Curriculum & Syllabi

of

Master of Technology

In

Structural Engineering

(w.e.f. 2018-19)

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Syllabi

Offered By

DEPARTMENT OF CIVIL ENGINEERING
M. M. M. UNIVERSITY OF TECHNOLOGY,
GORAKHPUR-273010, UP

August 2021

M. Tech. Structural Engineering

Vision

To become a premier centre of learning and research in Civil Engineering, nurturing sustainable development by the year 2025.

Mission

1. To provide the quality education in the area of Civil Engineering to transform students into graduates with high professional values.
2. To share and disseminate expertise for use in the solution of problems faced by Civil engineering industry and by society.
3. To ensure the continuous improvement in the quality of life of people in the society.
4. To conduct need based research projects giving priority to the needs of industry.

Programme Educational Objectives (PEO)

The graduates who choose to acquire post graduate degree in structural engineering should:

PEO1: Be able to apply the knowledge in the area of advanced Structural Analysis, Structural Dynamics, allied theory in elasticity and plasticity, FEM etc.

PEO2: Be capable of using latest design codes, as prescribed for Indian and International scenario on Structural Engineering and to motivate them in interdisciplinary involvement in problems related to Structural Engineering.

PEO3: Have an orientation to carry out high value research related to Structural Engineering so that they get impetus to pursue research and lifelong learning.

Programme Outcome (POs)

The students should be able to acquire the following outcomes by fulfilling the Program Educational objectives (PEOs) after successful completion of the courses:

PO1: Acquire in-depth knowledge of Structural Engineering discipline and build capability to apply that knowledge to real world problems.

PO2: Program graduates will gain knowledge and skill to integrate Structural engineering concepts across multiple disciplines.

PO3: Ability to employ technical knowledge and leadership skills to Structural Engineering research and consultancy problems.

PO4: Capability to carry out original and useful research in key areas of Structural Engineering.

PO5: Identify and analyze the impact of Structural Engineering in infrastructure projects and find a suitable solution from number of alternatives.

PO6: Develop skills to communicate technical values of Structural Engineering research with the public, learners, practitioners, and other community members of concern.

PO7: Apply the knowledge of Structural analysis and management with high ethical value towards society and environment economically.

PO8: Enthusiasm and confidence to pursue lifelong learning for professional advancement.

PO9: Decision making skills and innovation capability in a team for common objectives.

PO10: The interest to pursue higher studies and research on continuous basis.

Programme Specific Outcome (PSOs):

The students should be able to acquire the following outcomes by fulfilling the objectives (PSOs) after successful completion of the courses:

PSO1: Use the appropriate software in the area of structural engineering.

PSO2: Ability of critical thinking based on in-depth knowledge in structural engineering to obtain optimal solutions to the complex engineering problems.

PSO3: Apply knowledge of materials and analysis for design of RCC, steel, masonry, and other innovative materials for structural design.

Credit Structure

Category	Semesters	I	II	III	IV	Total
Maths (M)		4	-	-	-	4
Programme Core (PC)		13	13	-	-	26
Programme Electives (PE)		-	4	8	-	12
Minor Project (MP)		-	-	4	-	4
Dissertation (D)				4	14	18
Seminar (S)		-	-	-	2	2
Total		**17**	**17**	**16**	**16**	**66**

Curriculum

Junior Year, Semester I

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	M	MMS606/ MAS-112	Advanced Engineering Mathematics	3	1	0	4
2.	PC	MCE-301	Advance Structural Analysis	3	1	0	4
3.	PC	MCE-302	Concrete Structures	3	1	2	5
4.	PC	MCE-000	Advances in Civil Engineering	3	1	0	4
5.	AC		Audit Subject				
			Total	**12**	**4**	**2**	**17**

Junior Year, Semester II

S.N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	PC	MCE-304	Analysis and Design of Dynamic Effects	3	1	2	5
2.	PC	MCE-305	Metal Structures	3	1	0	4
3.	PE1	MCE–***	ProgrammeElective-1	3	1	0	4
4.	PC	MCE-303	Prestressed Concrete	3	1	0	4
5.	AC		Audit Subject				-
			Total	**12**	**4**	**2**	**17**

Senior Year, Semester III

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	PE2	MCE-***	Programme Elective-2	3	1	0	4
2.	PE3	MCE-***	Programme Elective-3	3	1	0	4
3.	MP	MCE-320	Minor Project	0	0	8	4
4.	D	MCE-330	Dissertation Part-I	0	0	8	4
			Total	**6**	**2**	**16**	**16**

Senior Year, Semester IV

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	S	MCE-340	Seminar	0	0	4	**2**
2.	D	MCE-350	Dissertation Part-II	0	0	28	**14**
			Total	**0**	**0**	**32**	**16**

Programme Core for M. Tech. (Structural Engineering)

S. N.	Paper Code	Subject Name	Prerequisite Subjects	L	T	P	Credits
1.	MCE-301	Advance Structural Analysis	-	3	1	0	4
2.	MCE-302	Concrete Structures	-	3	1	2	5
3.	MCE-303	Prestressed Concrete	-	3	1	0	4
4.	MCE-304	Analysis and Design of Dynamic Effects	-	3	1	2	5
5.	MCE-305	Metal Structures	-	3	1	0	4
6.	MCE-320	Minor Project	-	0	0	8	4
7.	MCE-330	Dissertation Part-I	-	0	0	8	4
8.	MCE-340	Seminar	-	0	0	4	2
9.	MCE-350	Dissertation Part-II	Dissertation Part-I	0	0	28	14

Programme Electives (PEI)

