Viessman, Jr. and G L Lewis, (2008*), "Introduction to Hydrology",* PrenticeHall IndiaPvt.Ltd., New Delhi
3. McCuen R.H. (2005), *Hydrologic Analysis and Design*", Prentice Hall Inc. NYork.

Course Outcomes: At the end of the course, students will be able to:s

CO- 1	understand various hydrological processes, classification of hydrological models. They would be in a position to apply fundamental equations in solving hydrological problems.
CO- 2	apply infiltration equations in estimating water percolation under different scenarios.
CO- 3	understand unit hydrograph principle and apply such techniques in prediction of runoff.
CO- 4	apply statistical principles in hydrological problems.
CO- 5	apply the principles of flood frequency techniques in estimating floods

CODE	Advanced Hydraulics	L	T	P	C
CE-5502	M.Tech. (Water resources Engineering), 1st Sem (Core)	3	0	0	3

Dimensional analysis, equation of continuity, motion and energy, Irrotational flow, Laminar flow, turbulent flow

Boundary layer theory, drag and lift on immersed bodies.

<u>Text/Reference books:</u>

1. V.T. Chow: Open-channel hydraulics. McGraw HillPublications (1959,1973)
2. Rajesh Srivastava: Flow through open channels. OxfordUniversity Press (2008)
3. K. Subramanya: Flow in open channels. Tata McGraw Hill(1997)
4. H. Chaudhury: Open channel flow. Second Edition. Springer(2008)

Course Outcomes: At the end of the course, students will be able to:

CO- 1	apply the concept of different similarities in experimental model studies.
CO- 2	understand and analyze three dimensional ideal and real flow and their application in practical situations.
CO- 3	understand the concept of formation of boundary layer around an object placed in a flowing fluid and also the force exerted on the body due to the relative motion including rotational effect.

CODE	Unsteady Open Channel Flow	L	T	P	C
CE-5503	M.Tech. (Water resources Engineering), 1st Sem (Core)	3	0	0	3

Introduction to Open Channel Flow – Types of flows – Velocity and Pressure Distribution – Equation of continuity – Energy equation – Momentum equation.

Energy-Depth relationship – Specific energy – Critical depth – Calculation of critical depth – Section factor –Computations.

Uniform flow – Chezy equation – Darcy-Weisbach friction factor f – Manning's formula – Other resistance formulae – Velocity and Shear stress distribution – Uniform flow computations – Hydraulically efficientchannel sections.

Gradually varied flow – Differential equation of a GVF – Classificationof flow profiles – Features of flow profiles – Control sections – Analysis of flow profiles.

Rapidly varied flow – Momentum equation for jump formulation –Hydraulic jump is a horizontal rectangular channel – Jumps in horizontal non rectangular channels – Use of jump as an energy dissipator – Locationof jump.

Unsteady flows – Introduction to Gradually varied unsteady flow (GVUF) and Rapidly varied unsteady flow, Review of basic equations; 2D Shallow water flow equations: Boussinesq equations, Finite - difference solutions: explicit and implicit methods; Supercritical flow computation; Sediment routing models.

Mobile bed channel hydraulics – Introduction – Sediment properties – Initiation of motion of sediment – Bed forms – Sediment load – Design ofstable channels carrying clear water – Regime channels – Scour.

Text/Reference books:

1. Chow, V.T., Maidment, D.R. and Mays, L.W. (2010),"AppliedHydrology", Tata McGraw Hill Edition

2. Warren Viessman, Jr. and G L Lewis, (2008), "Introduction toHydrology", Prentice Hall IndiaPvt.Ltd., New Delhi

3. McCuen R.H. (2005), Hydrologic Analysis and Design", Prentice Hall Inc.NYork.

4. K.Subrahmanya, Open Channel Flow,TMH

Course Outcomes: At the end of the course, students will be able to:

CO- 1	solve uniform and non-uniform flow problems in open channel flows.
CO- 2	analyze and Solve Gradually Varied Flow (GVF) and Rapidly Varied Flow (RVF)problems.
CO- 3	understand basic concepts of Gradually Varied Unsteady Flow (GVUF) and Surges
CO- 4	design channels in mobile bed boundary conditions.

CODE	Computational Methods in Water Resources Engineering	L	T	P	C
CE-5504	M.Tech. (Water resources Engineering), 1st Sem (Core)	2	2	0	4

Numerical Methods and solution techniques, curve fitting

Modelling concepts and overview of computer models for: Surface and subsurface water systems, irrigation engineering and managements, coastal engineering. Practical applications and exercise on selected computer models.

