M.Tech.

IN

ENVIRONMENTAL GEOTECHNOLOGY

CURRICULUM & SYLLABI

(Applicable from 2023 admission onwards)

Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech. in Environmental Geotechnology

PEO1	Demonstrate advanced knowledge in Environmental Geotechnology, enabling them to excel in their profession and pursue higher academic goals
PEO2	Exhibit strong communication, technical writing and interpersonal skills
PEO3	Be strongly committed to ethical practices, maintenance of quality and performance standards, sustainability, and self-directed life-long learning

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M.Tech. in Environmental Geotechnology

PO1	Attain an ability to conduct research/ investigation independently and develop the work to solve practical problems.
PO2	Attain an ability to write and present a substantial technical report/ document.
PO3	Demonstrate a degree of mastery over the area as per the specialisation of the program.
PSO1	Attain an ability to identify formulae, solve complex Environmental Geotechnical / Geotechnical Engineering problems, and develop the confidence for self-education and knowledge for lifelong learning.
PSO2	Identify environmental aspects and issues related to infrastructure development and provide sustainable solutions.

CURRICULUM

Total credits for completing M.Tech. in Environmental Geotechnology is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	23+35 (Projects)
2.	Program Electives (PE)	15
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minutes duration)
T: Tutorial (One unit is of 50 minutes duration)
P: Practical (One unit is of one-hour duration)
O: Outside the class effort / self-study (One unit is of one-hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE6401E	Ground Improvement	3	0	0	6	3	PC
2.	CE6402E	Fundamentals of Soil Behaviour	3	0	0	6	3	PC
3.	CE6403E	Advanced Design of Foundations	3	0	0	6	3	PC
4.	CE6491E	Environmental Geotechnical Laboratory	0	0	2	1	1	PC
5.	CE6404E	Geoenvironmental Engineering	3	0	0	6	3	PC
6.	******E	Programme Elective I	3	0	0	6	3	PE
7.	******E	Programme Elective II	3	0	0	6	3	PE
8.	******E	Institute Elective	2	--	--	4	2	IE
		Total					**21**	

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE6411E	Solid and Liquid Waste Management	3	0	0	6	3	PC
2.	CE6412E	Geosynthetics and Reinforced Soil Structures	3	0	0	6	3	PC
3.	CE6413E	Dynamics of Soils and Foundations	3	0	0	6	3	PC
4.	CE6492E	Foundation Engineering Design studio	0	0	2	1	1	PC
5.	CE6496E	Project phase I	0	0	0	6	2	PC
6.	******E	Programme Elective III	3	0	0	6	3	PE
7.	******E	Programme Elective IV	3	0	0	6	3	PE
8.	******E	Programme Elective V	3	0	0	6	3	PE
		Total					**21**	--

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE7497E	Project Phase II*	0	0	0	9	3	PC
2.	CE7498E	Project Phase III	0	0	0	45	15	PC
		Total					**18**	--

*Summer Internship/Project to be carried out during the summer break.

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE7499E	Project Phase IV	0	0	0	45	15	PC
		Total					**15**	--

List of Programme Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	CE6421E	Design of Engineered Landfills	3	0	0	6	3
2.	CE6422E	Foundation Engineering for Difficult and Contaminated Grounds	3	0	0	6	3
3.	CE6423E	Wastewater Engineering	3	0	0	6	3
4.	CE6424E	Analysis and Design of Earth Retaining Structures	3	0	0	6	3
5.	CE6425E	Landslide Mitigation Methods	3	0	0	6	3
6.	CE6426E	Groundwater Contamination	3	0	0	6	3
7.	CE6427E	Earthquake aspects of Geotechnical Engineering	3	0	0	6	3
8.	CE6428E	Bioremediation Technologies	3	0	0	6	3
9.	CE6429E	Engineering Rock Mechanics	3	0	0	6	3
10.	CE6430E	Pavement Geotechnics	3	0	0	6	3
11.	CE6431E	Unsaturated Soil Mechanics	3	0	0	6	3
12.	CE6432E	Constitutive modelling for soils	3	0	0	6	3
13.	CE6433E	Earth and Rockfill Dams	3	0	0	6	3
14.	CE6434E	Forensic Geotechnical Engineering	3	0	0	6	3
15.	CE6101E	Theory of Elasticity and Plasticity	3	0	0	6	3
16.	CE6111E	Finite Element Method	3	0	0	6	3
17.	CE6203E	Pavement Materials, Design, and Construction	3	0	0	6	3
18.	CE6213E	Pavement Evaluation and Management	3	0	0	6	3
19.	CE6226E	Geographic Information System and its Applications	3	0	0	6	3
20.	CE6312E	Marine Foundations	3	0	0	6	3
21.	CE6512E	Flow and Transport in Porous Media	3	0	0	6	3

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	IE6001E	Entrepreneurship Development	2	0	0	4	2
2.	MS6174E	Technical Communication and Writing	2	1	0	3	2
3.	ZZ6002E	Research Methodology	2	0	0	4	2

List of Electives (Environmental Engineering)

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	CE6435E	Applied Environmental microbiology	3	0	0	6	3
2.	CE6436E	Atmospheric processes and air quality management	3	0	0	6	3
3.	CE6437E	Biological process design for wastewater treatment	3	0	0	6	3
4.	CE6438E	Environmental Chemistry and microbiology	3	0	0	6	3
5.	CE6439E	Environmental forensics	3	0	0	6	3
6.	CE6440E	Environmental quality and monitoring	3	0	0	6	3

Note: The elective courses related to Environmental Engineering are added to separate electives basket for the registration of the PhD students in Environmental Engineering specialisation.

CE6401E GROUND IMPROVEMENT

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire about various techniques of ground improvement.
CO2: Techniques to utilize native soil for construction activities.
CO3: Technique to accelerate rate of construction projects.
CO4: Various technique to rectify settlements, restoration etc.

Vibration techniques, dynamic compaction, depth of treatment, environmental considerations, practical application of vibro_techniques and dynamic compaction.

Classification of stabilizing agents, deleterious effects of organic substances and sulphates on inorganic stabilization, lime stabilization, lime column method, bearing capacity and settlement of lime columns, slope stability, stability of trenches, laboratory and field investigations, lime-sand columns, stone columns, Engineering treatment of mine spoils, Geo and bio polymers and Nano technology in Geotechnical treatment of soils.

Grouting techniques, chemical grouting, principles of injection, grout systems, grouting operations, applications, design methods, jet grouting, the jet grouting process, geometry and properties of soil used, properties of treated ground, application of jet grouting.

Soil fracturing techniques for terminating settlements and restoring levels of buildings and structures, injection technology and its effects, typical examples, in situ soil mixing techniques, construction techniques, testing procedures.

References:

1. Moscly, M.P. “A Text book on Ground Improvement”, Blackie Academic and Professional, 1994.
2. Raj, P. Purushothama, “Ground Improvement Techniques”, Laxmi Publications, New Delhi, 2005
3. F.G. Bell, Engineering treatment of soils, E & FN Spon publishers, 1993, Taylors & Francie E-library 2005
4. Klaus Kirsch & Fabian Kirsch. Ground improvement by deep vibro methods. Spon press, London & NY, 2010
5. Bikash Chattopadhyay & Joyanta Maity. Ground Improvement Techniques, PHI Learning Pvt. Ltd., Delhi, 2017

CE6402E FUNDAMENTALS OF SOIL BEHAVIOUR

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the probable soil formation history
CO2: They will be able to evaluate the soil fabric by indirect and direct methods
CO3: Identify and solve soil water interaction problems
CO4: Properly evaluate the soil compressibility aspects and estimate probable settlements.
CO5: Asses the shear strength characteristics by conducting the most appropriate tests

Soil Mineralogy:
Origin, nature and distribution of soil, description of individual particle, clay mineralogy, clay- water electrolytes, soil fabric and structure.

Permeability, Effective Stress and Consolidation
Effective stress principle, steady state flow in soil, effect of flow on effective stress, determination of coefficient of permeability, consolidation, one, two, three and radial direction, variation of effective stress during consolidation, consolidation tests and determination of consolidation parameters

Shear Strength
Stress path, tri-axial and direct shear tests, shear behaviour of granular soils, factors affecting shear behaviour, determination of shear strength parameters, shear behaviour of fine grained soils, pore pressure parameters, UU,CU,CD tests, total and effective shear strength parameters, total and effective stress paths, water content contours, factors affecting shear strength-stress history, rate of loading, structure and temperature, anisotropy of strength, thixotropy ,creep, determination of in situ undrained strength.

Critical state model
Introduction models and soil mechanics, use of models in engineering, elasticity, soil elasticity, plasticity and yielding, yielding of metal tubes in combined tension and torsion, elastic-plastic model for soil, elastic volumetric strains, a particular elastic-plastic model

References:

1. Holtg,R.D and Kovacs W.D., “An Introduction to Geotechnical Engineering” , Prentice hall CO, N.J., 1981.
2. Ishihara, K - Soil Behaviour in Earthquake Geotechnique, Oxford University Press, 1996.
3. Mitchell, J. K., “Text book in Fundamentals of Soil Behaviour”, 2Ed, John Wiley &Sons, New York, 1993.
4. Muir Wood - Soil Behaviour and critical State Soil Mechanics, Cambridge University Press, 1994.
5. Nagaraj T.S and Srinivasa, B.S. - Analysis and Prediction of Soil Behaviour, Taylor and Francis, 1994.
6. Schofield and Worth - Critical State Soil Mechanics, McGraw Hill, 1968

CE6403E ADVANCED DESIGN OF FOUNDATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze and interpret soil properties for foundation design.
CO2: Utilize advanced geotechnical analysis methods for complex foundation systems.
CO3: Evaluate and analyze bearing capacity and immediate settlement of foundations.
CO4: Understand design considerations for retaining walls and earth retaining structures.

Ground Exploration and Shallow Foundation
Introduction, soil exploration (SPT, CPT, PLT) − analysis and interpretation of soil exploration data − estimation of soil parameters for foundation design. Bearing capacity theories − Methods for bearing capacity estimation − total and differential settlements of footing and raft, code provisions − Design of individual footings, strip footing, combined footing, rigid and flexible mat, buoyancy raft, basement raft, underpinning.

Pile and Well Foundations
Estimation load carrying capacity of single and pile group under various loading conditions − Pile load testing (static, dynamic methods and data interpretation) − settlement of pile foundation, codeprovisions, design of single pile and pile groups, and pile caps. Well or Caisson foundation types, components, construction methods, design methods (Terzaghi, IS and IRC approaches), check for stability, base pressure, side pressure and deflection.

Retaining Walls and Reinforced Earth
Types (types of flexible and rigid earth retention systems: counter fort, gravity, diaphragm walls, sheet pile walls, soldier piles and lagging) − Support systems for flexible retaining walls (struts, anchoring), construction methods, stability calculations − design of flexible and rigid retaining walls, design of cantilever and anchored sheet pile walls. Geotechnical properties of reinforced soil − shallow foundation on soil with reinforcement, retaining walls with reinforcements, design considerations.

Soil Foundation Interaction
Idealized soil, foundation and interface behavior − Elastic models of soil behavior; Elastic-plastic and time dependent behavior of soil − Beams and plates on elastic foundation; numerical analysis of beams and plates resting on elastic foundation.

References:

1. A.P.S. Selvadurai, “Elastic Analysis of Soil-Foundation Interaction”, Elsevier Scientific Publishing Company.
2. B. M. Das, “Principles of Foundation Engineering”, PWS Publishing Company.
3. J. Bowles, “Foundation Analysis and Design”, McGraw-Hill Book Company.
4. V.N.S. Murthy, “Advanced Foundation Engineering”, CBS Publishers and Distributors.
5. S. Saran, “Analysis and Design of Substructures”, 2nd Edition, Oxford & IBH Publishing Company Pvt. Ltd., 2009.

CE6404E GEOENVIRONMENTAL ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the methods to carry out geoenvironmental site investigation.
CO2: Explain the processes that lead to the contamination of a site and its consequences.
CO3: Recommend and guide the implementation of suitable techniques to remediate a site contaminated with a particular type of pollutants.
CO4: Recommend and design a suitable containment system based on the site conditions.

Scope of Geo-environmental Engineering- Various Sources of Contaminations- Need for contaminated site characterization- Characterization methods- Preliminary site assessment- exploratory and detailed site investigation- Geostatistical Applications. Solid and Hazardous Waste Management: Classification of waste, Characterization wastes, Environmental Concerns with waste. Contaminant Release Mechanisms: Vaporization, Dusting, Leaching. Groundwater Contaminant Transport: Transport process- Mass-transfer process. Remediation of contaminated sites - Introduction to Exposure Assessment - Risk-Based Estimation of Required Clean-Up Levels.

Remediation Techniques: Treatment Approaches - In-Situ Versus Ex-Situ Treatment - Basis for Treatment Technology Selection - Pump-and-Treat Principles - In-Situ Soil Flushing - Volatilization and Air Pressurization Principles - In-Situ Vitrification Principles -In-Situ Chemical Treatment in Reactive Walls - Solidification/Stabilization- Ex-Situ Chemical Treatment Principles - In-Situ Natural Attenuation Principles - In-Situ Phytoremediation Principles - In-Situ Bioremediation Principles - Other Techniques.