S. N.	Paper Code	Subject Name	Prerequisite Subjects	L	T	P	Credits
1.	MCE-351	Maintenance and Rehabilitation of Structures	-	3	1	0	4
2.	MCE-352	Pre-cast and Composite Structures	-	3	1	0	4
3.	MCE-368	Bridge Engineering	-	3	1	0	4
3.	MCE-353	Rock Engineering	-	3	1	0	4
4.	MCE-354	Continuum Mechanics	-	3	1	0	4

Programme Electives (PE2)

S. N.	Paper Code	Subject Name	Prerequisite Subjects	L	T	P	Credits
1.	MCE-356	Retrofitting of Buildings	-	3	1	0	4
2.	MCE-357	Hydraulic Structures	-	3	1	0	4
3.	MCE-358	Machine Foundations	-	3	1	0	4
4.	MCE-369	Ground Improvement Technique	-	3	1	0	4
5.	MCE-359	Finite Element Method	-	3	1	0	4

Programme Electives (PE3)

S. N.	Paper Code	Subject Name	Prerequisite Subjects	L	T	P	Credits
1.	MCE-361	Nonlinear Analysis of Structures	-	3	1	0	4
2.	MCE-362	Earth & Rock fill Dam.	-	3	1	0	4
3.	MCE-366	Design of Plates and Shells	-	3	1	0	4
3.	MCE-363	Project Planning and Control	-	3	1	0	4
4.	MCE-367	Industrial Structures	-	3	1	0	4
4.	MCE-364	Soil Structure interaction	-	3	1	0	4

Audit Courses for M. Tech. (Structural Engineering)

S. No.	Paper Code	Subject	Prerequisite Subject	L	T	P	Credits
1.	MAS-105	Applied Probability and Statistics	-	3	1	0	4
2.	MBA-109	Research Methodology	-	3	1	0	4
3.	MAS-109	Foreign Language-French	-	2	1	0	3
4.	MAS-110	Foreign Language-German	-	2	1	0	3
5.	BCS-68	Neural Network and Fuzzy System	-	3	1	0	4

Besides above electives, the students may be offered others electives subject to prior approval form competent authority.

SYLLABI

MMS 606 ADVANCED ENGINEERING MATHEMATICS

Course category	:	Basic Sciences & Maths (BSM)
Pre-requisites	:	NIL
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical: 0
Number of Credits	:	4
Course Assessment methods	:	Continuous assessment through tutorials, assignments, quizzes, One Minor and One Major Theory Examination.
Course Outcomes	:	The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course

1. To find out the dimension of vector spaces
2. To describe the differences between finite-difference and finite-element methods for solving PDEs;
3. To solve Elliptical (Laplace/Poisson) PDEs using finite differences;
4. To solve functional using Euler method.

Topics Covered

UNIT-I

Vector spaces and Linear transformation: Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernel & images, matrix representation of linear transformation, change of basis, Eigen values and Eigen vectors of linear operators, diagonalization. 9

UNIT-II

Numerical Techniques: Solution of algebraic and transcendental equations using bisection, Regula Falsi and Newton Raphson's method, Numerical solution to linear system, LU factoring decomposition, Cholesky method, Gauss Seidal method, Numerical eigen value problem, Jacobi, Givens method 9

UNIT-III

Calculus of Variation: Functionals, Euler's equation and its generalization. One and several independent variables. Initial value problems. Weierstrass's sufficiency condition for weak and strong minima and maxima 9

UNIT-IV

Numerical Solution of Partial Differential Equations: Classification of partial differential equations of the second order. Laplace equations and its solution by Liebmann's process. Poisson equation. Solution of Parabolic, Eliptic and Hyperbolic Equations. Applications to Engineering. 9

Textbooks

1. K. Hoffman, R Kunze, Linear Algebra, Prentice Hall of India, 1971.
2. I. M. Gelfrand, S. V. Fomin, Calculus of Variation, Dover Publications.
3. M. D. Raisinghania, Advanced Differential Equations, Schand Publishers.
4. P. Kandasamy, K.Thilagavathy & K.Gunavathy, Numerical Methods, S. Chand Publ.

MCE-301 ADVANCED STRUCTURAL ANALYSIS

Course category	:	Department Core (DC)
Pre- requisites	:	Structural Analysis, Strength of Material
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, student will be able:

1. To differentiate between various methods of analysis for multistorey frames.
2. To categorize and choose appropriate structural analysis method.
3. To analyze the structure using software.
4. To prepare algorithm and flowchart for analysis of structure.
5. To formulate and analyze beams on elastic foundation.

Topic Covered

UNIT I **9**

Static and kinematic indeterminacies stiffness and flexibility matrices, force & displacement methods

UNIT II **9**

Stiffness matrices for prismatic and non- prismatic members, solution techniques, substructure analysis techniques, application to plane and space frame analysis.

UNIT III **9**

Organization of computation, programming considerations, applications to practical problems

UNIT IV **9**

Techniques of non-linear structural analysis, material and geometrically non- linear problems, incremental and iterative procedures, convergence criteria.

List of Experiments:

1. Modelling of a Pin jointed Plane Frame Via STAAD Pro
2. Modelling of a Rigid Jointed Plane Frame through STAAD Pro
3. Modelling of a Bridge by STAAD Pro
4. Modelling of a Multi-Story Building for Earthquake Load.

Books & References:

1. Matrix Method of Structural Analysis - Madhu B. Kanln (Willey Eastern Limited, NewDelhi)
2. Matrix Structural Analysis-William Mc Guire Richard, H. Gallghare, Ronald D. Ziemian (Willey International)

MCE-302 CONCRETE STRUCTURES

Course category	:	Department Core (DC)
Pre- requisites	:	Concrete Technology
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:2
Number of Credits	:	5
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	After successful completion of this course the student will be able to:

1.Apply principles of RCC to design slabs and walls.
2.Analyze the loads to assess critical bending moments, shear forces and torsion.
3. Understand the behaviour of beam column joint.
3. Design & detailing of reinforcement for RCC building frames & Box frames.