Text/Reference Books:

1. An introduction to numerical analysis by Kendall Atkinson
2. Simulation Modelling and analysis by Law and Kelton
3. Jain, S.K. and V.P. Singh, Water Resources Systems Planning andManagement, Vol. 51, Elsevier Science, 2003.

Course Outcomes: At the end of the course, students will be able to:

CO-1 develop skill of formulation and writing computer programme in differentplatform.

CO- 2 develop skills in formulating mathematical model for water resourcesproblems.

CO- 3 identify and apply specific computational models for specific waterresources problems.

CODE	Water Resources Engineering Lab	L	T	P	C
CE-5505	M.Tech. (Water resources Engineering), 1st Sem (Core)	0	0	3	2

List of Experiments

1. Rainfall – Runoff relationships (Storm Hydrograph) using RainfallSimulator.
2. Estimation of soil loss in a watershed using Rainfall Simulator.
3. Water abstraction from a well in an aquifer using Rainfall Simulator.
4. 3D flow measurements using ADV
5. Computation of critical flow condition in a laboratory flume.
6. Study of hydraulic jump in a laboratory flume.
7. Determination of Manning's and Chezy's coefficients of roughness.

Course Outcomes: At the end of the course, the student will be able to:

CO-1 understand Rainfall-Runoff relationships using Rainfall Simulator.

CO-2 determine velocity of a river flow.

CO-3 study various open channel flow conditions such as Critical flow, Gradually varied flow and Rapidly varied flow.

CO-4 study characteristics and features of well hydraulics.

ELECTIVE -I

CODE	Application of Remote sensing and GIS in Water Resources Engineering	L	T	P	C
CE 5531	M.Tech. (Water resources Engineering), 1st Sem (Elective-I)	3	0	0	3

Remote sensing and basic principles – Introduction, Components of remote sensing, energy source and its characteristics, atmospheric interaction, types of remote sensing.

Platforms and sensors – Introduction, satellite system parameters, sensor parameters, sensor Radar technology.

Image interpretation – Visual techniques, Types of Pictoral Data Products, General procedure for photo interpretation, Basic elements of Image Interpretation, Key Elements of Visual Image Interpretation. Digital Techniques – Basic Characteristics of Digital Image, Preprocessing, Image Enhancement, Image classification and GIS.

GIS – Introduction to Geographic Information system, Terminology, GIS Architecture, Raster and vector-based GIS

GIS Applications – Land use/land cover, Classification, NDVI, DEM

Text/ Reference Books:

1. Anji Reddy M., “Textbook of Remote Sensing and Geographical Information Systems”, BS Publications, 2006.
2. Demers, Michael N., “Fundamentals of Geographic Information System”, 2nd Ed. Wiley.2008.
3. Lillesand. T. M. and Kiefer. R. W, “Remote Sensing and Image interpretation”, 6th Edition, John Wiley & Sons, 2000.
4. Ghosh, S.K. and Chandra, A.M., “Remote Sensing and GIS”, Narosa Publishing House.2008.

Course Outcomes: After completion of this course, the students will be able to,

CO-1 develop basic knowledge about remote sensing and GIS
CO- 2 know about various satellites launch programs and understanding their technical detailsCO-3 analyze and rectify the errors in an image using various techniques.
CO- 4 apply remote sensing data in solving various societal problems using GIS.

CODE	Watershed Management	L	T	P	C
CE 5532	M.Tech. (Water resources Engineering), 1st Sem (Elective-I)	**3**	**0**	**0**	**3**

Introduction to Watershed Management – Introduction to Watershed Management – Hydrology – Hydrologic cycle – Hydrologic design – Analysis vs. Synthesis – Hydrologic budget- Problems

Statistical Methods in Hydrology –Statistical terminology – Characteristics of a Sample or Distribution Function – Hypothesis testing – Regression analysis – Stepwise Regression – Analysis of Nonlinear equations - Problems

Watershed Characteristics –Watershed delineation – Drainage area – Linear measurements – Basin shape – Watershed relief – Descriptors of the drainage pattern – Uniform flow computation – Time parameters – Land cover and use – Problems.

Peak Discharge Analysis and Design –Historical review – Rational Method – The SCS Rainfall- Runoff Depth Relation – Estimating Runoff Curve Numbers – Estimating runoff volumes – SCS Graphical Peak Discharge Method – Single Return-Period equations – Problems.

