B. Tech. Civil Engineering/ Elective				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE 330: Geotechnical Processes	**L**	**T**	**P**	**Nil**
	3	**0**	**2**	
Course Objective: Students can solve field-based problems in the geotechnical process to implement the design of civil infrastructure projects.				

S. No	Course Outcomes (CO)
CO1	Understanding of the principles of ground conditions.
CO2	Exposure to prevalent techniques such as prefabricated vertical drains, stabilisation, chemical modifications, and hydraulic modification, including geosynthetics.
CO3	Proficiency in dynamic stabilization techniques suitable for wide applications.
CO4	Proficiency in ground modification by reinforcement techniques in various applications.
CO5	Students can solve field-based problems in the ground improvement-related process and implement them in the design projects.

S. No	Contents	Contact hours
Unit 1	Introduction: importance and history of ground improvement. Mechanical Modifications: properties of compacted soil, compaction control tests, field compaction, and applications. Precompression: technique, procedure, and applicants. Sand Drains: method, procedure, and applications.	8
Unit 2	Prefabricated vertical drains: method of installation and design. Soil Stabilisation: shallow stabilisation with additives- lime, fly ash cement, and other materials. Chemical modifications and Grouting. Hydraulic modification: dewatering systems, filtration, drainage, and seepage control with geosynthetics.	8
Unit 3	Vibroflotation technique, stone columns, sand compaction piles, dynamic compaction technique, ground freezing, and electro-osmosis.	8
Unit 4	Ground modification by soil reinforcement: reinforcement techniques, use of flexible geosynthetic reinforcement in bearing capacity improvement, slope stability, erosion control, retaining walls, and pavement.	8
Unit 5	Difficult soils: collapsible soils, physical parameters, and identification, collapse settlement, improvement techniques; expansive soils, general nature, swell test and swelling pressure tests, classification, improvement of expansive soils.	12
	Total	42

S.N.	Name of Books/ Authors	Year of Publication
1	Das, B.M. (2011). Principles of Foundation Engineering. Cengage Learning. (ISBN 0-07-525486-7.	2007
2	Koerner, R.M. (2012). Designing with Geosynthetics, Vol. 1&2. Xlibris Corporation. (ISBN 0-25—755246-7).	2007

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure,**			**Pre-Requisite**
CE 332: Transportation Geotechniques	**L**	**T**	**P**	**CE:206 Soil Mechanics; CE305: Transportation Engineering**
	3	**1**	**0**	

Course Objectives:

- To understand the geotechnical aspects of railway engineering, including track substructure, subgrade evaluation, and embankment design.
- To study the behaviour of railway subgrades under cyclic and dynamic loading.
- To analyse the settlement, stability, and drainage requirements in railway track foundations.
- To explore the use of geosynthetics in railway track design for reinforcement and filtration.
- To apply geotechnical engineering principles for the safe design and maintenance of railway embankments, tunnels, and bridges.

S. No.	Course Outcomes (COs)
CO1	To evaluate the geotechnical properties of railway track subgrades and their significance.
CO2	To analyse the dynamic loading effects on railway track foundation stability.
CO3	To design railway embankments considering settlement, drainage, and slope stability.
CO4	To study the role of geosynthetics in railway engineering for track reinforcement.
CO5	To assess track maintenance, rehabilitation, and stabilization techniques in railway geotechniques.

S. No.	Contents	Contact Hours
UNIT 1	Introduction to railway geotechniques, track substructure components (subgrade, ballast, formation), geotechnical properties of railway track materials, testing methods for railway subgrades.	7
UNIT 2	Dynamic behaviour of railway track subgrade, effect of cyclic loading, settlement and stability of railway track foundation, field and laboratory evaluation of track deformation characteristics.	7
UNIT 3	Design and construction of railway embankments, ground improvement techniques for weak subgrades, drainage and filtration requirements in railway track systems.	7
UNIT 4	Use of geosynthetics in railway track stabilization, functions of geotextiles and geogrids in railway foundation, design of reinforced track embankments and ballast layers.	7

UNIT 5	Railway track failures, maintenance and rehabilitation of railway subgrades, case studies on geotechnical challenges in railway infrastructure, emerging trends in railway track geotechniques.	6
TOTAL		**34**

References		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Satish Chandra & M.M. Agarwal (*Railway Engineering* (ISBN: 978-0198083535), Publisher: Oxford	2013
2	M. M. Agarwal, *Indian Railway Track 2nd Edition*, Publisher: Prabha & Co.	2018
3	S. C. Saxena & S. P. Arora, *A Textbook of Railway Engineering* (ISBN: 978-8189928834), Publisher: Dhanpat Rai	2010
4	J S Mundrey, *Railway Track Engineering, 4th Edition.* (ISBN: 9780070680128) Publication Date & Copyright: 2009. McGraw-Hill Education (India) Private Limited.	2009

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure. Credit=4**			**Pre-Requisite**
CE 334: Design of Hydraulic Structures	**L**	**T**	**P**	Nil
	3	**0**	**2**	
Course Objective: The objective of this course is to provide students with the comprehensive knowledge and skills necessary for the design, analysis, and evaluation of hydraulic structures. The course focuses on the principles, methodologies, and practical aspects of designing various hydraulic structures such as dams, spillways, weirs, and culverts, with an emphasis on safety, efficiency, and sustainability.				

S. No	Course Outcomes (CO)
CO1	Understanding of the fundamental principles and concepts involved in the design and functioning of various hydraulic structures, including the forces acting on these structures and the methods to analyse them.
CO2	Ability to design hydraulic structures such as dams, spillways, weirs, and culverts.
CO3	Safety assessments and risk analyses for hydraulic structures, understanding the potential hazards, failure modes, and designing structures to mitigate these risks effectively.
CO4	Proficient in using computational tools and software.
CO5	Enhance their project management skills, including planning, executing, and presenting design projects.

S. No	Contents	Contact Hours
Unit 1	Gravity dams: Design Criteria, forces acting on gravity dams, elementary profile, low and high gravity dams, stability analysis, evaluation of profile by method of zoning, practical profile, foundation treatment, construction joints, galleries in gravity dams.	12
Unit 2	Earth and Rock fill dams: Earth Dams: Types, causes of failure and design criteria, soils suitable for earth dam construction, construction methods, foundation requirements, typical earth dam sections, estimation of seepage through and below the dam, seepage control, stability of slopes by slip circle method of analysis, pore pressures, sudden drawdown, steady seepage and construction pore pressure condition. Rock fill dams: Types, merits and demerits, conditions favourable for their adoption.	7

Unit 3	Spillways: Ogee spillway and its design, details of syphon, shaft, chute, and side channel spillways, emergency spillways.	8
Unit 4	Energy dissipators and gates: Principles of energy dissipation. Energy dissipators based on tail water rating curve and jump height curves, Spillway crest gates - vertical lift and radial gates, their design principles and details. Design of canal regulating structures, Detailed design of Sarda Falls, design of cross drainage works, and syphon aqueduct.	10
Unit 5	Hydropower Plants: Introduction of Hydropower development, assessment of power potential, types of hydropower plants, general features of hydro-electric schemes, selection of turbines, draft tubes, surge tanks, penstocks, power house dimensions, development of micro hydel stations, tidal plants, pumped storage plants, and their details.	5
	Total	**42**

Suggested Books:

S. No.	Name of Books/ Authors	Year of Publication
1	Garg, S.K, "Irrigation Engineering and Hydraulic Structures", Khanna Publishers, New Delhi. (ISBN 0-07-06487-1).	2014
2	Modi , P.N., "Irrigation Water Resources and Water Power Engineering", Standard Book House, Delhi. (ISBN 0-07-078546-7).	1990
3	Asawa, G. L. "Irrigation and Water Resources Engineering", New Age International Publishers. (ISBN 0-07-795568-3).	1993
4	Sharma, R. K. and Sharma, T. K., "Water Power Engineering", S. Chand & Company, New Delhi	2003
5	Varshney, R.S., "Hydropower Structures", Nem Chand and Bros., Roorkee (U.P.),	2014
6	Deshmukh, M.M., "Water Power Engineering, Dhanpat Rai Publications", New Delhi,	1998

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE336: Groundwater Hydrology	**L**	**T**	**P**	Nil
	3	**1**	**0**	
Course Objectives: The objective of this course is to provide students with a comprehensive understanding of the principles and practices of groundwater hydrology. The course aims to equip students with the skills necessary to analyse, model, and manage groundwater systems, addressing issues related to groundwater flow, contamination, and sustainable use.				

S. No	Course Outcomes (CO)
CO1	Develop a thorough understanding of the physical principles governing groundwater flow, including aquifer properties, Darcy's law, and the groundwater flow equations.
CO2	Proficiency in constructing and utilizing groundwater flow models using tools such as MODFLOW, enabling them to simulate and analyse groundwater flow under various conditions.
CO3	Learn to model contaminant transport in groundwater, understanding the processes of advection, dispersion, and chemical reactions, and develop strategies for groundwater contamination remediation.
CO4	Ability to design and implement sustainable groundwater management practices.
CO5	Enhance their research skills by investigating contemporary issues in groundwater hydrology.