Topic Covered

UNIT I **9**
Limit state design philosophy
UNIT II **9**
Redistribution of moments in continuous span beams, plastic hinge concept, and rotation capacity of sections and detailing for ductility, Beam column joints
UNIT III **9**
Yield line theory for slabs, Equilibrium, and virtual work methods.
UNIT IV **9**
Shrinkage and creep, Building frames, box frames.

List of Experiments:
1. High performance Concrete Mix design.
2. Design and testing of R.C.C. beam for Two Points loading.
3. Design & Testing of a one-way slab.
4. Design & Testing of a two slab.

Books & References:
1. Limit State Method of Design - Dr. B.C. Punmia, Ashok Kumar Jain, and Arun Jain (Lakshmi Publication)
2. IS 456:2000.

MCE-000 ADVANCES IN CIVILENGINEERING

Course category : Engineering Fundamental (EF)

Pre- requisites : Structural Analysis, Strength of Material

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Objective : This course has been designed to brush-up as well to enhance the knowledge of all freshly admitted students of the department.

Course Outcome : The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Know different methods for calculating the stress strain.
2. Able to apply Hook's law.
3. Able to draw the Mohr's circle for calculating the stress and strain in different direction.
4. Understand how to calculate the reactions, bending moment and shear force, and also able to draw the bending moment and shear force diagram for different type of structures The students may learn to design a water or wastewater treatment component.
5. The students can learn how to characterize source water, for physical and chemical treatment of drinking water.
6. The students can learn how to characterize wastewater, physical, chemical and microbiological treatment of wastewater.
7. The students will learn the water demand, sources of water and intake structures.
8. To identify the different types of flow in open channel.
9. To understand the concept of hydraulic jump.
10. To classify the various types of flow profile able to understand how to control project schedule, cost, quality and risk.
11. Develop the ability to analyze the risk and feasibility of real estate projects throughout their lifecycle.
12. Students will be able to know the different types of equipment to be used in the construction projects.

Topics Covered

UNIT-I

Shear Strength of Soils: Mohr-Coulomb Failure Criterion, Methods of Shear Strength Determination: Direct Shear Test, Triaxial test. Total and effective Stress Parameters, Pore Water Pressure Parameters, Stress-Strain Behaviour of Sands.

Compression and Consolidation of Soils: Compressibility Characteristics, Normally Consolidated and Over- Consolidated Clays, Estimation of Preconsolidation Stress, Terzaghi's Theory.

UNIT-II

Hydraulic Jump, Hydraulic Jump characteristics and its application in Civil Engineering, Stilling Basin types and Design (One complete problem on stilling Basin Design and Drawing).

UNIT-III

Equipment Management; Productivity, operational cost, owning and hiring cost and the work motion study. Simulation techniques for resource scheduling. Construction Equipment for earth moving, Hauling equipment, Hoisting equipment Conveying equipment, Concrete Production equipment. Importance of estimation, different types of estimates, specifications: general and detailed. Methods of estimation, Estimates of RC works, Estimates of Buildings.

UNIT-IV

Beneficial uses of water and quality requirements, standards, sources of water, unit operations, process, and flow sheets in water treatment.

Wastewater characteristics, Preliminary, primary, secondary and tertiary treatment processes of wastewater, aerobic and anaerobic treatment process, recycling, reuse and recrimination of wastewater, wastewater disposal.

Textbooks/ Reference books

1. Brij Mohan Das – Geotechnical Engineering, CENGAGE Learning
2. Gopal Ranjan and A. S. R. Rao–Basic and Applied Soil Mechanics, New Age Intl(P)Ltd.
3. K. R. Arora–SoilMechanics&FoundationEngg.StandardPublishers&Distributors, Delhi
4. Chow, V.T., Open channel Hydraulics, McGraw Hill International, NewYork,1959
5. Subramanya, K., Flow in Open Channels, TataMcGrawHill.,4th Edn.,2015
6. IS 4997: Criteriafordesignofhydraulicjumptypestillingbasinswithhorizontalandslopingapron.by Bureau of Indian Standards
7. Construction Planning and Management by U.K. Srivastava.
8. Construction, Planning, Equipment and Methods by R. L. Peurify
9. Estimating and Costing by B. N. Dutta.
10. Estimating, Costing and Valuation in Civil Engineering by M. Chakraborty.
11. Peavy, Rowe and Tchobanoglous: Environmental Engineering
12. Metcalf and Eddy Inc.: Wastewater Engineering
13. Garg: Water Supply Engineering (Environmental Engineering Vol.–I)
14. Garg: Sewage Disposal and Air Pollution Engineering (Environmental Engineering Vol.–II).

MCE-303 PRESTRESSED CONCRETE

Course category : Department Core (DC)

Pre- requisites : Advanced Concrete Technology

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : On successful completion of the course, student will be able:

1. To differentiate between behavior of P.S.C. and R.C.C. members.
2. To visualize the effect of prestressing on stress condition across the cross-section of the member.
3. To analyze the stresses, evaluate the losses of prestress and determine the behavior of determinate and indeterminate prestressed concrete members.
4. To determine the ultimate flexural, shear, and torsional strength of PSC member.
5. To design the PSC members using limit state concept (IS-1343) and apply to various members like beams, poles and pipes.

Topic Covered

UNIT I **9**

General principles of prestressing- Materials for prestressing, Prestressing systems

UNIT II **9**

Losses of prestress, Load balancing concept

UNIT III **9**

Partial prestressing, Circular prestressing, Prestressed Concrete Beams, End Blocks

UNIT IV **9**

Prestressed concrete pipes and poles.