Reservoir Routing –The routing equation – Derivation of a Stage-Storage- Discharge Relationship – Storage-Indication routing – Modified Puls Routing Method – Design Procedure – Problems.

Erosion and Sedimentation – Introduction to Sediment transport - Physical processes in erosion and sedimentation – Channel stability – Splash erosion – Sheeterosion – Erosion in gullies – Suspended sediment transport – Estimating bedload transport – Tractive force approach to stable channel design– Estimating sediment yield – Problems.

Watershed Modeling – SCS Watershed Model – Calibration of simple watershedmodels – Application with hydrologic data.

Text/References Book:

1. Ghanashyam Das, Watershed Mangement,PHI
2. Richard H. McCuen, Hydrologic Analysis & Design, PHI

Course Outcomes: At the end of the course, the student will be able to

CO-1	appreciate the significance of Watershed Management.
CO-2	understand the various statistical methods in hydrology.
CO-3	calculate peak discharge in a watershed using SCS-CN Method
CO-4	determine the volume and rate of sediment transport.

CODE	Flood Control and Drainage Engineering	L	T	P	C
CE 5533	M.Tech. (Water resources Engineering), 1st Sem (Elective-I)	**3**	**0**	**0**	**3**

Introduction to flood problems, Estimates of benefits of flood control, Estimation of design of flood, flood routing, flood forecasting, flood warning, flood mitigation, flood damage, cost-benefit analysis for a flood control project, flood plain delineation and flood hazard assessment

Design of subsurface drainage system, design of surface drainage system, water logging and salinity, water logging, causes of the drainage problems, design of leaching requirement.

Text/Reference Books:

1. Flood Control and Drainage Engineering by S. N. Ghosh
2. Irrigation Engineering and Hydraulics structure S. R Sahasrabudhe
3. Irrigation Engineering and Hydraulics structure S K Garg

Course Outcomes: At the end of the course, the student will be able to

CO-1 understand flood problem, flood control, design flood estimation, flood routing.

CO-2 understand flood forecasting, warning, mitigation, flood plain delineation and taking measures for flood control and management.

CO-3 understand and design of the surface and subsurface drainage system, to water logging and salinity.

Semester - II

CODE	**Advanced Groundwater Hydrology**	**L**	**T**	**P**	**C**
CE-5511	M.Tech. (Water resources Engineering), 2ndSem (Core)	3	0	0	3

Groundwater Resources: Introduction, Overview of Groundwater System, GroundwaterModelling.

Groundwater Equations: Flow Equations, Transport Equations, Boundary and InitialConditions, Partially Saturated Flow Systems.

Finite Difference Methods applied to study and transient groundwater systems, Introduction tofinite element methods in groundwater problems.

Introduction to Optimization methods for Groundwater Management.

Text/Reference books:

1. Groundwater Hydrology David K Todd; Larry W. Mays, ISBN:978-0-471-05937-0,Wiley
2. Groundwater Hydrology H.M. Raghunath, Wiley Eastern Ltd.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand the individual hydrologic processes and their integrated behavior in watersheds.

CO- 2 understand and analyze the subsurface water flow process, estimation of usable groundwater, analysis of pollutant movement.

CO- 3 understand application of various statistical and numerical methods in the analysis of hydrologic data for developing hydrologic model.

CODE	Hydraulic Structure and Hydropower Engineering	L	T	P	C
CE 5512	M.Tech. (Water Resources Engineering), 2ndSem (Core)	3	0	0	3

Dams: Analysis and Design of Gravity Dam, Earthen Dam, Arch Dam.

Design of Hydropower Installation Components: Intake Structures; Water ConductorSystems Tunnels; Surge-Tanks; Penstocks; Gates and Valves

Power House Structures: Turbines and their foundations

Introduction to structures and Geotechnical aspects of power house design

Text/Reference books

1. Irrigation Engineering and Hydraulic Structures S.K. Garg, Khanna Publications
2. Irrigation and Water Power Engineering Dr. B.C. Punmia, Dr. Pande B. Lal, Ashok K.Jain and Arun K. Jain Lakshmi Publications Pvt. Ltd.
3. Hydraulic Structures P. Novak, A.I.V Moffet, C. Nalluri and R. Narayan, Taylor &Francis

Course Outcomes: At the end of the course, student will be able to:

CO- 1	learn the concept and uses of various hydraulic structures
CO- 2	understand the causes of failures of different hydraulic structures.
CO- 3	plan and design various hydraulic structures for water diversion, storage and conveyance 55for purposeful use.