S. No.	Contents	Contact Hours
UNIT 1	Introduction: Definition of groundwater, role of groundwater in the hydrological cycle, groundwater bearing formations, classification of aquifers, flow and storage characteristics of aquifers, Darcy's law, anisotropy, and heterogeneity.	8
UNIT 2	Wells and Well Hydraulics: Different types of wells, construction of wells, steady and unsteady state solutions for confined, unconfined, and leaky aquifers, effect of boundaries, Multiple Well Systems, Partially Penetrating Wells, Well for special Conditions, Characteristics of Well Losses, Specific Capacity.	10
UNIT 3	Surface investigation of groundwater: Geologic methods, Remote sensing, geophysical exploration, Electric resistivity Method, Seismic Refraction Method, Gravity and Magnetic Methods, Water Witching.	8

UNIT 4	Concept of Artificial Recharge of Groundwater, recharge methods, research on water spreading, Wastewater recharge for reuse, Recharge Mounds. Artificial Recharge on Long Island, New York, includes recharge, artificial Recharge for Energy purposes.	8
UNIT 5	Groundwater Flow Modelling: Porous media models, Analog models, Electric Analog Models, and Digital computer models.	8
	Total	**42**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Todd, D.K., "Groundwater Hydrology", John Wiley.	1959
2	Bear, J., "Hydraulics of Groundwater", McGraw-Hill.	1979
3	Bouwer, H., "Groundwater Hydrology", McGraw-Hill.	1978
4	Walton, W.C., "Groundwater Resources Evaluation", McGraw-Hill.	1970

B. Tech Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE338: Advanced Transportation Engineering	L	T	P	**CE305: Transportation Engineering**
	3	1	0	

Course Objective: This course aims to expose the students to advanced topics of transportation engineering: the process of transportation planning, urban transport technology, aspects of transport economics and financing, and guidelines for pavement design and maintenance.

S. No.	**Course Outcomes (CO)**
CO1	To expose students to carry out various planning studies for travel demand estimation.
CO2	To expose students to the features of different modes of urban transportation and urban infrastructure.
CO3	To expose students to various aspects of transportation economics and finance.
CO4	To equip students with the knowledge of pavement design.
CO5	To expose students to identify pavement defects and their rectification methods.

S. No	**Contents**	**Contact Hours**
UNIT 1	Transportation system planning: transportation policy, types of surveys, OD matrix, travel demand forecasting process, trip generation, modal split analysis, trip distribution, trip assignment.	10
UNIT 2	Urban transport technology: mass and rapid transit system, introduction to intelligent transportation system (ITS), public transport policy, intermediate transport modes. Introduction to BRT, Mono rail, sky bus, metro. Grade separated interchanges such as flyovers, under passes, overpasses, concept of integrated inter model transit system.	10
UNIT 3	Transport economics: vehicle operations cost, running cost, pollution cost, value of travel time, road damage cost, congestion cost, accident cost. Highway financing: pay as you go method, credit financing, private financing, BOT, BOOT, dedicated road funds, road pricing, tolls, advantages and limitations.	10
UNIT 4	Criteria of pavement design, comparison of flexible and rigid pavement, study of distress in pavements, Design of flexible and rigid pavement as per guidelines.	10

REFERENCES

S. No	**Name of Books/ Authors/ Publishers**	**Year of**

		Publication/ Reprint
1.	Khanna, S.K., Justo, C.E.G., and Veeraragavan A. "Highway Engineering", Nem Chand & Bros., Roorkee, U.K	2014
2.	Kadiyali, L. R., "Traffic Engineering and Transportation Planning", Khanna Publishers, New Delhi	2018
3.	Sharma, S.K., "Principles, Practice and Design of Highway Engineering including Airport Pavements," S. Chand and Company, New Delhi	2012
4.	Khanna S.K., Arora M.G. and Jain S.S., "Airport Planning and Design", Nem Chand & Bros., Roorkee, U.K	2022

B. Tech Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE340: Solid Waste Management and Air Pollution	L	T	P	NIL
	3	0	2	

Course Objective: This course focuses on the classification and characterisation of solid waste, including waste estimation, collection, transportation, processing, and disposal methods such as engineered landfilling and deep-well injection. It also explores strategies for waste reduction, material reuse, and energy recovery. The course also covers air quality characteristics, national standards, pollutant classification, and the impacts of key pollutants on health, plants, and buildings. It introduces meteorological principles, dispersion mechanisms, and enables the computation of ambient air quality. It also explores the engineered system for air pollution control, including control devices for particulate and gaseous pollutants.

S. No.	**Course Outcomes (CO)**
CO1	To provide an overview of the sources, classification, and characteristics of solid waste and air pollutants.
CO2	To develop solid waste collection and transportation plans based on waste generation patterns and urban planning principles.
CO3	To decide appropriate processing technologies, such as composting, incineration, and landfilling, for a typical solid waste management facility.
CO4	To assess pollution spread in the ambient air based on the pollution inventory and the dispersion model.
CO5	To plan integrated solutions for environmental sustainability based on pollution control technologies and regulatory frameworks for both air pollution and solid waste management.
CO6	To develop a material and energy recovery plan for promoting sustainable reuse and circular economy principles.

S. No	**Contents**	**Contact Hours**
UNIT 1	**Definition, Characteristics, and Perspectives:** Types of solid wastes; municipal, Industrial, and Hazardous waste. Sources of municipal waste, physical and chemical composition. Reduction in raw materials usage, reduction in solid waste quantities, reuse of solid waste materials, material recovery, and energy recovery.	**6**
	Engineered System for Solid Waste Management: functional elements, typical generation rates of solid waste, estimation of solid waste quantity, factors affecting generation rates, On-Site handling, storage, and processing of solid waste.	

UNIT 2	Types of collection systems, determination of vehicles and labor requirements, collection routes, transfer stations and their siting factors, mechanical volume reduction, and thermal volume reduction techniques. Landfilling: design and operation of landfills. Deep-well injection technique of waste disposal	**8**
UNIT 3	**Engineered Systems for Resource and Energy Recovery:** Processing techniques; mechanical size reduction, component separation, magnetic and electromechanical separation, and drying and dewatering. Materials and energy recovery; composting, anaerobic digestion, combustion, incineration, gasification, and pyrolysis.	**7**
UNIT 4	**Air Quality:** Definition, characteristics and perspectives of air quality. Historical air pollution episodes, units of measurement, sources and classification of pollutants, primary and secondary pollutants, particulates, PM_{10}, $PM_{2.5}$ and their significance, health effects of particulates accompanied with other pollutants. Detection, analysis and effects of air pollutants (Hydrocarbons, CO, oxides of Sulphur and nitrogen) on human health, plant and building materials. National ambient air quality standards. Indoor air pollution.	**6**
UNIT 5	**Meteorology and Natural Purification Processes:** atmospheric properties, scales of motion, influence of meteorological phenomenon on air quality, Lapse rates and dispersion, pressure systems and dispersion, wind and dispersion, moisture and dispersion, Gaussian dispersion modeling, determination of stack height.	**7**
UNIT 6	**Engineered Systems for Air Pollution Control:** Atmospheric cleansing processes, and control at source approach. Control devices for particulate contaminants; gravitational settling chambers, centrifugal collectors, wet collectors, fabric filters (baghouse filters), and electrostatic precipitators (ESP). Control devices for gaseous contaminants, and automotive emission control.	**8**
Total		**42**

REFERENCES

S. No	Name of Books/ Authors/ Publishers	Year of Publication
1.	Peavy, Howard S., Rowe, Donald R., and Tchobanoglous, George, "Environmental Engineering," McGraw-Hill Education (India) Pvt. Ltd., New Delhi.	1985
2.	CPHEEO manual on Municipal Solid Waste Management, Ministry of Urban Development, New Delhi.	2016
3.	Rao, C.S., "Environmental Pollution and Control Engineering", New Age International publishers.	2006

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure. Credit=4**			**Pre-Requisite**
CE 342: Experimental Mechanics	L	T	P	CE104: Mechanics of solids
	3	0	2	

Course Objective: Fostering students' competence in experimental mechanics suitable for research, industrial, defence, and space applications.

S. No	Course Outcomes (CO)
CO1	Introduction to Basic Theory of Elasticity.
CO2	Introduction to Full-field method using Photoelasticity (2D and 3D) for both static and dynamic stress analysis, including Digital Photoelasticity.
CO3	Introduction to the Full-field method using Moire method of stress analysis and the DIC (Digital Image Correlation) method.
CO4	Introduction to Point-wise application of Electrical resistance Strain Gauge, Piezo-Electric, Photo-Electric method, and apply to develop transducers for various research, Industrial, Defence, and Space applications. Application of AI & ML in strain assessment.
CO5	Students are able to design and analyse data for Research, Industrial, Defence, and Space applications.