Books & References:

1. Prestressed Concrete-N. Rajagopalan (Narosa) 2. NBC:2005.

MCE-304 ANALYSIS AND DESIGN OF DYNAMIC EFFECTS

Course category : Department Core (DC)

Pre- requisites : Structural Analysis, Numerical Methods

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:2

Number of Credits : **5**

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : On successful completion of the course, student will be able:

1. To provide the fundamental understanding of the structural dynamics and the problem-solving ability for dynamic response.
2. To convert structure into SDOF system and find response of free and force vibration (harmonic, periodic and transient),
3. To find natural frequency and mode shapes of MDOF system and carry out modal analysis.
4. To compute the dynamic parameters of SDOF and MDOF systems using free vibration and forced vibrations.
5. To differentiate and choose appropriate methods of dynamic analysis for structural engineering problems.
6. To construct response spectrum of an earthquake and correlate to the construction of design spectra.

Topic Covered

UNIT I **9**

Single degree freedom systems, damping, impact, Earthquake and blast loads

UNIT II **9**

Duhamel integral, Rayleigh method, Green's function, elastic response spectra, Fourier series, Fast Fourier Transform, complex frequency response function, response of SDF system in frequency domain, time history analysis of SDF system

UNIT III **9**

New mark method and Wilson theta method for linear problems, convergence criteria. Multi degree of freedom systems, application to multistory buildings, SRSS and CQC mode superposition techniques

UNIT IV **9**

Introduction to computer program(s) on dynamics, vibration of continuous systems including axial effects, lumped and consistent mass matrix, introduction to inelastic response spectra, design specifications in IS:875(Pt.3)

EXPERIMENTS

1. Earthquake resistant detailing of Non-Engineered Buildings
2. Earthquake resistant detailing of Brick Masonry Buildings
3. Earthquake resistant detailing of R. C. C. Buildings
4. Modelling, Design & Detailing of a moment resisting frame.

Books & References:

1. Structural Dynamics - Mario Paz (CBS Publishers)
2. Earthquake Resistant Design of Structure - Pankaj Agrawal, Manish Shrikhande (PHI Pvt Ltd.)

MCE-305 METAL STRUCTURES

Course category	:	Department Core (DC)
Pre- requisites	:	Steel Structures, Structural Analysis
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, student will be able:

1. To identify the structural behavior of components of steel factory shed and steel building.
2. Learn the various complex connection design.
3. To assess the suitability of light gauge steel sections for structural members and design.
4. To familiar with the design of Tubular structures.

Topic Covered

UNIT I **9**

Limit State Design Philosophy- Overview of IS 800- 2007 Codal provisions for Welded and Bolted Connections, Slip resistant connections. Defects in welds

UNIT II **9**

Beam Column joints- Eccentric Connections, Seat connections, Flexible connections, Splices in Beams and columns.

UNIT III **9**

Light gauge structures

UNIT IV **9**

Tubular structures

Books & References:

1. IS:800 2007
2. Limit State Design of Steel Structure - Dr. S.K. Duggal (TMH)

MCE-351 MAINTENANACE AND REHABILITATION OF STRUCTURES

Course category	:	Programme Elective 1 (PE 1)
Pre- requisites	:	Building Materials, Construction Technology
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	Students will be able to understand

1. the importance of maintenance and assessment method of distressed structures.
2. the strength and durability properties, their effects due to climate and temperature.
3. recent development in concrete
4. the techniques for repair protection methods and understand the properties of repair materials
5. repair, rehabilitation and retrofitting of structures and demolition methods.

Topic Covered

UNIT I **9**

Maintenance, repair and rehabilitation, Facets of Maintenance, importance of Maintenance various aspects of Inspection, Assessment procedure for evaluating a damaged structure, causes of deterioration

UNIT II **9**

Quality assurance for concrete construction concrete properties- strength, permeability, thermal properties, and cracking - Effects due to climate, temperature, chemicals, corrosion - design and construction errors - Effects of cover thickness and cracking

UNIT III **9**

Special concretes and mortar, concrete chemicals, special elements for accelerated strength gain, Expansive cement, polymer concrete, Sulphur infiltrated concrete, ferro cement and polymers coating for rebars loadings from concrete, mortar and dry pack, vacuum concrete, Gunite and Shotcrete, Epoxy injection, Mortar repair for cracks, shoring and underpinning. Methods of corrosion protection, corrosion inhibitors, corrosion resistant steels and cathodic protection

UNIT IV **9**

Repair of structures distressed due to earthquake – Strengthening using FRP -Strengthening and stabilization techniques for repair, Engineered demolition techniques for structures -case studies.

Books & References:

1. Concrete Structures, Materials, Maintenance and Repair- Denison Campbell, Allen and Harold Roper, (Longman Scientific and Technical, UK),1991
2. Repair of Concrete Structures -Allen R.T and Edwards S.C. (Blakie and Sons, UK),1987
3. Learning from Failures, Deficiencies in Design, Construction and Service-Raikar, R.N., R and D Centre (SDCPL), Raikar Bhavan, Bombay,1987.
4. Concrete Technology-Santha kumar A. R. (Oxford University Press), 2007, Printed in India by Radha Press, New Delhi
5. Concrete Repair and Maintenance Illustrated -Peter H. Emmons (Galgotia Publications Pvt. Ltd.),2001
6. Maintenance and Durability of Concrete Structures-Dayaratnam. P and Rao.R (University Press),1997.

MCE-352 PRECAST AND COMPOSITE STRUCTURES

Course category	:	Programme Elective 1 (PE 1)
Pre- requisites	:	Structural Analysis, Advanced Concrete Technology
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, students will be able:

1. Ability to know the composite construction, design criteria, material properties, partial shear connection, partial interaction, buckling, shear lag.
2. Ability to understand elastic analysis of composite beams, rigid plastic analysis of simply supported beams, mechanical shear connectors.
3. Ability to learn about transfer of longitudinal shear forces, stocky columns, slender columns, composite beams with service ducts.

Topic Covered

UNIT I **9**

Precast and cast in situ concrete structures

UNIT II **9**

Prestressed and cast in situ concrete structures, Steel, and concrete Composite structures

UNIT III **9**

Encased beams and columns

UNIT IV **9**

Applications to bridge decks, girders, and precast building systems Pre-Engineered Buildings.

Books & References:

1. Advances in Building Materials & Construction, CBRI Roorkee
2. Precast Concrete Structures – Habber Benchmann & Altreid Stainle (Wille VCH).

MCE-368 BRIDGE ENGINEERING

Course category	:	Programme Elective 1 (PE 1)
Pre- requisites	:	Structural Analysis, Advanced Concrete Technology
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, students will be able:

1. To enlist, classify and recommend the structural forms used for bridges.
2. To select different standard loads for road/railway bridges conforming to IRC, MOST, Railway Ministry codes as per current practice.
3. To analyze the bridge spans for train of moving loads.
4. To design road bridges using different forms and materials and prepare detailed drawings of the same.
5. To design railway bridges using different forms and materials and prepare detailed drawings of the same.

Topic Covered

UNIT I **9**

General Considerations- Types of Bridges, Economic Spans

UNIT II **9**

Suitability of different types of Bridges, Design loads for highway and Railway Bridges.

UNIT III **9**

Solid slab bridge, Slab and beam bridge

UNIT IV **9**

Lattice girder Bridge Plate girder bridge, Bridge substructure and bearings Note: Detailed design shall be worked out for at least one concrete bridge and one steel bridge.

Books & References:

1. Introduction to Bridge Engineering-Victor Jophn Streeter
2. Bridge Engineering -Ponnwwami.

MCE-353 ROCK ENGINEERING

Course category : Programme Elective 1 (PE 1)

Pre- requisites : Structural Analysis, Advanced Concrete Technology

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : On successful completion of the course, students will be able:

1. Define the characteristics and the mechanical properties (strength and failure criteria) of rock mass, rock matrix and discontinuities.
2. Explain methods for in situ investigation and laboratory testing of rock matrix and discontinuities.
3. Use rock mass classification systems (RMR, Q, GSI).
4. Conduct rock slope stability analyses.
5. Analyse the stress distribution (isotropic, anisotropic) in situ and around an opening in rock (competent rock, jointed rock mass, blocky rock).
6. Propose designs of excavation supports.

Topic Covered

UNIT I **9**

Introduction, Geological considerations, Index properties and rock mass classifications

UNIT II **9**

Strength and failure criteria for rocks and rock masses, Insitu stresses in rocks and their measurement. Strength and deformation behaviour of discontinuities in rocks

UNIT III **9**

Deformation behaviour of rocks and rock masses, Time dependent behaviour of rocks

UNIT IV **9**

Application of Rock mechanics to Underground Structures, Slopes and Foundations, Improving the properties of insitu rock masses.

Books & References:

1. Bhawani Singh and R.K. Goel (2016) Engineering Rock Mass Classification Tunnelling, Foundations and Landslides, Butterworth-Heinemann, Elsevier
2. Richard E Goodman (1988) Introduction to Rock Mechanics, Wiley
3. Barry H.G. Brady and E.T. Brown (2004) Rock Mechanics: For underground mining, 3rd Edition, Springer, UK
4. J W Bull (1993) Soil-Structure Interaction: Numerical Analysis and Modelling, CRC Press

MCE-354 CONTINUUM MECHANICS

Course category : Programme Elective 1 (PE 1)

Pre- requisites : Engineering Geology

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : On successful completion of the course, students will be able:

1. Apply the classical theory of Elasticity and plasticity in two- and three-dimensional state of stress
2. Analyse the behavior of solids under different loads
3. Evaluate the stress and strain in two- and three-dimensional problems.
4. Formulate equations governing the behavior of two-dimensional solids.

Topic Covered

UNIT I **9**

Vectors and tensors, analysis for stresses, principal stresses and principal planes, stress invariants, equations of equilibrium, octahedral stresses, Analysis of strains, principal strains, octahedral strains, large deformations, and finite strains

UNIT II **9**

Elgerian, Lagrangian and Almansi, Green's and Cauchy's strain tensors Compatibility equations, elastic stress strain equations, generalized Hookean Law, principle of virtual work, nonlinear constitutive laws, hypo and hyper elastic solids, linearised theory of elasticity, two-dimensional plane stress, plane strain and axi-symmetric formulations

UNIT III **9**

Cartesian and polar coordinate systems, three-dimensional elasticity formulation for isotropic and anisotropic solids, boundary Value problems Torsion and bending theory Material yield criteria- Von Mises, Tresca, Mohr Coulomb, Drucker-Prager etc.

UNIT IV **9**

Isotropic and kinematic hardening, normality principle, plastic flow rule, Plastic Potential, Elasto-plastic Stress strain relations- Prandtl- Rauss equations, Levy-Meses Relations, Hardening Modulus, Generalised elasto-plastic stress-strain relations.

Books & References:

1. Continuum Mechanics for Engineers - G. Thoma Mase (CRC Press)
2. Tensor & Tensor Algebra for Engineers - Mikhail Ibkov (Springer Publication)

MCE-356 RETROFITTING OF BUILDINGS

Course category : Programme Elective 2 (PE 2)

Pre- requisites : Building Material

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : Upon completion of this course, the students will be able to

1. Develop design concepts for Lateral loads on the buildings and will get the knowledge of ductile detailing
2. Understand repairs, rehabilitation and retrofitting of structures
3. Get an idea of repair and retrofitting strategies and techniques.
4. Understand the earthquake resistant masonry features
5. Develop design concepts for Lateral loads on the buildings and also will get the knowledge of ductile detailing

Topic Covered

UNIT I **9**

Seismic Hazard Evaluation, Methodologies for seismic evaluation, Components of seismic evaluation Methodology, seismic evaluation of RC Columns, Beams, Joints and Slabs, Non-destructive evaluation techniques, Principles of Repair and Retrofitting.