CODE	Seminar	L	T	P	C
CE 5513	M.Tech. (Water Resources Engineering), 2nd Sem (Core)	**0**	**0**	**3**	**2**

Course Outcomes: At the end of the course, student will be able to:
CO- 1 understand the importance of presentation and improve confidence for oral delivery.CO- 2 explore the updated literature in the interested area or topic and interaction thereon. CO- 3 demonstrate scope and problem statement on specific theme.

ELECTIVE - II

CODE	Fluvial Hydraulics	L	T	P	C
CE 5541	M.Tech. (Water Resources Engineering), 2ndSem (Elective II)	3	0	0	3

Sediment – Components and properties

Transport of sediment – Incipient motion; bed forms; bed load and Suspended load; totalload; Meandering of rivers; Braided Rivers

General and local scouring – sediment sampling; density current Mathematical models ofsediment transport; effect of coherent turbulence on sediment transport.

Text/Reference Books:

1. Garde, R.J., Raju, K.G.R (1985). Mechanics of Sediment Transportation and AlluvialStream, Problems. (2nd edition) Wiley Eastern Ltd., 618 pages [ISBN 0-85226-306-6]
2. Bogardi, J. (1974). Sediment Transport in Alluvial Streams. AkademiaiKiado, Budapest,826 pages [ISBN 963-05-0278-x]
3. Graf, W.H. (1971). Hydraulics of Sediment Transport. McGraw-Hill, 513 pages [ISBN 07-023900-2]
4. Chien, N., Wan, Zhaohui (1999). Mechanics of Sediment Transport. ASCE Press,Virginia, 913 pages [ISBN 0-7844-0400-3]

Course Outcomes: At the end of the course, the student will be able to

- CO-1 understand sediment properties and various components.
- CO-2 understand sediment movement, bed forms, meandering and braided river.
- CO-3 understand sediment transport mechanism and scouring.
- CO-4 do fluvial design for river bank protection.

CODE	Coastal Engineering and Coastal Zone Management	L	T	P	C
CE 5542	M.Tech. (Water Resources Engineering), 2ndSem (Elective II)	3	0	0	3

Introduction – Wind, Waves, Cyclones, Strom Surges, Shoreline Change, Indian Coast.
Fundamentals of wind, waves and tides – Interaction of wind and water mass, wave and their generation, wave propagation, wave transformations, wave decay, Tides, Ocean currents.
Wave theories – Introduction, Linear wave theory, Boundary conditions, water particle characteristics, wave energy, superposition of waves, Finite amplitude wave theories.
Wave forces – wave force on coastal structure, wave force regimes, Froude – krylov force, wave force on small diameter cylinder and large fixed vertical cylinder.
Coastal Zone Management – Sediment transport in coastal region, Principle, CRZ act, sustainable development, integrated CZM, issues, constraints. Implementation of ICZM: world scenario, Indian scenario - case studies. Risk analysis of coastal structures, Socio economic analysis, tourism. Territorial water, EEZ and contiguous zone. Living and non-living resources.

Text/Reference Books:

1. J. S. Mani., "Coastal Engineering", 2nd edition, PHI Learning Pvt. Ltd., 2018.
2. V. Sundar, "Ocean Wave Mechanics: Applications in Marine Structures", 1st Ed.Wiley. 2017.
3. M C Deo, "Wave and Structures", Notes published in IITB website. https://www.civil.iitb.ac.in/~mcdeo/waves_book1/wave.pdf
4. USACE Publications, "Coastal Engineering Manual (Part 1 – 6)", 2008.

Course Outcomes: At the end of the course, the student will be able to

CO-1	understand the basics of ocean and its components.
CO-2	demonstrate the ability to apply linear long wave theory to selected problems on coastal engineering.
CO-3	demonstrate the ability to calculate basic wave forces on structures.
CO-4	understand sediment transport mechanism, coastal zone management and implement the various coastal protection techniques to minimize erosion.

ELECTIVE –III

CODE	Water Resources Planning and Management	L	T	P	C
CE 5551	M.Tech. (Water Resources Engineering), 2ndSem (Elective III)	3	0	0	3

Objectives of water resource development; needs and opportunities;

Spatial and temporal characteristics of water resources; constraints for its development likenon-reversibility; planning region and horizon.

Financial analysis of water resources projects; allocation of cost of multipurpose projects;repayment of cost.

Demand for drinking water; irrigation, hydropower; navigational; planning for flood control.

Characteristics and functions of reservoir; reservoir sedimentation; conservation storage; conflict among uses, Reservoir operation studies-effect on river regime; long term simulation; reliability; resiliency and vulnerability assessment.