Waste Containment- Containment System Implementation - Essentials of Waste Containment - Hydraulic and Physical Containment - Containment Site Selection - Containment Site Improvement -Configurations of Containment Systems: Landfills - Slurry Walls - Drainage Trenches and Wells - Surface Impoundments - Grout Curtains - Composite Systems. Elements of Containment System Design - Leachate Generation - Water Balance in Waste Containment Systems - Leachate Collection and Removal Systems (LCRS) - Flow and Transport Through Barriers - Stability of Waste Containment Systems - Barrier Composition and Performance - Containment System Performance Elements - System Performance Pattern - Types of Barrier Materials -Material Deterioration Mechanisms - System Performance Monitoring Techniques.

References:

1. Reddi, Lakshmi, and Hilary I. Inyang. *Geoenvironmental engineering: principles and applications*. CRC Press, 2000.
2. Sharma, Hari D., and Krishna R. Reddy. *Geoenvironmental engineering: site remediation, waste containment, and emerging waste management technologies*. John Wiley & Sons, 2004.
3. Sarsby, Robert W. *Environmental Geotechnics*. Thomas Telford, 2000.
4. Bagchi, Amalendu. *Design of landfills and integrated solid waste management*. John Wiley & Sons, 2004.

CE6411E SOLID AND LIQUID WASTE MANAGEMENT

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the importance of the treatment and proper disposal of liquid and solid wastes
CO2: Decide the method of treatment and disposal suitable for a given waste under a given circumstance.
CO3: Quantify and evaluate the impacts of disposing wastes on human health and ecosystem.
CO4: Implement suitable management measures to reduce the impacts of waste disposal.

Waste management- introduction- need for treatment- disposal: disposal philosophies- dilute and disperse, concentrate and contain, delay and decay. Quantifying impacts of Waste Disposal- impacts of disposing wastes- quantification of the impacts- quantitative risk analysis- human health risk analysis- carcinogenic, non-carcinogenic, microbial (QMRA)- concept of DALY- ecological risk analysis. Treatment of waste water (designs not required): Stages in treatment of waste water- Secondary treatment methods: Suspended and attached growth biological processes, membrane process- advanced treatments.

Disposal of waste water: Wastewater disposal by use in irrigation- application methods- impacts of waste water reuse in irrigation- impacts on crop, impacts on human beings, impacts on ecosystem- guidelines for waste water reuse in irrigation. Disposal by groundwater recharge: soil aquifer treatment systems- configurations- design considerations- guidelines. Disposal into surface waters: Organic self-purification- Streeter–Phelps equation, Microbial self-purification; Indian regulations on wastewater disposal.

Treatment and disposal of Sewage Sludge: Sludge processing for disposal- preliminary treatments, composting, anaerobic digestion- bio-solids- land application of bio-solids- application methods- guidelines. Municipal Solid Waste treatment and disposal: Processing prior to disposal- material recovery, incineration, waste-to-energy conversion- disposal of MSW- engineered landfills- design consideration- Indian regulations on MSW disposal; Guidelines on the disposal of special wastes: Hazardous, biomedical, construction and demolition.

References:

1. National Research Council, Risk Assessment in the Federal Government: Managing the Process, Washington, DC: The National Academies Press, 1983
2. WHO, Quantitative microbial risk assessment -Application for water safety management, Geneva: World Health Organization, 2016
3. Glenn W. Suter II, Ecological Risk Assessment (II Edition), Florida: CRC Press, 2006
4. Velz, Clarence J. Applied stream sanitation, 1984.
5. George Tchobanoglous and Frank Kreith, Handbook of Solid Waste Management, New York, USA: McGraw-Hill Education, 2002.
6. Metcalf & Eddy Inc., George Tchobanoglous, H. David Stensel, Ryujiro Tsuchihashi, Franklin L. Burton, Wastewater Engineering: Treatment and Resource Recovery, New York, USA: McGraw-Hill Education, 2014
7. WHO, Guidelines for the safe use of wastewater, excreta and graywater (Vol 2- Wastewater use in agriculture), World Health Organization, 2006
8. Relevant Indian statutes

CE6412E GEOSYNTHETICS AND REINFORCED SOIL STRUCTURES

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Types and functions of various geosynthetics and its manufacturing process.
CO2: Testing and valuation of various properties of geosynthetics used in soil structures.
CO3: Apply the principle of reinforced soil and design various reinforced structures. Estimate the length and spacing of reinforcement in reinforced retaining walls.
CO4: Estimate the bearing capacity improvement and settlement of embankments on soft soils reinforced with geosynthetics.

Introduction on reinforced earth and Geotextiles, the nomenclature on various types of geosynthetics, functions of geotextiles, application areas, raw materials of geosynthetics and manufacturing methods. principle and mechanism of reinforced soil.

Geotextile Testing and evaluation, design methods on selection of the geotextiles, hydraulic characteristics of geotextiles, geogrid testing and evaluation, allowable versus ultimate geotextile properties-strength and flow related problems, designing with geotextiles for various functions of separation, filtration, and drainage applications. Applications of geosynthetics in landfills.

Designing with geotextiles for soil reinforcement and roadway reinforcement functions, Geotextiles for improved bearing capacity in soft soils, Modes of failures, In-situ slope stabilization, Embankments on soft soils, Design and construction of Geosynthetic Reinforced soil retaining structures, Walls and slopes, and Codal provisions.

References:

1. BS8006 (2010) Code of Practice for Strengthened/reinforced soils and other fills, British Standards Institution, U.K.
2. Federal Highway Administration Guidelines for Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Volumes I & II, Report No. FHWANHI- 10-025, Washington, D.C. 2010.
3. Koerner, R.M. (2012) Designing with Geosynthetics, Vols. 1&2, 6th Edition, Xlibris Corporation, USA.
4. Jewell, R.A. (1996) Soil reinforcement with geotextiles, CIRIA & Thomas Telford, London, U.K.
5. Saran, Swami (2006) Reinforced Soil and its Engineering Applications, I.K. International, New Delhi.
6. Shukla, S.K. (2012) Handbook of Geosynthetic Engineering, 2nd Edition, ICE Publishing, London, U.K.
7. G L Sivakumar Babu (2009) An introduction to soil reinforcement and geosynthetics, second edition, universities press Pvt. Ltd., Hyderabad, 2009.
8. J.N Mandal, “Reinforced Soil and Geotextiles”, Oxford and IBH Publishers Co. Pvt. Ltd, New Delhi, 1988.
9. National Research Council, Risk Assessment in the Federal Government: Managing the Process, Washington, DC: The National Academies Press, 1983.

CE6413E DYNAMICS OF SOILS AND FOUNDATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Theory of vibrations, spring-mass system, and wave propagation
CO2: Dynamic properties of soils and liquefaction related phenomenon
CO3: Soil structure interaction under dynamic loads, earth pressure, design of retaining walls and slopes, and pile dynamics.
CO4: Design criteria of various types of machine foundations and IS codal procedures.

Introduction, theory of vibrations: Definitions, properties of harmonic motion, free vibrations of a spring-mass-system, undamped and damped free vibrations, forced vibrations with damping, frequency dependent exciting force, system under transient forces, Reyleigh's method, logarithmic decrement, determination of viscous damping, transmissibility, vibration isolator; Wave propagation in an elastic rod, elastic infinite medium, and semi-infinite elastic half space, waves generated by a surface footing.

Dynamic Soil properties: representation of stress conditions by the Mohr Circle, measurement of dynamic soil properties-Field and laboratory tests; Stress-strain behavior of cyclically loaded soils-equivalent and cyclic nonlinear models; Strength of cyclically loaded soils-definition of failure, cyclic strength and monotonic strength; Liquefaction of soils: theory, criterion of liquefaction, factors affecting liquefaction characteristics, evaluation of liquefaction potential, Field and laboratory studies on liquefaction, mitigation methods.

Soil structure interaction: Illustration soil-structure interaction effects and methods of analysis; Dynamic earth pressure and retaining walls, modification of coulomb's theory, modified Cullman's construction, analytical solutions for c-ϕ soils, displacement analysis, Indian standard code of practice, pile hammers, effect of vibrations on piles, method of analysis of piles under lateral loads, solution for piles in non-cohesive and cohesive soils, soil-pile interaction under dynamic loads, method of a seismic analysis and design of piles.

Machine foundations –criteria for a satisfactory machine foundation, methods of analysis, degrees of freedom of a block foundation, definition of soil spring stiffness; vertical, sliding, rocking, and yawing vibrations of a block; simultaneous rocking, sliding, and vertical vibrations of a block, Indian standard for design and construction of foundations for reciprocating machines; design procedure for a block foundation; vertical vibrations according to the elastic half space theory, sliding, rocking, and torsion vibrations according to the elastic half space theory, foundations for impact machines and Indian standard design procedure, vibration isolation and screening waves.

References:

1. Alexander Major, Dynamics in Soil Engineering, Akademiai,1980
2. Braja M Das, Principles of soil dynamics, Cengage Engineering, 2014.
3. Bharat Bhushan Prasad, Fundamentals of soil dynamics and Earthquake engineering, prentice hall India learning Pvt. Ltd., 2009
4. D D Barkan, Dynamics of bases and foundations, McGraw-Hill publications, 1962
5. IS 2974 - Part I and II, Design Considerations for Machine Foundations
6. IS 5249: Method of Test for Determination of Dynamic Properties of Soils
7. Kramer S L, Geotechnical Earthquake Engineering, Pearson education India, prentice hall Int. series, 2003
8. Shamsher Prakash, Soil Dynamics, McGraw-Hill, 1981.
9. Sreenivasalu and Varadarajan, Handbook of Machine Foundations, Tata McGraw-Hill, 2007.

CE6491E ENVIRONMENTAL GEOTECHNICAL LABORATORY

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical sessions: 26

Course Outcomes:

CO1: To determine the engineering properties of different soils.

CO2: To evaluate the tensile strength of geosynthetic material.

CO3: To analyse and quantify the chemical constituents of soils.

Syllabus / List of Experiments:

1. Permeability tests – Constant and Variable Head
2. Swelling and Shrinkage tests – DFSI, Free Swell Pressure, Shrinkage Limit
3. Consolidation test - Oedometer/CRS
4. Triaxial shear test – UU/CU/CD
5. Tensile strength test of Geotextile/Geogrid
6. Determination of total soluble solids and organic matter in soil
7. Determination of calcium carbonate and pH of soil
8. Determination of cation exchange capacity of clay
9. Analysis of leachate contaminated soil – Iron, Manganese, Chloride
10. Determination of surface area of soil

References:

1. B.M. Das, “Soil Mechanics Laboratory Manual”, 6th Ed., London, University Press, 2001.
2. IS 2720: “Method of Test for Soil (relevant parts)”
3. Directorate of Irrigation Research & Development, Pune, “Laboratory testing procedure for soil & water sample analysis”, Water Resource Department, Government of Maharashtra, 2009.
4. K.H. Head and R. J. Epps, “Manual of Soil Laboratory Testing vol II”, 3rd Edition, Whittles Publishing, 2011.

CE6492E FOUNDATION ENGINEERING DESIGN STUDIO

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical sessions: 26

Course Outcomes:

CO1: Make use of the standard geotechnical engineering software packages like Geo-Studio, PLAXIS 2D and 3D for the solution of geotechnical engineering problems such as consolidation, seepage, slope stability, foundation and retaining structures.
CO2: Carry out scientific documentation and drafting using various software packages.

Recommended packages

- PLAXIS 2D and 3D
- Geo-Studio
- AUTO CAD
- MS office

Description of topics of Geotechnical Engineering problems

1. Introduction to geotechnical software packages
2. Slope Stability Analysis
3. Settlement analysis of shallow and deep foundations
4. Analysis of a retaining structures and road embankments
5. Analysis of diaphragm walls
6. Dynamic analysis of foundations

The student has to carry out a mini project work using the software packages and submit a report for evaluation.

References:

1. Joseph E. & Bowles, “Foundation Analysis & Design”,5th edition, McGraw Hill Pub., 2001
2. Manuals of Software such as Geo-Studio, PLAXIS 2D and 3D, ANSYS

CE6496E PROJECT PHASE I

Pre-requisites: NIL

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Identify the current research trends / needs in any specific GE / EGE Area.
CO2: Gather relevant information on any specific topic.
CO3: Technical documentation of the collected information.
CO4: Proper technical presentation of the collected information.

Course Objectives:

1. To introduce the students to various sub fields in Geotechnical / Environmental Geotechnical Engineering.
2. To expose them to current developments / research activities in the above areas.
3. To train the students to gather in depth information on any specific area / topic.
4. To train the students to make proper technical documentation on any selected topic.
5. To train the students to give effective technical presentations.