UNIT II **9**

Terminology in Repair, Restoration, Strengthening and Rehabilitations, Criteria for Repair

UNIT III **9**

Restoration and Retrofitting; Repair Materials; In-situ testing methods for RC and masonry structure; Techniques of repair and retrofitting of masonry buildings.

UNIT IV **9**

Techniques of Repair and Retrofitting in RC buildings; Retrofitting of buildings by seismic base isolation and supplemental damping; Retrofitting of heritage structures; Retrofitting of bridges; Case studies in retrofitting.

Books & References:

1. Retrofitting Design for Building Structures-Xin Lin Lu (CRC Press)
2. Earthquake Resistant Design of Structures- Pankaj Agrawal, Manish Shikhande (PHI Pvt Ltd.)

MCE-357 HYDRAULIC STRUCTURES

Course category : Programme Elective 2 (PE 2)

Pre- requisites : Fluid Mechanics, Flow in Open channel

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : On successful completion of the course, students will be able:

1. 1. Understanding of the design of canal and its maintenance.
2. To know the types of canals, distributaries, canal headworks, cross-drainage and canal regulator works.
3. Understanding the various methods of analysis of canal.
4. Application of the canal, dam, and distributaries in civil engineering structures.

Topic Covered

UNIT I **9**

Types of Head works: Component parts of a diversion headwork, Failure of hydraulic structures founded on permeable foundations, Principles of design, Bligh's Theory, Khosla's theory for determination of pressure and exit gradient. Regulation Works: Falls, Classification, Introduction to design principle of falls, Design of Sarda type and straight glacis tall. Principle and design of Distributary head regulator and cross regulator.

UNIT II **9**

Canal head works: Functions, Location, Layout of head works. Weir and Barrage, Canal head Regulator, Introduction to the design principles of Weirs on permeable foundations, Design of vertical drop and sloping glacis weir. Cross drainage works: Necessity and types. Aqueduct, Siphon Aqueduct, super passage, canal siphon, level crossing, Introduction to design principles of cross drainage works.

UNIT III **9**

Dams: classification and selection criteria. Earth Dams: Classification, causes of failure Phreatic line, and its determination Introduction to stability analysis Gravity dams: Forces method of analysis, modes of failure and factor of safety, Elementary profile, stability analysis, galleries, joints, control of cracks.

UNIT IV **9**

Spillways: Spillway capacity, types of spillways, Design of ogee spillway, Energy dissipation below spillway, Design criteria for Hydraulic Jump type stilling basins with horizontal and sloping aprons, spillway gates. Hydro-Electric Power: assessment of potential specially in reference to India, classification of power plants, important terms, types of turbines and their suitability. Powerhouse layout and important structures of a powerhouse.

Books & References:

1. Irrigation, Water Resources and Hydraulic Structures -S.K. Garg (Khanna Publication, New Delhi)

2. Water Resources and Irrigation Engineering - G.H. Asawal (New Age International Pvt. Ltd., New Delhi).

MCE-358 MACHINE FOUNDATIONS

Course category : Programme Elective 2 (PE 2)

Pre- requisites : Structural Dynamics

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : This course aims to make the student well versed with theoretical, analysis/ design and practical aspects, including field measurements, of block and frame type of machine foundations.

Topic Covered

UNIT I **9**

Dynamic Properties of soils, various types of machine foundations, factors affecting the resonant frequency and amplitudes of vibrations

UNIT II **9**

Foundations under reciprocating machine; behaviour and design of block foundations, framed foundations, advantage for high-speed machines, design principles

UNIT III **9**

Vibration Isolation, IS Code of Practice, critical review

UNIT IV **9**

Structural design; general principles of design, construction aspects, case histories of failures o machine foundations.

Books & References:

1. Handbook of Machine Foundation – Srinivaslu &Vandyanathan (McGraw Hill)
2. Theory of Vibrations - Shabana A. (Springer)
3. Vibration of Soil & Foundation - Hall &Wood (Prentice Hall)
4. Foundation of Machines: Analysis & Design - Shamsher Prakash (John Wiley, N. Y.)

MCE-369 GROUND IMPROVEMENT TECHNIQUES

Course category : Programme Elective 2 (PE 2)

Pre- requisites : Soil Mechanics

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : Depending on the site conditions, student will be able to identify suitable

ground improvement technique for specific project and its implications.

Topic Covered

UNIT I **9**

Introduction, Review of compaction theory, effect of compaction on surface behaviour, Field methods of compaction, Quality Control, Design of soil-lime, soil-cement, soil-bitumen and soil-lime-fly ash mixes.

UNIT II **9**

In-situ densification methods in granular soils, Deep compaction: Introduction, Terra-Probe, Vibro flotation techniques, Ground Suitability for Vibro flotation, Advantages, Mueller Resonance Compaction, Dynamic Compaction, Depth of Improvement In-situ densification methods in cohesive soil: Introduction, Pre-loading and de-watering, Vertical drains, Electrical method, Thermal method

UNIT III **9**

Grouting: introduction, suspension grout, solution grout, grouting equipment's and methods, Grouting design, and layout

UNIT IV **9**

Geotextiles: types, functions, specifications, precautions in transportation and storage. Fiber-Reinforcement, Advantage, Applications.