Ground water evaluation; conjunctive use of surface and ground water.

benefit cost parameters; estimation of benefits and costs; appraisal criteria; social benefit cost analysis.

Basin planning; inter-basin transfer of water.

Environmental impacts assessment guidelines and case studies.

Text/Reference Books:

1. James, L.D., and Lee, R. R., "Economics of Water Resources Planning", McGraw Hill.1971
2. Simulation Modelling and analysis by Law and Kelton
3. Jain, S.K. and V.P. Singh, Water Resources Systems Planning and Management, Vol.51, Elsevier Science, 2003.
4. Haimes, Hierarchical Analyses of Water Resources Systems: Modeling and Optimization of Large scale systems, McGraw-Hill, New York, 1977.
5. Operations Research – An introduction by H. A. Taha
6. Engineering optimization – theory and Practice by S. S. Rao
7. Optimization for Engineering Design- algorithms and Example By Kalyanmoy Deb

Course Outcomes: At the end of the course, student will be able to:

CO- 1	Understand system, system design, modeling and its components.
CO- 2	Analyze and planning of surface and sub-surface water resources system.
CO- 3	Plan, design and develop operation policies of feasible water resources system under constraints.
CO- 4	Analyze economic and Environmental aspect of water resources system

CODE	Computational Fluid Dynamics	L	T	P	C
CE 5552	M.Tech. (Water Resources Engineering), 2nd Sem (Elective III)	3	0	0	3

Introduction: Numerical vs Analytical vs Experimental, Modeling vs Experimentation, Conservation equations; Mass, momentum and energy equations; Conservative forms of the equations and general description.

Classification of Partial Differential Equations and Physical Behavior: Classification intovarious types of equations -- parabolic elliptic and hyperbolic; Boundary and initial conditions;Overview of numerical methods.

Finite Difference Method: Introduction, finite difference approximations, Taylor series expansion, polynomial fitting, approximation of boundary conditions, applications to WRE problems.

Finite Volume Method: Basic methodology, finite volume discretization, approximation of surface and volume integrals, interpolation methods – central, upwind and hybrid formulationsand comparison for convection-diffusion problem.

Finite Element Method: Introduction to Rayleigh-Ritz, Galerkin and least square methods, interpolation functions, one and two dimensional elements, applications.

Methods of Solution: Solution of finite difference equations, iterative methods, ADI (Alternating direction implicit) method, applications.

Time integration Methods: Single and multilevel methods; predictor-corrector methods; stability analysis; Applications to transient conduction and advection-diffusion problems.

Grid Geometry: Basic ideas, transformation and mapping, unstructured grid generation,various methods of grid generations (Algebraic, Transfinite, Poissonequation methods)..

Navier-Stokes Equations: Explicit and implicit methods; SIMPLE type methods; fractional step methods Phase Change Problems: Different approaches for moving boundary, variable time step method, enthalpy method.

Uncertainty of numerical results: Sources of uncertainties, studies on grid independence,time-step independence, domain independence, initial condition dependence.

Turbulence modeling: Reynolds averaged Navier-Stokes equations, RANS modeling, DNSand LES.

Text/Reference Books:

1. Anderson, D.A., Tannehill, J.C. and Pletcher, R.H., "Computational Fluid Mechanicsand Heat Transfer", 3rd Ed., Taylor & Francis , 2011
2. Anderson, J.D., Jr., "Computational Fluid Dynamics", McGraw Hill., 1995
3. J. Blazek, Computational Fluid Dynamics:Principlesand Applications, Elsevier.
4. Ferziger, J. H. and Peric, M., "Computational Methods for Fluid Dynamics",

3rd Ed.,Springer., 2003

5. Versteeg, H. and Malalasekra, M., "An Introduction to Computational FluidDynamics: The Finite Volume Method", 2nd Ed., Pearson Education, 2007
6. Computer Simulation of Flow and Heat Transfer by *P. S. Ghosh dastidar (4th Edition,Tata McGraw-Hill)*,1998.
7. Chung, T. J., "Computational Fluid Dynamics". 2nd Ed., Cambridge University Press,2010
8. Patankar, S. V., "Numerical Heat Transfer and Fluid Flow", Taylor and Francis, 1980

Course Outcomes: At the end of the course, student will be able to:

CO-1	solve non-linear partial differential equations (PDE).
CO- 2	have knowledge of CFD techniques for solving incompressible andcompressible N-S equation in primitive variables, grid generation in complex geometry
CO- 3	have exposure in the use of modern CFD software and interpretation of results obtained for the analysis of complex fluid-flow/Water resources systems.