The students are expected to make a report and presentation on relevant topic related to Environmental Geotechnology either a research or a case study, covering various aspects like scope of the problem, methodology used for the study conclusions arrived at etc. At the end of the academic session, the students will document their work and make a presentation before the designated “Evaluation Committee”.

CE7497E PROJECT PHASE II

Pre-requisites: NIL

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: To get the work experience and provide the internship in the field of practice or laboratory.

CO2: To expose with the practical relevance of Geotechnical Engineering.

CO3: To analyse the Geotechnical / Geoenvironmental Engineering problems.

Course Objectives:

- To better understand work experiences in Geotechnical Engineering and industry best practices.
- To familiar with Geotechnical professional software and analysing the problem of interest
- To prepare and practice with real work environment in outside the construction industry and helping the students to get the placements.

At the end of the academic session, the students will document their work and make a presentation before the designated "Evaluation Committee". This also applies to those who take this up as an internship in an industry/ company/ an institute as well.

For students opting for internship course outcomes will depend on the actual work performed during the internship.

CE7498E PROJECT PHASE III

Pre-requisites: NIL

L	T	P	O	C
0	0	0	45	15

A student should have registered for all theory and laboratory courses in the first and second semester of the programme and secured a grade other than 'W'.

Course Outcomes:

CO1: Develop the essential personal, organisational, management, theoretical and research skills to become independent researchers.
CO2: Demonstrate a degree of analysis and a degree of originality in advanced investigations.
CO3: Develop understanding of research philosophies, design and terminology as well as personal transferable skills.
CO4: Describe a process that has previously been unexplained, difficult or poorly/ partially understood and to conduct an active, systematic process of inquiry.
CO5: To prepare professional documentation of research work carried out.

Course Objectives:

The major course objectives are:

1. To introduce the students to various sub fields in Geotechnical / Environmental Geotechnical Engineering.
2. To expose them to current developments / research activities in the above areas.
3. To train the students to gather in depth information on any specific area / topic.
4. To train the students to make proper technical documentation on any selected topic.
5. To train the students to give effective technical presentations.

The subject of study should be based on the latest works ongoing in the field of Geotechnical and or GeoEnvironmental Engineering. The students should select a topic of his/her interest and in consultation with his/her guide should carry out in depth study / research / experimentation etc. as appropriate for the topic selected. At the end of the academic session, the students will document their work and make a presentation before the designated "Evaluation Committee". This also applies to those who take this up as an internship in an industry/ company/ an institute as well.

For students opting for internship course outcomes will depend on the actual work performed during the internship.

CE7499E PROJECT PHASE IV

Pre-requisites: Project Phase III

L	T	P	O	C
0	0	0	45	15

This course is a continuation of the work initiated in third semester and the student is expected to submit a consolidated report of the work undertaken in the third and fourth semester, at the end of the fourth semester.

Course Outcomes:

CO1: Develop the essential personal, organisational, management, theoretical and research skills to become independent researchers.
CO2: Demonstrate a degree of analysis and a degree of originality in advanced investigations.
CO3: Develop understanding of research philosophies, design and terminology as well as personal transferable skills.
CO4: Describe a process that has previously been unexplained, difficult or poorly/ partially understood and to conduct an active, systematic process of inquiry.
CO5: To prepare professional documentation of research work carried out.

Course Objectives:

The major course objectives are:

1. To introduce the students to various sub fields in Geotechnical / Environmental Geotechnical Engineering.
2. To expose them to current developments / research activities in the above areas.
3. To train the students to gather in depth information on any specific area / topic.
4. To train the students to make proper technical documentation on any selected topic.
5. To train the students to give effective technical presentations.

The subject of study should be based on the latest works ongoing in the field of Geotechnical and or GeoEnvironmental engineering. The students should select a topic of his/her interest and in consultation with his/her guide should carry out in depth study / research / experimentation etc. as appropriate for the topic selected. At the end of the academic session, the students will document their work and make a presentation before the designated "Evaluation Committee". This also applies to those who take this up as an internship in an industry/ company/ an institute as well.

For students opting for internship course outcomes will depend on the actual work performed during the internship.

CE6421E DESIGN OF ENGINEERED LANDFILLS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand concepts and principles of subsurface contamination.
CO2: Plan and design landfills of municipal solid waste.
CO3: Acquire knowledge of control and remediation of contaminated sites.
CO4: Develop a plan for reclaiming combustible sites.

Site Selection and Geo-Environmental Investigations
Environmental-geotechnical application, introduction − basic considerations of ground improvement systems − load environmental factor design criteria − load factor design criteria and approaches, environmental load factor design criteria − soil structure − structural soil interaction, soil foundation structure interactions − load factor of safety and allowable condition − bearing capacity of granular soil, friction forces and angle between two materials.

Landfill Liners
Liners, different types, properties of liners, clay liners, geo-synthetic liners, composite liners, design aspects.

Landfill Gases
Reclaiming potentially combustible sites − introduction to combustion process, combustion tests, use of combustion potential tests − land fill gases, principal gases and their properties − gas monitoring, data assessment and remedial solutions.

Post-Closure of Engineered Landfills
Establishment of new landscapes, Introduction, plant requirements, soil cover, soil fertility, site preparation, establishing grass cover − establishing trees and shrubs, maintenance.

References:

1. H. Y. Fang, “Introduction to Environmental Geotechenology” CRC press Newyork, 1997
2. T. Cairmey., “Contominated land problems and solutions”, Blackie Academic & Professional, NewYork, 1993.
3. R.W. Sarsby, “Environmental Geotechnics”, ICE publishing, 2013.
4. I. S. Oweis, and R. P. Khera, “Geotechnology of Waste Management” 2ndEdition, PSW Publishing Company, USA, 1998.
5. X. Qian, R. M. Koerner, D. H. Gray, “Geotechnical Aspects of Landfill Design and Construction” Pearson; 1st edition, 2002.
6. H. D. Sharma, K. Reddy, “Geoenvironmental Engineering Site Remediation, Waste Containment, and Emerging Waste Management Technologies”, John Wiley & Sons Inc., 1st edition, 2004.

CE6422E FOUNDATION ENGINEERING FOR DIFFICULT AND CONTAMINATED GROUNDS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Determination of bearing capacity and settlement of shallow foundations in layered soils using the field and laboratory test data.
CO2: Design of various deep foundations in contaminated soils.
CO3: Understand the design features of caissons and special foundations in soils with chemically aggressive environment.
CO4: Analyze the various case studies reported in literature.

Clay Mineralogy
Nature of Soils-Clay Mineral Structure-Diffused double layer Theory-Cation Exchange

Mechanisms of soil-water interaction
Force of attraction and repulsion; Soil-water-contaminant interaction; Theories of ion exchange; Influence of organic and inorganic chemical interaction

Swelling Characteristics
Swelling-Factors effecting Swelling-Swelling Potential-Swell Pressure-Methods of Determination-Factors effecting Swelling potential and swell pressure-Heave-Factors effecting Heave-Methods of determination of heave.

Foundation Practices in Expansive Clays
Sand Cushion-Belled Piers-CNS layer technique-Under Reamed Pile Foundation-Construction Techniques-Design Specifications-Load-carrying capacity in compressive and uplift of single and multi under reamed piles -Granular Pile Anchors.

Improvement Techniques
Lime Soil columns and Lime Slurry Pressure Injection-Stabilization with Admixtures-Propounding-Vertical and Horizontal Moisture barriers.

Soil Modification by Environmental Changes
Mitigating acid and alkali contamination in soils by use of additives; effect of lime on sulphate bearing clays; Effect of phosphoric acid, fly ash, hydroxy-aluminium and chemicals in clay stabilization.

Well Foundation
Design and construction. Bearing capacity, settlement and lateral resistance. Tilts and shifts,

Discussion
Discussion of various case studies reported in literature.

References:

1. James K. Mitchell and Kenichi Soga. “Fundamentals of Soil Behavior” John Wiley & Sons, Inc. New York, 3rd Edition, 2014
2. Joseph E. Bowles, “Foundation Analysis and Design”, McGraw Hill Companies, Inc. New York, 1996.
3. Laxmi N Reddy, Hilary N Inyang. ‘Geo-Environmental Engineering – Principles and Foundations’. Published by CRC Press, 1st Edition, 2000.
4. M.J Tomlinson, “Foundation Design and construction”, Pitman Publishing Limited, London, 1975
5. R W Sarsby. ‘Environmental Geotechnics’ Thomas Telford, 2000.
6. Swami Saran, “Analysis and Design of Substructures”, oxford & IBH publishing Co Pvt. Ltd, New Delhi, 1996

CE6423E WASTE WATER ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze for the various characteristics of wastewater important in treatment and decide on the method of treatment to be adopted
CO2: Design the various units of the conventional wastewater treatment system.
CO3: Design wastewater treatment systems for specific requirements.

Waste water treatment-objectives, methods-An Overview-Effluent and sludge disposal and reuse. Waste water characteristics- (Physical, Chemical and biological)-waste water composition-variation in concentration of waste - Water loading Data-Flow Rates-Analysis of wastewater flow rate Data.

Waste water Treatment-methods and design classification and application of waste water treatment methods, elements of plant analysis and design, other important considerations. Fundamentals of process analysis-Reactions and reaction kinetics.

Physical Unit Operations-Screening flow measurement, Grit removal, Flow equalization, mixing, plain sedimentation, flocculation, (sedimentation aided with coagulation), Floation, Granular medium filtration, chemical Unit Processes-Chemical precipitation, Gas transfer, absorption, disinfection-by various methods-odour control. Design facilities for physical chemical treatment of wastewater.

Biological waste water treatment-Microbial metabolism, Kinetics of biological growth, suspended growth biological treatment, attached growth biological treatment, Design facilities for the biological treatment of waste water.

References:

1. Metcalf & Eddy Inc., George Tchobanoglous, H. David Stensel, Ryujiro Tsuchihashi, Franklin L.
2. Burton, Wastewater Engineering: Treatment and Resource Recovery, New York, USA:
3. McGraw-Hill Education, 2014
4. Karia, G. L., and R. A. Christian. Wastewater treatment: Concepts and design approach, New
5. Delhi: PHI Learning Pvt. Ltd., 2013
6. The Central Public Health and Environmental Engineering Organisation (CPHEEO), Manual on
7. Sewerage and Sewage Treatment, *Ministry of Urban Development, Government of India*, 1993.
8. Nath, Kaushik, Membrane separation processes, New Delhi: PHI Learning Pvt. Ltd., 2017.

CE6424E ANALYSIS AND DESIGN OF EARTH RETAINING STRUCTURES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total lecture sessions: 39

Course Outcomes:

CO1: Familiar with graphical and analytical methods to determine the lateral earth pressure under various influencing factors.
CO2: Analyse all types of earth retaining structures for the stability against sliding, overturning and bearing failure.
CO3: Analyse the stability of braced excavations and develop the pressure distribution diagrams along the various braced cuts in different types of soils.
CO4: Determine the load carrying capacity and lateral deflection along the various types of laterally loaded piles.

Earth pressure- Types, at rest, active, passive, Rankine's theory; Backfill features, Soil type, surface inclination, loads on surface, soil layers, water level Coulomb's theory, Effect due to wall friction and wall inclination, Graphical methods, Earthquake effects.

Rigid retaining structures- Types, Empirical methods, stability analysis Flexible Retaining structures, Types, Material Cantilever sheet piles, Anchored bulkheads, free earth method, fixed earth method, moment reduction factors, anchorages, Cofferdams, diaphragm walls.

Braced excavation- Types, Construction methods, Pressure distribution in sands and clays, stability, bottom heave, seepage, ground deformation Reinforced soil walls, Elements, construction methods, External stability, and internal stability

Laterally loaded piles- short and long piles, free head and fixed head piles, lateral load capacity of single piles, Lateral deflection, Elastic analysis, Group effect, Lateral load test, Codal provision, underground structures in soils, pipes, conduits, Trench less technology.

References:

1. Gregory P. Tschebotarioff, "Foundations, Retaining and Earth Structures", Mc Graw-Hill Kogakusha, 1978.
2. Shamsher Prakash, Gopal & Ranjan, Swami Saran, "Analysis and design of foundations and retaining structures", Sarita Prakashan, New Delhi, 1979.
3. Chris R.I. Clayton, Rick I. Woods, Andrew Bond, Jarbas Milititsky, "Earth Pressure and Earth-Retaining Structures", CRC Press; 3rd edition, 2014.
4. Zhang, Wengang, and Hanlong Liu, "Design of Deep Braced Excavation and Earth Retaining Systems Under Complex Built Environment: Theories and Case Studies", Springer Nature, 2021.
5. Cui ZD, Zhang ZL, Yuan L, Zhan ZX, Zhang WK., "Design of underground structures", Springer Singapore; 2020.

CE6425E LANDSLIDE MITIGATION METHODS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the existing natural and manmade problems in landslide perspective.
CO2: Bringing in new projects without landslide occurrence.
CO3: Evolve and execute Landslide Mitigation Strategy for a place or region.