Books & References:

1. Ground Improvement Techniques – Raj. P (Fare wall Media)
2. Ground Improvement Technique – Patre (Vikas Publisher)
3. Geosynthetic World - Mandel J. N. (Wiley Eastern)

MCE-359 **FINITE ELEMENT METHOD**

Course category	:	Programme Elective 2 (PE 2)
Pre- requisites	:	Matrix Analysis of Structures
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, students will be able:

1. To describe the finite element method, identify different types of finite elements and apply to structural analysis.
2. To formulate variational methods for analysis of various types of structures.
3. To choose appropriate Isoparametric elements and solve structural problems.
4. To estimate errors in a finite element analysis to arrive at convergence of the solution.
5. To create appropriate finite element models in accordance with physics of the problems. The students would be able to analyze structural engineering problems either with the help of commercial software's or self-developed computer programs in suitable computer language.

Topic Covered

UNIT I **9**

Introduction to Finite: Element Model-concept of nodes and elements, Formulation of stiffness and transformation matrices, Implementation details.

UNIT II **9**

Basic equations of elasticity Finite element formulations, Isoparametric elements, Formulation of mass and damping matrices, Dynamic equilibrium equation and methods of solution for seismic loading

UNIT III **9**

Accuracy and mesh-locking aspects in plane strain and plane stress analysis

UNIT IV **9**

Brief introduction to Fourier analysis of folded plates, geometric and material non-linearity; Node numbering; Plate and shell elements, soil structure interaction; Modelling of unbounded media and singularities.

Books & References:

1. Finite Element Procedure - K.O. Bathe (Prentice Hall)
2. Finite Element Method: Its Basics & Fundamentals-O.C. Zienkiewicz &R. l. (Taylor Pus: Elsevier BH).

MCE-361 NONLINEAR ANALYSIS OF STRUCTURES

Course category	:	Programme Elective 3 (PE 3)
Pre- requisites	:	Matrix Method of Structural Analysis
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	By the end of the course, the student must be able to:

1. Use numerical technique to solve nonlinear system of equilibrium equations.
2. Develop geometric stiffness matrix for plane frame structures.
3. Analyze structures considering geometric as well a material non-linearity
4. Able to recognize the principal peculiarities of nonlinearity and similarities or difference with linear analysis.
5. Understand and explain basic principles and numerical procedures of nonlinear structural analysis and dynamics, its capabilities, and limitations.
6. Conduct nonlinear static and dynamic analyses of complete structures.
7. Choose appropriate constitutive laws, element formulations and solution methods for structures undergoing inelastic deformations.

Topic Covered

UNIT I **9**

Introduction to nonlinear mechanics; statically determinate and statically indeterminate flexible bars of uniform and variable thickness Inelastic analysis of uniform and variable thickness members subjected to small deformations; inelastic analysis of flexible bars of uniform and variable stiffness members with and without axial restraints.

UNIT II **9**

Vibration theory and analysis of flexible members; hysteretic models and analysis of uniform and variable stiffness members under cyclic loading

UNIT III **9**

Elastic and inelastic analysis of uniform and variable thickness plates

UNIT IV **9**

Nonlinear vibration and Instabilities of elastically supported beams.

Books & References:

1. Non-Linear Mechanics- Delmetor E. Firtis (CRC, Press)
2. Non-Linear Modelling & Analysis of Solids & Structures - Stein Krak (CRC Press).

MCE-362 **EARTH & ROCK FILL DAM**

Course category	:	Programme Elective 3 (PE 3)
Pre- requisites	:	Water Resource Engineering
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	After successful completion of the course, it is expected that students will be able to

1. Analyze the given site for the construction of the earth dam
2. Analyze the local material and design the earth dam by using the same
3. Understand about the dam instrumentation for distress. 4. Understand the dam distresses and its remedial measures.

Topic Covered

UNIT I **9**

Performance of earth and rockfill dams during past earthquakes, Homogenous and non-homogenous dams, zoned dams, Dams with upstream impervious linings, composite dams, seepage in earth and rockfill dams, flow net, piping, and liquefaction

UNIT II **9**

Stability analysis, effective and total stress methods, analysis by Fellinius, Moregenstern-Price, Carter, Spencer, and Bishop methods

UNIT III **9**

Pseudo-static analysis, Shear beam analysis using Bellel's function. Design criteria for Earth Dams.

UNIT IV **9**

Selecting a suitable Preliminary Section for an Earth Dam, Stability of the foundation against shear, Seepage control in earth dams, Seepage control through foundations.

Books & References:

1. Irrigation and Water Resources Engineering - B.C. Punmia & Pande B.B. Lal (Luxmi Publications)
2. Water Resources and Hydraulic Structures -S.K. Garg (Khanna Publications).

MCE-366 **DESIGN OF PLATES AND SHELLS**

Course category	:	Programme Elective 3 (PE 3)
Pre- requisites	:	Advanced Structural Analysis, Strength of Material
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, students will be able:

1. To classify various types of plates and shells
2. To apply various methods for the analysis of plates and shells
3. To choose a method for the analysis
4. To compare the results of analysis by various methods
5. To examine the structural behavior of plates and shells.

Topic Covered

UNIT I **9**

Classification of plates, governing equations, boundary conditions, analysis of rectangular and circular plates, buckling of plates, design criteria and code specifications.

UNIT II **9**

Classification of shells, membrane theory for shells of revolution with axi-symmetric and non-symmetric loading, bending analysis of shells of revolution for axi-symmetric loadings

UNIT III **9**

Membrane and bending theories of cylindrical shells, theory of edge beams, doubly curved shells, membrane theory and design of hyperbolic shells, buckling of shells, design applications

UNIT IV **9**

Analysis and design of folded plates, codal specifications, practical considerations, computer applications.