ELECTIVE – IV

CODE	Introduction of Soft Computing Technique in Engineering	L	T	P	C
CE 5561	M.Tech. (Water Resources Engineering), 2ndSem (Elective IV)	3	0	0	3

Introduction to Soft Computing: Definitions, advantages and disadvantages, soft vs Hard computing, solution of complex real life problems

Artificial Neural Networks: Fundamentals, Neural Network Architectures, Feedforward Networks, Back propagation Networks.

Genetic Algorithms: Generation of population, Encoding, Fitness Function, Reproduction, Crossover, Mutation, probability of crossover and probability of mutation, convergence.

Fuzzy Logic: Fuzzy Sets, Fuzzy numbers, Fuzzy Systems, membership functions,fuzzification, defuzzification.

Multi-objective Optimization Problem Solving: Concept of multi-objective optimization problems (MOOPs) and issues of solving them. Multi-Objective Evolutionary Algorithm (MOEA), Non-Pareto approaches to solve MOOPs**,** Pareto-based approaches to solve MOOPs**,** Some applications with MOEAs.

Applications in EngineeringText/Reference Books:

1. Neural Networks and Learning Machines, (3rd Edn.), Simon Haykin, PHI Learning, 2011.
2. Fuzzy Logic with Engineering Applications (3rd Edn.), Timothy J. Ross, Willey, 2010.Foundations of Neural Networks, Fuzzy Systems, and Knowldge Engineering, Nikola K.Kasabov, MIT Press, 1998.
3. Fuzzy Logic for Embedded Systems Applications, Ahmed M. Ibrahim, Elesvier Press, 2004.
4. An Introduction to Genetic Algorithms, Melanie Mitchell, MIT Press, 2000.
5. Genetic Algorithms In Search, Optimization And Machine Learning, David E. Goldberg,Pearson Education, 2002.
6. Neural Networks, Fuzzy Logis and Genetic Algorithms : Synthesis, and Applications, S.Rajasekaran, and G. A. VijayalakshmiPai, Prentice Hall of India, 2007.
7. Soft Computing, D. K. Pratihar, Narosa, 2008.
8. Neuro-Fuzzy and soft Computing, J.-S. R. Jang, C.-T. Sun, and E. Mizutani, PHI Learning,2009.

Course Outcomes: At the end of the course, student will be able to:

CO-1	understand the basic areas of **Soft Computing** including ANN, **Fuzzy** Logic and Genetic Algorithms.
CO-2	understand basic theory of ANN and several ANN architecture, training algorithm and application in engineering.
CO-3	have knowledge of Fuzzy sets, rules and applications.
CO-4	understand genetic algorithm concepts and theory and application in optimization and planning problem.
CO-5	get mathematical background for carrying out the multi objective optimizations in engineering.

CODE	Optimization Methods in Engineering and Design	L	T	P	C
CE 5562	M.Tech. (Water Resources Engineering), 2ndSem (Elective IV)	3	0	0	3

Introduction to Optimization: Definitions, Classifications, Overview of

TopicsIntroduction to Numerical Linear Algebra

Single Variable Optimization Algorithms – Optimality criteria, Bracketing Methods, RegionElimination Methods, Point Estimation Methods, Gradient-Based Methods, Root finding using Optimization Techniques

Multivariable Optimization Algorithms-Optimality criteria, Direct Search Methods,Gradient Based Methods

Constrained Optimization Algorithms-Kuhn-Tucker Conditions, Transformation Methods,Direct search methods

Specialized Algorithms-Integer Programming, Geometric

Programming Introduction to Genetic Algorithms, Particle Swam

Optimization, fire-fly

Introduction to Genetic Algorithms, Particle Swam Optimization, fire-fly algorithms andothers.

Text/Reference Books:

4. Engineering Optimization: Theory and Practice, Singiresu S. Rao, Willey
5. Optimization of Engineering Design: Algorithms and Examples, Kalyanmay Deb, PHI.
6. Engineering Optimization-Methods and Applications, A.Ravindran, G.V. Reiklaitis and M. Rangsdell, Wiley.

Course Outcomes: At the end of the course, student will be able to:

CO- 1 understand the basic concept and overview of optimization.

CO- 2 compare various existing optimization tools and algorithms particularly for problems in water resources engineering.

CO- 3 formulate the problem and apply specific optimization tools/techniques related to the problem.