Natural and manmade disasters, Description of development by disasters, Factors affecting disasters, Characteristics of particular hazards and disasters, Landslide classification, types, distribution and size, Landslide triggered by volcanic activity, Tsunami, Earthquake seismic wave and ground motion, Spatial pattern of earthquake triggered landslide, Preparation of Geological maps for fault, unconformity, fold.

Rapid rock slope failures, Landslide in quick clay, Landslide and geologic environments, Landslide Deformation Monitoring using InSAR, Climate change in landslide occurrence, Slow rock slope deformation, Rock fall: Specific case of landslide, Landslide Risk assessment and management, Landslide Mitigation measures, Technique's for reducing landslide hazards.

Preliminary and geological investigation on landslides, Geotechnical investigation on landslides, Landslide Remediation Practices, Mitigations methods for various types of landslide hazard, Varunawat Landslide, Malpa Landslide, Uttarakhand - Case Study, Hong Kong Landslide - case study, Landslide case study in Idukki, Wayanad Kerala, Landslide in Dams, Landslide documentation.

Landslide inventory, Landslide Monitoring, Landslide prediction, Landslide Zonation, Landslide susceptibility map, Joshimath crisis, Application GPR, Siesmic studies in Landslides, Dump Slope Stability, BioEngineering as an Effective and Eco-friendly Soil Slope, Landslide field visit around Wayanad, Idukki district.

References:

1. Douglas Stead, John J Clague Landslides Types, Mechanism and modeling, Cambridge University Press, 2012.
2. T Glade, M Anderson, M. J. Crozier, Landslide Hazard and Risk, Wiley Publication, 2005.
3. Mowen Xie, Landslide Hazard Assessment Using GIS, Alpha Science International Ltd, 2014.
4. E.M Lee, D.K.C Jones, Landslide Risk Assessment, Thomas Telford Ltd, 2004.
5. Quido Zaruba, Vojtech Mencl, Landslide and their control, Elsevier, 1969.
6. S.P. Pradhan, V.Vishal, T.N.Singh, Landslide, Theory, Practice, Modelling, Springer, 2018.

CE6426E GROUND WATER CONTAMINATION

Pre-requisites**:** NIL

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Graduate will demonstrate knowledge on different types of aquifers
CO2: Graduate will be able to solve groundwater flow equations
CO3: Graduate will able to model and solve groundwater contaminant transport problems
CO4: Graduate will be able demonstrate knowledge on the analysis and interpretation of ground water quality parameters

Geology of Groundwater – occurrence: aquifers, Aquifers characteristics: Homogeneity and Isotropy. Types of aquifers, perched, unconfined, semi-confined and confined aquifers. Storage co-efficient of aquifer, specific retention, Specific yield, method of determination of specific yield. Force potential and hydraulic head. Darcy's law: Principal of groundwater flow: Properties of water in relation to flow, Head distribution, Hydraulic Head. Equation of ground water flow, solution of flow equation. Gradient of Hydraulic Head in aquifer.

Groundwater flow modeling; analysis and model refinement, prediction for different scenarios using calibrated model. Uncertainties in model prediction. Groundwater contamination. Mass Transport equation, advection, dispersion. Groundwater Contamination modeling: Introduction, Principles and concepts. Classification of groundwater, contamination models. Guidelines for groundwater contamination models. Limitations and source of error in groundwater contamination models. Modelling as a tool for groundwater management. Use of various modeling packages-MODFLOW.

Groundwater quality monitoring: Planning groundwater monitoring program. Installing groundwater monitoring wells. Withdrawing water samples from monitoring wells. Chemical analysis of natural water. Interpretation of physical and chemical data of water; Methods of illustration pictorial stiff diagram, horizontal and vertical scale diagram. Plotting of piper diagram, Willcox, Gibbs and Durov plots. Outline of global hydrochemical software wateq, PHREEQ, AQUACHEM, MINTEQAZ. Sources of groundwater contamination- septic tanks and pools, landfills, chemical spills and leaking underground tanks, mining and other source of contamination.

References:

1. Fetter, Charles Willard. *Applied hydrogeology*. Waveland Press, 2018.
2. Todd, David Keith, and Larry W. Mays. *Groundwater hydrology*. John Wiley & Sons, 2004.
3. Karanth, K. R. *Ground water assessment, development, and management*. Tata McGraw-Hill Education, 1987.
4. Mazor, Emanuel. *Chemical and isotopic groundwater hydrology*. Vol. 98. CRC press, 2003.

CE6427E EARTHQUAKE ASPECTS OF GEOTECHNICAL ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total lecture sessions: 39

Course Outcomes:

CO1: The sources and reasons of earthquakes as well as various seismic hazards
CO2: Strong ground motion parameters to characterise the earthquake motion and ground response analyses
CO3: To develop the local site design spectra and practise the GRA software's

Earthquake seismology
Causes of earthquakes - Internal structures of earth, continental drifts and plate tectonics, Earthquake Fault sources, elastic rebound theory, other sources of seismic activity, Geometric notation, location of earthquakes, and quantification of earthquakes – Intensity and magnitudes.

Earthquake ground motion
Strong motion measurement, seismograph, data acquisition, strong motion records, ground motion characteristics and parameters, other measures of ground motion and estimation of ground motion parameters, attenuation relations, evidences of evaluation of earthquake sources, deterministic and probabilistic seismic hazard analysis.

Ground response analysis
1D and 2D GRA, linear approaches, equivalent linear approximation of non-linear approaches, computer codes Proshake, NERA, PLAXIS, Deepsoil, Geostudio and others. Soil-structure interaction and Sassi software.

Local site effects and design ground motions
Effects of local site conditions on ground motion, design earthquakes and design spectra, site specific and code-based development of design parameters, development of ground motion time histories.

References:

1. Alexander Major, "Dynamics in Soil Engineering", Akademiai,1980.
2. Braja M Das, "Principles of soil dynamics", Cengage Engineering, 2014.
3. Bharat Bhushan Prasad, "Fundamentals of soil dynamics and Earthquake engineering", prentice hall India learning Pvt. Ltd., 2009.
4. Kramer S L, "Geotechnical Earthquake Engineering", Pearson education India, prentice hall Int. series, 2003
5. R W Day, "Geotechnical Earthquake Engineering handbook", McGraw-Hill publishers, 2001
6. Shamsher Prakash, "Soil Dynamics", McGraw-Hill, 1981.
7. Swami Saran, "Analysis and design of foundations and retaining structures subjected to seismic loads", Wiley India Pvt Ltd, 2020.

CE6428E BIOREMEDIATION TECHNOLOGIES FOR CONTAMINATED SOILS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To examine the sources, causes and effects of soil contamination.
CO2: To distinguish the suitable bioremediation mechanism based on contaminant types.
CO3: To implement appropriate bioremediation technique considering the soil site conditions.

Soil Contamination
Introduction - Basic concepts - Sources of soil contaminants – Natural and man-made – Inorganic and Organic pollutants - Effects of soil contamination - Types of contaminants - Role of physical and chemical properties of soil in contamination; Factors effecting retention and transport of contaminants in soil - Sampling of contaminated soil - Site investigation and monitoring parameters.

Bioremediation mechanism
Bioremediation - Microbial systems of bioremediation - Factors influencing bioremediation (environmental, physical and chemical factors) - Genetic responses of microorganisms to thepresence of pollutants - Application of microorganisms for soil treatment - Microbial transformation reactions (aerobic and anaerobic bio-transformations) - Microbial detoxification of specialty chemicals (insecticides, heavy metals, etc).

Bioremediation methods
Methods of bioremediation – In-situ (Intrinsic and Enhanced) – Bio-venting, bioslurping, Biosparging, bioaugmentation, biostimulation, phytoremediation – Ex-situ – slurry phase, solid phase, land farming, soil biopiles, composting – Bioreactors – Slurry reactor, aqueous reactor – Applicability to contaminants - Advantages – Disadvantages – Case histories – Economic and regulatory considerations.

References:

1. Baker, K.H., and Herson, D.S., Bioremediation, McGraw-Hill Publishing Company, New York, 1994.
2. Cairns, John E. Biological monitoring in water pollution. Elsevier, 2017.
3. Eweis, J.B., Ergas, S.J., Chang D.P.Y., and Schroeder E.D., Bioremediation Principles, McGraw-Hill Publishing Company, Singapore, 1998
4. Fingerman, Milton, ed. Bioremediation of aquatic and terrestrial ecosystems. CRC Press, 2016.
5. Prashanthi, Marimuthu., eds. Bioremediation and Sustainable Technologies for Cleaner Environment. Springer,2017.
6. Reddy, K.R., and Cameselle, C. Editors, Electrochemical Remediation Technologies for Polluted Soils, Sediments and Groundwater, John Wiley & Sons, Inc., Hoboken, New Jersey, 2009, 760p. (ISBN: 0-470-38343-7).
7. Reddy, K.R., and Adams, J.A., Sustainable Remediation of Contaminated Sites, Momentum Press, New York, December 2014.
8. Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004, 992p.
9. Walker, Colin Harold, R. M. Sibly, and David B. Peakall. Principles of ecotoxicology. CRC press, 2014.

CE6429E ENGINEERING ROCK MECHANICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To understand laboratory and field testing for rock characterization.
CO2: To design and suggest tunnel support system.
CO3: To model complex rock engineering problem based of strength criteria.
CO4: To assess and design foundations on slopes and rocks.

Rock and Rock Mass
Introduction, rock and rock mass formation, rock forming minerals, joints, folds, faults, thrusts – physical and mechanical properties of rock material, tensile, compression and shear tests − rock mass classification, rock quality designation (RQD), rock structure rating (RSR), rock mass rating (RMR), Norwegian geotechnical classification (Q-system) − geological structures, joints, folds, faults, thrust.

Strength criteria for Rocks and Field Testing
Mode of failure of rock, strength, modulus and stress-strain response of rocks − Failure criteria for rock and rock masses; Mohr-Coulomb yield criterion, Hoek-Brown criterion,Drucker-Prager criterion, effect of size on strength – Rock anisotropy. In-situ stresses − Deformability tests in rock mass, field shear test, hydro fracturing method to determine in-situ stresses − Estimation of stresses in rock mass − field permeability test.

Tunneling and Design of Support
Convergence confinement analysis − rock loads from empirical methods − design of supports, empirical approaches − drilling and blasting for underground and open excavation − stages of excavation − methods to improve rock mass responses − rock bolt and grouting.

Slopes and Foundations on Rocks
Stability of rock slopes − Modes of failure, plane failure, wedge failure, circular failure, toppling failure − foundation on rocks − estimation of bearing capacity − stress distribution in rocks, settlement in rocks, pile foundation in rocks, rock socketing.

References:

1. Goodman, R. E., Introduction to Rock Mechanics, John Wiley & Sons, 1988.
2. Ramamurthy, T., Engineering in Rocks for Slopes, Foundation and Tunnels, Prentice Hall India Pvt. Ltd, 2014.
3. Jaegar, J.C., Cook, N.G.W., Zimmerman, R., Fundamentals of Rock Mechanics, Fourth Edition, BlackwellPublishing, 2007.
4. Obert, L., Duvall, W. I. Rock mechanics and the design of structures in rock, John Wiley & Sons, Inc.
5. Hudson, J.A., Harrison, J.P. Engineering Rock Mechanics: An Introduction to the Principles, 2005.
6. Singh, B., Goel, R. K., Tunnelling in weak rocks, Elsevier geo-engineering book series, 2006.
7. Jaegar, C., Rock mechanics and engineering, Second Edition, Cambridge University Press, 2009.

CE6430E PAVEMENT GEOTECHNICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To classify the suitability of subgrade soil by evaluating their geotechnical properties.
CO2: To characterize suitable paving geomaterial under varying compaction techniques.
CO3: To implement appropriate stabilization technique considering site specific drainage system.

Stresses in Subgrade Soils
Functions - Importance of subgrade soil properties - Subgrade soil classification for highway engineering purpose - Evaluation of properties - Compaction system - Theories and elastic and plastic behaviour of soils - Methods of reducing settlement - Estimation of rate of settlement due to consolidation - Foundation of road embankment - Static and cyclic triaxial test on subgrade soils - Resilient deformation, resilient strain, resilient modulus - CBR test - Effect of lateral confinement on CBR and E value of subgrade soil - static and cyclic plate bearing test - Estimation of modulus of subgrade reaction - Correction for plate size, correction for worst moisture contents, etc.

Material Characterization
Functions - Geotechnical properties of geomaterials (soils, rocks, soil and rock mixtures, and recycled and alternative materials) for rational and sustainable design and construction - Behavior of compacted geomaterials - behavior of stabilized geomaterials (mixtures of soils with - cement, lime, fly ash, polymers and other kind of geomaterials), compaction technology - compaction management - maintenance technology.

Ground Improvement Techniques and Highway Drainage
Different methods of soil stabilization - Use of geosynthetics and fibres in the highway subgrade and highway construction - Other ground improvement techniques (sand drains, band drains, stone columns, gabions, etc.) in highway construction, reinforced earth. General principles – Significance - Different drainage systems (surface/ subsurface) - Drainage systems in the hilly areas, pumping systems, water body, holding ponds – Frost action, frost susceptible soils, depth of frost penetration, loss of strength during frost melting - Design of drainage systems.