Books & References:

1. Design & Construction of Concrete shell Roof - G.S. Ramaswammy (CBS. Publisher)
2. Reinforced Concrete Structures - B.C. Punmia, Volume-II (Lakshmi Publications)

MCE-363 PROJECT PLANNING AND CONTROL

Course category	:	Programme Elective 3 (PE 3)
Pre- requisites	:	Building Construction and Planning
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, students will be able:

1.Understand project characteristics and various stages of a project.
2. Understand the conceptual clarity about project organization and feasibility analyses – Market, Technical, Financial and Economic.
3. Analyse the learning and understand techniques for Project planning, scheduling, and Execution Control.
4. Apply the risk management plan and analyse the role of stakeholders.
5. Understand the contract management, Project Procurement, Service level Agreements and productivity.
6. Understand the How Subcontract Administration and Control are practiced in the industry.

Topic Covered

UNIT I **9**

Work-study, work breakdown structure, Time estimates, Applications of CPM/PERT, statistical concepts, Man Material-Machinery money optimization, scheduling, monitoring, updating.

UNIT II **9**

Cost functions, time-cost trade off, resource planning-leveling and allocation.

UNIT III **9**

Resources - based networks, crashing, master networks, interface activities and dependencies, line of balancing techniques, application of digital computers.

UNIT IV **9**

Material management- purchases management and inventory control, ABC analysis. Human Resource management.

Books & References:

1. PERT & CPM - B.C. Punmia (Luxmi Publications)
2. Construction Planning & Management -P. K. Bhatnagar.

MCE-367 INDUSTRIAL STRUCTURES

Course category	:	Programme Elective 3 (PE 3)
Pre- requisites	:	Concrete Structures, Steel Structures
Contact hours/week	:	Lecture: 3, Tutorial: 1, Practical:0
Number of Credits	:	4
Course Assessment	:	Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination
Course Outcome	:	On successful completion of the course, students will be able:

To interpret and apply the provisions of relevant IS-code for design of various RCC structure.
2. To identify structural behavior and compute the stresses developed in various components of RCC structures due to different loading.
3. To design various large span roof structures, Suspension roof structures.
4. To give complete detailing of the designed RCC structure.

Topic Covered

UNIT I **9**
Planning of industrial structures
UNIT II **9**
Design of single and multi-bay industrial structures in steel and concrete, Bunkers and silos
UNIT III **9**
Pressure vessels and chimneys, Cooling towers.
UNIT IV **9** Large span roof structures, Suspension roof structures. Structural aspects of machine foundations.

Books & References:

1. IS: 8002007
2. Limit State Design of Steel Structures - S.K. Duggal (TMH)
3. Reinforced Concrete Structure, Volume II - B.C. Purnima (Lakshmi Publications)

MCE-364 SOIL STRUCTURE INTERACTION

Course category : Programme Elective 1 (PE 1)

Pre- requisites : Soil Mechanics, Advanced Foundation Design

Contact hours/week : Lecture: 3, Tutorial: 1, Practical:0

Number of Credits : 4

Course Assessment : Continuous assessment through tutorials, assignments, Methods Quizzes and Minor test and Major Theory & Practical Examination

Course Outcome : On successful completion of the course, students will be able:

1. Designing structures under seismic conditions considering effect of SSI.
2. Modelling under static and dynamic SSI.
3. Ground response analysis for different soil conditions.
4. Exposure to various different codes of practices.
5. Finite element approach in solving in SSI problems.

Topic Covered

UNIT I **9**

Definition of soil- foundation interaction, soil- foundation-structure interaction, soil-fluid-structure interaction, idealization of soil by linear and non-linear Winkler model, elastic continuum model (isotropic and anisotropic), two parameter elastic models-heteny model, pastemak model, reissner model, soil-parameters; Interpretation of parameters elastic and elastic-continuum models, experimental investigations, finite beams on elastic foundation: finite beams on Winkler model

UNIT II **9**

Finite beams on two parameter elastic medium, finite beams on two parameter elastic medium, finite beams on homogeneous, isotropic elastic continuum, finite difference solution to problems of beams on linear and nonlinear Winkler models

UNIT III **9**

plates on elastic foundation: rectangular and continuous plates on elastic foundation, plates carrying rows of equidistant columns, rectangular and circular plates on Winkler medium, two parameter elastic medium and no elastic continuum, finite difference solution of problems of rectangular plates on linear and non-linear elastic foundation, soil-structure interaction in framed structures: structures with isolated foundations- spring analog approach, determination of spring parameters, structures with continuous beams and rafts as foundation-finite element modeling, sub-structure technique of analysis.

UNIT IV **9**

Concept of relative stiffness, interactive behaviour of some framed structures, soil-pile interaction: laterally loaded single piles-concept of coefficient of horizontal subgrade reaction, finite difference and finite element solutions, soil-structure interaction of framed structures with pile foundations, interaction of other structures with soil-foundation system: tanks with annular ring foundation, chimneys, silos, cooling towers, underground subways and tunnels, introduction to dynamic soil-structure interaction, as well as non-linear soil/concrete behavior.

Books & References:

1. John P. Wolf, Soil-structure interaction
2. Bowels, J.E., "Analytical and Computer methods in Foundation" McGraw Hill Book Co., New York.
3. Desai C.S. and Christian J.T., "Numerical Methods in Geotechnical Engineering" McGraw Hill Book Co. New York.
4. Soil Structure Interaction, the real behaviour of structures, Institution of Structural Engineers, 1989. 5. Elastic Analysis of Soil Foundation Interaction, Developments in Geotechnical Engg.vol-17, Elsevier Scientific Publishing Co.
6. Prakash, S., and Sharma, H. D., "Pile Foundations in Engineering Practice." John Wiley & Sons, New York, 1990.