S. No	Contents	Contact hours
UNIT 1	Introduction to the Theory of Elasticity, Concept of Stress and Strain Tensor, Transformation equations in 2D and 3D stress and Strain analysis. Dynamic Stress Analysis.	8
UNIT 2	Introduction to Nature of Light, Wave Plate, Plane Polariscope, Circular Polariscope. Effect of the stressed photoelastic model on Plane Polariscope, Circular Polariscope. Determination of Isoclinics on a Circular Disc. Determination of Isochromatics on a Circular disc subjected to diametrical compression. Separation of Principal stresses. Determination of Material fringe value using monochromatic light. Casting of the photoelastic sheet using Araldite (CY-230) and Hardener (HY-951). Application on the model beam of photoelastic material subjected to concentrated loads (3- 3-point and 4-point loadings). Application to 2D and 3D stress analysis and use of Digital Photoelasticity.	10
UNIT 3	Introduction to Moiré methods and shape determination. Moiré methods using electronic grating. Moiré methods using Laser Interferometer for in-plane and out-of-plane strain determination. Introduction to Digital Image Correlation (DIC) method and application to Research, Industrial, Defence, and Space problems. Full-field stress analysis Method of brittle coating.	8

UNIT 4	Introduction to Point-wise application of Electrical resistance Strain Gauge, Piezoelectric, Photo-Electric method, and apply to develop transducers for various research, Industrial, Defence, and Space applications.	8
UNIT 5	Point-wise Static and Dynamic Stress analysis using Electrical resistance strain gauges. Application of AI & ML in strain assessment. Application to research, industrial, Defence, and Space problems. Strain measurement using piezo sensors, fiber-optic sensors, etc.	8
	TOTAL	**42**

REFERENCES		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Dally and Riley, "Experimental stress analysis," McGraw-Hill.	2021
2	Handbook of Stress Analysis, SEM publication.	2021
3	Engineering Mechanics, Timoshenko, Young, and Rao. TMH books.	2017
4	K. Ramesh: Special Issue OLEN: Developments in Photoelasticity and Diverse Applications.	2025
5	K. Ramesh: New Book: Developments in Photoelasticity - A Renaissance.	2024
6	Instrumentation, Measurement and Analysis by B. C. Nakra and K. K. Chaudhary, Tata McGraw-Hill.	1985
7	Experimental Methods for Engineers by J P Holman and W J Gajda, McGraw-Hill Co.	1978

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure. Credit=4**			**Pre-Requisite**
CE 344: Building Materials, Masonry, Prestressing, and Construction Management	**L**	**T**	**P**	**CE203: Design of Structures-I**
	3	**0**	**2**	

Course Objective: Fostering students' competence in the use of different building materials, including masonry, prestressed concrete, and management of construction practices.

S. No	Course Outcomes (CO)
CO1	Introduction to the common building materials for civil infrastructure.
CO2	Proficiency for the design of special concrete structures**.**
CO3	Proficiency for the design of prestressed concrete structures.
CO4	Proficiency for the design of masonry and other materials of construction.
CO5	Students are able to implement knowledge of construction practices, planning and management in field works.

S. No	Contents	Contact hours
UNIT 1	**Building Materials**: Stone, Lime, Glass, Plastics, Steel, FRP, Ceramics, Aluminium, Fly Ash, Basic Admixtures, Timber, Bricks and Aggregates: Classification, properties and selection criteria; Cement: Types, Composition, Properties, Uses, Specifications and various Tests; Lime & Cement Mortars and Concrete: Properties and various Tests; Design of Concrete Mixes: Proportioning of aggregates and methods of mix design.	8
UNIT 2	**Design of Special Concrete Structures:** Design of Staircases; Counterfort-type retaining walls. Water tanks: Design requirements for Rectangular and circular tanks resting on the ground. Principles of earthquake-resistant design of structures.	6
UNIT 3	**Prestressed concrete**: Principles of pre-stressed concrete design including materials and methods; Methods and systems of prestressing, anchorages, Analysis and design of sections for flexure based on working stress, loss of prestress.	10
UNIT 4	**Masonry and other materials**: Specific use of materials like Ferro cement, fibre reinforced concrete, and timber construction. Masonry principles and construction detailing, Types of plastering, pointing, flooring, roofing, and common repairs, Functional planning of buildings and Building code provisions, Design of Masonry Structure as per I.S. Codes.	8

UNIT 5	**Construction Practices, Planning and Management**: Construction - Planning, Equipment, Site investigation and Management including Estimation with latest project management tools and network analysis for different Types of works; Analysis of Rates of various types of works; Tendering Process and Contract Management, Quality Control, Productivity, Operation Cost; Land acquisition; Labour safety and welfare. Construction activity schedules and organization, Quality assurance principles. Basic principles of network analysis (CPM and PERT), Economic analysis and methods, Project profitability and financial planning.	10
	TOTAL	**42**

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REFERENCES

S. No.	Name of Books/Authors/Publishers	Year of Publication / Reprint
1	Prestressed Concrete. N. Krishna Raju, McGraw-Hill Co.	2018
2	Prestressed Concrete Structures, Dayaratnam Pasala, Oxford and I B H Publishing Co	2015
3	Design Of Masonry Structures, A.W. Hendry, B.P. Sinha, and S.R. Davies. Routledge- Informa UK Limited.	2004
4	Review of Design Codes for Masonry Buildings, Document No. :: IITK-GSDMA-EQ10-V1.0, Dr. Durgesh C Rai, IIT Kanpur	2010
5	Punmia B. C., and Khandelwal K. K., "PERT and CPM", Laxmi Publications, New Delhi. (ISBN 0-07-23998904-1)	1999
6	R. L. Peurify, Construction Planning: Equipment and Methods, Tata McGraw-Hill, Inc. (ISBN 0-07-0476158-7	2000
7	Satyanarayanan & Saxena, Construction Planning and Equipment, Standard Publishers Distributors, New Delhi. (ISBN 0-01-257859-8)	1998
8	Advanced Reinforced Concrete Design, Varghese, P. C., Phi Learning.	2016
9	Design of Reinforced Concrete Structures, N. Subramanian, Oxford and IBH Publishing Co.	2013

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE406: Pre-stressed Concrete Structures	**L**	**T**	**P**	CE203: Design of Structures-I
	3	1	0	

Course Objective: To equip students for analysing, designing prestressed concrete structures**.**

S. No	Course Outcomes (CO)
CO1	Understand the principles and necessity of prestressing in concrete structures. Analyse different prestressing systems and materials.
CO2	Learn the design methodologies for prestressed concrete beams, slabs, and other structural elements.
CO3	Study losses in prestress and deflection considerations.
CO4	Examine the behaviour of prestressed structures under various loading conditions.
CO5	Gain exposure to real-world applications in bridges, buildings, and special structures.

S. No	Contents	Contact hours
UNIT 1	**Introduction:** Design of simply-supported beams, slabs, and bridges, Concept of prestressing: Need and advantages, Comparison between Reinforced Concrete (RC) and Prestressed Concrete (PC), Historical background and development, Applications of prestressed concrete in infrastructure.	6
UNIT 2	**Materials & Prestressing Systems:** High-strength concrete and high-tensile steel, Pre-tensioning vs. post-tensioning, requirement of minimum grade of concrete. Prestressing systems, Anchorage devices, jacking equipment, and prestressing cables.	6
UNIT 3	**Analysis of Prestressed Concrete Members:** Stress calculations at transfer and service loads, Load balancing method, stress concept method, and strength concept method. Pressure line and thrust line concepts.	8
UNIT 4	**Losses of Prestress:** Types of losses: Elastic shortening, creep, shrinkage, friction, relaxation of steel, anchorage slip, Calculation of short-term and long-term losses, Methods to minimize prestress losses	6
UNIT 5	**Design of Prestressed Concrete Sections:** Flexural design of beams, Limit state design: Serviceability and ultimate strength, IS Code provisions (IS:1343), Shear and torsion in prestressed concrete. Design of simply supported beams, slabs, and bridges. **Deflections and Cracking:** Short-term and long-term deflections, Factors affecting deflections, Control of cracking in prestressed	10

	concrete, Design considerations for deflection control.	
UNIT 6	**Special Topics and Applications:** Prestressed concrete in bridge structures, Prestressed concrete in tall buildings, Segmental construction and precast prestressed elements, Prestressed concrete tanks and pavements, Case studies of failure and durability concerns.	6
	TOTAL	**42**

REFERENCES		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Prestressed concrete. Krishna Raju N., Tata McGraw-Hill Company, New Delhi.	2007
2	Prestressed concrete, Mallik S.K. and Gupta A.P., Oxford and IBH.	1987
3	Design of Prestressed Concrete Structures, Lin T .Y and Burns N.H, John Wiley and Sons.	1982
4	Fundamentals of Prestressed Concrete, Sinha N.C and Roy S.K., S. Chand and Co., New Delhi.	1985
5	Prestressed Concrete. R. Rajagopalan	2010
6	IS: 1343 Code of Practice Prestressed Concrete.	2012

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE 407: Introduction to Building Information Modelling (BIM)	L	T	P	Nil
	3	0	2	

Course Objective: Fostering students' competence in the use of modern tools of Building Information Modelling, including software usage towards engineering, construction & operation projects of infrastructures.

S. No	Course Outcomes (CO)
CO1	Introduction to the concept of Building Information Modelling.
CO2	To understand the workflow followed in the industry during the creation of a BIM 3D Model using Revit.
CO3	Proficiency for creating BIM models and Asset Information Model (AIM).
CO4	Proficiency in the application of the BIM model.
CO5	Students are able to implement BIM and digital solutions in engineering and construction projects.

S. No	Contents	Contact hours
UNIT 1	**Introduction to BIM Concepts and Design:** Engineering from 2D drawings to BIM Model, Isometric View, concept of 3D-Modeling, Design Authoring – Concepts and workflow, stages of BIM Modelling process as per ISO 19650, Federated model- concepts and demonstrations, workflow of design coordination, Engineering Analysis – Concept and types of analysis, Process and workflow of Design Review in BIM, exposure to software, Revit.	8
UNIT 2	**Visualization and Interference/Clash check:** Views in BIM Model, Modes, Walkthrough, Fly through the model, Layers & Properties, viewpoints, Sectioning and Visualization through Tablet and Mobile, BIM Kiosk & BIM Rooms, Visualization through Augment Reality (AR), Virtual Reality (VR) & Mixed Reality (MR). Clash Check – Types, Clash avoidance/ detection process, Clash Detection Priority Matrix and Report generation.	6
UNIT 3	**Documentation & CDE & Level of Development**. Documentation and CDE (Common Data Environment) -2D drawings generation from BIM Model, Computer Network types, Concept of Cloud Computing, Setting up the workflow and process for CDE- Request for Information and Review Process. Concept of LOD (Level of Development), Progression matrix- Level of Detail and Information, LOD- Wall foundation, Precast Structural Inverted T-Beam, Domestic Water Piping, Plumbing Fixture, Packaged Generator Assembly.	10

UNIT 4	**4D / Field BIM & Its Applications**. Introduction, construction sequence and project schedule, using Gantt Chart and its limitations, Modelling- Project demo and workflow, Synchronization with project schedule. Reviewing project progress, Generation of Reports. Application of Field BIM/ 4D BIM: for coordination- 3D Coordination and Visual Communication, Site utilization planning and Construction analysis, wearables in coordination. 3D Control and planning. Other Applications: for safety, disaster and risk analysis, digital fabrication and scan to BIM, Condition Modelling, Phase Planning, As-built/ Record Models	8
UNIT 5	**5D BIM, AIM & Beyond BIM - Emerging Trends:** Concepts of 5D BIM, UoM, QTO with UoM, QTO for Wall, Plaster & Tile, BIM Maturity LOD, Cost Breakup structures, cost control. AIM: Introduction to Asset Information Model (AIM), COBie structures and Asset Information Deliverables, Space Attributes and Asset Attributes- Examples. Discipline-wise Infrastructure System, Classification code, and Information Exchange, Information Exchange with Facility Management. Beyond BIM: Industrialisation, IoT, Big Data, Data Analytics and applications in BIM: Data Analytics using AI & ML. Smart Infrastructure and connected infrastructure, Digital twins- Concepts and benefits, National Digital Twin policy, in a Smart City, Digital Twin applications in diverse industries.	10
	TOTAL	**42**

REFERENCES

S. No.	Name of Books/Authors/Publishers	Year of Publication / Reprint
1	Building Information Modelling (BIM) in Design, Construction and Operations IV. WIT Transactions on The Built Environment	2021
2	Building Information Modelling: Global & Indian Perspective, Harshul Savla, Chandrahauns Chavan, Pallavi Patil.	2021
3	ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling, Part 1: Concepts and principles.	2018/ 2024
4	Building Information Management. A Standard Framework and Guide to BS 1192.	2007
5	BIM Handbook: A Guide to Building Information Modelling for Owners, Designers, Engineers, Contractors, and Facility Managers, Rafael Sacks, Charles Eastman, Ghang Lee, Paul Teicholz, Wiley Co.	2018
6	Building Information Modelling- BIM, Ngibjörg Birna Kjartansdóttir et al., Erasmus, Construction Managers Library.	2017

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE408: Retrofitting of Structures	**L**	**T**	**P**	
	3	**1**	**0**	

Course Objective: This subject imparts a broad knowledge in the area of repair and rehabilitation of Structures.

S. No	**Course Outcomes (CO)**
CO1	Evaluate/ assess the existing buildings through field investigations and RVS, and conduct a Preliminary forensic assessment of existing or damaged structures through NDT.
CO2	Understand the different techniques for structural retrofitting at the local and global level.
CO3	Analyse the deficiency in the existing building and recommend the type of strengthening techniques for RCC structures.
CO4	Able to understand the process of adding new components in structures for retrofitting.
CO5	Analyse the energy dissipation involved in the retrofitting of structures.
S. No	**Contents**
UNIT 1	Introduction: Terminology; Basic principles of seismic evaluation and retrofitting. Qualitative Methods of Seismic Evaluation: Rapid visual screening procedure (RVSP) and simplified evaluation of buildings; Visual inspection method and non-destructive testing (NDT) method.
UNIT 2	Quantitative Methods of Seismic Evaluation: Performance based method using nonlinear static push-over analysis (NSP) and non-linear dynamic method of analysis (NDP); Estimation of seismic capacity (strength and ductility).
UNIT 3	Local and Global Methods of Seismic Retrofitting of RC Buildings: System completion; Strengthening of existing components; RC, Steel and FRP Jacketing;
UNIT 4	Addition of new components – frames, shear walls and braced frames; Design of connections for retrofitting of structures.
UNIT 5	Introduction to supplemental energy dissipation and base isolation.

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Agarwal, Pankaj, Shrikhande, Manish. (2006), "Earthquake Resistant Design of Structures"- Prentice–Hall India.	2006
2	Duggal, S.K. (2007)., "Earthquake Resistant Design of Structures"- Oxford University Press.	2007

3	Priestley, M. N., Seible, F., & Calvi, G. M. (1996). Seismic design and retrofit of bridges"- John Wiley & Sons.	1996
4	Seismic Evaluation and retrofit of concrete building" – Vol. I & II"- Applied Technology Council, California, ATC 40. (1996)	1996
5	Rapid Visual Screening of Buildings for Potential Seismic Hazards, Federal Emergency Management Agency, Building Seismic Safety Council, Washington, D.C., FEMA 154/155. (2002)	2002
6	FEMA-356. "Commentary for the Seismic Rehabilitation of Buildings," Federal Emergency Management Agency, Washington, DC. (2000)	2000
7	FEMA, P-695. "Quantification of Building Seismic Performance Factors"- Federal Emergency Management Agency. (2009)	2009
8	FEMA-440, A., "Improvement of nonlinear static seismic analysis procedures"- . FEMA-440, Redwood City. (2005)	2005
9	A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India by National Disaster Management Authority (2020)	2020

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure. Credit=4**			**Pre-Requisite**
CE 409: Design of Bridges	**L**	**T**	**P**	**CE203: Design of Structures-I**
	3	**1**	**0**	

Course Objective: To equip students with skills to design and manage the bridge stocks.

S. No	Course Outcomes (CO)
CO1	Introduction to the bridge system and components; the collection of data for the design.
CO2	Exposure to loading and other parameters required for the design of bridge structures**.**
CO3	Proficiency in the design of superstructures using various approaches.
CO4	Proficiency in the design of substructures using various approaches.
CO5	Proficiency in the design of various appurtenances, bearings, expansion joints, etc.
CO6	Development of systems to maintain and manage the bridges with exposure to state-of-the-art knowledge in the domain of Bridge Management Systems.

S. No	Contents	Contact hours
UNIT 1	Introduction, components of bridges, classification of bridges, related structures, classical examples of various types of bridges. Selection of site and initial decision process, survey and alignment, geotechnical investigations, collection of bridge design data, hydrological calculations, waterway calculations, scour, depth of foundation, freeboard considerations, vertical clearance.	8
UNIT 2	Standard loadings for bridge design as per different codes of practice, IRC, BS and AASHTO codes, various types of loads considered for design of bridges, impact factor, centrifugal force, wind and seismic considerations, width and roadway considerations, influence lines, load combinations, limit and working stress design considerations, pre-design considerations, roadway vs. railway bridges.	8
UNIT 3	Superstructure of bridge: selection of main bridge parameters, design methodologies, choice of superstructure type, load distribution in various types of superstructures, RCC and PSC superstructures, longitudinal analysis of bridges, transverse analysis of bridge, temperature analysis, effect of differential movements of supports, reinforced earth structures, box girder bridges.	8

UNIT 4	Substructure of bridge: pier, abutment, wing walls, importance of substructure soil interaction, open foundation, pile foundation, well foundation, simply supported and continuous bridges.	8
UNIT 5	Appurtenances, Bearings and deck joints: types of bearings, expansion joints, design of bearings and joints, parapets and railings for highway bridges, definitions, classifications of bridge parapets, related details.	6
UNIT 6	Bridge inspection, maintenance and management strategies, lessons learned from failure of bridges, life extension and lifecycle analysis with case studies.	4
	TOTAL	**42**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	M.J. Ryall, Parke G.A.R. and Harding J.E.,' The manual of bridge engineering', Thomas Telford Publishers ASIN 8000Q91ZDY.	1997
2	Raina V.K., 'Concrete bridge practice – analysis, design and economics, Tata McGraw-Hill Publishing Company Ltd. (ISBN 8184043783).	2002
3	Ponnuswamy S., 'Bridge engineering', Tata McGraw-Hill Publishing Company Ltd. ISBN: 9780070656956.	2000
4	Essentials of Bridge Engineering, 6th Edition, by D.J. Victor. CBS Publishers.	2018
5	IRC:5. Standard Specifications and Code of Practice for Road Bridges. Section I- General Features of Design.	2015
6	IRC:6 Standard Specifications and Code of Practice for Road Bridges Section II. Loads and Load Combinations.	2017
7	IRC: 112 Code of Practice for Concrete Road Bridges.	2011

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE410: Advanced Geotechnical Engineering	**L**	**T**	**P**	**CE 301 Geotechnical Engineering**
	3	**0**	**2**	

Course Objective: To familiarize the students with modern and advanced concepts of Geotechnical Engineering and its related applications in Civil Engineering.

S. No	Course Outcomes (CO)
CO1	Application of knowledge and practical skills in soil exploration techniques, in-situ testing, reliability-based site characterization, and microstructural soil analysis for geotechnical engineering.
CO2	Knowledge of innovative ground improvement techniques, sustainable geotechnical practices, and eco-friendly materials, waste utilization, and sustainability assessment in foundation design.
CO3	Identify, formulate, and analyse the retaining structure substantiated and concluded using the engineering knowledge
CO4	Advancements in geotechnical engineering, AI, and geosynthetics with embedded sensor technologies.
CO5	Provide an in-depth understanding of advanced foundation engineering, including load transfer mechanisms, foundation behaviour under complex conditions, non-destructive testing techniques, and numerical modelling for accurate performance prediction

S. No	Contents	Contact hours
UNIT 1	**Introduction:** Soil Exploration & Site Characterization; Geophysical methods: seismic refraction, electrical resistivity; Soil microstructure analysis: Scanning Electron Microscopy, X-Ray Diffraction	8
UNIT 2	**Ground Improvement:** Microbially induced calcite precipitation, biopolymers, geosynthetics, and soil stablisation; vacuum preloading, thermal ground modification, electro-osmosis and energy geotechniques; fly ash, industrial by-products for sustainable soil stabilization; harnessing microbially induced calcite precipitates to use in improving the engineering properties of loose sandy soils	8
UNIT 3	**Earth Pressure Theories & Retaining Structures:** Introduction, determination of lateral earth pressure at rest; retaining structures under active and passive earth pressure; deformation necessary for dynamic elastic and plastic conditions, Mononobe-Okabe solution, plastic flow and stress distribution, vibration control of flexible retention systems.	8

UNIT 4	**Sensors in Geotechnical Engineering:** Geotechnical Infrastructure: Adaptive designs for rural and urban areas with locally available geomaterials; sustainable geotechnical construction materials and methodologies; utilization of AI in geotechnical Engineering, including machine learning and image processing; sensors in geostructures; influence of frequency on piezo-dynamics of confined geomaterials.	8
UNIT 5	**Foundations:** Load transfer in foundations: elastic and plastic soil-foundation interaction models; pile foundations under cyclic loading, scouring effects, offshore and marine pile behaviour; Numerical analysis of shallow and deep foundation; heavy axle loads on mining roads; Pile groups subjected to axial and torsional loads in flow-controlled geomaterial.	10
	TOTAL	**42**

List of experiments:

1. To determine shear strength parameters of soil using unconfined compressive shear test.
2. To obtain load-displacement curves for dynamic loads using digital vibration meter
3. To obtain stress-strain plot for soil subjected to dynamic load using piezo-sensors.
4. To determine acceleration-velocity-displacement profile of a geomaterial
5. To determine the dynamic response of foundations using block vibration test
6. Numerical simulation of retaining wall for active and passive earth pressure
7. Numerical simulation of shallow & deep foundations

References

S. No.	Name of Books/Authors/Publishers	Year of Publication / Reprint
1	Foundation analysis and design by J.E. Bowles, published by McGraw-Hill.	1982
2	Fundamentals of Soil Dynamics by B M Das, Published by Elsevier Science Ltd.	1982
3	Introduction to Geosynthetic Engineering by S.K. Shukla, published by CRC Press.	2016
4	Analysis and Design of Foundations and Retaining Structures Subjected to Seismic Loads by Swami Saran, published by Dreamtech Pres.s	2020

B. Tech. Structural Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE411: Forensic Engineering	**L**	**T**	**P**	**Nil**
	3	**1**	**0**	

Course Objective: The proposed course is expected to enhance and strengthen the knowledge on role and responsibility of a forensic engineer, different cause of deterioration in structures and its prevention, the uses of different NDT equipment's, awareness regarding the structural health monitoring, knowledge in Different modern techniques of retrofitting will be discussed.

S. No	Course Outcomes (CO)
CO1	Enable to conduct thorough investigations, adhere to global standards, and contribute to the advancement of safe and resilient structural systems.
CO2	A comprehensive understanding of the causes and consequences of structural failures, the importance of accountability, and the strategies to prevent and address such failures in engineering practice.
CO3	Equipped with the knowledge and skills to diagnose and assess structural distress effectively, utilizing a range of inspection and testing techniques.
CO4	Equipped with the knowledge and skills to design, assess, and strengthen buildings to ensure their durability, safety, and resilience in the face of environmental and natural hazards.
CO5	Equipped with the knowledge and skills to effectively repair, retrofit, and maintain structural components using modern techniques and materials.

S. No	Contents	Contact Hours
UNIT 1	An Introduction to Forensic Structural, Standards and Codes & Practices in FSE (Understanding various codes, standards, applicable practices and ethics involved in various parts of the globe on Forensic Structural Engineering), The Process of Forensic Investigation: Basic steps in a forensic investigation, Presentation of "Life cycle" and "Pathology Base" Approaches as investigation techniques.	8
UNIT 2	Engineering Failure of Structures: Review of the construction theory – performance problems – responsibility and accountability – case studies (Failure of Bridges, Fire Damaged Structures, Pre-cast segmental construction, Geotechnical Failures, Tunnel Collapse) – learning from failures – causes of distress in structural members – design and material deficiencies – over-loading.	8
UNIT 3	Diagnosis and Assessment of Distress: Visual inspection – non-destructive tests, crack detection techniques – case studies – single and multistorey buildings – Fibre optic method for prediction of structural weakness.	8

UNIT 4	Environmental Problems and Natural Hazards: Effect of corrosive, chemical and marine environment – pollution and carbonation problems – durability of RCC structures – damage due to earthquakes and strengthening of buildings – provisions of BIS 1893 and 4326.	8
UNIT 5	Methods of repair in concrete, steel and timber structural components.- Modern Techniques of Retrofitting: Structural first aid after a disaster – guniting, jacketing – use of chemicals in repair – application of polymers – ferrocement and fiber concretes as rehabilitation materials – strengthening by pre-stressing – case studies.- Maintenance – inspection and planning, budgeting, and management.	10
	Total	**42**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Design and Construction Failures, Dovkaminetzky, Galgotia Publication, New Delhi, 2009.	2009
2	Concrete – Building Pathology, Macdonald S, John Wiley and Sons, 2002.	2002
3	Forensic Structural Engineering Handbook, Robert. T Ratay, Mc Graw Hill, 2009.	2009
4	Understanding Building Failures, James Douglas and Bill Ransom, Taylor and Francis Group, 2007.	2007
5	Concrete Repair and Maintenance, Peter H Emmons, Galgotia Publications, 2010.	2010

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure**		**Pre-Requisite**	
CE 412: Climate Change and Sustainable Development	**L**	**T**	**P**	Nil
	3	1	0	

Course Objective: To familiarise students with the concept of sustainability in view of climate change

S. No	Course Outcomes (CO)
CO1	Introduction to importance of climate
CO2	Understanding fundamental concepts of climate and its implications to environment
CO3	
CO4	Familiarisation with sustainable development and practices

S. No	Contents	Contact hours
UNIT 1	Climate systems: Overview, climate change and variability and indicators; Earth atmosphere- structure, composition, interactions; biogeochemical cycles; radiative budget; Indian Summer Monsoon- clouds, precipitation, storms; Essential Climate Variables (ECV); National Information System for Climate and Environmental Studies (NICES)	8
UNIT 2	Climate change and modelling: Global warming- Causes, GHGs, RCPs; Policies- IPCC and ither initiatives; climate models- energy balance, radiation, GCM	6
UNIT 3	Climate change impact on Natural resources: Impact assessment on agriculture, and crop systems; drought; impact assessment on biodiversity, forest fires and species migration; carbon sequestration; geomorphological hazards; cryosphere impacts	10
UNIT 4	Sustainable Development and Policies: SDGs and reliance; SDGs with specific targets for Climate action; Target achievements in relation to RCPs; international climate policies- IPCC, Kyoto, UNFCC, Paris agreement	8
UNIT 5	Renewable energy and climate mitigation- solar and wind and hydro energy systems; energy efficiency; green infrastructure; bioenergy and biofuels; carbon capture utilisation and storage (CCUS)	4
UNIT 6	Climate resilient cities and sustainable development- smart cities and low carbon urban development; sustainable transportation; waste management and circular economy; green infrastructure and nature-; urban microclimate studies; based solutions; urban temperature and urban precipitation issues	6
	TOTAL	**42**

REFERENCES		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication /**

		Reprint
1	Anil Markandya & Kirsten Halsnaes, "Climate Change and Sustainable Development: Prospects for Developing Countries", Earthscan, USA	2013
2	Mishra, R. K., Janaki-Krishna, P. S., & Kumari, L., "Climate Change and Sustainable Development: Global Perspective", Academic Foundation	2017
3	Mitsova, D., & Esnard, A. M., "Geospatial Applications for Climate Adaptation Planning", Routledge, T&F	2019
4	Palme, M., & Salvati, A., "Urban Microclimate Modelling for Comfort and Energy Studies", Springer	2021

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure. Credit=4**			**Pre-Requisite**
CE 413: Vulnerability and Risk Management	**L**	**T**	**P**	**Nil**
	3	**0**	**2**	

Course Objective: To impart knowledge and skill involving basic concepts and processes required for vulnerability and risk assessment and management to infrastructures due to different hazards.

S. No	Course Outcomes (CO)
CO1	Introduction to the various hazards encountered for civil infrastructure.
CO2	Introduction to randomness associated with hazards and probability.
CO3	Proficiency for modelling random variables for the design of structures.
CO4	Proficiency for the vulnerability assessment including **d**amage statistics and cumulative damage models.
CO5	Students are able to implement knowledge for risk assessment and management in civil infrastructures.

S. No	Contents	Contact hours
UNIT 1	**Introduction:** Overall view of Hazard, Vulnerability, and Risk assessments for Natural Hazards, Risk, terminology, randomness, uncertainty, Sources of Uncertainty, Steps in the Modelling of Uncertainty. Modelling of Uncertainty: Descriptors of Randomness.	8
UNIT 2	**Basics of Probability:** Sample space and events, Interpretation of probability, Probability axioms, Elementary theorems, conditional probability, Bayes' theorem. Random Variables: Definition of random variables - discrete and continuous; Probability definitions - PMF, PDF, CDF; Moments and expectations. **Probability Distributions:** Discrete distributions - binomial distribution, Poisson's distribution; Continuous distributions – uniform distribution, exponential distribution, gamma distribution, Weibull, Normal, and lognormal distributions. Extreme value distributions, Multivariate Distribution-Bivariate Normal distribution, other bivariate distributions, Transformations to Normal distribution	10
UNIT 3	**Determination of Distributions a Parameters from Observed Data:** Determination of Probability Distribution, Estimation of Parameters of a Distribution, Interval estimation of Mean and Variance, Tests of goodness-of-fit	8

	(chi-square test, Kolmogorov-Smirnov test), Modelling random variables like loads, material properties etc.	
UNIT 4	**Vulnerability Assessment:** Damage statistics and cumulative damage models, analytical and hybrid methods, calibration of models. Simulation Methods: Basis of simulations methods, random number generation, concept of Monte Carlo simulation and applications, Case study of Monte Carlo simulation.	8
UNIT 5	**Risk Assessment and Management:** Risk assessment due to various types of structures, Probabilistic and deterministic risk analysis**,** Probabilistic risk assessment application to Civil engineering problems using MATLAB	10
	Total	**42**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Haldar, A., and Mahadevan, S. "Probability, reliability and statistical methods in engineering design." John Wiley and Sons, New York.	1999
2	J R Benjamin and C A Cornell, "Probability, statistics and decisions for civil engineers," John Wiley, New York.	1976
3	A Papoulis, "Probability, random variables and stochastic processes" 3rd Edition, McGraw-Hill, New York.	1991
4	HAZUS-MH, MR1& MR2 Technical Manual, Federal Emergency Management Agency	2020

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE414: Urban Planning and Flood Management	**L**	**T**	**P**	**Nil**
	3	**0**	**2**	

Course Objective: The course introduces students to the fundamental principles of urban planning and flood management. It covers planning methodologies, flood risk assessment, and sustainable management strategies. Students will gain theoretical and practical knowledge to design and implement effective flood mitigation measures in urban environments.

S. No	Course Outcomes (CO)
CO1	Understand urban hydrology and its impact on flood occurrences.
CO2	Analyze flood risk and design appropriate flood management strategies.
CO3	Evaluate urban planning techniques for mitigating flood risks.
CO4	Apply GIS and remote sensing tools for flood risk mapping.
CO5	Implement sustainable urban drainage systems and flood resilience measures.

S. No.	Contents	Contact Hours
UNIT 1	**Introduction to Urban Planning and Floods**: Urban planning concepts and their relationship with flooding. The causes and types of urban flooding, impact of urbanization on water management. Case studies on major urban flood disasters highlighting key challenges and solutions.	8
UNIT 2	**Flood Hydrology and Risk Assessment**: Hydrologic cycle, flood hydrograph analysis, and rainfall-runoff relationships. Flood frequency analysis techniques and flood risk assessment ethodologies, vulnerability mapping to understand the extent and severity of urban floods.	10

UNIT 3	**Urban Drainage and Flood Management Strategies**: Traditional and modern urban drainage systems. Sustainable urban drainage systems (SUDS), green infrastructure for flood mitigation, and urban flood modeling techniques. Strategies for reducing flood risks through improved drainage planning and management.	8
UNIT 4	**IS and Remote Sensing in Flood Management**: GIS and remote sensing applications in flood management. Flood risk mapping, satellite-based flood monitoring, and case studies showcasing how GIS tools assist in flood preparedness and mitigation planning.	8
UNIT 5	**Policy, Governance, and Climate Change Impacts**: Urban flood management policies, governance frameworks, and the role of different stakeholders in flood mitigation. The impact of climate change on urban flooding and strategies for enhancing urban resilience to extreme weather events, Future trends in flood management.	8
	Total	**42**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Kundzewicz, Z.W., "Flood Risk Science and Management", Cambridge University Press.	2012
2	Ashley, R., Garvin, S., Pasche, E., Vassilopoulos, A., Zevenbergen, C., "Advances in Urban Flood Management", CRC Press.	2007
3	Chow, V.T., "Handbook of Applied Hydrology", McGraw-Hill.	1964
4	Schanze, J., Zeman, E., Marsalek, J., "Flood Risk Management: Hazards, Vulnerability and Mitigation Measures", Springer.	2006

B. Tech. Engineering				
Course code and name	**Course Structure**			**Pre-Requisite**
CE415: Geotechnical Exploration and Excavation Methods	**L**	**T**	**P**	**CE206: Soil Mechanics**
	3	**1**	**0**	

S. No	Course Outcomes (CO)
CO1	Students understand: origin and nature of soils, geotechnical exploration, borings, and their layout
CO2	Students understand: samples and samplers, mechanisms, and work procedures of a variety of in-situ tests
CO3	Students understand: various correlations developed from in-situ tests and their usage. Exploration in rocks, equipment, results and correlations
CO4	Students understand: mechanisms, equipment, procedures, and correlations for geophysical exploration. Preparation of exploration report. Exploration of landfills and objectives of excavation.
CO5	Students understand: various geotechnical excavations, their protection, stability, and construction.

S. No	Contents
UNIT 1	Origin of soils, nature of different types of soils. Objectives and procedures of geotechnical exploration. Methods of exploratory borings, required depth, and spacing of borings.
UNIT 2	Various samplers and collections of samples. Various in-situ tests: standard penetration test, static cone penetration test (both mechanical and piezocone), dynamic cone penetration test, vane shear test, pressuremeter test, and dilatometer test.
UNIT 3	Various correlations and charts to be developed on the basis of in-situ tests. Methods of exploration in rocks, various types of core barrels and coring bits, typical results, and correlations.
UNIT 4	Various geophysical explorations: methods, equipment, procedures, and correlations. Preparation of subsoil exploration report. Exploration of closed landfill sites. Objectives of geotechnical excavation.
UNIT 5	Protection of excavations and surrounding structures, various methods such as sheet pile walls, braced walls, and coffer dams, their procedures for construction, types of construction, and analysis of stability. Ditches and Tunnels: excavation, stability, and loads.

REFERENCES		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Bowles, J. E. “Foundation Analysis and Design”, McGraw-Hill International.	1997
2	Das, B. M. “Principles of Foundation Engineering”, Cengage.	2016
3	Murthy V. N. S., “Advanced Foundation Engineering”, CBS Publishers and Distributers.	2012
4	Singh, Alam. “Soil Engineering in Theory and Practice Volume 1”, CBS Publishers and Distributors.	2014
5	Powrie, William “Soil Mechanics Concepts and Applications.”, CRC Press.	2014
6	Punmia B. C. Jain A. K. Jain A. K. “Soil Mechanics and Foundations” Laxmi Publications.	2022

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE416: Masonry, Timber, and Bamboo Structures	L	T	P	Nil
	3	0	2	

Course Objective: This course aims to provide students with an understanding of the properties, behaviour, and design principles of masonry, timber, and bamboo structures, focusing on their resistance to earthquake, wind, and cyclone forces. Students will learn to design and evaluate these structures under various loads, understand failure mechanisms, and apply relevant codes (IS 1905, IS 4326, IS 15912). The course also covers emerging trends in sustainable construction and heritage preservation.

S. No	Course Outcomes (CO)
CO1	Understand the engineering properties of masonry, timber, and bamboo materials.
CO2	Analyse the structural behaviour of masonry, timber, and bamboo under various loads.
CO3	Apply earthquake, wind, and cyclone-resistant design principles to these structures.
CO4	Design masonry, timber, and bamboo structures considering axial, flexural, and shear loads.
CO5	Explore emerging trends in construction, preservation of heritage structures, and sustainable innovations.

S. No	Contents	Contact Hours
UNIT 1	**Engineering Properties of Materials**: Engineering properties of masonry, timber, and bamboo; Types of masonry: Brick, stone, concrete blocks, reinforced masonry; Types of timber: Solid wood, engineered wood, laminated wood products; Types of bamboo used in construction; Durability, fire resistance, pest resistance, and preservative treatments.	8
UNIT 2	**Structural Behaviour Under Various Loads**: Principles of earthquake, wind, and cyclone-resistant design; Structural behaviour of masonry, timber, and bamboo under gravity, seismic, wind, and extreme weather conditions; Failure mechanisms and response to axial, flexural, shear, and torsional loads; Strengthening techniques; Stability criteria; Relevant codes (IS 4326 for masonry, IS 15912 for bamboo, and timber codes).	8
UNIT 3	**Design of Masonry Structures**; Structural Limit state design of masonry walls, arches, bridge substructures, and retaining walls for Gravity, seismic, wind, and cyclone loads; Relevant codes: IS 1905, Eurocode 6, ACI 530, IS 4326 (for seismic design).	10
UNIT 4	**Design of Timber and Bamboo Structures**: Structural limit state design of timber and bamboo beams, columns, and trusses for axial, flexural, shear, and torsional loads; Design of joints and fasteners: Bolted, nailed, glued, and dowel connections; Relevant codes IS 15912 (for bamboo), ISO 22156 (for bamboo), and timber codes.	8

UNIT 5	**Emerging Trends and Preservation of Archaeological Structures**: Seismic retrofitting techniques, Prefabrication and modular construction in masonry, timber, and bamboo; Smart materials and composites; Sustainable innovations in heritage preservation; Case studies of successful preservation and adaptive reuse of historical buildings; Challenges in maintaining structural integrity of ancient masonry and timber structures; Techniques for seismic retrofitting of heritage structures.	8
	TOTAL	**42**

References

S. No	Name of Books/Authors/Publishers	Year of Publication Reprint
1	M. D. Bondy, Design of Masonry Structures, McGraw-Hill, ISBN: 978-0070666667, 1st Edition.	2012
2	E. S. Hearn, Masonry Design and Construction, Routledge, ISBN: 978-0367338931, 1st Reprint.	2017
3	James R. McDonald, Structural Masonry: Design and Construction, Wiley, ISBN: 978-1118291567	2015
4	R. L. Taylor, Masonry Design and Construction, Longman Scientific and Technical, ISBN: 978-0582247369, 2nd Reprint.	1996
5	IS 1905: 2002, Code of Practice for Structural Use of Masonry, Bureau of Indian Standards (BIS).	2002
6	IS 4326: 2013, Code of Practice for Earthquake Resistant Design and Construction of Buildings, Bureau of Indian Standards (BIS).	2013
7	Eurocode 6: 2005, Design of Masonry Structures, European Committee for Standardization, ISBN: 978-1841193664.	2005
8	ACI 530: 2019, Building Code Requirements for Masonry Structures, American Concrete Institute (ACI), ISBN: 978-1942837657.	2019
9	A. S. Arya, Masonry and Timber Structures, Name Chand and Brothers, ISBN: 978-8185780092	2011, -
10	M. A. Green, Timber Design: Principles and Practice, Wiley-Blackwell, ISBN: 978-0470626366	2013, 1st Edition
11	B. J. Givoni, Design of Timber Structures, Elsevier, ISBN: 978-0444872076	1985, -
12	C. E. W. Lutterodt, Timber Engineering: A Design Guide, CRC Press, ISBN: 978-0367338092	2019, -
13	K. J. Williams, Structural Timber Design, John Wiley & Sons, ISBN: 978-0470663506	2010, 2nd Reprint
14	Johan V. L. Rook, Bamboo: Seismic and Wind Resistant Design for Sustainable Buildings, ISBN: 978-1138922325	2017, 2nd Reprint
15	Hannah C. Webb, Designing for Earthquakes and Cyclones with Bamboo, ISBN: 978-1138925692	2016, -

16	P. R. Bhandari and S. K. Gupta, Seismic Performance of Bamboo Structures: Challenges and Solutions, ISBN: 978-8184246250	2014, -
17	David Brown, Building with Bamboo for Extreme Weather: Cyclone and Earthquake Resilience, ISBN: 978-1138746709	2018, -
18	C. E. S. Thompson, Bamboo Structures and Earthquake Engineering, ISBN: 978-3319071174	2014, 1st Reprint
19	Ravi K. R. Sundar, Seismic Design of Bamboo Buildings: A Guide for Engineers and Architects, ISBN: 978-1138748611	2020, -
20	IS 15912: 2012, Code of Practice for Bamboo for Structural Use, Bureau of Indian Standards (BIS)	2012, 1st Reprint
21	ISO 22156: 2004, Bamboo Structures – Structural Design of Bamboo for Building and Construction, ISBN: 978-9284200962	2004, 1st Reprint
22	R. S. Dhawan & R. S. Sharma, Design of Bamboo Structures: Seismic and Cyclone Safety, ISBN: 978-8189766790	2013, -
23	B. G. L. Suresh, Bamboo in Construction: Seismic and Cyclone-Resistant Design, ISBN: 978-8126909391	2015, -
24	Duggal, V., Earthquake Resistant Design of Structures, Oxford Higher Education, ISBN: 978-0198069704	2007, 1st Edition

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE 417: Computer Methods in Geotechnical Engineering	**L**	**T**	**P**	**CE206: Soil Mechanics**
	3	**0**	**2**	
Course objective: To understand the role of computer-based methods in geotechnical engineering. Apply numerical methods in solving soil and rock mechanics problems. To use the geotechnical software for modelling and solving real-world problems. To apply AI and Machine learning for geotechnical data analysis and prediction.				

S. No	Course Outcomes (CO)
CO1	Understand Computational Methods
CO2	Apply Numerical Techniques
CO3	Use Geotechnical Software
CO4	Apply AI and Machine Learning
CO5	Solve Real-World Geotechnical Problems

S. No	Contents	Contact Hours
UNIT 1	Introduction to Computational Methods in Geotechnical Engineering: Importance of computational methods in geotechnical engineering. Overview of numerical modelling techniques (FEM, FDM, DEM) Review of fundamental soil mechanics concepts. Introduction to geotechnical problem-solving using computers.	8
UNIT 2	Numerical Methods for Geotechnical Problems. Finite Difference Method (FDM) and its application in geotechnical engineering. Finite Element Method (FEM) concepts and basics of meshing. Introduction to Discrete Element Method (DEM) for granular materials. Application of numerical methods for: Slope stability analysis, Seepage, and groundwater flow Consolidation and settlement.	8
UNIT 3	Geotechnical Engineering Software Applications, Overview and application of PLAXIS (FEM-based geotechnical modelling). GeoStudio (Seepage, stability, and stress analysis). FLAC (Finite difference modelling for soil and rock mechanics). ABAQUS (Advanced finite element analysis for soil-structure interaction). Hands-on practice: Modelling soil behaviour, boundary conditions, and interpretation of results	8

UNIT 4	Data Analysis and Machine Learning in Geotechnical Engineering Introduction to data-driven approaches in geotechnical engineering Use of MATLAB/Python for geotechnical data processing Machine learning applications in soil classification and prediction AI-based predictive modelling for geotechnical failures	8
UNIT 5	Case Studies and Practical Applications. Real-world case studies on geotechnical failures and their computational analysis. Project-based learning: Students work on real geotechnical problems using software tools. Report preparation and technical presentation of findings.	10
	Total	**42**

REFERENCES		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Numerical Methods in Geotechnical Engineering: Michael A. Hicks, Ronald B.J. Brinkgreve, Alexander Rohe Publisher: CRC Press (Routledge)	2014
2	Finite Element Analysis in Geotechnical Engineering: Application: David M. Potts, Lidija Zdravković. Publisher: Thomas Telford Ltd	2001
3	Finite Element Analysis in Geotechnical Engineering: Theory: David M. Potts, Lidija Zdravković. Publisher: Thomas Telford Ltd.	1999
4	PLAXIS: A Practical Guide for Geotechnical Engineers: Helmut Schweiger Publisher: CRC Press.	2019

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure**			**Pre-Requisite**
CE418: Water Resource Management	**L**	**T**	**P**	**Nil**
	3	**1**	**0**	

Course Objective: To familiarize the students with the concepts of soil and water conservation, flood estimation and forecasting, engineering economics, and water resources management. Application of this knowledge in the management of water resources is demonstrated through solved examples.

S. No	Course Outcomes (CO)
CO1	The students will be able to apply appropriate rainwater harvesting techniques and estimate reservoir capacity requirements. They will be able to analyze for optimal capacity of reservoirs and spillways as per hydrological considerations.
CO2	The students will be able to estimate the effects of silting on the life of reservoirs and design soil conservation structures in their watershed as preventive measures.
CO3	The students will be able to estimate and forecast floods with the application of hydrological concepts like frequency analyses and unit hydrograph techniques.
CO4	The students will be able to select an optimal scale of water resources projects with the use of economic analysis and optimization techniques. They will also be able to plan for the sequencing and scheduling of the project components.
CO5	The students will understand the utility of computer programs in the design of water resources systems.

S. No	Contents	Contact Hours
UNIT 1	**Water conservation**: Rain water harvesting techniques, water shed development, ground water recharging, check dams, reservoirs and aquifers, control of infiltration, seepage and evaporation.	8

UNIT 2	**Soil Conservation:** Introduction to soil erosion, mechanisms and its causes and control, sheet erosion, rill erosion, gully erosion, control of erosion by bunding, terracing, contour trenching, gully stabilizing, check dams.	8
UNIT 3	**Floods and Flood Routing:** Stream flows and their measurement, stage-discharge curves. **U**nit hydrograph, instantaneous unit hydrograph and synthetic unit hydrograph theories; and their applications. Flood estimation; flood frequency, risk and reliability analysis. Reservoir and channel routing. Flood forecasting and flood management.	8
UNIT 4	**Principles of Engineering Economics:** discounting techniques, un-certainty, planning horizon. Selection of optimal alternatives. Application of linear, nonlinear and dynamic programming in water resources. Optimal sequencing and scheduling of resources.	8
UNIT 5	**Planning of Water Resources Projects:** factors affecting irrigation and power development, cost – benefit analysis for irrigation, water power and floods control projects. Computer applications in the designs of water resources systems**.**	10
	Total	**42**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Hall, W.A. and Dracup, J.A., "Water Resources Systems Engineering", McGraw-Hill Book Company.	1970
2	Loucks, D.P., "Water Resource Systems Planning and Analysis", Prentice Hall.	1981
3	Maass et al., "Design of Water-Resource Systems", Harvard University Press. 1962	1961
4	Vedula S. and Mujumdar, P.P., "Water Resources Systems", Tata McGraw-Hill.	2005
5	Das, Ghanshyam, “Hydrology and Soil Conservation Engineering: Including Watershed Management”, PHI Learning Private Limited	2009

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE 419: Environmental Geo-Techniques	**L**	**T**	**P**	**CE206: Soil mechanics CE208: Environmental Engineering**
	3	**1**	**0**	

Course Objective: To understand the fundamental principles of environmental geotechnics and its role in sustainable engineering practices. To study the behavior of soils and rocks in response to environmental factors such as contamination, seepage, and waste disposal. To explore various waste containment systems, landfill engineering, and remediation techniques for contaminated sites. To apply geotechnical engineering principles to the assessment and mitigation of environmental hazards. To introduce advanced techniques such as geosynthetics, bioremediation, and soil stabilization for environmental protection.

S. No	Course Outcomes (CO)
CO1	Understand the fundamental concepts of environmental geotechnics and its importance.
CO2	Analyse soil contamination mechanisms and apply suitable remediation techniques.
CO3	Design waste containment systems considering geotechnical principles.
CO4	Evaluate groundwater contamination and implement appropriate control measures.
CO5	Apply sustainable geotechnical solutions for environmental protection and infrastructure development.

S. No	Contents	Contact hours
UNIT 1	Introduction to Environmental Geotechnics: Scope and importance of environmental geotechnics, Soil-water-contaminant interaction, Sources of contamination in soil and groundwater, Physicochemical and biological behaviour of contaminated soils, Impact of environmental factors on soil properties	8
UNIT 2	Soil Contamination and Remediation Techniques: Mechanisms of soil contamination – Adsorption, Diffusion, Leaching, Contaminant transport in soils – Advection, Dispersion, and Biodegradation, Remediation techniques: In-situ methods – Bioremediation, Soil Vapor Extraction, Electrokinetic Remediation, Ex-situ methods – Soil Washing, Stabilization/Solidification, Thermal Desorption, Case studies of contaminated site remediation	8
UNIT 3	Waste Management and Landfills: Types and classification of waste – Municipal, Industrial, Hazardous, Landfill design and construction, Geotechnical	8

	considerations in landfill engineering, Role of geosynthetics in waste containment – Liners, Covers, Drainage, Leachate generation and management	
UNIT 4	Groundwater Pollution and Control Measures: Sources and types of groundwater pollution, Hydrogeological factors affecting contaminant migration, Groundwater monitoring and sampling techniques, Contaminant transport modelling in groundwater, Groundwater remediation techniques – Pump-and-Treat, Permeable Reactive Barriers, Natural Attenuation	8
UNIT 5	Sustainable Practices and Case Studies: Sustainable geotechnical practices in environmental engineering, Use of recycled materials in geotechnical applications, Climate change impacts on geotechnical structures, Case studies of environmental geotechnics applications in infrastructure projects, Future trends in environmental geotechnics	8
	Total	**40**

REFERENCES

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	Sharma, H. D., & Reddy, K. R. “Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies". John Wiley & Sons.	2004
2	Rowe, R. K. "Geotechnical and Geoenvironmental Engineering Handbook". Springer.	2011
3	Reddi, L. N., & Inyang, H. I. "Geoenvironmental Engineering: Principles and Applications". CRC Press.	2000
4	Daniel, D. E. "Geotechnical Practice for Waste Disposal". Springer.	1993
5	Das, B. M. "Principles of Geotechnical Engineering". Cengage Learning.	2017
6	Hari D. Sharma, Sangeeta P. Lewis. “Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation”. John Wiley & Sons.	1994

B. Tech. Civil Engineering				
Course code: Course Title	**Course Structure.**			**Pre-Requisite**
CE421: Geosynthetics	**L**	**T**	**P**	**CE206: Soil Mechanics**
	3	**1**	**0**	

Course Objective:
To introduce students to the classification, properties, and applications of geosynthetics in geotechnical engineering. To understand the functions of geosynthetics such as reinforcement, separation, filtration, drainage, and containment. To study the mechanical and hydraulic properties of geosynthetics and their interaction with soil. To analyse the design methodologies for geosynthetic applications in slopes, retaining walls, pavements, embankments, and landfills. To explore recent advancements and case studies related to geosynthetics in geotechnical engineering projects.

Course Outcomes (COs)	
S. No.	**Course Outcomes (COs)**
CO1	To understand the types, properties, and functions of geosynthetics in civil engineering
CO2	To analyse the mechanical and hydraulic properties of geosynthetics and their interaction
CO3	To design geosynthetic-reinforced slopes, retaining walls, pavements, and embankments.
CO4	To study the role of geosynthetics in filtration, drainage, and containment systems.
CO5	To explore case studies, recent advancements, and sustainability aspects of geosynthetics.

Course Content		
S. No.	**Contents**	**Contact Hours**
UNIT 1	Basic description of geosynthetics, overview of (geotextiles, geogrids, geomembranes, geo-composites).	8
UNIT 2	Geotextile properties and test methods, geotextile function and mechanisms, design for (separation, reinforcement, stabilization, filtration, drainage, multiple functions), construction methods and techniques using geotextile.	8
UNIT 3	Geogrid properties and test methods, designing for reinforcement, designing for	8

	stabilisation, construction methods using geogrids	
UNIT 4	Geomembrane properties and test methods, survivability requirements, liquid containment, covers for reservoirs, water conveyance, solid material, caps and closures, dam and embankments, miscellaneous aspects of geomembrane	8
UNIT 5	Geo-composites in (separation, reinforcements, geo-webs and geocells, filtration, sheet drains, strip (wick) drains, moisture barrier)	8
Total		**40**

References		
S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1	R. M. Koerner, *Designing with Geosynthetics* (ISBN: 978-0137261758), Publisher: Pearson	2005
2	R. D. Holtz, B. R. Christopher, & R. R. Berg, *Geosynthetic Engineering* (ISBN: 978-0071481985) Publisher: McGraw-Hill	2008
3	J. N. Mandal, *Geosynthetics: Innovative Solutions for Sustainable Development* (ISBN: 978-8123918552) Publisher: CBS Publishers & Distributors	2011
4	C. V. S. K. Rao, *Ground Improvement Techniques* (ISBN: 978-8122424795) Publisher: I.K. International Publishing House	2010