References:

1. Sharma, S.K., 2014. Principles, Practice and Design of Highway Engineering (Including Airport Engineering); S. Chand and Company Pvt. Ltd., New Delhi.
2. Srinivasakumar, R., 2015. Pavement Design; University Press, Hyderabad (First Published 2013; Preprinted in 2015).
3. Srinivasakumar, R., 2013. A Text Book of Highway Engineering; University Press, Hyderaba
4. Kadiyali, L.R.and Lall, N.B., 2005. Principles and Practice of Highway Engineering; Khanna Publishers,Delhi
5. Yang H. Huang, 2008. Pavement Analysis and Design; Pearson Prentice Hall, USA
6. Das, Animesh, 2017. Analysis of Pevement Structures; CRC Group, Taylor and Francis Group
7. Khanna, S.K., Justo, C.E.G. and Veeraraghavan, A., 2015. Highway Engineering; Nem Chand and Bros.,Roorkee (Revised 10th Edition).
8. Saxena, Subhash Chandra, 2014. A Text Book of Highway and Traffic Engineering; CBS Publishers andDistributors, New Delhi
9. Venkatramaiah, C., 2016. Transportation Engineering (Vol.-I)- Highway Engineering.; University Press,Hyderabad.
10. Rao, G.V., 2000. Principles of Transportation and Highway Engineering; Tata Mc-Graw Hill PublishingHouse Pvt. Ltd., New Delhi.

CE6431E UNSATURATED SOIL MECHANICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To differentiate the behaviour of unsaturated soil from saturated soil.
CO2: To relate the stress state variables of unsaturated soil with that of saturated soil.
CO3: To analyse the hydraulic conductivity of unsaturated soil under air and liquid diffusion.
CO4: To determine the suction parameters of unsaturated soil by various means.

Introduction and Physics in Unsaturated Soil
Definition – Interdisciplinary nature of unsaturated soil – Soil classification – Nature and practice – Stress profiles, stress state variables - Material variables – Constitutive law – Suction potential of soil water - Physical properties of Air and water – Partial pressure and relative humidity - Density of moist air – Surface Tension – Cavitations of water - Solubility of Air in water – Air–water solid interface – vapor pressure lowering – Soil water characteristic-curve.

Stress state variables and shear strength
Effective-stress – Stress between two spherical particles – Hysteresis in SWCC – Stress parameter, stress tensor – Stress control by Axis Translation – Analytical representation of stress – Volume change characteristics - Extended Mohr–Coulomb criterion – Shear strength parameters – Interpretation of Direct shear test results and triaxial test results – Unified representation of failure envelope – Influence of suction in earth pressure distribution.

Steady and Transient Flow Analysis
Driving mechanism – Permeability and Hydraulic conductivity – Capillary barriers – Steady infiltration and evaporation – Vapor flow – Air diffusion in water - Principles for pore liquid flow – Rate of infiltration, Transient suction and moisture profiles - Principles for Pore Gas flow – Barometric pumping Analysis.

Suction Measurements
Measurement of total suction – psychrometers – Filter paper measurement of matric suction – High Air Entry disks – Direct measurements – Tensiometers – Air translation technique – Indirect measurements – Thermal conductivity sensors –Measurement of osmotic suction – Squeezing technique.

References:

1. Azad Koliji (2008). Mechanical Behavior of Unsaturated Aggregated Soils
2. D. G. Fredlund, H. Rahardjo, M. D. Fredlund (2012). Unsaturated Soil Mechanics in Engineering Practice,John Wiley & Sons, Inc
3. G.E. Blight and E.C. Leong (1997). Mechanics of Residual Soils, CRC Press Taylor & Francis Group.
4. Jhon, D. and Miller, D. J. (1992). Expansive soils-Problems and practice in foundation and pavement Engineering, Jhon Wiley & Sons, Inc
5. Kasmalkar, J.B. (1997). Geotechnical Engineering, Pune Vidyarthi Graha Prakashan- 1786, Pune-411030.
6. Ning Lu and William, J. Likes, Unsaturated Soil Mechanics, John Wiley &sons, INC. New Jersey, 2004
7. Ng Charles, W.W., Menzies Bruce, Advanced unsaturated Soil Mechanism and Engineering, Taylor & FrancisGroup, 2007.
8. Ning Lu, Laureano R. Hoyes and Lakshmi Reddi, Advances in unsaturated soil, seepage and EnvironmentalGeotechnics, ASCE., Geotechnical special publication No.148

CE6432E CONSTITUTIVE MODELLING FOR SOILS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To analyse stress and strain states in a soil mass.
CO2: To apply appropriate constitutive model to simulate behaviour of soil.
CO3: To perform numerical modelling of ground engineering problems using geomechanics concepts.

Elasticity and Plasticity
Introduction - deformation and strain, strain compatibility, forces and tractions - Concept of stress, principal stresses and strains, invariants, Mohr circles, effective stress principles, equilibrium - Determination of displacements, conditions of compatibility, principle of superposition - Role of constitutive modelling - Importance of laboratory testing with relation to constitutive modelling - Elasticity - linear, quasilinear, anisotropic - Winkler model, elastic continuum models, two-parameter elastic models - Plasticity basics - yield criteria - Plastic potential, hardening/softening.

Elasto-plasticity models
Elasto-Plastic Behavior of Material, Elasto-Plastic Formulations, Material Yield Criteria- von Mises, Tresca, Mohr-coulomb, Ducker-Pager, Isotropic and Kinematic Hardening, Normality Principle, Plastic Flow Rule - Associated flow rules, non-associated flow rules - Plastic Potential, Elasto-Plastic Stress-Strain Relations, Prandtl-Rauss Equations, Levy-Mises Relations, Hardening Modulus, Generalized Elasto-Plastic Stress-Strain Relations.

Critical State Soil Mechanics
Critical state soil mechanics - critical state concept, cam-clay models - Simulation of single element test using cam-clay – Cam-clay models in consolidation, drained and undrained triaxial test - Critical state for normally consolidated and over consolidated soil - Significance of Roscoe and Hvorslev state boundary surface - Stress-dilatancy theory - Work hardening plasticity theory - formulation and implementation - Applications of elasto-plastic models - Hypoelasticity-plasticity - Disturbed state concept.

References:

1. Das, B. M., Advanced Soil Mechanics, Taylor and Francis, 2nd Edition, 1997
2. Parry, R. H. G., Mohr Circles, Stress Paths and Geotechnics, CRC Press, 2004.
3. Budhu, M., Soil Mechanics., Soil Mechanics and Foundations, 3rd Edition, Wiley 2010
4. Holtz, R. D., and Kovacs, W. D., An Introduction of Geotechnical Engineering, Prentice Hall, 1981.
5. Wood, D.M., Soil Behavior and Critical State Soil Mechanics, Cambridge University Press, 1990.
6. Schofield, A. and Wroth, P., Critical State Soil Mechanics, McGrawhill, 1968.
7. Atkinson, J.H. and Bransby, P.L, The Mechanics of Soils: An introduction to critical soil mechanics, University Series in Civil Engineering, I A Books, 2013.
8. Atkinson J.H, An introduction to the Mechanics of soils and Foundation, McGraw- Hill Co., 1993.
9. Potts, D.M. and Zdravkovic, L., Finite Element Analysis in Geotechnical Engineering: Theory, Thomas Telford, USA, 1999.
10. Yu, M-H and Li J-C., Computational Plasticity, Zhejiang University Press, Springer, 2012.

CE6433E EARTH AND ROCKFILL DAMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	0	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Select a suitable site, materials and equipment for construction of earth/rockfill dams.
CO2: Analyze seepage through a given earth/rockfill dam section and select effective seepage control measures for the prevailing site conditions.
CO3: Design earth and rock fill dams, get familiarity with slope stability calculations, and prevention techniques for slope failures.

Earth and Rock fill Dams
General features, Selection of site; Merits and demerits of the earth and rock fill dams, Classification of earth dams, Materials of construction and requirements, Causes of failure, Safe design criteria. Instrumentation in earth dams: Pore pressure measurements, Settlement gauges, Inclinometers, Stress measurements, Seismic measurements.

Failures, Damages and Protection of Earth Dams
Nature and importanceof failure, Piping through embankment and foundations, Methods of seepage control through embankments and foundations, Design Criteria for filters, Treatment of upstream and downstream of slopes, Drainage control, Filter design.

Slope Stability Analysis
Types of Failure: Failure surfaces – Planar surfaces, Circular surfaces, Non-circular surfaces, Limit equilibrium methods, Total stress analysis versus effective Stress analysis, Use of Bishop's pore pressure parameters, Short term and Long-term stability in slopes. Taylor Charts, Method of Slices, Effect of Tension Cracks, Vertical Cuts. Bishop's Analysis, Bishop and Morgenstern Analysis, Non-circular Failure Surfaces: Morgenstern and Price Analysis, Janbu Analysis, Spencer Analysis, Sliding Block Analysis, Seismic stability, Stabilization of slopes: Drainage measures, Soil reinforcement (geosynthetics/soil nailing/micro piles etc), soil treatment (cement/lime/thermal treatment), surface protection (vegetation/erosion control mats/shotcrete).

Rock fill Dams
Requirements of compacted rock fill, Shear strength of rock fill, Rock fill mixtures, Rock fill embankments, Earth-core Rock fill dams, Stability, Upstream & Downstream slopes. Design of dam section, concrete face and earth core, Nature of failures and damages, case studies.

References:

1. Christian, K. Earth & Rock fill Dams – Principles of Design and Construction, CRC Press, 1997.
2. Sowers, G.F. – Earth and Rock fill Dam Engineering, Asia Publishing House, 1962.
3. Bharat Singh and Sharma, H. D. – Earth and Rock fill Dams, 1999
4. Abramson, L. W., Lee, T. S. and Sharma, S. – Slope Stability and Stabilisation methods – John Wiley & sons. (2002)
5. Sherard, Woodward, Gizienski and Clevenger. Earth and Earth-Rock Dams. John Wiley &. Sons. 1963.
6. US Army Corp of Engineers, Earth and Rock-fill Dams, General Design and construction Considerations, University Press of the Pacific (2004)
7. Sherard, et.al., "EARTH AND ROCK DAMS", john wiley inc..1963.
8. H. D. Sharma, "Embankment dams", Oxford and IBH Publishing Co..1991.
9. Bharath Singh and R. S. Varshney, "engineering for embankment dams" A. A. Balekema publications, 1995

CE6434E FORENSIC GEOTECHNICAL ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	0	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand and investigate soil-interaction related failures of engineered facilities or structures.
CO2: Analyze failures connected with geotechnical and geological origin to improve professional practice, codes of analysis and design as well as practice
CO3: Understand and implement the legal aspects in geotechnical engineering

Introduction
Historical failures of geotechnical structures (finite and infinite slopes, high embankments such as earthen dams, tunnels, excavations, foundations-shallow and deep, retaining structures etc.), characterization of failures, Inadequateness of Limit state design, principles and advantages of Mobilize able strength design. Numerical problems.

Technical Forensic Investigation
Collection of data, problem characterization, development of failure hypotheses, a realistic back-analysis, field observations and performance monitoring, modelling of failure hypothesis and quality control of formal and technical aspects of the work. Numerical Problems.

Guidelines for Forensic Investigation of Geotechnical Cases
Scope of the work, types of distress, diagnostic tests: field and laboratory tests, analysis, legal issues such as facts, interpretations, opinions, negligence.

Technical issues related to geotechnical failures
Primary shortcomings causing failures, shortcomings in design, inadequate site investigations, unforeseen occurrences and phenomena, shortcomings in construction; recommendations to limitfuture occurrence of failures.

Case Histories
Construction of historic monuments, destruction due to environmental changes and survival of monuments among them, such as leaning tower of Pisa, Egyptian pyramids, tall structural foundations in Mexico City, pre historic caves in India etc., Consideration of geotechnical aspects such as settlement, shear strength, permeability, slope stability, etc., in construction of survived historic monuments as well as for the structures which have collapsed due to the new adjacent constructions or disturbances due to human activities etc.,. Numerical problems.

Geotechnical Engineering and Legal System
Legal conflict of geotechnical failures, sanctions in the legal code of construction, geotechnical work for documentation of forensic cases; case studies of legal conflict of prominent structures (such as landslides, deep excavations, unexpected settlements of oil tanks, distress in soil walls, failure due to slow creep of hills etc.

References:

1. Forensic Geotechnical Engineering Developments in Geotechnical Engineering- V.V.S. Rao and G.L. Shivakumar Babu (eds) Springer India
2. Geomechanics of failures- A.M. Puzrin et al, Springer Science + Business Media B.V.2010.
3. Forensic Geotechnical and Foundation Engineering – Robert W Day (2011)
4. Bolton M (1991) A Guide to Soil Mechanics, Universities Press

CE6435E APPLIED ENVIRONMENTAL MICROBIOLOGY

Pre-requisites**:** NIL

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Understand the basics of living cells and their composition, and metabolism.

CO2: Detect and enumerate the different types of bacteria, viruses and fungi.

CO3: Apply the knowledge of biology for waste remediation.

CO4: Analyze the different microbial cultures using bioinformatics software at their molecular level.

Introduction; cell elements and composition Cell and its composition, cytoplasmic membrane Prokaryotic cell division Microbes and their environmental niches Historical roots of microbiology Nucleic acids and amino acids DNA structure, replication, and manipulation Protein and its structure Regulation. Bright Field Microscope, Dark Field Microscope, Phase Contrast Microscope, Fluorescence Microscope, Transmission, Electron Microscope, Scanning Electron Microscope. Microbial energetics and diversity Stoichiometry and bioenergetics Oxidation-reduction NAD, energy-rich compounds and energy storage Mathematics of microbial growth Glycolysis Respiration Citric-acid cycle Catabolic, Alternatives Phototrophy, Chemolithotrophy, anaerobic respiration (Nitrate and Sulfate reduction; Acetogenesis; Methanogenesis; Metal, Chlorate, and organic electron acceptors). Microbial metabolism and functional diversity of bacteria, Prokaryotic diversity, Classical taxonomy, Origin of life Tree of life, Major catabolic pathways, Catalysis and enzymes, Energy conservation, Sugars and polysaccharides, amino acids, nucleotides, lipids.

Microbial ecosystems Population, guilds, and communities Environments and microenvironments Microbial growth on surfaces Environmental effects on microbial growth. Environmental genomics and microbial ecology; genetic exchange Environmental genomics Microbial ecology, Horizontal and vertical gene transfer: Replication, Transformation Transduction. Investigations in environmental microbiology: sampling, detection, isolation, taxonomic and functional annotation and quantification; Pure culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation/stocking of pure cultures; Introductory bioinformatics and data analysis. Microbial sampling, Molecular biology tools: Cloning, amplification, sequencing.

Bioremediation: Principles and degradation of common pesticides, organic (hydrocarbons, oil spills) and inorganic (metals) matter, biosurfactants; Acid mine drainage, Enhanced metal recovery. Drinking water microbiology, drinking water microbiome and treatment, Microbial instability, Waterborne microbial diseases. Liquid waste management: Wastewater microbiology, Composition and strength of sewage (BOD and COD), Primary, Secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment. Solid waste microbiology and antimicrobial resistance, Landfills, Leachate, Anaerobic degradation phases, antimicrobial resistance. Built microbiology, exposomes and bioinformatics, Exposure routes, Microbes living around us, Exposomes Basic bioinformatics, and Bioinformatics tools available online.

References:

1. Bruce E. Rittmann, and Perry L. McCarty. Environmental Biotechnology: Principles and Applications. McGraw-Hill, 2001. ISBN: 0071181849. 2017.
2. Madigan, M., Bender K. S., Buckley D.H., Sattley W. M., and Stahl D.A. Brock Biology of Microorganisms. 15th ed. New York: Pearson, 2017. ISBN: 0134261925. 2001
3. Maier RM, Pepper IL and Gerba CP. (2009). Environmental Microbiology. 2nd edition, Academic Pr.
4. Singh A, Kuhad, RC & Ward OP (2009). Advances in Applied Bioremediation. Volume 17, Springer-Verlag, Berlin Hedeilberg.
5. Coyne MS. (2001). Soil Microbiology: An Exploratory Approach. Delmar Thomson Learning.
6. Lynch JM & Hobbie JE. (1988). Microorganisms in Action: Concepts & Application in Microbial Ecology. Blackwell Scientific Publication, U.K.

CE6436E ATMOSPHERIC PROCESSES AND AIR QUALITY MANAGEMENT

Pre-requisites**: NIL**

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Understanding about atmospheric dynamics and chemical processes.
CO2: Knowledge of stratospheric and tropospheric chemistry and its role on meteorology and air quality.
CO3: Knowledge of atmospheric aerosols and their role in climate change.
CO4: Knowledge of instruments used for monitoring and control of various air pollutants

Earth's Atmosphere: History and Evolution, Layers of atmosphere, Vertical temperature and pressure profile of atmosphere, General Circulation of atmosphere, atmospheric composition, atmospheric life time, scale height, atmospheric radiation and photochemistry, chemistry of stratosphere, Chapman mechanism, Chemistry of troposphere, Properties of atmospheric aerosols, size distribution function, aerosol chemical composition, Nucleation, Interaction of Aerosol with radiation.

General Meteorology: Thermodynamics of dry and moist air: atmospheric stability and dry adiabatic lapse rate, saturated adiabatic lapse rate, potential temperature. Micrometeorology: Atmospheric fluid mechanics, turbulence, surface roughness and convective boundary layer. Variation of wind height in the atmosphere, Atmospheric diffusion, Gaussian plume equations, Steady state atmospheric diffusion equations, Aerosol and Climate.

Air pollutants, classification of air pollutants, properties of gaseous and particulate matter, effects of Air pollution on plants, animals, materials, human health, Sources of Air pollution and emission inventory, Sampling and Analysis: Ambient air sampling, stack sampling, Air quality standards and Air Quality Index, Air quality monitoring - sampling and instruments, Air pollution control devices, Control of Particulate matter and gaseous air pollutants.

References:

1. F. K. Lutgnes, E. J. Tarbuck, D. G. Tasa, The Atmosphere: An Introduction to Meteorology, Pearson, 11th edition.
2. J. R. Holton, An Introduction to Dynamic Meteorology, Academic Press, 4th edition, 2004.
3. Atmospheric Chemistry and Physics, John H. Seinfeld and Spyros N. Pandis, Wiley Interscience Publication, 2006
4. K. N. Liou, An introduction to atmospheric radiation, Academic press, 2nd edition, 2002
5. T. P. DeFelice, An Introduction to Meteorological Instrumentation and Measurement, Prentice Hall, 1st edition, 1997.
6. David G. Andrews, An introduction to atmospheric physics, Cambridge University press, 2nd Edition, 2010
7. J. Houghton, Physics of Atmospheres, Cambridge University press, 3rd edition, 2002
8. W. F. Ruddiman, Earth's climate: past and future, W.H.Freeman & Co Ltd, 2nd edition.
9. Air Pollution Control Equipment H. Brauer and Y. B. G. Verma, Berlin Heidelberg, New York, latest edition

CE6437E BIOLOGICAL PROCESS DESIGN FOR WASTEWATER TREATMENT

Pre-requisites**: NIL**

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: To describe the range of conventional and advanced biological treatment processes for the treatment of bulk organics, nutrients and micro pollutants
CO2: To design the biological reactors based on biokinetics
CO3: To select appropriate processes for specific applications, and have some knowledge of practical design considerations
CO4: To execute and asses the performance of bioreactors in laboratory scale

Constituents of Wastewaters - Sources - Significant Parameter - Fundamentals of Process Kinetics, Zero Order, First Order, Second Order Reactions, Enzyme Reactions - Bio Reactors - Types, Classification, Design Principles - Design of Wastewater Treatment Systems -Primary, Secondary and Tertiary Treatments - Evaluation of Biokinetic Parameters.

Activated Sludge and its Process - Modifications, Biological Nitrification and Denitrification - Attached Growth Biological Treatment Systems -Trickling Filters - Rotating Biological Contactors – Waste Stabilization Ponds and Lagoons - Aerobic Pond, Facultative Pond, Anaerobic Ponds- Polishing Ponds, Aerated Lagoons.

Anaerobic Processes – Process Fundamentals - Standard, High Rate and Hybrid Reactors, Anaerobic Filters- Expanded /Fluidized Bed Reactors - Upflow Anaerobic Sludge Blanket Reactors - Expanded Granular Bed Reactors - Two Stage/Phase Anaerobic Reactors – Sludge Digestion, Sludge Disposal.

References

1. Benefield, L.D. and Randall C.W. Biological Processes Design for wastewaters, Prentice-Hall, Inc. Eaglewood Cliffs, 1989.
2. Grady Jr. C.P.L and Lin H.C. Biological wastewater treatment: Theory and Applications, Marcel Dekker, Inc New York, 1980.
3. Metcalf & Eddy, Inc. Wastewater Engineering, Treatment and Reuse. 3rd Edition, Tata McGraw-Hill, New Delhi, 2003.
4. Arceivala, S. J. and Asolekar, S. R., Wastewater Treatment for Pollution Control, 3rd Edition, McGraw-Hill Education (India) Pvt. Ltd., New Delhi, 2006.

CE6438E ENVIRONMENTAL CHEMISTRY AND MICROBIOLOGY

Pre-requisites**: NIL**

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Understand the basics of applied environmental chemistry

CO2: Analyze the wastewater parameters by colourimetric and instrumental methods.

CO3: Identify and enumerate the microbes present in the water, air and soil environment.

CO4: Demonstrate the suitable culture methods for bacteria, viruses and fungi.

Introduction: Importance of Environmental Chemistry as applied to Environmental Engineering, types of reactions, acid/base, precipitation, reversible and irreversible reactions. Concepts of equivalent mass in relation to acids, bases, salts and oxidizing and reducing agents. Chemical equilibrium – redox and ionic equations. Modes of expression for molarity, normality, molality, ppm, etc. Electrolytes, types of conductance. Method of determining the specific conductance of water/wastewater and its correlation with dissolved salts. Electrode, types of electrodes, electrode potential, etc. Measurement of emf and pH (using slam electrode) and their applications in Environmental Engineering, electrode potential, etc. Buffers and buffer index.

Colloidal Chemistry: Colloids – Types, properties and environmental significance. Colloidal dispersions in water, air and emulsions. Theory of colloids – double layer theory, zeta potential, destabilization of colloids (Schulze – Hardy rule) as applied to coagulation process. Absorption and adsorption process, adsorption isotherms. Water and wastewater analysis: Acidity, alkalinity, and hardness. Colour, Fluoridation and Defluoridation – significance and determination. Chlorination – residual chlorine and breakpoint chlorination. Biochemical oxygen demand (BOD) – dissolved oxygen (DO determination and environmental significance). Instrumental methods of analysis: Lambert's and Beer's law. Colourimetry – estimation of iron and manganese in water samples. Methods of determining the trace organic and inorganic contaminants using emission and absorption techniques and ICP.

Microbiology: Microscopic flora and fauna and their importance in environmental protection, microorganisms of importance in air, water and soil environment. Microbial enumeration techniques. Microbial Metabolism: Metabolic activity, anabolism and catabolism, influencing parameters, microbial metabolism of toxic chemicals and trace organics, bioconcentration and biomagnification. Bacteria: Morphology, typical bacterial growth curve, Nutritional requirements, Growth Models specific growth rate and generation time, numerical problems. Fungi: Classification, characteristics and environmental applications. Virus: Types, characteristics and enumeration methods. Enzymes: Classification, the kinetics of enzymatic reactions, Michaelis - Menton equation, factors influencing enzyme reactions, problems.

References:

1. Sawyer C.N. and McCarty, P.L., (2003), "Chemistry for Environmental Engineering and Science", 5th Edition, TATA McGraw Hill Publishing Co. Ltd., New Delhi.
2. McKinney R.E. "Microbiology for Sanitary Engineers", McGraw Hill.
3. Gaudy and Gaudy (1980), "Microbiology for Environmental Scientists and Engineers", McGraw Hill.
4. Chakraborthy P, (2005), "Textbook of Microbiology", 2 nd Edition, New Central Book Agency Pvt. Ltd.,
5. Pelzer, Chan and Ried (1998), "Microbiology", Tata McGraw Hill Publishers

CE6439E ENVIRONMENTAL FORENSICS

Pre-requisites**: NIL**

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Graduate will demonstrate knowledge in the different environmental acts and statues pertaining to Environmental forensics cases in India.
CO2: Graduate will be able to advice on the scientific tools/techniques suitable for a particular environmental forensics investigation
CO3: Graduate will able to adopt proper sampling and testing method for Environmental forensics investigation.
CO4: Graduate will be able to lead an Environmental forensic investigation

Principles of in international environment law -liability principles-polluter pays principle, principle of preventive action-precautionary principle-principle of public trust. Environmental redress mechanism in India-Constitutional provisions, IPC provisions, tort law provisions, Environmental (Protection) Act, 1986-Water (Prevention and Control of Pollution) Act, 1974 and corresponding rules -Air (Prevention and Control of Pollution) Act, 1981 and corresponding rules -The National Green Tribunal Act, 2010 -Other environment related rules at the national and state level- Case law.

Types of environmental forensic problem- Forensic techniques used in environmental litigation-Aerial photography, Remote sensing, Underground tank corrosion models, Inventory reconciliation, Chemical finger printing, Use of stable and radioactive isotopes, dendroecology, Microbial techniques-traditional microbial forensics, DNA Fingerprinting techniques, Use of Geographic Information System (GIS), Use of contaminant transport models, source apportionment methods-Chemical mass balance(CMB) modelling, Principle component analysis (PCA), Positive matrix factorization (PMF).

History, chemistry and transport of chlorinated solvents, petroleum hydrocarbons, crude oil and refined products, Transport in groundwater. Environmental sampling and analysis for forensic applications -soil collection for chemical analysis, groundwater sampling, air sampling, analysis methods. Indian Standards for sampling and testing –Air, Water and Soil. Standard protocol for environmental forensic investigation- INTERPOL procedure for typical cases.

References:

1. Sands, Philippe, Principles of International Environment Law, 2nd ed., Cambridge, UK: Cambridge University Press, 2003.
2. Morrison, Robert D, Environmental Forensics: Principles and Applications, CRC Press, 2000.
3. Hester, R. E and R. M. Harrison (Ed.), Environmental Forensics, RSC Publishing, 2008.
4. Murphy, Brian L. and Robert Morrison (Ed.), Introduction to Environmental Forensics, Elsevier Academic Press, Burlington, USA, 2007.
5. INTERPOL, Pollution crime forensic investigation manual (Vol 1&2), Lyon: INTERPOL General Secretariat, 2014
6. Website of the Ministry of Environment, Forest and Climate Change, Government of India.

CE6440E ENVIRONMENTAL QUALITY AND MONITORING

Pre-requisites**: NIL**

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Graduate will demonstrate knowledge on the parameters that describe the quality of water, air and soil environment.
CO2: Graduate will be able to plan and undertake sampling for monitoring environmental quality
CO3: Graduate will able to interpret the results of surface and ground water quality analysis results
CO4: Graduate will be able to carry out monitoring of the ambient air quality given the instruments and interpret the results

Definition of Environment; Link between source/environment/receptor; Exposure; Health effects; Toxicology; Human health risk assessment, Defining the need for fate and transport. Chemicals of concern; relevant properties for environmental fate and transport; Definition of Equilibrium – partition constants, solubility, vapor pressure, Henry's constant, Koc, Kow etc. Equilibrium partitioning of chemicals between different phases of the environment.

Parameters for environmental quality-water/ air / soil / sediment – screening parameters, priority air pollutants – definitions of PM. Monitoring of environmental parameters – screening parameters – BOD, COD, TOC, TDS; Environmental sampling – definition and synthesis of a monitoring/sampling/analysis method. Quality Assurance and quality control (QA/QC). Methods for sampling/processing/analysis of organic and inorganic constituents in air/water/soil/sediment.

Introduction to environmental transport – BOX Models and the application to multimedia transport of pollutants. Atmospheric Dispersion – Gaussian Dispersion model. Fundamentals of mass transport – definition of intraphase and inter-phase chemical flux; interphase mass transport, diffusion coefficient and convection mass transfer coefficients.

References:

1. Howard S. Peavy,Donald R. Rowe,George Tchobanoglous. Environmental Engineering. McGraw-Hill Inc.,US
2. Janick Artiola, Ian L Pepper, Mark Brusseau, Environmental Monitoring and Characterization, 1st ed., Elsevier Academic Press, 2004
3. G. Bruce Wiersma, Environmental Monitoring ,1st ed. CRC Press, 2004.
4. Meghan Higgins (Ed.), Environmental Quality, Monitoring and Management, Callisto Reference, 2019.
5. Frank M. Dunnivant,Elliot Anders. A Basic Introduction to Pollutant Fate and Transport: An Integrated Approach with Chemistry, Modeling, Risk Assessment, and Environmental Legislation. John Wiley & Sons, Inc. 2006.

CE6312E MARINE FOUNDATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	0	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Introduce the students to the relevance of marine geotechnical engineering and study different types of marine sediments and their properties.
CO2: Study the behaviour of marine deposits under static and cyclic loading conditions.
CO3: To Know the different methods/techniques adopted for offshore soil investigations.
CO4: To understand the typical foundations for the different type of offshore structures.
CO5: To expose the students to partial design of typical offshore foundation components.

Introduction to Marine Geotechnical Engineering
Scope of marine geotechnical engineering- Marine and submarine soils- Classification of marine soils- Relative distribution of marine soils in the different marine regions- General characteristics of marine deposits in some specific locations and in the Indian subcontinent.

Sedimentological characteristics of marine soils
Structure of marine soils- Cementation Bonding-Morphology and genesis of marine and submarine sediments- Post-depositional changes- Effect of calcium carbonate in marine deposits.

Engineering behaviour of marine soils
Fine and coarse-grained deposits- Strength and deformation behaviour of fine and coarse-grained marine deposits- Effect of cementation- Strength and deformation behaviour under static and cyclic loading.

Offshore Soil Investigation
General characteristics of offshore soil exploration - Sampling using free corer, gravity corer, tethered systems and manned submersibles - Deep penetration sampling using wire line techniques - In-situ determination of strength of submarine soils - Penetrometer, piezocone, vane and pressure meter techniques -General reconnaissance procedure for installation of fixed structures (gravity and piled type), floating structures, sea bed anchors and submarine pipelines.

Foundations for Gravity Structures
Types of gravity structures- Installation techniques- Movement of gravity structures- Settlement of soil beneath gravity structures- Stress distribution beneath gravity structures- Stability of gravity structures under static and cyclic loads- Foundations for jacket type structures: Types- Installation techniques- Design considerations- Axial and lateral load capacity of piles- Lateral load deformation behaviour of piles- Calculation of bearing capacity of piles- Design of piles subjected to lateral loads- Reese-Matlock method & p-y curves method.

Foundations for jack up platforms
Foundations for jack up platforms: Types of jack up platforms- Piles and mat supported- Spud Cans-Different types- Techniques for installation and removal of jack up- Stability of jack up platforms-Determination of penetration of supports- Stability under lateral loads- Stability under static and cyclic load effects. Sea bed anchors, submarine pipe lines: General introduction to sea bed anchors, moorings, submarine pipe line etc.-General design considerations (brief outline only)- geotechnical aspects in the design and installation of sea bed anchors, moorings, submarine pipelines etc

References:

1. Chaney, F. Marine Geotechnology and nearshore/offshore structures, ASTM, STP-, 1986.
2. Chaney, R. C andDemars, K. R., Strength Testing of Marine Sediments - Laboratory and In-situ Measurements, ASTM, STP -883, 1985.
3. Poulos, H. G and Davis, E. H., Pile Foundation Analysis and Design, John Wiley, 1980.
4. Numerical Methods in offshore Piling, Proc. Conf. Inst. of Civil Engineers, London, 1980.
5. Le Tirant, Sea Bed Reconnaissance and Offshore Soil Mechanics for the Installation of Petroleum Structures, Gulf Publ. Co., 1979.
6. George, P and Wood, D, Offshore Soil Mechanics, Cambridge University Press, 1976

CE6226E GEOGRAPHIC INFORMATION SYSTEM AND ITS APPLICATIONS

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the components of a GIS and the reference systems for mapping and data acquisition

CO2: Select suitable data representation tools and methods for analysis

CO3: Process the data to derive meaningful inferences for decision making

CO4: Apply the tools and techniques available in GIS for the selected practical applications

Introduction: Definitions of GIS – Components of GIS – Geographic data presentation: maps – mapping process – coordinate systems – transformations – map projections – geo-referencing – data acquisition

Geographic Data Representation, Storage, Quality and Standards: Storage - Digital representation of data – Data structures and database management systems – Raster data representation – Vector data representation – Concepts and definitions of data quality – Components of data quality – Assessment of data quality – Managing data errors – Geographic data standards

GIS Data Processing, Analysis and Modeling: Raster-based GIS data processing – Vector-based GIS data processing – Queries – Spatial analysis – Descriptive statistics – Spatial autocorrelation – Quadrant counts and nearest neighbour analysis – Network analysis – Surface modeling – DTM

GIS Applications: Applications of GIS in Environment monitoring – Natural hazard management – Natural resources management urban planning – utility management – Land information – Business development

References

1. Burrough, P.A., Principles of Geographical Information Systems, Oxford Publication, 1998.
2. Chang, K-T., Introduction to Geographic Information Systems, McGraw Hill Education, 2016.
3. Clarke, K., Getting Started with Geographic Information Systems, Prentice Hall, New Jersey, 2010.
4. DeMers, M.N., Fundamentals of Geographic Information Systems, John Wiley and Sons, New York, 2002.
5. Heywood, I., Cornelius S. and Carver S., An Introduction to Geographical Information Systems, Pearson Education Ltd, Delhi, 2006.
6. Jeffrey, S. and John E., Geographical Information System – An Introduction, Prentice-Hall, 1990.
7. Jensen J R and Jensen R R, Introductory Geographic Information Systems, Pearson Education Ltd, Delhi, 2013.
8. Lo, C.P. and Yeung A.K.W., Concepts and Techniques of Geographic Information Systems, Prentice Hall of India, New Delhi, 2006.
   Reddy, A. M., Remote Sensing and Geographical Information Systems, B.S. Publications, Hyderabad, 2001.

CE6203E PAVEMENT MATERIALS, DESIGN AND CONSTRUCTION

Pre-requisites: NIL

L	T	P	O	C
4	0	0	8	4

Total Lecture Sessions: 52

Course Outcomes:

CO1: Assess the pavement components with respect to their material composition.
CO2: Analyse pavement behaviour under varying traffic and environmental conditions.
CO3: Design the pavement with respect to field conditions.
CO4: Suggest suitable methodologies for the construction of durable and cost-effective pavements.

Pavement Materials
Types and Component parts of Pavements - A brief study on aggregates, bitumen and modified bitumen like cutback, emulsion, polymer modified bitumen - Bituminous mix design methods, specifications and testing – Superpave mix design and material testing - artificial aggregates – Industrial waste materials – Geo-polymer – waste plastics - fibres – recycled aggregate - nanomaterials.

Factors affecting Design and Performance of Pavements
Comparison between Highway and Airport pavements - Functions and Significance of Subgrade properties, Various Methods of Assessment of Subgrade Soil Strength for Pavement Design - Causes and Effects of variation in Moisture Content and Temperature - Depth of Frost Penetration.

Analysis and Design of Flexible Pavement
Stresses and Deflections in Homogeneous Masses - Burmister's 2- layer, 3- layer Theories - Wheel Load Stresses - ESWL of Multiple Wheels - ESAL – VDF - Repeated Loads and EWL factors - Sustained Loads and Pavement behaviour under Traffic Loads - Empirical, Semiempirical, Analytical and Mechanistic-empirical approaches - Development, Principle, Design steps, Advantages and Applications of different Pavement Design Methods – Mechanistic Empirical Pavement Design – IRC guidelines and examples.

Analysis and Design of Rigid pavements
Types of Stresses and Causes, Factors influencing the Stresses; General conditions in Rigid Pavement Analysis, ESWL, Wheel Load Stresses, Warping Stresses, Friction Stresses, Combined Stresses - Types of Joints in Cement Concrete Pavements and their Functions, Joint Spacing, Design of Slab Thickness, Design of Joint Details for Longitudinal Joints, Contraction Joints and Expansion Joints - Mechanistic Empirical Pavement Design - IRC guidelines and examples.

Pavement Construction
Earthwork – roadway excavation, embankment construction; Drainage - surface/subsurface, different types of drains; Subbase – Construction of gravel and stabilised bases; Base – WBM base, wet mix macadam; Bituminous pavements – interface treatments, binder course, surface and wearing course - Cement concrete pavements – base course, surface course - joints in plain and reinforced cement concrete pavements.

Sustainable Construction
Pavement Recycling - Full Depth Reclamation – porous pavements – warm mix technologies – Cold mix technologies.

References:

1. Harold N. Atkins, Highway Materials, Soils, and Concrete, Prentice Hall, 2002.
2. IRC: 37, Guidelines for the Design of Flexible Pavements.
3. IRC: 58, Guidelines for the Design of Rigid Pavements.
4. Kett I, Asphalt Materials & Mix Design Manual, Noyes Publications, 1999.
5. Kim Y R, Modelling of asphalt Concrete, ASCE Press, 2008.
6. Lavin P G, Asphalt Pavements, Spon Press, 2003.
7. Mechanistic Empirical Pavement Design Guide, NCHRP, TRB, 2008.
8. MORTH Specifications for Road and Bridge Works.
9. Yang, Design of functional pavements, McGraw-Hill, 1973.
10. Yoder and Witezak, Principles of Pavement Design, John Wiley and sons, 1975.
11. ASTM, AASHTO, SHRP and BIS publications.

CE6213E PAVEMENT EVALUATION AND MANAGEMENT

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Identify the causes of pavement surface distresses and suggest suitable remedial measures
CO2: Interpret the field condition and pavement design data with respect to present and future traffic
CO3: Optimize the maintenance alternatives based on the economic analysis of the project alternatives
CO4: Provide the feedback data for updating the pavement performance monitoring system.

Pavement Surface Condition and Its Evaluation
Various Aspects of Surface and their Importance; Causes, Factors Affecting, Deterioration and Measures to Reduce: i) Pavement Slipperiness ii) Unevenness iii) Ruts, Pot holes, and Cracks; Methods of Measurement of Skid Resistance, Unevenness, Ruts and Cracks. Pavement Surface Condition Evaluation by Physical Measurements, by Riding Comfort and Other Methods; their Applications.

Pavement Structure and Its Evaluation
Factors affecting Structural Condition of Flexible and Rigid Pavements; Effects of Subgrade Soil, Moisture, Pavement Layers, Temperature, Environment and Traffic on Structural Stability, Pavement Deterioration; Evaluation by Non-Destructive Tests such as FWD, Benkelman Beam Rebound Deflection, Plate Load Test, Wave Propagation and other methods of Load Tests; Evaluation by Destructive Test Methods, and Specimen Testing

Pavement Overlays and Design
Pavement Overlays, Design of Flexible Overlay over Flexible Pavement by Benkelman Beam Deflection and other Methods, Flexible Overlays and Rigid Overlays over Rigid Pavements, Use of Geosynthetics in Pavement Overlays.

Pavement Management System
Concepts of pavement management systems, pavement performance prediction – concepts, modelling techniques, structural conditional deterioration models, mechanistic & empirical models, functional condition deterioration models, unevenness deterioration models and other models, ranking and optimization methodologies.

References:

1. David Croney, The Design and Performance of Road Pavements, HMSO Publications, 2008.
2. Haas and Hudson, Pavement Management System, McGraw Hill Book Co., New York, 1982.
3. HRB/TRB/IRC/International Conference on Structural Design of Asphalt Pavements, 1988.
4. Per Ullidtz, Pavement Analysis, Elsevier, Amsterdam,1998.
5. SHAHIN, M Y, Pavement management for airport, roads and parking lots, Chapman and hall 2005.
6. Woods, K.B., Highway Engineering Hand Book, McGraw Hill Book Co.
7. Yang H. Huang, Pavement Analysis and Design, Prentice Hall, 2003.
8. Yoder and Witezak, Principles of Pavement Design, John Wiley and sons, 1975.

CE6101E THEORY OF ELASTICITY AND PLASTICITY

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand mathematical formulation of elasticity problem as a well-posed boundary value problem.
CO2: Solve simple engineering problems with mathematical rigour. Such solutions can act as bench-mark solutions for testing computational methods and software.
CO3: Appreciate the Cartesian tensor notation, thereby understand modern technical literature well
CO4: Introduction to plasticity will enable understanding advanced books on theory of plasticity.

Introduction to the Mathematical Theory of Elasticity
Elasticity, stress, strain, Hooke's law, two- dimensional idealisations, plane stress and plane strain problems, equations of equilibrium, strain- displacement relations, constitutive relations, compatibility conditions, displacement and traction boundary conditions. Two-dimensional problems in rectangular coordinates: Stress function, solution by polynomials, Saint Vénant's principle, bending of a cantilever, determination of displacements. Two-dimensional problems in polar coordinates: General equations, problems of axisymmetric stress distribution, pure bending of curved bars, effect of circular hole on stress distribution in plates, concentrated force at a point on a straight boundary.

Introduction to Cartesian Tensors
Transformation laws of cartesian tensors, special tensors and tensor operations, the Kronecker's delta, the permutation tensor, the e-δ identity, symmetry and skew- symmetry, contraction, derivatives and the comma notation, Gauss' theorem, the base vectors and some special vector operations, eigenvalue problem of a symmetric second order tensor, equations of elasticity using index notation.
Stress-strain Problems in Three Dimensions: Principal stresses, principal strains, three- dimensional problems.

Energy Theorems and Variational Principles of Elasticity
Strain energy and complementary energy, Clapeyron's theorem, virtual work and potential energy principles, principle of complementary potential energy, Betti's reciprocal theorem, principle of linear superposition, uniqueness of elasticity solution. Torsion of straight bars: Elliptic and equilateral triangular cross-section, membrane analogy, narrow rectangular cross-section, torsion of rectangular bars, torsion of rolled profile sections, hollow shafts and thin tubes.

Introduction to Plasticity
One-dimensional elastic-plastic relations, isotropic and kinematic hardening, yield function, flow rule, hardening rule, incremental stress-strain relationship, governing equations of elastoplasticity.

References:

1. Timoshenko, S.P. and Goodier, J.N., Theory of Elasticity, Mc Graw Hill, Singapore, 1982.
2. Srinath, L.S., Advanced Mechanics of Solids, Second Edition, Tata McGraw Hill, India, 2003.
3. Ameen, M., Computational Elasticity–Theory of Elasticity, Finite and Boundary Element Methods, Narosa Publishing House, 2004.
4. Leipholz, H., Theory of Elasticity, Noordhoff International Publishing, Layden, 1974.
5. Sokolnikoff, I.S., Mathematical Theory of Elasticity, Tata Mc Graw Hill, India, 1974.
6. Xu, Z., Applied Elasticity, Wiley Eastern Ltd, India, 1992.
7. Chakrabarty, J, Theory of Plasticity, Elsevier, London, 2006.
8. Hill, R., Mathematical Theory of Plasticity, Oxford University Press, 1998.
9. Chen, W.F., and Han, D.J., Plasticity for Structural Engineers, Springer Verlag, 1998.

CE6111E FINITE ELEMENT METHOD

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To formulate finite element model of a physical system
CO2: To derive element stiffness matrix for a given problem
CO3: To write a computer code and analyse a structure using the finite element method
CO4: To use latest commercial FE software

Introduction: Finite element analysis, Problem classification, Modelling and discretization, interpolation, elements, nodes and D.O.F, Example applications, History of FEA. One-Dimensional Elements: Bar element, Beam element, Bar and beam elements of arbitrary orientation, Assembly of elements, Properties of stiffness matrices, Boundary conditions, Exploiting sparsity, Mechanical loads, Thermal loads, Stresses, Structural symmetry. Basic Elements: Interpolation and shape functions, Linear triangle, Bilinear rectangle, Rectangular solid element, Nodal loads, Stress calculation, Nature of finite element solution.

Formulation Techniques: Variational Methods: Principle of stationary potential energy, Problems having many D.O.F., Potential energy of an elastic body, Rayleigh-Ritz method, Strong and weak forms, Finite element form of Rayleigh-Ritz method, Convergence of finite element solutions. Formulation Techniques: Galerkin and Other Weighted Residual Methods: Methods of weighted residuals, Galerkin FEM in one dimension, Integration by parts, Galerkin FEM in two dimensions. Isoparametric Elements: Bilinear quadrilateral, Quadrature for obtaining [k] by numerical integration, Quadratic isoparametric elements, Hexahedral isoparametric elements, Stress calculation, Patch test, Validity of isoparametric elements.

Isoparametric Triangles and Tetrahedra: Reference coordinates, shape functions, analytical integration, area and volume coordinates, numerical integration. Coordinate Transformation and Selected Topics: Displacement, strain, stress, material property and stiffness matrix transformations, Changing the direction of restraints, Connecting dissimilar elements, Structural modification, Reanalysis. Modelling Considerations: Repetitive symmetry, Static condensation, Substructures.

References:

1. Cook, R.D., et al, Concepts and Applications of Finite Element Analysis, John Wiley, 2003.
2. Krishnamoorthy, C.S., Finite Element Analysis – Theory and Programming, Tata McGraw Hill, 1996.
3. Bathe, K.J., Finite Element Procedures, Prentice Hall of India, 1996.
4. Desai, C.S., Elementary Finite Element Method, Prentice Hall of India, 1998.
5. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vol. I and II, Mc Graw Hill, 1991.
6. Buchanan, G.R., Finite Element Analysis, Schaum's Outlines, Tata McGraw-Hill, India, 1995.
7. Rajasekaran, S., Finite Element Analysis in Engineering Design, Wheeler Pub, 1998.

CE6512E FLOW AND TRANSPORT IN POROUS MEDIA

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Formulate and solve governing equations for steady and transient groundwater flow.
CO2: Perform groundwater resource and recharge estimation and plan schemes for recharge
CO3: Perform numerical modelling of transport problems in the subsurface

Groundwater and the hydrologic cycle. Occurrence and movement of groundwater - origin, age, distribution, types of aquifers. Darcy's law, hydraulic head and fluid potential, hydraulic conductivity and permeability, heterogeneity and anisotropy of hydraulic conductivity, porosity and void ratio, compressibility and effective stress, transmissivity and storativity. Steady State and transient flow - formulation of the governing equations, limitations of the Darcian approach. Groundwater and well hydraulics - steady flow to a well fully penetrating an aquifer (confined and unconfined), unsteady radial flow to a well fully penetrating an aquifer (confined, unconfined and leaky), effect of well bore storage.

Multiple well systems, partially penetrating wells, bounded aquifers, characteristic well losses, specific capacity. Slug tests. Introduction to flow in the unsaturated zone and flow in fractured formations. Saline water intrusion in coastal aquifers: occurrence, shape and structure of the interface, upconing, control of saline water intrusion. Groundwater modelling, Inverse modelling in groundwater. Artificial recharge of aquifers - concepts, hydraulics and methods. Groundwater budget. Groundwater resource estimation.

Introduction to groundwater contamination. Quality of groundwater - measures of quality, groundwater samples, physical, chemical and biological analyses, water quality criteria, and salinity. Transport and transformation of contaminants in groundwater - processes, formulation of the governing equations and initial and boundary conditions, modelling, solutions for simple cases.

References

1. R.A. Freeze and J. A. Cherry, *Groundwater*, Prentice Hall, Inc. 1979
2. C. W. Fetter, *Applied Hydrogeology*, 4th ed., Prentice Hall, Inc. 2001
3. C. W. Fetter, *Contaminant Hydrogeology*, 2nd ed., Waveland Press, 2008
4. P. A. Domenico and F. W. Schwartz, *Physical and Chemical Hydrogeology*, 2nd ed., John Wiley & Sons, Inc., 1998
5. F. W. Schwartz and H. Zhang, *Fundamentals of Groundwater*, John Wiley & Sons, Inc., 2003
6. D. K. Todd and L. W. Mays, *Groundwater*, 3rd ed., John Wiley & Sons, Inc., 2004
7. A. K. Rastogi, *Numerical Groundwater Hydrology*, Penram International Publishing (India) Pvt. Ltd., 2007.
8. Vedat Batu, *Applied Flow and Solute Transport Modeling in Aquifers*, Taylor and Francis/ CRC Press, 2006
9. E. Scott Bair, Terry D. Lahm, *Practical Problems in Groundwater Hydrology*, Pearson Prentice Hall, 2006

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification
Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution
Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies
Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V. (Indian Adoption) (2022). *Patterns of entrepreneurship management.* John Wiley & Sons.
2. Kuratko, D. F. (2016). *Entrepreneurship: Theory, process, and practic*e. Cengage learning.
3. Barringer, B. R. (2015). *Entrepreneurship: Successfully launching new ventures*. Pearson Education India
4. Rajiv Shah, Zhijie Gao, Harini Mittal, I*nnovation, Entrepreneurship, and the Economy in the US, China, and India*, 2014, Academic Press
5. Sundar,K.(2022). *Entrepreneurship Developmen*t, 2nd Ed, Vijaya Nichkol Imprints, Chennai
6. E. Gordon,Dr. K. Natarajan., (2017).*Entrepreneurship Development*, 6th Ed, Himalya Publishers, Delhi
7. Debasish Biswas, Chanchal Dey, *Entrepreneurship Development in India*, 2021, Taylor & Francis.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations.

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements – Proofreading.

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes.

References:

1. Foley, M., & Hall, D. (2018). *Longman advanced learner's grammar, a self-study reference & practice book with answers*. Pearson Education Limited.
2. Gerson, S. J., & Gerson, S. M. (2009). *Technical writing: Process and product*. Pearson.
3. Kirkwood, H. M. A., & M., M. C. M. I. (2013). *Hallidays introduction to functional grammar* (4th ed.). Hodder Education.
4. Markel, M. (2012). *Technical Communication* (10th ed.). Palgrave Macmillan.
5. Tuhovsky, I. (2019). *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills.* Rupa Publications India.
6. Williams, R. (2014). *The Non-designer's Design Boo*k. Peachpit Press.

ZZ6002E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes

CO1: Explain the basic concepts and types of research.
CO2: Develop research design and techniques of data analysis
CO3: Present research to the scientific community
CO4: Develop an understanding of the ethical dimensions of conducting research.

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis

Literature review :Tools and Techniques - Collection and presentation of data, processing and analysis of data - Descriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Probability distributions – Single population and two population hypothesis Testing - Parametric and non-parametric tests - Design and analysis of experiments: Analysis of Variance (ANOVA),completely randomized design – Measures of relationship: Correlation and regression, simple regression analysis, multiple regression – interpretation of results - Heuristics and simulation

Research writing and Ethics

Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews. The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey.

References:

1. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M. (2006). *Management Research Methodology,* Pearson Education.
2. Leedy, P, D. (2018). *Practical Research: Planning and Design* (12 e) Pearson.
3. Kothari, C.R. (2004). Research Methodology – Methods and Techniques, New Age International Publishers.
4. Mike Martin, Roland Schinzinger, (2004) *Ethics in Engineering*, Mc Graw Hill Education
5. Vinod V Sople (2014) *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd.