Master of Technology
(Geotechnical Engineering)

CURRICULUM

(Effective from 2024 - 25 Onwards)

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015, INDIA.

VISION OF THE INSTITUTE

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

Shaping infrastructure development with societal focus

MISSION OF THE DEPARTMENT

Achieve International Recognition by:

- *Developing Professional Civil Engineers*
- *Offering Continuing Education*
- *Interacting with Industry with emphasis on R&D*

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1	Graduates of the program will possess the ability to provide solutions to Geotechnical Engineering problems with the highest standards economically, socially, and ethically.
PEO2	Graduates of the program will become Geotechnical Engineers in government, public, and private sector industries and work for the betterment of the global community.
PEO3	Graduates of the program will continue their lifelong learning to remain effective professionals to maintain and enhance technical and professional growth.

PROGRAMME OUTCOMES (POs)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

CURRICULUM STRUCTURE

M. Tech. (GEOTECHNICAL ENGINEERING)

Components	Number of Courses	Credits	Total Credits
Programme Core (PC)	3 / Semester (6 / Year)	24	**42**
Programme Elective (PE)*	3 / Semester (6 / Year)	18	
Essential Laboratory Requirements (ELR)	3 / Year	6	**6**
Internship/Industrial Training/ Academic Attachment (I/A)	1	2	**2**
Open Elective (OE) / Online Course (OC)#@	2 (I – IV Semester)	6	**6**
Project Phase-I	1	12	**12**
Project Phase-II	1	12	**12**
Total	**20**	**80**	**80**

Note:

* ***ONLINE COURSES EQUIVALENT TO PROGRAMME ELECTIVES (Optional):*** *Out of 6 programme electives, students have the option to study two online courses (Maximum of 1 per semester in the 1st year of Study) equivalent to programme elective courses through NPTEL / Swayam.*

\# ***OPEN ELECTIVES (OE) / ONLINE COURSE (OC) (Compulsory):*** *Students must complete 6 credits between I and IV semester either through online courses of their choice from NPTEL / Swayam (discipline electives / other electives) or through open electives offered by the PG programmes of the institute other than the progamme specialization.*

@ ***MICROCREDITS (Optional):*** *Students may opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC.*

CURRICULUM

SEMESTER I

Code	Course of Study	Credit
MA602	Applied Mathematics	4
CE801	Advanced Soil Mechanics	4
CE803	Soil Exploration and Field Testing	4
	Programme Elective I	3
	Programme Elective II	3
	Programme Elective III / Online (NPTEL)	3
CE807	Advanced Geotechnical Engineering Laboratory	2
		23

SEMESTER II

Code	Course of Study	Credit
CE802	Foundation Analysis and Design	4
CE804	Earth Retaining Structures	4
CE806	Dynamics of Soils and Foundations	4
	Programme Elective IV	3
	Programme Elective V	3
	Programme Elective VI / Online (NPTEL)	3
CE808	Geosynthetics and Field Testing Laboratory	2
CE810	Geotechnical Design Studio	2
		25

SUMMER TERM (evaluation in the III semester)

Code	Course of Study	Credit
CE845	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	2

SEMESTER III

Code	Course of Study	Credit
CE847	Project Work (Phase I)	12

SEMESTER IV

Code	Course of Study	Credit
CE848	Project Work (Phase II)	12

OPEN ELECTIVES (OE) / ONLINE COURSE (OC)

Code	Course of Study	Credit
	# (To be completed between I to IV semester)	6

PROGRAMME ELECTIVES

Sl. No.	Code	Course of Study	Credit
1.	CE811	Geotextile From Design to Applications	3
2.	CE812	Geomechanics -Theory and Applications	3
3.	CE813	Finite Element Methods in Geotechnical Engineering	3
4.	CE814	Slope Stability and Earth Dams	3
5.	CE815	Ground Improvement Techniques	3
6.	CE816	Analysis of Deep Foundation	3
7.	CE817	Machine Foundations	3
8.	CE818	Marine Foundation Engineering	3
9.	CE819	Soil-Structure Interaction	3
10.	CE820	Geotechnical Constitutive Modelling	3
11.	CE821	Rock Mechanics	3
12.	CE822	Unsaturated Soil Mechanics	3
13.	CE823	Design of Underground Excavation	3
14.	CE824	Geotechnical Earthquake Engineering	3
15.	CE825	Geo-environmental Engineering	3
16.	CE826	Geosynthetics Engineering	3
17.	CE827	Forensic Geotechnical Engineering	3
18.	CE828	Geotechnics in Practice	3
19.	CE829	Ports and Harbour Structures	3
20.	CE830	Risk and Reliability in Geotechnical Engineering	3
21.	CE831	Geotechnology of Waste Disposal Facilities	3

OPEN ELECTIVES (OE) (List some courses from Programme Electives, that will be Open Electives for other PG Specialization, if it is offered as Programme Elective for the respective specialization)

Sl. No.	Code	Course of Study	Credit
1.	CE815	Ground Improvement Techniques	3
2.	CE816	Analysis of Deep Foundation	3
3.	CE819	Soil-Structure Interaction	3
4.	CE825	Geo-environmental Engineering	3
5.	CE829	Ports and Harbour Structures	3

(For OE courses refer the curriculum of other PG specializations)

MICROCREDITS (MC) [Students can opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC]

Sl. No.	Code	Course of Study	Credit
			3

Electives [Choices]

1. Program Elective (PE) Courses

Option 1:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	3	0	9
II	3	0	9

Option 2:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	2	1	9
II	3	0	9

Option 3:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	3	0	9
II	2	1	9

Option 4:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	2	1	9
II	2	1	9

2. Online Courses (OC) / Open Elective (OE) Courses

Option 1:

Semester	No. of Open Elective Courses	No. of online Courses		
		3 Credit courses	2 credit courses	1 credit course
I - IV	-	2	-	-
	-	1	1	1
	-	1	-	1+1+1

Option 2:

Semester	No. of Open elective Courses	No. of online Courses		
		3 credit courses	2 credit courses	1 credit course
I - IV	1	1	-	-
	1	-	1	1
	1	-	-	1+1+1

Option 3:

Semester	Open elective Courses	No. of online Courses		
		3 credit courses	2 credit courses	1 credit course
I - IV	2	-	-	-

COURSE OUTCOME AND PO MAPPING

PROGRAMME CORE

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

Course Code	Course Title	CO	Course outcomes At the end of the course student will be able	PO1	PO2	PO3
MA602	APPLIED MATHEMATICS	CO1	To solve boundary value problems using Laplace and Fourier transform techniques.	2	1	2
		CO2	To solve fluid flow and heat flow problems using conformal mapping.	2	1	2
		CO3	To develop the mathematical methods of applied mathematics and mathematical physics with an emphasis on calculus of variation and integral transforms	3	1	2
		CO4	To apply vector calculus in linear approximations, optimization, physics and engineering	2	1	3
		CO5	To solve physical problems such as elasticity, fluid mechanics and general relativity.	2	1	3
CE801	ADVANCED SOIL MECHANICS	CO1	Understand the physio-chemical behavior of soils, including diffused double layer theory, soil-water interactions, and	3	1	3

			swelling and shrinkage behavior			
		CO2	Comprehend soil fabric, compaction, and the concept of effective stress, and apply theories of stress distribution in soil.	3	1	3
		CO3	Evaluate shear resistance in soils, including stress-strain relationships, failure criteria, and pore pressure in saturated and unsaturated soils.	3	2	3
		CO4	Understand the mechanics of soil consolidation and apply Terzaghi's theory to estimate settlements and determine precompression history.	3	2	3
		CO5	Analyze flow through soils, including unidimensional, radial, and spherical flow, and understand the concepts of quicksand, piping, and flow nets.	3	2	3
CE803	SOIL EXPLORATION AND FIELD TESTING	CO1	To extract samples as per requirement and perform field and laboratory tests.	3	2	3
		CO2	To understand the practical significance of the results obtained from geophysical test methods.	3	1	3
		CO3	To be familiar with Pressure Meter and dilatometer testing and interpretation of test data.	3	1	3
		CO4	To be exposed to measurement of in-situ stresses in rocks and post failure testing of rocks	3	1	3
		CO5	To be exposed to Geotechnical Instrumentation for field monitoring	3	2	3

CE802	FOUNDATION ANALYSIS AND DESIGN	CO1	To do select and types of shallow foundations	3	1	3
		CO2	To do analyse the load bearing capacity of soil.	3	1	3
		CO3	To gain to estimate the settlement of foundations.	3	1	3
		CO4	To select appropriate foundation type based on available soil conditions and Load carrying capacity of single pile as per codes	3	1	3
		CO5	To determine the load carrying capacity of group pile foundation	3	1	3
CE804	EARTH RETAINING STRUCTURES	CO1	Understand earth pressure theories and their applications.	2	1	3
		CO2	Analyze the stability of retaining structures under different conditions.	3	1	3
		CO3	Design and analyze cantilever and anchored sheet pile walls.	3	1	3
		CO4	Assess lateral pressures and stability in braced excavations and tunnel linings.	3	1	3
		CO5	Master the design principles of diaphragm and bored pile walls	3	1	3
CE806	DYNAMICS OF SOILS AND FOUNDATIONS	CO1	To interpret the principles of dynamics in Geotechnical Engineering.	3	1	3
		CO2	To predict liquefaction and suggest measures for its mitigation.	3	2	3
		CO3	To reason the response of any soil-structure system.	3	2	3
		CO4	To apply the principles of soil dynamics.	3	1	3
		CO5	To become the proficiency in designing machine foundations and implementing vibration isolation techniques based on dynamic analysis.	3	2	3

ESSENTIAL LABORATORY REQUIREMENTS (ELR)

Course Code	Course Title	CO	Course Outcomes At the end of the course student will be able	PO1	PO2	PO3
CE807	ADVANCED GEOTECHNICAL ENGINEERING LABORATORY	CO1	To perform basic tests on soil to identify its index properties	3	2	1
		CO2	To carry out advanced laboratory tests to identify the engineering properties of soil.	3	2	2
CE808	GEOSYNTHETICS AND FOUNDATION ENGINEERING LABORATORY	CO1	To be able to conduct various field test in soil	3	2	1
		CO2	To understand the properties of geosynthetics from laboratory tests	3	2	2
CE810	GEOTECHNICAL DESIGN STUDIO	CO1	To understand the concept of software based numerical modelling.	3	2	2
		CO2	To carry out basic numerical modelling for practical Geotechnical issues on PLAXIS 2D, 3D, FLAC3D v7.0 and OASYS Geotechnical software.	3	2	3

PROGRAMME ELECTIVES

Course Code	Course Title	CO	Course outcomes	PO1	PO2	PO3
CE811	GEOTEXTILE FROM DESIGN TO APPLICATIONS	CO1	Understand the history and manufacturing processes of geotextiles, including natural fiber geotextiles.	2	1	3
		CO2	Learn about geotextile testing standards and their physical,	3	1	3

			mechanical, and hydraulic properties.			
		CO3	geotextile durability, degradation modes, and quality assurance practices.	2	1	2
		CO4	Understand various applications of geotextiles in separation, filtration, drainage, and reinforcement.	3	1	3
		CO5	Explore advanced uses of geotextiles in waste containment, marine engineering, and agriculture.	3	1	2
CE812	GEOMECHANICS - THEORY AND APPLICATIONS	CO1	Understand key elasticity problems and their applications in soil-foundation interaction.	2	1	3
		CO2	Analyze effective stresses in soils using stress-path concepts and constitutive models.	3	1	3
		CO3	Apply plasticity theory to analyze slope failure and sheet pile bearing capacity.	3	1	3
		CO4	Understand the application of slip line theory to soil pressure and stability analysis.	3	1	3
		CO5	Gain insights into critical state soil mechanics and work-hardening theories.	3	1	3
CE813	FINITE ELEMENT METHODS IN GEOTECHNICAL ENGINEERING	CO1	Demonstrate knowledge of FEM principles and their significance in geotechnical engineering.	3	1	3
		CO2	Apply mathematical and numerical	3	1	3

			methods to solve FEM problems.			
		CO3	Develop and analyze FEM models for various geotechnical applications.	3	2	3
		CO4	Integrate soil properties and constitutive models in FEM analyses for effective geotechnical design and assessment.	3	2	3
		CO5	Utilize FEM for practical geotechnical engineering problems, ensuring accurate and reliable results.	3	2	3
CE814	SLOPE STABILITY AND EARTH DAMS	CO1	Analyze earth pressures in retained soil masses using classical and graphical methods for various conditions.	3	2	3
		CO2	Evaluate slope stability using methods like the Method of Slices and Bishop's method under seismic conditions	3	2	3
		CO3	Design earth and rock fill dams with stability provisions for construction, reservoir conditions, and drawdown scenarios	3	2	3
		CO4	Address design issues including slope protection, filter design, and foundation treatments using geosynthetic materials	3	2	3

		CO5	Understand landslide impacts, triggering factors, and implement remediation and early warning systems	3	2	3
CE815	GROUND IMPROVEMENT TECHNIQUES	CO1	To be identify problematic soils and select appropriate ground improvement methods.	3	1	3
		CO2	To be understand mechanical modification and deep replacement techniques	3	1	3
		CO3	To be understand the concept of hydraulic modification methods	3	1	3
		CO4	To suggest soil stabilization techniques for problematic soils	3	1	3
		CO5	To be utilize in-situ ground reinforcement techniques and geo-synthetics for various purposes	3	2	3
CE816	ANALYSIS OF DEEP FOUNDATION	CO1	Understand the functions, requisites, and types of foundations.	3	2	2
		CO2	Calculate the load carrying capacity of piles using static formulae.	3	2	3
		CO3	Analyze the load carrying capacity of piles using dynamic formulae.	3	2	3
		CO4	Evaluate the behavior and efficiency of piled foundation groups.	3	3	3
		CO5	Assess lateral load resistance of piles.	3	2	3

CE817	MACHINE FOUNDATION	CO1	To estimate the dynamic properties of soils required for analysis and design of machine foundations.	3	1	3
		CO2	To define the behaviour of different types of machine foundations.	3	1	3
		CO3	To analyse and design different types of machine foundations	3	2	3
		CO4	To analyse and design vibration isolation systems	3	2	3
		CO5	Apply active and passive vibration isolation methods to reduce vibrations in existing foundations and critically review IS code provisions for machine foundation design.	3	2	3
CE818	MARINE FOUNDATION ENGINEERING	CO1	Master offshore soil sampling and strength testing techniques.	3	2	2
		CO2	Understand design and installation of gravity and jacket foundations.	3	2	3
		CO3	Design and analyze pile foundations for various loads.	3	2	3
		CO4	Learn about jack-up platform foundations and stability.	3	2	2
		CO5	Gain insights into sea bed anchors and submarine pipeline design.	3	2	2
CE819	SOIL STRUCTURE INTERACTION	CO1	To understand soil foundation interaction and its importance.	3	1	3
		CO2	To be familiar with model analysis,	3	2	3

			Winkler model for soil structure interaction analysis			
		CO3	To be exposed to beams and plates on elastic foundation	3	2	3
		CO4	To carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction	3	2	3
		CO5	To better understand the concepts of laterally loaded pile	3	1	3
CE820	GEOTECHNICAL CONSTITUTIVE MODELLING	CO1	Ability to apply stress-strain invariants and elastic laws to soil behavior.	3	1	3
		CO2	Competence in using Mohr-Coulomb and Tresca models for geotechnical analysis.	3	1	3
		CO3	Proficiency in critical state models and understanding soil parameters and yield functions.	3	2	3
		CO4	Skills in finite element analysis for static, quasi-static, and dynamic problems in soil mechanics.	3	2	3
		CO5	Capability to analyze and simulate the transient response of saturated soils, including consolidation and liquefaction.	3	2	3
CE821	ROCK MECHANICS	CO1	Demonstrate comprehensive knowledge of rock mechanics and geological aspects	3	1	3

			relevant to tunneling.			
		CO2	Apply appropriate testing methods to determine rock properties and characterize rock masses effectively.	3	2	3
		CO3	Evaluate rock mass classification systems and apply failure criteria in practical scenarios.	3	2	3
		CO4	Design tunnels and foundations on rock, employing suitable excavation and support techniques.	3	2	3
		CO5	Conduct stress analysis and utilize instrumentation and ground improvement methods to ensure the safety and stability of tunneling projects.	3	2	3
CE822	UNSATURATED SOIL MECHANICS	CO1	To understand the stress state variables, material variables and constitutive law of unsaturated soil.	3	1	3
		CO2	To understand the various physical mechanism of soil-water interaction and have a idea on concept of soil water characteristic curve.	3	1	3
		CO3	To understand the techniques for suction measurement and select the suitable SWCC fitting model.	3	2	3
		CO4	To understand about the evaluation of flow and shear strength characteristics of	3	2	3

			soil in unsaturated state.			
		CO5	To understand the volume change behaviour of problematic soisl in unsaturated state.	3	2	3
CE823	DESIGN OF UNDERGROUND EXCAVATION	CO1	Understand planning and exploration methods for underground construction.	3	2	2
		CO2	Learn tunneling methods and support systems for various subsoil and rock conditions.	3	2	3
		CO3	Analyze stress distribution around tunnels using various methods.	3	3	3
		CO4	Understand elastic stress distribution and numerical modeling techniques for tunnel design.	3	3	3
		CO5	Analyze rock mass-tunnel support interaction and design support systems.	3	2	3
CE824	GEOTECHNICAL EARTHQUAKE ENGINEERING	CO1	To conduct site investigations, evaluate dynamic soil properties, and understand soil improvement techniques.	3	2	3
		CO2	To design earthquake-resistant foundations and retaining walls, assess slope stability, liquefaction susceptibility, and develop design ground motions.	3	2	3
		CO3	To create risk maps, perform hazard assessments, develop mitigation	3	2	3

			strategies, understand seismic microzonation, and follow design code recommendations.			
		CO4	To assess reinforced slope stability, design seismic-resistant retaining walls, apply pseudo-static/dynamic analysis, and evaluate foundation bearing capacity and settlement under seismic conditions.	3	2	3
		CO5	To implement soil improvement techniques for seismic hazard mitigation and adhere to seismic design code recommendations in geotechnical earthquake engineering projects.	3	2	3
CE825	GEOENVIRONMENTAL ENGINEERING	CO1	To understand the various causes and how to safely dispose the waste through different containment process	3	2	3
		CO2	To understand the various mechanism of transport of contaminants into subsurface	3	2	3
		CO3	To understand the concept of soil and waste characterization techniques.	3	2	3
		CO4	To understand on how to decontaminate the site to reuse the site	3	2	3

			for human settlement.			
		CO5	To understand the consequences of soil waste interaction and its modifications.	3	2	3
CE826	GEOSYNTHETICS ENGINEERING	CO1	Students will understand the definition, history, types, and raw materials used in geosynthetics.	2	2	2
		CO2	Students will be able to describe different geosynthetics manufacturing techniques and properties (physical, mechanical, and hydraulic).	2	2	3
		CO3	Students will learn about geosynthetics's general applications in civil engineering projects.	3	2	3
		CO4	Students will be able to identify and apply the functions of geosynthetics, including separation, reinforcement, filtration, drainage, containment, and protection	3	2	3
		CO5	Students will learn the use of geosynthetics in roadway and railway applications, including design and construction considerations.	3	2	3
CE827	FORENSIC GEOTECHNICAL ENGINEERING	CO1	Demonstrate knowledge of planning and conducting geotechnical investigations.	3	2	3

		CO2	Characterize and diagnose distress in geotechnical structures using appropriate methods.	3	2	3
		CO3	Conduct back analysis and address technical shortcomings in geotechnical projects.	3	2	3
		CO4	Assess and enhance the reliability of geotechnical structures through observation and performance evaluation.	3	2	3
		CO5	Analyze various geotechnical failures, understand their causes, and apply relevant codal provisions and performance-based analysis procedures.	3	2	3
CE828	GEOTECHNICS IN PRACTICE	CO1	To adopt the procedural activities as part of a consultancy project	3	2	2
		CO2	Understand and apply factors for site selection, land reclamation techniques, and financial estimation including fee, budget, and margins for design projects	3	2	2
		CO3	To follow and work according to the limitations given by IS and IRC codes.	3	2	3
		CO4	Understand and apply design procedures and IS codal recommendations for water resources	3	2	3

			and port infrastructure projects.			
		CO5	To comprehend to the quality requirements of any project.	3	2	2
CE829	PORTS AND HARBOUR STRUCTURES	CO1	Students will be able to design and plan effective port layouts	3	2	3
		CO2	Students will apply principles of load estimation, structural analysis, and design to various port structures	3	2	3
		CO3	To understand dredging and disposal of contaminated sediments, the design of offshore terminals and islands	3	2	3
		CO4	To familiarize students with integrity analysis of berthing structures	3	2	2
		CO5	To design piles and diaphragm walls for ports, apply retrofitting techniques	3	2	3
CE830	RISK AND RELIABILITY IN GEOTECHNICAL ENGINEERING	CO1	Understand the sources and types of uncertainties in geotechnical engineering and the importance of probabilistic methods and reliability-based analysis	3	2	3
		CO2	Apply statistical methods such as parameter estimation, hypothesis testing, and regression analysis to	3	2	3

			geotechnical problems			
		CO3	Characterize and analyze uncertainty in field-measured and laboratory-measured soil properties and interpret techniques considering spatial variability and scale of fluctuations.	3	2	3
		CO4	Perform probabilistic groundwater modeling, flow analysis through earth dams, and slope stability analysis using techniques like autocorrelation and autocovariance.	3	2	3
		CO5	Implement LRFD design methodology and conduct reliability-based design and analysis for shallow and deep foundations, settlement, liquefaction, and develop fragility curves for geotechnical problems.	3	2	3
CE831	GEOTECHNOLOGY OF WASTE DISPOSAL FACILITIES	CO1	To demonstrate comprehensive knowledge of waste management	3	2	2
		CO2	To evaluate geotechnical properties and interactions of waste	3	2	3
		CO3	To apply design principles for waste containment systems	3	2	3
		CO4	To implement effective remediation techniques	3	2	2

		CO5	To enhance knowledge in sustainable waste management	3	2	2

3 - High; 2 - Medium; 1 – Low

Course Code	**:**	MA602
Course Title	**:**	**APPLIED MATHEMATICS**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To develop students with knowledge in Laplace and Fourier transform**
CLO2	**To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications.**
CLO3	**To expose the students to calculus of variation, conformal mappings and tensor analysis.**
CLO4	**To familiarize students in the field of bilinear transformations.**
CLO5	**To expose students to the concept of vector analysis.**

Course Content

Laplace transform: Definitions, properties - Transform of error function, Bessel's function, Dirac Delta function, Unit Step functions – Convolution theorem – Inverse Laplace Transform: Complex inversion formula – Solutions to partial differential equations: Heat equation, Wave equation.

Fourier transform: Definitions, properties – Transform of elementary functions, Dirac Delta function – Convolution theorem – Parseval's identity – Solutions to partial differential equations: Heat equation, Wave equation, Laplace and Poisson's equations.

Concept of variation and its properties – Euler's equation – Functional dependent on first and higher order derivatives – Functionals dependent on functions of several independent variables – Variational problems with moving boundaries – Problems with constraints – Direct methods – Ritz and Kantorovich methods.

Introduction to conformal mappings and bilinear transformations – Schwarz Christoffel transformation – Transformation of boundaries in parametric form – Physical applications: Fluid flow and heat flow problems.

Polar co-ordinates - Expressions of gradient of scalar point function – divergence and curl of a vector point function in orthogonal curvilinear co-ordinates - Summation convention – Contravariant and covariant vectors – Contraction of tensors – Inner product – Quotient law – Metric tensor – Christoffel symbols – Covariant differentiation.

References

1.	**Sankara Rao K., Introduction to Partial Differential Equations, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.**

2.	**Gupta A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.**
3.	**Spiegel M.R., Theory and Problems of Complex Variables and its Application (Schaum's Outline Series), McGraw Hill Book Co., Singapore,1981.**
4.	**James. G, Advanced Modern Engineering Mathematics, Pearson Education, Third Edition, 2004.**
5.	**Lev. D. Elsgolc, Calculus of Variations, Dover Publications, New York, 2012.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To solve boundary value problems using Laplace and Fourier transform techniques.**
CO2	**To solve fluid flow and heat flow problems using conformal mapping.**
CO3	**To develop the mathematical methods of applied mathematics and mathematical physics with an emphasis on calculus of variation and integral transforms**
CO4	**To apply vector calculus in linear approximations, optimization, physics and engineering**
CO5	**To solve physical problems such as elasticity, fluid mechanics and general relativity.**

Course Code	**:**	CE801
Course Title	**:**	**ADVANCED SOIL MECHANICS**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To Analyze the effects of ion concentration, ionic valency, pH, dielectric constant, and temperature on the double layer distance and soil-water interactions.**
CLO2	**To Measure soil fabric properties, evaluate factors affecting soil compaction, and use Boussinesq and Westergaard's theories to analyze stress distribution in soils.**
CLO3	**To Apply Mohr-Coulomb failure criteria to determine shear parameters under different drainage conditions and predict pore water pressures analytically.**

CLO4	**To Use Terzaghi's unidimensional consolidation theory to estimate soil settlements and analyze creep and stress relaxation using rheological models.**
CLO5	**To Construct flow nets for confined and unconfined flow using relaxation techniques and conformal mapping, and analyze phreatic surfaces and seepage forces in soils.**

Course Content

Origin of soils - Physical and physio-chemical behaviour of soils – diffused double layer theory – computation of double layer distance – effect of ion concentration, ionic valency, pH, dielectric constant, temperature on double layer – stern layer – attractive and repulsive forces in clays – types of soil water – mechanism of soil – water interactions - soil structure. Problems associated with swelling and shrinkage behaviour of soils –Causes, consequences and mechanisms – factors influencing swell – shrink characteristics – swell potential – osmotic swell pressure

Soil fabric and measurement – sensitivity, thixotropy of soils – soil suction – soil compaction – factors affecting soil compaction. Stresses and displacements in soil: soil as elastic body -concept of effective stress - equations of equilibrium in soil mass -principal stresses and strains -problems of plane stresses and strains -stress distribution by Boussinesq, Westergaard's theory – Newmark's chart - influence of anisotropy on stress distribution - applications to geotechnical problems.

Shear resistance: stress - strain relationship in soils -failure criteria –Mohr Coulomb's failure – Stress Path - shear parameters under different drainage conditions - pore pressure in saturated and unsaturated soils -analytical predictions of pore water pressures - stress dilatancy theory – results of plane strain shear tests -factors affecting shear parameters.

Mechanics of consolidation: phenomenon of consolidation -Terzaghi's theory of unidimensional consolidation - methods to determine precompression history – Radial Consolidation - applications to estimate settlements -introduction of creep and stress relaxation by rheological models.

Mechanics of flow through soils: flow through soils -unidimensional - radial and Spherical flow cases -seepage forces quick sand and piping - flow nets of confined and unconfined flow by relaxation techniques - phreatic surfaces by conformal mapping -flow net for anisotropic non- homogeneous soils. Introduction to Unsaturated Soil Mechanics.

References

1.	**Mitchell, J.K., Fundamentals of Soil Behaviour, John Wiley, New York, 2005 third edition**
2.	**Scott R F, "Principles of Soil Mechanics", Addition Wesley Publishing Co. Inc., 1988**
3.	**Yong, R.N. and Warkentin, B.P., Introduction to Soil Behaviour, Macmillan, Limited, London, 1979**

4.	**Bowles, J.E, Physical and Geotechnical Properties of Soil, McGraw-Hill Book Company,1985.**
5.	**Gopal Ranjan and Rao, A.S.R, Basic and Applied Soil Mechanics, Wiley Eastern Limited, third edition 2016**
6.	**Das, B.M.,Principles of Geotechnical Engg, PWS Publishing Comp, Boston, seventh edition**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand the physio-chemical behavior of soils, including diffused double layer theory, soil-water interactions, and swelling and shrinkage behaviour**
CO2	**Comprehend soil fabric, compaction, and the concept of effective stress, and apply theories of stress distribution in soil.**
CO3	**Evaluate shear resistance in soils, including stress-strain relationships, failure criteria, and pore pressure in saturated and unsaturated soils.**
CO4	**Understand the mechanics of soil consolidation and apply Terzaghi's theory to estimate settlements and determine precompression history.**
CO5	**Analyze flow through soils, including unidimensional, radial, and spherical flow, and understand the concepts of quicksand, piping, and flow nets.**

Course Code	**:**	CE803
Course Title	**:**	**SOIL EXPLORATION AND FIELD TESTING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To recall the various soil investigation techniques**
CLO2	**To familiarize students with Geophysical techniques**
CLO3	**To make students understand the applications of Pressure Meter and dilatometer Testing**
CLO4	**To make students understand the drilling in difficult subsoil conditions**
CLO5	**To familiarize students with Instrumentations used in soil engineering**

Course Content

Principles of exploration; Modern methods of boring and sampling, advanced sampling techniques, offshore sampling; stabilization of boreholes; Preservation and transportation of samples; Basic Field tests - penetration tests - Field vane shear - plate load test – monotonic and cyclic; field permeability tests.

Geophysical exploration and interpretation - seismic and electrical methods; Electrical Resistivity Methods: Principle, Resistivity of soils and rocks, Resistivity Technique- Wenner and Schlumberger arrangements, Electrical Soundings, Methods of electrical resistivity profiling. Cross bore hole, single bore hole – up hole -down hole method. Analysis and interpretation of field test data

Pressure Meter Testing of Soils and Weak Rocks: Menard pressure meter equipment, Probe calibration and corrections, Limit pressure, Creep pressure, Tests in soils and weak rocks, Interpretation of test data, Pressure meter modulus of soils & weak rocks. Dilatometer Testing of Soils: Equipment and procedure of testing, Interpretation of test data, Geotechnical parameters of clay- OCR, k0, un-drained shear strength, soil stiffness, coefficient of consolidation, Geotechnical parameters of clay- friction angle, state parameter, soil stiffness,

Drilling in difficult subsoil conditions - various drilling techniques and limitations - In-situ shear Strength of Jointed Rocks: Equipment and test procedure, interpretation for peak and residual strength of rock mass. Measurement of In-situ Stresses in Rocks: Flat jack technique, Hydro-fracturing method - In-situ Deformation Modulus of Jointed Rocks : Goodman Jack test, Plate jacking test, Plate jacking test down the drill hole, radial jacking test etc., interpretation of test data. Post Failure Testing of Rocks: Servo-controlled uni-axial and tri-axial testing of different rock types, effect of confining pressure, brittle-ductile transition, effect of L/D ratio, Cyclic testing of rock cores, analysis and interpretation of test data

Instrumentation in soil engineering, strain gauges, resistance and inductance type, load cells, earth pressure cells, settlement and heave gauges, pore pressure measurements - slope indicators, sensing units, case studies.

References

1.	**Dunnicliff, J. and Green, G.E, Geotechnical Instrumentation for Monitoring Field Performance, John Wiley & Sons, 1982.**
2.	**GopalRanjan and Rao, A.S.R, Basic and Applied Soil Mechanics, Wiley Eastern Limited,1991**
3.	**Lunne, T., Robertson, P.K. and Powell, J.J.M, Cone Penetration Testing in Geotechnical Practice, Blackie Academic & Professional, 1997.**
4.	**Compendium of Indian Standards on Soil Engineering Parts 1 and II 1987 – 1988**
5.	**All related ASTM codes and Eurocode 7 - Part 2.**
6.	**Clayton, C. R. I., Matthews, M. C. and Simons, N. E. (1995) Site Investigation (Second Edition). Oxford, Blackwell Sciences..**
7.	**Hunt, R. E. (2005) Geotechnical Engineering Investigation Handbook (Second Edition), CRC Press Taylor & Francis Group**

8.	**Schnaid, F. (2009) In Situ Testing in Geomechanics : The Main Tests. Taylor & Francis**
9.	**Simons, N., Menzies, B. and Matthews, M. (2002) A Short Course in Geotechnical Site Investigation. Thomas Telford.**
10.	**Hudson, J. A., Harrison, J. P., “Engineering Rock Mechanics”, Pergamon Press 1997**
11.	**Ramamurthy, T., “Engineering in Rocks for Slopes, Foundations and Tunnels”, Prentice Hall. 2007**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To extract samples as per requirement and perform field and laboratory tests.**
CO2	**To understand the practical significance of the results obtained from geophysical test methods.**
CO3	**To be familiar with Pressure Meter and dilatometer testing and interpretation of test data.**
CO4	**To be exposed to measurement of in-situ stresses in rocks and post failure testing of rocks**
CO5	**To be exposed to Geotechnical Instrumentation for field monitoring**

Course Code	**:**	CE802
Course Title	**:**	**FOUNDATION ANALYSIS AND DESIGN**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To select and types of shallow foundations**
CLO2	**To analyse the load bearing capacity of soil.**
CLO3	**To estimate the settlement of foundations.**
CLO4	**To familiarize different types of deep foundation and Load carrying capacity of single pile as per codes**
CLO5	**To familiarize with Load carrying capacity of group piles as per codes**

Course Content

Introduction-Need of Foundation Engineering - Responsibility of Foundation Engineer-Types of foundations-General requirements of foundations-Additional Considerations-Modes of shear failure-Bearing capacity equations (Terzaghi’s, Meyerhof’s, Brinch Hansen’s, Vesic and IS code method)-Footings with eccentric loadings-Effect of water table on bearing capacity-Bearing capacity from in-situ tests (SPT, SCPT, DCPT and Field plate load tests) - Codal recommendations-Numerical Problems.

Bearing Capacity for footings on homogeneous and layered soils- near slopes-Bearing capacity of foundations with uplift or tension forces-Bearing capacity of foundations on rock- Bearing capacity based on Building codes (Presumptive pressure)-partial safety factor approach-Numerical Problems.

Settlement of foundations: Immediate settlement-Consolidation settlement and Secondary consolidation settlements-Codal provisions, construction period correction-stress path method of settlement evaluation-evaluation from insitu tests-Numerical problems. Contact pressure under footings – Contact pressure under rigid rectangular footing, strip foundation, rigid circular footing, Principles of footing design, Design of non – rigid combined footings. Numerical problems.

Load carrying capacity of piles by static formulae - Introduction: IS code method - API method - Piles in cohesive and cohesionless soils. Piles in layered cohesive and cohesionless soils – Settlement of single pile – Piles bearing on rock – Piles in fill and Negative skin friction.Load carrying capacity of piles by dynamic formulae: Introduction - Pile driving formulae - selection of pile hammers - Determination of temporary elastic compression - Driving stresses in piles - Field measurement - Wave equation analysis.

Group action in piled foundations: Introduction - Minimum spacing of piles - efficiency - bearing capacity - pile arrangement - installation methods - Settlement–I Pile-raft foundations. Pile subjected to lateral load: Introduction - Lateral resistance of single pile - IS 2911 - Broms charts– Elastic analysis - p-y curves, use of p-y curves - - field test on piles

References

1.	**Peck R.B., Hanson W.E. &Thornburg T.H., Foundation Engineering, Second Edition, Wiley , 1991.**
2.	**Braja M. Das., "Principles of Foundation Engineering", Thomson Asia Pvt Ltd, 1987.**
3.	**Tomlinson, M.J., Boorman R., Foundation design and construction, ELBS, Seventh Edition, Longman Group, U.K, 2001.**
4.	**Das B.M., Shallow Foundations: Bearing Capacity and Settlement, Third Edition, CRC Press, 2017.**
5.	**Bowles, J.E., Foundation Analysis and Design, Fifth Edition, McGraw Hill, New York, 1996.**
6.	**Varghese, P.C., Design of Reinforced Concrete Foundations, PHI Learning Pvt. Ltd., 2009.**
7.	**M. J. Tomlinson, "Pile Design and Construction Practice (6th Edition)", CRC Press, 2014**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To do select and types of shallow foundations**

CO2	**To do analyse the load bearing capacity of soil.**
CO3	**To gain to estimate the settlement of foundations.**
CO4	**To select appropriate foundation type based on available soil conditions and Load carrying capacity of single pile as per codes**
CO5	**To determine the load carrying capacity of group pile foundation**

Course Code	**:**	CE804
Course Title	**:**	**EARTH RETAINING STRUCTURES**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To apply classical and graphical techniques to determine earth pressures in various scenarios.**
CLO2	**To evaluate lateral pressures and the influence of compaction, wall flexibility, and drainage on retaining structures.**
CLO3	**To use free and fixed earth support methods for sheet pile wall design and anchor systems.**
CLO4	**To design solutions to manage lateral pressures and ensure stability against piping and bottom heaving.**
CLO5	**To apply slurry characteristics and stability analysis in designing diaphragm and bored pile walls.**

Course Content

Introduction – State of stress in retained soil mass – Earth pressure theories – Classical and graphical techniques – Active and passive cases – Earth pressure due to external loads, empirical method - Wall movement and complex geometry.

Retaining structure – Selection of soil parameters - Lateral pressure due to compaction, strain softening, wall flexibility, drainage arrangements and its influence. – Stability analysis of retaining structure both for regular and earthquake forces.

Types of sheet piles - Analysis and design of cantilever and anchored sheet pile walls – free earth support method – fixed earth support method - Design of anchor systems - isolated and continuous.

Lateral pressure on sheeting in braced excavation, stability against piping and bottom heaving. Earth pressure around tunnel lining, shaft and silos – Soil anchors – Soil pinning –Basic design concepts.

Basic principles – Slurry characteristics – Specifications - Diaphragm and bored pile walls – stability analysis and design

References

1.	**Winterkorn.H.F and Fang.H.Y, "Foundation Engineering Handbook", Galgotia Book- source, 2000.**
2.	**Day.R.W, "Geotechnical and Foundation Engineering: Design and Construction", McGraw Hill, 1999.**
3.	**Muni Budhu, Foundations and Earth Retaining Structures, Wiley, 2010.**
4.	**Clayton.C.R.I, Militisky, J. and Woods, R.I., "Earth pressure and Earth-Retaining structures" (Third Edition), Survey University Press, 2014**
5.	**McCarthy.D.F, "Essentials of Soil Mechanics and Foundations: Basic Geotechnics" (Sixth Edition), Prentice Hall, 2002.**
6.	**S.C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2014**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand earth pressure theories and their applications.**
CO2	**Analyze the stability of retaining structures under different conditions.**
CO3	**Design and analyze cantilever and anchored sheet pile walls.**
CO4	**Assess lateral pressures and stability in braced excavations and tunnel linings.**
CO5	**Master the design principles of diaphragm and bored pile walls**

Course Code	**:**	CE806
Course Title	**:**	**DYNAMICS OF SOILS AND FOUNDATIONS**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To interpret the concept of dynamics in Geotechnical Engineering.**
CLO2	**To predict liquefaction and suggest mitigation.**
CLO3	**To recognize the significance of soil-structure interaction**
CLO4	**To apply the principles of dynamics for the design of machine foundation**
CLO5	**To learn the principles and techniques for designing machine foundations, including vibration absorption and isolation methods.**

Course Content

Introduction - Nature of dynamic loads - free vibrations of spring - mass systems - forced vibrations - viscous damping - principles of vibration measuring equipment Dynamic stress - Deformation and strength of soils - Dynamics bearing capacity and earth pressure - Effect of transient and pulsating loads - Resonant column apparatus – Field - test-Typical values of soil constants - Liquefaction of soils - Factors influencing - Liquefaction potential - vibration table studies - Field tests - Analysis - from standard penetration data.

Engineering problems involving soil dynamics; Role of inertia; Theory of Vibrations: Single and two-degree freedom systems, vibration measuring instruments, vibration isolation, Wave propagation in elastic media - General nature of soil behaviour under cyclic/dynamic loading; Field and Laboratory tests for measurement of small strain and large strain, dynamic properties of soils - Design criteria for machine foundations, elastic homogeneous half space solutions, lumped parameter solutions - Codal provisions.

Response of SDOF systems: Free vibration, Experimental determination of natural frequency and damping, Response of system to exciting forces and ground motions ranging from simple pulse like excitation to harmonic and complex histories, Transmissibility, Vibration measuring instruments, Response of 2 DOF and Multi degree of freedom systems. Propagation of seismic waves in soil deposits - Attenuation of stress waves, Stress-strain behaviour of cyclically loaded soils, Strength of cyclically loaded soils

Effect of vibration on residual soil settlements, effect on porosity and hydraulic methods to reduce residual dynamic settlement of foundations, stress distribution in soil under dynamic loading.

Dynamic stiffness and damping constants of shallow and pile foundation. Vibration absorption and isolation techniques.

References

1.	**Shamsher Prakash, V K Puri, "Foundations for Machines: Analysis and Design", John Wiley & Sons, 1988.**
2.	**Swami Saran, "Soil Dynamics and Machine Foundation", Galgotia publications Pvt. Ltd., New Delhi 1999.**
3.	**K.G. Bhatia, "Foundations for Industrial Machines: Handbook for Practising Engineers", CRC Press, London, 2009.**
4.	**Krammer.S.L, "Geotechnical Earthquake Engineering", prentice hall, international series, Pearson Education (Singapore) Pvt. Ltd., 2004.**
5.	**Kameswara Rao, "Vibration Analysis and Foundation Dynamics", wheeler Publishing, New Delhi, 1998.**
6.	**Richart, F.E. Hall J.R and Woods R.D., Vibrations of Soils and Foundations, Prentice Hall Inc., 1970.**
7.	**Richart, F.E. Hall J.R and Woods R.D., Vibrations of Soils and Foundations, Prentice Hall Inc., 1970.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To interpret the principles of dynamics in Geotechnical Engineering.**
CO2	**To predict liquefaction and suggest measures for its mitigation.**
CO3	**To reason the response of any soil-structure system.**
CO4	**To apply the principles of soil dynamics.**
CO5	**To become the proficiency in designing machine foundations and implementing vibration isolation techniques based on dynamic analysis.**

Course Code	**:**	CE811
Course Title	**:**	**GEOTEXTILES FROM DESIGN TO APPLICATIONS**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**Identify types and applications of natural fibers used in geotextiles.**
CLO2	**To Conduct tests to determine the properties and behavior of geotextiles.**
CLO3	**To Evaluate long-term performance and sustainability aspects of geotextiles.**
CLO4	**To Apply geotextiles in practical scenarios like roads, railroads, and soft soil foundations.**
CLO5	**To Implement geotextile composites for multiple functions and specific applications in different fields.**

Course Content

Early background and history of geotextiles - Geotextile resins and additives – geotextile manufacturing processes - Geotextiles made from natural fibres - Types of natural fibres used as geotextiles - Application of natural fibre geotextiles.

Geotextile/geosynthetic testing standards development organizations – Geosynthetics Research Institute - International Standards Organization - Physical properties, behavior, and testing of geotextiles - Mechanical properties, behavior, and testing of geotextiles – Hydraulic properties, behavior, and testing of geotextiles.

Geotextile durability - Geotextile degradation modes - Long-term dynamic loading (fatigue) of geotextiles - Long-term geotextile degradation mechanisms and exposed lifetime predictions. Quality control and quality assurance for geotextiles - Sustainability aspects of using geotextiles.

Geotextiles used in separation - Geotextiles used in filtration - Geotextiles used in drainage - Geotextiles used in reinforcing paved and unpaved roads and railroads - Geotextiles used in reinforcing walls, berms, and slopes - Geotextiles used to reinforce soft soil foundations - Geotextiles use for cushioning.

Geotextile composites having multiple functions - Geotextiles in waste containment - Geotextiles in marine engineering - Geotextile tubes for dewatering and decontamination of fine-grained soils - Geotextiles in commercial development - Geotextiles in agriculture and aquaculture - Geosynthetics in erosion and sediment control.

References

1.	**Sanjay Kumar Shukla and Jian-Hua Yin, Fundamentals of Geosynthetic Engineering, CRC Press**
2.	**Moseley, M.P. and Kirsch, K. Ground Improvement, Spon Press, Taylor and Francis Group**
3.	**Robert M. Koerner., Designing with Geosynthetics, Pearson Prentice Hall.**
4.	**Rao G. V. and Rao, G. V. S. Text Book on Engineering with Geotextiles, Tata McGraw Hill**
5.	**Koerner, R. M. Designing with Geosynthetics, Prentice Hall, Englewood Cliffs, New Jersey, U.S.A.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand the history and manufacturing processes of geotextiles, including natural fiber geotextiles.**
CO2	**Learn about geotextile testing standards and their physical, mechanical, and hydraulic properties.**
CO3	**geotextile durability, degradation modes, and quality assurance practices.**
CO4	**Understand various applications of geotextiles in separation, filtration, drainage, and reinforcement.**
CO5	**Explore advanced uses of geotextiles in waste containment, marine engineering, and agriculture.**

Course Code	**:**	CE812
Course Title	**:**	**GEOMECHANICS -THEORY AND APPLICATIONS**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36

Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To Apply theories such as Kelvin's and Boussinesq's to solve geomechanics problems.**
CLO2	**To Use microstructural considerations and stress-strain relations to model soil behavior.**
CLO3	**To Evaluate elastic-plastic deformation in geomechanics problems.**
CLO4	**To Analyze soil pressures on retaining walls and the stability of footings and slopes.**
CLO5	**To Apply Cam-clay models to understand soil behavior under different conditions.**

Course Content

Elasticity problems in Geomechanics: Point Load Problems – Point loads acting normal to the surface of an elastic - half space - Kelvin's problem - Flamant's problem - Boussinesq's problem - Cerrutti's problem - Mindlin's problem - Applications in soil - foundation interaction - Failure & yield in soils: Concepts of failure and yield in soils - Failure theories.

Effective stresses in soils - Microstructural considerations - Stress - path concepts and their applications - Field equations & Constitutive model: Framework and field equations for continuum - stress - strain relations for soils - elastic model - elasto - plastic model.

Plasticity theory - Elastic - plastic Plane Deformation Analysis: Elastic - Plastic deformation of failure of slope - Penetration of wedge and load bearing capacity of sheet piles.

Theory of slip lines - Pressure of soils on retaining wall - Stability of footings - Slope stability Work hardening and modern theories for soil behaviour

Introduction - Work - hardening of metals - Introduction to Critical state soil mechanics - Cam - clay & Beyond Cam – clay – applications.

References

1.	**Atkinson, J.H. and Bransby, P.L, The Mechanics of Soils: An introduction to critical soil mechanics, McGraw Hill, 1978.**
2.	**Atkinson J.H, An introduction to the Mechanics of soils and Foundation,McGraw- Hill Co., 1993.**
3.	**Das, B.M., Advanced Soil Mechanics, Taylor and Francis, 2nd Edition, 1997**
4.	**Wood, D.M., Soil Behavior and Critical State Soil Mechanics, Cambridge University Press, 1990.**
5.	**Craig, R.F., Soil Mechanics, Van Nostrand Reinhold Co. Ltd., 1987.**
6.	**Terzaghi, K., and Peck, R.B., Soil Mechanics in Engineering Practice, John Wiley & Sons, 1967.**

7.	**Lambe, T.W. and Whitman, R.V., Soil Mechanics, John Wiley & Sons, 1979**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand key elasticity problems and their applications in soil-foundation interaction.**
CO2	**Analyze effective stresses in soils using stress-path concepts and constitutive models.**
CO3	**Apply plasticity theory to analyze slope failure and sheet pile bearing capacity.**
CO4	**Understand the application of slip line theory to soil pressure and stability analysis.**
CO5	**Gain insights into critical state soil mechanics and work-hardening theories.**

Course Code	**:**	CE813
Course Title	**:**	**FINITE ELEMENT METHODS IN GEOTECHNICAL ENGINEERING**
Type of Course	**:**	PC / PE / OE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**Understand the significance and applications of FEM in geotechnical engineering.**
CLO2	**Apply matrix algebra and variational principles to develop finite element models.**
CLO3	**Analyze one-dimensional and two-dimensional finite element problems.**
CLO4	**Develop three-dimensional finite element models and apply numerical integration techniques.**
CLO5	**Conduct practical geotechnical analyses including settlement, seepage, and consolidation using FEM.**

Course Content

Significance of FEM - Overview of FEM and its applications in geotechnical engineering - introduction to matrix algebra- Basics of matrix operations- Application in FEM - Introduction to variational principles and the concept of discretization - Rayleigh-Ritz procedures in structural mechanics as a prelude to finite element techniques - Continuum, stress & strain states - equations of equilibrium, compatibility & linear elastic constitutive equations

Derivation of equilibrium equations for continuum - One-dimensional finite elements: bar and beam elements - Two-dimensional finite elements: plane stress, plane strain, and axisymmetric elements - Shape Functions and Interpolation.

Three-dimensional finite elements: tetrahedral and hexahedral elements - Shape functions and interpolation - Lagrange methods for shape functions 3-node CST element for finite element analysis and some simple calculations using this element - Numerical integration techniques - Isoparametric transformations

Formulation of Stiffness Matrix, Boundary Conditions, Solution Algorithms - Choice of Soil Properties for Finite Element Analysis - Constitutive models for soils: linear elasticity, nonlinearity, and plasticity

Settlement Analysis, 2-D elastic solutions for homogeneous, isotropic medium - Steady Seepage Analysis: Finite element solutions of Laplace's equation, Consolidation Analysis: Terzaghi consolidation problem – Analysis of Foundation – Analysis of excavations and built-up embankments

References

1.	**Robert D. Cook, Concepts and Applications of Finite Element Analysis, Third Edition, John Wiley and Sons.**
2.	**C.S. Desai, J.F. Abel, Introduction to the Finite Element Method, A numerical Method for Engineering Analysis, East-West Edition, 1972.**
3.	**O.C. Zienkiewicz and R.L. Taylor, Finite Element Method, McGraw-Hill, 1991.**
4.	**K.J. Bathe, Finite element procedures, PHI Ltd., 1996**
5.	**R.D. Cook, D.S. Malkus. and M.E. Plesha, Concepts and applications of finite element analysis, John Wiley and Sons, Third edition, 1989**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Demonstrate knowledge of FEM principles and their significance in geotechnical engineering.**
CO2	**Apply mathematical and numerical methods to solve FEM problems.**
CO3	**Develop and analyze FEM models for various geotechnical applications.**
CO4	**Integrate soil properties and constitutive models in FEM analyses for effective geotechnical design and assessment.**
CO5	**Utilize FEM for practical geotechnical engineering problems, ensuring accurate and reliable results.**

Course Code	**:**	CE814
Course Title	**:**	**SLOPE STABILITY AND EARTH DAMS**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To determine earth pressures for different wall movements and geometries, considering factors like compaction and drainage**
CLO2	**To perform slope stability analysis using the Method of Slices and Bishop's method.**
CLO3	**To conduct seepage analysis and design flow nets for earth and rock fill dams under various conditions.**
CLO4	**To design slope protection systems, filters, and foundations using geosynthetic materials**
CLO5	**To classify landslides, analyse triggering factors, and apply remediation techniques and early warning systems.**

Course Content

Introduction – State of stress in retained soil mass – Earth pressure theories – Classical and graphical techniques – Active and passive cases – Earth pressure due to external loads, empirical methods - Wall movement and complex geometry - Lateral pressure due to compaction, strain softening, wall flexibility, influence of drainage

Seismic Slope Stability – Slope stability analysis –Stability of infinite and finite slopes, Method of Slices, Bishop's method, Flow nets, Design consideration, Factors influencing design, Collection and analysis of geological data, field survey and testing, graphical presentation of geological data and evaluation of potential slope problems

Types of earth and rock fill dams, Design details, Provisions to control pore pressure - Stability conditions during construction, Full reservoir and drawdown - cut off walls – Trenches – Importance of drainage and filters, Seepage analysis, in-situ permeability tests, two-dimensional flow – Laplace equation and it's solution, graphical method, determination of phreatic line, flow nets in homogeneous and zoned earth dams under steady seepage and draw-down conditions, seepage control in earth dams

Special design problems, Slope protection, Filter design, Foundation treatment, Earth dams on pervious soil foundation, Application of Geosynthetic materials in filtration - Treatment of rock foundation, Construction Techniques, Quality control and performance measurement.

impacts of landslides; importance of landslide engineering: classification of landslides, landslide triggering factors; hillslope geomorphology and hydrology factors for rainfall induced landslides. laboratory investigations for landslide analyses. Groundwater system analysis for landslides, Remediation techniques, Early warning systems, Disaster Mitigation, Sustainability and environmental issues

References

1.	**Cheng, Y.M., Lau, C.K., 2014. Slope Stability Analysis and Stabilization New methods and Insights, edition 2**
2.	**Fenton, G.A., Griffiths, D.V., 2008. Risk Assessment in Geotechnical Engineering, John Wiley & Sons.**
3.	**Lu, N., Godt, J.W., 2013, Hillslope Hydrology and Stability, Cambridge University Press.**
4.	**Creager, W.P. Justin D, and Hinds, J., Engineering for Dams Vol. I, II and III.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Analyze earth pressures in retained soil masses using classical and graphical methods for various conditions.**
CO2	**Evaluate slope stability using methods like the Method of Slices and Bishop's method under seismic conditions**
CO3	**Design earth and rock fill dams with stability provisions for construction, reservoir conditions, and drawdown scenarios**
CO4	**Address design issues including slope protection, filter design, and foundation treatments using geosynthetic materials**
CO5	**Understand landslide impacts, triggering factors, and implement remediation and early warning systems**

Course Code	**:**	CE815
Course Title	**:**	**GROUND IMPROVEMENT TECHNIQUES**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To understand ground improvement methods to address challenges associated with problematic soil**
CLO2	**To familiarize with mechanical modification methods and deep replacement techniques**
CLO3	**To define the concept of hydraulic modification and grouting methods.**
CLO4	**To study the soil stabilization methods for problematic soils.**

CLO5	**To study the concepts of in-situ ground reinforcement and geo-synthetics for various purposes**

Course Content

Introduction - Engineering properties of soft–weak and compressible deposits – problematic geomaterials and conditions – Requirements of ground improvement – ground improvement methods and classification -Selection of ground improvement methods.

Mechanical Modification – shallow compaction and deep dynamic compaction – rapid impact compaction – vibro compaction – Deep replacement techniques- sand compaction columns – stone column – geosynthetic encased granular column – design - estimation of load carrying capacity

Hydraulic modification- Drainage by well points, deep wells, vacuum and electroosmosis dewatering method - Preloading with sand drains - prefabricated vertical drain - design

Soil stabilization – stabilization of problematic soil - chemical methods – Stabilization with lime and cement – utilization of industrial wastes for soil stabilization – biological stabilization methods – liquefaction mitigation methods Grouting – Deep jet mixing methods - Stabilization by thermal and freezing techniques – Applications

In-situ ground reinforcement – soil nailing – ground anchors – geosynthetics - earth reinforcement –Synthetic and natural fiber-based Geotextiles and their applications – Filtration – drainage – separation - erosion control - Reinforced earth wall – Mechanism – Simple design – Applications of reinforced earth

References

1.	**Hausmann, M. R., Engineering Principles of Ground Modification, McGraw – Hill International Editions, 1990**
2.	**Han,Jie, Principles and Practice of Ground Improvement, John Wiley and Sons, New Jersey, Canada2015.**
3.	**Purushotham Raj, Ground Improvement Techniques, Laxmi Publications, New Delhi, 1996**
4.	**Klaus Krisch, Alan Bell, Ground Improvement (3rd Edition), CRC Press, London, 2012**
5.	**Jones C. J. F. P, Earth Reinforcement and Soil Structures, Butterworths, London, 1988**
6.	**Moseley M. P., Ground Improvement, Blockie Academic and Professional, Chapman and Hall, Glassgow, 1993**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To be identify problematic soils and select appropriate ground improvement methods.**

CO2	**To be understand mechanical modification and deep replacement techniques**
CO3	**To be understand the concept of hydraulic modification methods**
CO4	**To suggest soil stabilization techniques for problematic soils**
CO5	**To be utilize in-situ ground reinforcement techniques and geo-synthetics for various purposes**

Course Code	**:**	CE816
Course Title	**:**	**ANALYSIS OF DEEP FOUNDATION**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To Identify and choose appropriate foundation types, including deep and pile foundations, based on governing factors and materials.**
CLO2	**To Apply IS code and API methods to determine pile capacity in different soil conditions, including settlement considerations.**
CLO3	**To Utilize pile driving formulae and wave equation analysis to determine pile capacity and driving stresses.**
CLO4	**To Estimate group bearing capacity, analyze pile group effects, and assess differential settlement in pile groups, including pile-raft foundations.**
CLO5	**To Use IS 2911, Broms charts, and p-y curves to evaluate and improve the lateral resistance of piles, and perform field tests for verification.**

Course Content

Functions and requisites of a foundation - Different types - Choice of foundation type – Types of deep foundation – Types of pile foundations - Factor governing choice of type of pile – Choice of pile materials.

Load carrying capacity of piles by static formulae - Introduction: IS code method - API method - Piles in cohesive and cohesionless soils – Piles in layered cohesive and cohesionless soils – Settlement of single pile – Piles bearing on rock – Piles in fill and Negative skin friction.

Load carrying capacity of piles by dynamic formulae: Introduction - Pile driving formulae - selection of pile hammers - Determination of temporary elastic compression - Driving stresses in piles - Field measurement - Wave equation analysis.

Group action in piled foundations: Introduction - Minimum spacing of piles - group efficiency - Estimation of group bearing capacity - Effect of pile arrangement - Effect on pile groups of installation methods - precaution against heave effect in pile group -

Settlement of pile group – Evaluation of differential settlement in pile group – I Pile-raft foundations.

Pile subjected to lateral load: Introduction - Lateral resistance of single pile - IS 2911 method for lateral resistance of pile - Broms charts for lateral load analysis – Elastic analysis - p-y curves, use of p-y curves - improving lateral resistance of piles - field test on piles

References

1.	**Poulos H.G, Tall Building Foundation Design (1st Edition), CRC Press, London, 2017.**
2.	**J. E. Bowles, "Foundation Analysis and Design", McGraw Hill, 1996.**
3.	**M. J. Tomlinson, "Pile Design and Construction Practice (6th Edition)", CRC Press, 2014.**
4.	**Braja M. Das., "Principles of Foundation Engineering", Thomson Asia Pvt Ltd, 1987.**
5.	**P. C. Varghese, "Foundation Engineering", Prentice-Hall of India, New Delhi, 2005.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand the functions, requisites, and types of foundations.**
CO2	**Calculate the load carrying capacity of piles using static formulae.**
CO3	**Analyze the load carrying capacity of piles using dynamic formulae.**
CO4	**Evaluate the behavior and efficiency of piled foundation groups.**
CO5	**Assess lateral load resistance of piles.**

Course Code	**:**	CE817
Course Title	**:**	**MACHINE FOUNDATION**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To estimate the dynamic properties of soils required for analysis and design of machine foundations.**
CLO2	**To understand the behaviour of different types of machine foundations.**
CLO3	**To analyse and design different types of machine foundations**
CLO4	**To analyse and design vibration isolation systems.**

CLO5	**To Implement vibration isolation techniques and evaluate IS code provisions for designing machine foundations.**

Course Content

Criteria for a satisfactory machine foundation - permissible amplitude of vibration for different type of machines - methods of analysis of machine foundations - methods based on linear elastic weightless springs - methods based on linear theory of elasticity (elastic half space theory) - methods based on semi graphical approach.

Degrees of freedom of a block foundation - definition of soil spring constants - nature of damping - geometric and internal damping - determination of soil constants – methods of determination of soil constants in laboratory and field based on IS code provisions –

Framed Foundations: Framed foundations, their advantage for high-speed machines; Permissible amplitudes, design principles. Vertical, sliding, rocking and yawing vibrations of a block foundation - simultaneous rocking, sliding and vertical vibrations of a block foundation.

Foundation of reciprocating machines - design criteria - calculation of induced forces and moments - multi-cylinder engines - numerical example (IS code method) – Foundations subjected to impact loads - design criteria - analysis of Vertical vibrations - computation of dynamic forces - design of hammer foundations (IS code method).

Vibration isolation - Methods of decreasing vibrations on existing foundation. active and passive isolation - transmissibility - methods of isolation in machine foundations.IS Code of Practice: Critical review of IS code provisions for design of machine foundations

References

1.	**Swami Saran, “Soil Dynamics and Machine Foundation”, Galgotia publications Pvt. Ltd., New Delhi 1999**
2.	**K.G. Bhatia, “Foundations for Industrial Machines: Handbook for Practising Engineers”, CRC Press, London, 2009**
3.	**Sreenivasalu and Varadarajan, Handbook of Machine Foundations, Tata McGraw-Hill, 2007**
4.	**Prakash.S and Puri.V.K, “Foundations for machines”, McGraw Hill, 1987.**
5.	**Kameswara Rao, "Vibration Analysis and Foundation Dynamics", wheeler Publishing, New Delhi, 1998**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To estimate the dynamic properties of soils required for analysis and design of machine foundations.**
CO2	**To define the behaviour of different types of machine foundations.**

CO3	**To analyse and design different types of machine foundations**
CO4	**To analyse and design vibration isolation systems**
CO5	**Apply active and passive vibration isolation methods to reduce vibrations in existing foundations and critically review IS code provisions for machine foundation design.**

Course Code	**:**	CE818
Course Title	**:**	**MARINE FOUNDATION ENGINEERING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To emphasize the importance of offshore soil investigations for offshore structures**
CLO2	**To analysis the response of foundations of gravity structures under offshore environmental loading**
CLO3	**To analysis the foundation response of jacket under static and dynamic loading**
CLO4	**To analysis the foundation response jack-up platforms under static and dynamic loading**
CLO5	**To provide a suitable foundation system for mooring structures and offshore pipe lines**

Course Content

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 – sampling disturbances – mechanical and environmental, In-situ determination of strength of submarine soils – penetrometer, piezocone, vane and pressure meter techniques – Penetration tests from tethered submersible
platforms, manned submersibles and using wire line techniques - 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 sub continent.

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.

Foundation for jacket type structures: Types – installation techniques – design considerations – axial and lateral load capacity of piles

Foundations for jack up platforms: Types of jack up platforms – piles and mat supported – spud cans – different types – installation techniques – techniques for removal of jack ups – 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)

References

1.	**Arous, D.A. (Ed.), Offshore Site Investigation, Graham Trotman**
2.	**Chaney, R.C and Demars, K.R , Strength Testing of Marine Sediments – Laboratory and In-situ Measurements, ASTM, STP-883**
3.	**George P. and Wood D., Offshore Soil Mechanics, Cambridge University Press.**
4.	**Le Tirant, Sea Bed Reconnaissance and offshore Soil Mechanics for the Installation of Petroleum Structures, Gulf Publ. Company**
5.	**Poulos, H.G and Davis, E.H, Pile Foundation Analysis Design, John Wiley, New York**
6.	**Randolph, M., & Gourvenec, S. (2017). Offshore geotechnical engineering. CRC press.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Recommend suitable offshore investigation techniques for the proposed project and able to provide appropriate soil design parameters**
CO2	**Perform foundation analysis for gravity structures offshore structures**
CO3	**Perform foundation analysis for jacket kind offshore structure**
CO4	**Perform foundation analysis for jack-up kind offshore structure**
CO5	**Analysis suitable anchor system for mooring structures and able to provide foundation system for offshore pipeline..**

Course Code	:	CE819
Course Title	:	**SOIL STRUCTURE INTERACTION**
Type of Course	:	PE
Prerequisites	:	NIL
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To familiarize students with model analysis, Winkler model for soil structure interaction analysis.**

CLO2	**To expose students to beams and plates on elastic foundation.**
CLO3	**To apply FEM, finite differences, and relaxation techniques to analyze geotechnical interaction problems and design computer programs for beams, footings, and rafts.**
CLO4	**To enable students to carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction.**
CLO5	**To make students understand the concepts of laterally loaded pile**

Course Content

Soil-Foundation Interaction: Introduction to soil-foundation interaction problems, Soil behaviour, Foundation behaviour, Interface behaviour, Scope of soil foundation interaction analysis, soil response models, Winkler, Elastic continuum, two parameter elastic models, Elastic plastic behaviour and Time dependent behaviour.

Beam on Elastic Foundation - Soil Models: Infinite beam, two parameters, Isotropic elastic half space, Analysis of beams of finite length - Classification of finite beams in relation to their stiffness. Plate on Elastic Medium: Thin and thick plates, Analysis of finite plates, Numerical analysis of finite plates, simple solutions.

Application of finite element method, finite differences, relaxation and interaction - Preparation of comprehensive design oriented computer programmes for specific problems- Interaction problems based on the theory of sub-grade reaction such as beams, footings, rafts, bulkheads etc-Analysis of different types of frame structures founded on stratified natural deposits with linear and nonlinear stress-strain characteristics.

Elastic Analysis of Pile: Elastic analysis of single pile, Theoretical solutions for settlement and load distributions, Analysis of pile group, Pile-cap pile-soil interaction, Load distribution in groups with rigid cap. Laterally Loaded Pile: Load deflection prediction for laterally loaded piles, Subgrade reaction and elastic analysis, Interaction analysis, Pile-raft system, Solutions through influence charts – Anchor piles and determination of pull out resistance; Well foundations.

Dynamics of foundations: Foundation input motion, Foundation embedded in a layered halfspace, Seismic soil structure interaction analysis in time domain for buildings and bridges.Examples and Case studies

References

1.	**Kameswara Rao N.S.V., Foundation Design – Theory and Practice, John Wiley & Sons (Asia), 2011.**
2.	**Poulos H.G, Tall Building Foundation Design (1st Edition), CRC Press, London, 2017.**
3.	**J. E. Bowles, “Foundation Analysis and Design”, McGraw Hill, 1996.**
4.	**J. W. Bull, Soil-Structure Interaction: Numerical Analysis and Modelling, CRC Press, 1st Edition, 1994.**
5.	**Chandrakant S. Desai, Musharraf Zaman, Advanced Geotechnical Engineering: Soil-Structure Interaction using Computer and Material Models, CRC Press, 2013.**

6.	**J.E., Bowles, Analytical and Computer Methods in Foundation Engineering, McGraw-Hill Book Co., New York, 1974.**
7.	**C.S. Desai and J.T. Christian (Eds.), Numerical Methods in Geotechnical Engineering, McGraw-Hill Book Co., Yew York.**
8.	**Elastic Analysis of Soil-foundation Interaction, Developments in Geotechnical Engineering, Vol.17, Elsevier Scientific Publishing Co.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To understand soil foundation interaction and its importance.**
CO2	**To be familiar with model analysis, Winkler model for soil structure interaction analysis**
CO3	**To be exposed to beams and plates on elastic foundation**
CO4	**To carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction**
CO5	**To better understand the concepts of laterally loaded pile**

Course Code	**:**	CE820
Course Title	**:**	**GEOTECHNICAL CONSTITUTIVE MODELLING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To understand stress-strain laws of soils and various elastic and plastic models.**
CLO2	**To learn Mohr-Coulomb and Tresca models, including their formulation for finite element analysis.**
CLO3	**To study critical state models, including Drucker-Prager and HiSS models.**
CLO4	**To gain knowledge in finite element analysis of soils, including two-phase formulation and transient response.**
CLO5	**To analyze the transient response of saturated soils using two-phase formulation and finite element methods, focusing on consolidation and liquefaction.**

Course Content

Stress-Strain Laws of Soils Stress and strain invariants, linear and bilinear elastic laws; K-G model, nonlinear elastic models (hyperbolic models), elasto-plastic and elastoviscoplastic models; Basic concepts of plasticity, yield function, flow rules-dilatancy, strain hardening and softening laws. Compression behaviour and plasticity, behaviour of Cam Clay under drained and undrained loading, relationship between undrained shear strength, effective stress and over-consolidation ratio, generalised equations of state boundary surface.

Mohr-Coulomb and Tresca Models: Yield functions, derivation of constitutive matrix; Formulation suitable for finite element analysis.

Critical State Models: Yield function, hardening law, soil parameters; Drucker-Prager Model, HiSS models and their performance. Bounding Surface Models: Multi-surface model, Dafalias two surface model; Kinematics hardening laws, soil parameters

Basic Formulation of Soil in Finite Element Analysis: Static and quasi static problems; Drained, undrained analysis and their discretisation in finite element procedure; Consolidation transient and its discretisation statement; Drained and undrained dynamic analysis.

Two Phase Formulation: Two phase formulation of saturated soil; Finite element discretisation of saturated soil; Transient response of saturated soil, consolidation, liquefaction.

References

1.	**A.N. Schofield, Disturbed soil properties and geotechnical design, Thomas Telford, 2006**
2.	**A.M. Britto and M.J. Gunn, Critical State Soil Mechanics via Finite Elements, Ellis Horwood, Chichester, 1987**
3.	**D.M. Wood, Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, New York, 1990**
4.	**M.D. Bolton, A Guide to Soil Mechanics, McMillan, London, 1984**
5.	**P.K. Banerjee and R. Butterfield, Advanced geotechnical analyses, Elsevier Science Publishers, Cambridge University Press, 1991**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Ability to apply stress-strain invariants and elastic laws to soil behavior.**
CO2	**Competence in using Mohr-Coulomb and Tresca models for geotechnical analysis.**
CO3	**Proficiency in critical state models and understanding soil parameters and yield functions.**
CO4	**Skills in finite element analysis for static, quasi-static, and dynamic problems in soil mechanics.**
CO5	**Capability to analyze and simulate the transient response of saturated soils, including consolidation and liquefaction.**

Course Code	**:**	CE821
Course Title	**:**	**ROCK MECHANICS**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**Understand the geological formation, classification, and characteristics of different rock types, including the rocks of Peninsular India and the Himalayas.**
CLO2	**Analyze the physical and mechanical properties of rocks and apply laboratory and field testing methods, including geophysical exploration techniques.**
CLO3	**Classify rock masses using established systems and evaluate failure criteria for rocks and rock masses.**
CLO4	**Design and evaluate tunneling methods and support systems, considering various subsoil conditions and rock types.**
CLO5	**Conduct stress analysis, implement instrumentation for monitoring tunnels, and apply ground improvement techniques to manage tunneling challenges.**

Course Content

Introduction to Rock Mechanics and Tunneling - Objective, scope, and associated challenges - Historical development and significance - Geological Formation and Classification of Rocks - Rocks of Peninsular India and the Himalayas- Discontinuities in Rock - Types, characteristics, and importance - Methods for mapping and analyzing discontinuities

Physical and Mechanical Properties of Rocks - Laboratory Testing of Rocks - Sampling and preparation techniques - Field Testing Methods - In-situ shear and tensile tests - Geophysical Methods for Rock Exploration- Characterization of intact Rock- strength, deformability, Hoek-Brown failure criterion- Empirical and analytical methods for determining rock properties – effect of temperature and weathering.

Characterization of Rock mass - Rock Mass Classification Systems - Rock and Rock Mass Failure Criteria - Mohr-Coulomb, Hoek-Brown criteria, and other empirical models - Stress-strain behavior, failure mechanisms, and influencing factors - Advanced failure models – Flow through rock mass – in-situ permeability test in jointed rocks.

In-situ stress, flat jack, hydraulic fracturing and over coring techniques and USBM type drill hole deformation gauge, single and multi-point borehole extensometers, load cells, pressure cells, etc

Applications of Rock Mechanics - Stability analysis of slopes: methods, factor of safety, remedial measures - Design principles for underground excavations: tunnels,

caverns, shafts. Foundations of Weak Rocks: Bells approach, bearing capacity based on classification
approaches, UCS, plate load test, special considerations, dam foundations

References

1.	**Hudson J.A. and Harrison J.P., "Engineering Rock Mechanics – An Introduction to the principles", Pergamon, 1997.**
2.	**Goodman.R.E, "Introduction to rock mechanics", John Willey and Sons, 1989.**
3.	**Hook.E and Bray.J, "Rock slope Engineering, Institute of Mining and Metallurgy", U.K. 1981.**
4.	**Hook.E and Brown.E.T, "Underground Excavations in Rock", Institute of Mining and Metallurgy, U.K. 1981.**
5.	**Obvert.L and Duvall.W, "Rock Mechanics and the Design of structures in Rock", John Wiley, 1967**

Course Outcomes (CO)

At the end of the course student will be able to

CO1	**Demonstrate comprehensive knowledge of rock mechanics and geological aspects relevant to tunneling.**
CO2	**Apply appropriate testing methods to determine rock properties and characterize rock masses effectively.**
CO3	**Evaluate rock mass classification systems and apply failure criteria in practical scenarios.**
CO4	**Design tunnels and foundations on rock, employing suitable excavation and support techniques.**
CO5	**Conduct stress analysis and utilize instrumentation and ground improvement methods to ensure the safety and stability of tunneling projects.**

Course Code	**:**	CE822
Course Title	**:**	**UNSATURATED SOIL MECHANICS**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To study about the basic definitions and variables involved in unsaturated soil mechanics.**
CLO2	**To familiarize with the water retention behavior of soil with associated physical mechanisms.**

CLO3	**To understand the state of art of suction measurement and controlling techniques to predict Soil water characteristic curve.**
CLO4	**To understand the various concepts in flow and shear strength estimation in unsaturated soils.**
CLO5	**To realize the importance in volume change aspect in unsaturated state of soil.**

Course Content

Introduction to Unsaturated soil mechanics and its application- State variables – material variables – constitutive laws- Physical properties of Air and water – partial pressure and relative Humidity - Density of moist air – surface Tension – cavitations of water - dissolution of air in water – Air-water solid interface – vapor pressure- Kelvin’s equation.

Unsaturated Soil phase system – concept of water retention – capillarity concept - suction potential of soil water- total, matric and osmotic suction - Soil water characteristic-curve (SWCC) - Hysteresis in SWCC – Effective stress parameter- stress tensor.

Suction measurements - psychrometers – Hanging column technique - Filter paper measurement of matric suction – Pressure plate apparatus - High Air Entry disks – Direct measurements – Tensiometers – Axis-translation technique – Indirect measurements –measurement of osmotic suction – squeezing technique- vapor equilibrium technique – SWCC curve fitting models- Pseudo transfer function- Software demonstration.

Steady and transient flow through unsaturated soil media – Laboratory techniques - Hydraulic conductivity models - 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- analytical representation of stress – volume change characteristics.

Identification and classification of expansive and collapsing soils, Laboratory evaluation of swell pressure and swell potential, tests to evaluate collapse potential

References

1.	**Lu, N. and Likos, W.J., Unsaturated soil mechanics, Wiley, 2004 (2)**
2.	**Fredlund, D. J., Rahardjo, R., and Fredlund, M.D. Unsaturated Soil Mechanics in Engineering Practice, Wiley, 2012.**
3.	**Ng C.W.W and Menzies B, Advanced unsaturated soil mechanics and engineering, CRC Press, 2019.**
4.	**Murray E.J, Sivakumar V., Unsaturated Soils: A fundamental interpretation of Soil behaviour, Wiley-Blackwell, 2010.**
5.	**Jean-Louis**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To understand the stress state variables, material variables and constitutive law of unsaturated soil.**
CO2	**To understand the various physical mechanism of soil-water interaction and have a idea on concept of soil water characteristic curve.**
CO3	**To understand the techniques for suction measurement and select the suitable SWCC fitting model.**
CO4	**To understand about the evaluation of flow and shear strength characteristics of soil in unsaturated state.**
CO5	**To understand the volume change behaviour of problematic soisl in unsaturated state.**

Course Code	**:**	CE823
Course Title	**:**	**DESIGN OF UNDERGROUND EXCAVATION**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To Apply stereographic projection and geotechnical investigation techniques to underground excavation design.**
CLO2	**To Design temporary and permanent tunnel support systems and solve challenges in different ground conditions.**
CLO3	**To Use Kirsch and Greenspan's methods for stress analysis and ensure safety through instrumentation and monitoring.**
CLO4	**To Apply finite element and elastoplastic analysis to tunnel design and evaluate stress conditions.**
CLO5	**To Design and evaluate support systems including rock bolts, shotcrete linings, and steel sets, and assess load carrying capacity.**

Course Content

Introduction, planning of and exploration for various underground construction projects Stereographic projection method, principle and its application in underground excavation design – geological and geotechnical investigations-Tunnel Excavation Methods- - Tunneling in various subsoil conditions and rocks: challenges and solutions - Tunnel Support Systems - Temporary and permanent support systems- Application of rock mass classification systems, ground conditions in tunneling, analysis of underground openings in squeezing and swelling ground,

Stress Analysis Around Underground Excavations – Kirsch equation and its applications - Greenspan's method for stress analysis - Concepts for lined, unlined, and pressure tunnels - Instrumentation and Monitoring in Tunnels - Instruments used:

inclinometers, piezometers, extensometers, strain gauges - Ensuring safety and performance through instrumentation

Elastic stress distribution around tunnels, stress distribution for different shapes and under different in-situ stress conditions, introduction to numerical modeling techniques (e.g., finite element method) for tunnel design – elastoplastic analysis of tunnels – application of Daemen's theory in tunnel design

Empirical methods, estimation of elastic modulus and modulus of deformation of rocks; uni axial jacking/plate jacking tests, radial jacking and Goodman jacking tests, long-term behavior of tunnels and caverns, construction dewatering

Rock mass-tunnel support interaction analysis, ground response, and support reaction curves, design of various support systems including concrete and shotcrete linings, steel sets, rock bolting and rock anchoring, combined support systems, estimation of load carrying capacity of rock bolts, Design of foundation on Rock – Bearing capacity of rock- Case studies of foundation design on rock

Instrumentation and monitoring of underground excavations, during and after construction, various case studies

References

1.	**Hoek, E and and Brown, E. T.," Underground Excavations in Rocks", Institute of Mining Engineering**
2.	**Singh, B. and Goel, R.K., "Tunnelling in Weak Rocks", Elsevier**
3.	**Obert, L. and Duvall, W.I., "Rock Mechanics and Design of Structures in Rocks", John Wiley.**
4.	**Ramamurthy, T., "Engineering in Rocks", PHI Learning.**
5.	**Y. O. Chang, Deep Excavation Theory and Practice, Taylor & Francis Group, London, UK, 2006.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand planning and exploration methods for underground construction.**
CO2	**Learn tunneling methods and support systems for various subsoil and rock conditions.**
CO3	**Analyze stress distribution around tunnels using various methods.**
CO4	**Understand elastic stress distribution and numerical modeling techniques for tunnel design.**
CO5	**Analyze rock mass-tunnel support interaction and design support systems.**

Course Code	**:**	CE824
Course Title	**:**	**GEOTECHNICAL EARTHQUAKE ENGINEERING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To study the theory of vibration and mechanism of earthquake.**
CLO2	**To understand the concept of ground motion and the process of estimating the frequency.**
CLO3	**To analyse the seismic force and the foundation provided to resist that seismic forces**
CLO4	**Analyze and design geotechnical structures for seismic conditions using advanced methods and code recommendations.**
CLO5	**Conduct risk mapping and hazard assessment, implement mitigation measures, and apply seismic microzonation and design code recommendations in geotechnical earthquake engineering.**

Course Content

Mechanism of Earthquakes - Causes of earthquake - Earthquake Fault sources - Elastic Rebound theory - Seismic wave in earthquake shaking - terminology - Locating an earthquake - Quantification of earthquakes.

Earthquake ground motion – Seismograph, Characteristics of ground motion, Effect of local site conditions on ground motions, Design earthquake, Design spectra, Site-specific and code-based design. Ground response analysis – One-dimensional ground response analysis: Linear approaches, Equivalent linear approximation of non-linear approaches, Computer applications.

Seismic site investigations – Selected Case Studies - Evaluation of Dynamic soil properties – Codal Provisions. Response of foundations, slopes and retaining walls to earthquake - Earthquake Resistant Design of foundations, slopes and retaining walls – Codal Provisions.

Liquefaction and lateral spreading - Liquefaction related phenomena, Liquefaction susceptibility: Historical, Geological, Compositional and State criteria. Evaluation of liquefaction by cyclic stress and cyclic strain approaches, Lateral deformation and spreading, Criteria for mapping liquefaction hazard zones

Risk mapping - Hazard assessment – Mitigation measures - Seismic micro zonation and its importance. Recommendations of Seismic Design Codes related to Geotechnical Earthquake Engineering.

References

1.	**Steven L. Kramer, "Geotechnical Earthquake Engineering", Prentice Hall Inc.1996.**
2.	**Robert W. Day, "Geotechnical Earthquake Engineering Handbook", McGraw Hill, New York, 2001.**
3.	**Ikuo Towhata, "Geotechnical Earthquake Engineering", Springer-Verlag Heidelberg, 2008.**
4.	**Kenji Ishihara, "Soil Behaviour in Earthquake Geotechnics", Oxford University Press, USA, 1997.**
5.	**Takaji Kokusho, Innovative Earthquake Soil Dynamics, CRC Press, 2017**
6.	**IS 1893, Indian Standard Criteria for earthquake resistant Design of Structures.**
7.	**Indian Standard Criteria for Earthquake Resistant Design of Structures, New Delhi. 5. B.M. Das (2011).**
8.	**Dynamic Soil-Structure Interaction for Sustainable Infrastructures. Springer, Switzerland, Online ISBN: 978-3-030-01920-4; Print ISBN: 978-3-030-01919-8, pp. 1-230. 8. D. Choudhury (2013)**
9.	**Geotechnical Earthquake Engineering, NPTEL Video course. http://nptel.ac.in/courses/105101134/**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To conduct site investigations, evaluate dynamic soil properties, and understand soil improvement techniques.**
CO2	**To design earthquake-resistant foundations and retaining walls, assess slope stability, liquefaction susceptibility, and develop design ground motions.**
CO3	**To create risk maps, perform hazard assessments, develop mitigation strategies, understand seismic microzonation, and follow design code recommendations.**
CO4	**To assess reinforced slope stability, design seismic-resistant retaining walls, apply pseudo-static/dynamic analysis, and evaluate foundation bearing capacity and settlement under seismic conditions.**
CO5	**To implement soil improvement techniques for seismic hazard mitigation and adhere to seismic design code recommendations in geotechnical earthquake engineering projects.**

Course Code	**:**	CE825
Course Title	**:**	**GEOENVIRONMENTAL ENGINEERING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL

Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To identify the sources of soil contamination and its impact on geoenvironment.**
CLO2	**To familiarize with the retention and flow behavior of contaminants in soil.**
CLO3	**To realize the significance of sampling techniques in geoenvironmental**
CLO4	**characterization.**
CLO5	**To understand the state-of-the-art methodologies for soil decontamination and containment.**

Course Content

Role of Geoenvironmental Engineering – Soil phase systems - Basic concepts related to soil pollution – Evolution of waste materials – Risk assessment - potential reuse-waste disposal methods – Types and impact of contaminants – soil - waste interaction – design of Engineered Landfill- types.

Physical and physio-chemical mechanisms- diffuse double layer- Sorption characteristics –Adsorption, absorption mechanisms- Adsorption measurements (Batch and Column tests) - Isotherms – Retention behavior - Contaminant transport-saturated, unsaturated and coupled flow.

Site investigation for geoenvironmental problems - Soil sampling - sample handling, transportation, characterization, preservation and storage – Soil properties - Mineralogical characterization of soil and waste - pore size distribution- swell and shrink cycle – cracking and thermal characteristics of soil- Non-destructive techniques - electromagnetic, thermal imagery and seismic techniques.

Soil remediation - need and approach, Techniques – Basis of selection of techniques - soil washing, Chemical surfactants - permeable reactive barriers, solidification, Soil air sparging- vacuum extraction, electro-kinetic remediation with mechanisms, thermal desorption- soil fracturing- Bioremediation – microbial transformations - phytoremediation.

Case studies on polluted sites and issues related to the environment - Containment systems and basic principles – carbon dioxide sequestration, Grout curtains, Ground freezing, Compacted soil liners, Geosynthetic clay liners - Environmental laws and regulations.

References

1.	**Acar, Y.B. and Daniel, D.E., "Geoenvironmental 2000: Characterization, Containment, Remediation & Performance in Environmental Geotechnics, ASCE, NY.**

2.	**Reddi L.N. and Inyang, H. I., "Geoenvironmental Engineering, Principles and Applications" Marcel Dekker Inc. New York, 2000.**
3.	**Hari D. Sharma and Krishna R. Reddy, Geo-Environmental Engineering – John Wiley and Sons, INC, USA, 2004.**
4.	**Daniel B.E, Geotechnical Practice for waste disposal, Chapman & Hall, London, 1993.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To understand the various causes and how to safely dispose the waste through different containment process**
CO2	**To understand the various mechanism of transport of contaminants into subsurface**
CO3	**To understand the concept of soil and waste characterization techniques.**
CO4	**To understand on how to decontaminate the site to reuse the site for human settlement.**
CO5	**To understand the consequences of soil waste interaction and its modifications.**

Course Code	**:**	CE826
Course Title	**:**	**GEOSYNTHETICS ENGINEERING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To introduce the definition, history, and various types of geosynthetics.**
CLO2	**To explain geosynthetics' raw materials, manufacturing techniques, and properties (physical, mechanical, and hydraulic).**
CLO3	**To provide an overview of the general applications of geosynthetics in civil engineering.**
CLO4	**To teach the functions of geosynthetics (separation, reinforcement, filtration, drainage, containment, and protection) and their application in real-world projects.**
CLO5	**To develop the ability to select appropriate geosynthetics based on project requirements and understand the design considerations for reinforced soil structures.**

Course Content

Introduction to Geosynthetics; Basic description of geosynthetics; Types and functions of geosynthetics; Engineering properties of geosynthetics and their evaluation; Testing of geosynthetic materials; Design methodologies with geosynthetics; Geotechnical applications: bearing capacity, settlement, stability analysis, retaining walls, embankments; Manufacturing techniques for different types of geosynthetics. Physical, mechanical, and hydraulic properties. Standard testing methods and specifications.

General applications in civil engineering projects Case studies highlighting successful applications Functions of Geosynthetics Separation, reinforcement, filtration, drainage, containment, and protection. • Design methodologies for each function. Selection criteria for geosynthetics based on project requirements. Geosynthetic Reinforcement: Mechanisms of soil reinforcement. Design considerations for reinforced soil structures.

Geosynthetics in Roadway Applications: Use of geotextiles and geogrids in pavement design. Benefits in terms of durability and cost-effectiveness.Geosynthetics in Railways: Applications in track stabilization and drainage.Case studies of geosynthetics in railway projects. Design and Construction: Design considerations for roadway and railway projects.

Geoenvironmental applications: covers and liners of landfills; Hydraulic applications: liners for ponds, canals, and reservoirs. Applications in water reservoirs, canals, and ponds. Design considerations for containment systems. Analysis of successful environmental projects using geosynthetics.

Innovations in geosynthetic materials and manufacturing. New applications and emerging technologies. Environmental impact of geosynthetics. Long-term performance and durability studies. International and national standards for geosynthetics. Regulatory requirements for various applications. Future directions in geosynthetic research and application. Potential challenges and opportunities in the field.

References

1.	**Sanjay Kumar Shukla and Jian-Hua Yin, Fundamentals of Geosynthetic Engineering, CRC Press**
2.	**Moseley, M.P. and Kirsch, K. Ground Improvement, Spon Press, Taylor and Francis Group**
3.	**Robert M. Koerner., Designing with Geosynthetics, Pearson Prentice Hall.**
4.	**Rao G. V. and Rao, G. V. S. Text Book on Engineering with Geotextiles, Tata McGraw Hill**
5.	**Koerner, R. M. Designing with Geosynthetics, Prentice Hall, Englewood Cliffs, New Jersey, U.S.A.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Students will understand the definition, history, types, and raw materials used in geosynthetics.**
CO2	**Students will be able to describe different geosynthetics manufacturing techniques and properties (physical, mechanical, and hydraulic).**
CO3	**Students will learn about geosynthetics's general applications in civil engineering projects.**
CO4	**Students will be able to identify and apply the functions of geosynthetics, including separation, reinforcement, filtration, drainage, containment, and protection**
CO5	**Students will learn the use of geosynthetics in roadway and railway applications, including design and construction considerations.**

Course Code	**:**	CE827
Course Title	**:**	**FORENSIC GEOTECHNICAL ENGINEERING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**Understand the various types of geotechnical damage and the planning process for geotechnical investigations.**
CLO2	**Characterize distress in geotechnical structures and develop hypotheses for failure mechanisms.**
CLO3	**Perform back analysis and identify technical shortcomings in geotechnical investigations.**
CLO4	**Evaluate the reliability of geotechnical structures and understand performance evaluation methods.**
CLO5	**Analyze geotechnical failures, understand related legal issues, and apply codal provisions and performance-based analysis procedures.**

Course Content

Overview of different types of geotechnical damage - Steps in planning a geotechnical investigation - Importance of a systematic approach – Methodologies used in geotechnical investigations - Techniques for effective data collection - Types of data needed for geotechnical investigations - Tools and methods for data collection

Identifying and characterizing types of distress in geotechnical structures - Formulating hypotheses for the cause of failures - Methods for validating failure hypotheses - Types of tests used in diagnosing geotechnical failures - Procedures and importance of diagnostic testing

Techniques for performing back analysis in geotechnical engineering - Case studies and examples - Common technical shortcomings in geotechnical investigations - Strategies for overcoming technical issues - Understanding the legal aspects related to geotechnical failures - Case histories involving legal disputes.

Assessing the reliability of geotechnical structures - Methods for enhancing reliability - Techniques for observing and evaluating the performance of structures - Case Histories - Settlement of structures - Lateral movement and backfill settlements - Causes due to soil types: collapsible soil, expansive soil, soluble soils.

Causes and case studies of slope failures, landslides, debris flow - Slope softening, creep, and trench collapses - Failures due to earthquakes, erosion, deterioration, tree roots, groundwater, and moisture problems - Common issues and failures in retaining structures and pavements - Types and causes of failures in soil reinforcement and geosynthetics - Development and significance of codal provisions - Performance-based analysis

References

1.	**Bolton M, A Guide to Soil Mechanics, Universities Press,1991.**
2.	**Robert W. Day (2011) Forensic Geotechnical and Foundation Engineering, Second Edition, McGraw-Hill Companies, Inc.**
3.	**Rao, V.V.S. and Sivakumar Babu, G.L (2016) Forensic Geotechnical Engineering, Springer Nature.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Demonstrate knowledge of planning and conducting geotechnical investigations.**
CO2	**Characterize and diagnose distress in geotechnical structures using appropriate methods.**
CO3	**Conduct back analysis and address technical shortcomings in geotechnical projects.**
CO4	**Assess and enhance the reliability of geotechnical structures through observation and performance evaluation.**
CO5	**Analyze various geotechnical failures, understand their causes, and apply relevant codal provisions and performance-based analysis procedures.**

Course Code	**:**	CE828
Course Title	**:**	**GEOTECHNICS IN PRACTICE**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36

Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To learn the procedural activities as part of a consultancy project.**
CLO2	**To learn the Estimation of fee for design projects**
CLO3	**To understand the foundations of Heavy and settlement-sensitive structures**
CLO4	**To understand the foundations of Water Resource and Port Infrastructure**
CLO5	**To understand the foundations of Transport infrastructure and about tunneling**

Course Content

Geotechnical Interpretation Report (GIR) – deriving design parameters for a particular site – data analysis – Design Basis Report (DBR). Back analysis of field data - soft ground – application of ground improvement techniques – Considerations - short term effects such as slope stability - long term effects such as settlement and creep – Liquefaction potential. Damage assessment of structures due to tunnelling - Empirical methods. Elevated structures – foundation design – Shallow, Pile and Pile-raft – IS and IRC Codal recommendations – application of design procedures. Estimation of fee for design projects – work breakdown structure – Budgets – Gross and Net margins – Work-in-progress- ISO 9001 requirements.

References

1.	**All relevant IS and IRC codes.**
2.	**Bowles, J. E. (1988). Foundation Analysis and Design. McGraw-Hill, New York, USA**
3.	**Tomlinson, M. J. (1986). Foundation Design and Construction., English Language Book Society, Longman Group Ltd., Singapore.**
4.	**Wintercorn, H. F. and Fang, H. (Ed.) (1975). Foundation Engineering Handbook. Van Nostrand Reinhold Company, N. Y., USA**
5.	**Peurifoy, R. L. Ledbetter, W. B., and Schexnayder, C. J. (1996). Construction planning, equipment and methods, McGraw Hill, Singapore.**
6.	**ISO 9001:2015, All relevant ASTM and Euro codes**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To adopt the procedural activities as part of a consultancy project**
CO2	**Understand and apply factors for site selection, land reclamation techniques, and financial estimation including fee, budget, and margins for design projects**
CO3	**To follow and work according to the limitations given by IS and IRC codes.**

CO4	**Understand and apply design procedures and IS codal recommendations for water resources and port infrastructure projects.**
CO5	**To comprehend to the quality requirements of any project.**

Course Code	**:**	CE829
Course Title	**:**	**PORTS AND HARBOUR STRUCTURES**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To understand the port and harbour layouts and navigation channels.**
CLO2	**To gain knowledge of analysis and design of port and harbour structures.**
CLO3	**To study concepts of dredging and disposal of contaminated sediments, design offshore terminals and islands**
CLO4	**To learn the integrity analysis of berthing structures**
CLO5	**To understand designing of piles and diaphragm walls for ports and harbours.**

Course Content

Layout of ports – ships and size of ships – harbour layout - site characterisation & navigation channel – bathymetric survey – tide, surge, tsunami and waves – wind rose diagram.

Estimation of loads - analysis, design and construction of berthing structures and breakwaters, jetties, wharves, quays, diaphragm walls, slipways and docks –- limit state and working stress method of design - crack width calculations.

Dredging and disposal of contaminated sediments - offshore terminals and island types of mechanical handling and conveying system types of fenders and mooring facilities.

Integrity analysis of berthing structures - low strain and high strain integrity tests - UPV and HCP tests - case studies of breakwater failures and other types of structures - partial safety factors - codal requirements.

Design of piles and diaphragm walls for ports and harbours - retrofitting of port structures, corrosion of steel piles and protection methods – coastal structures environmental management

References

1.	**C. A. Thoresen, "Port Design - Guidelines and recommendations", Thomas Telford Publishing, 2003.**
2.	**J. W. Gaythwaite, Van Nostrand, "Design of Marine Facilities: Engineering for Ports and Harbour Structures (3rd Edition)", ASCE, 2016.**
3.	**S.K. Chakrabarti, "Handbook of Offshore Engineering", Elsevier, 2005.**
4.	**Agerschou, H., Lundgren, H., Sorensen, T., Ernst, T., Korsgaard, J., Schmidt, L.R. and Chi, W.K., "Planning and Design of Ports and Marine Terminals", A Wiley-Interscience Publication, 1983.**
5.	**Per brun, "Port Engineering", Gulf Publishing Co, 1983.**
6.	**A. D. Quinn, "Design and Construction of Port and Marine Structures", McGraw-Hill Book Company**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Students will be able to design and plan effective port layouts**
CO2	**Students will apply principles of load estimation, structural analysis, and design to various port structures**
CO3	**To understand dredging and disposal of contaminated sediments, the design of offshore terminals and islands**
CO4	**To familiarize students with integrity analysis of berthing structures**
CO5	**To design piles and diaphragm walls for ports, apply retrofitting techniques**

Course Code	**:**	CE830
Course Title	**:**	**RISK AND RELIABILITY IN GEOTECHNICAL ENGINEERING**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To identify and categorize different sources of uncertainties in geotechnical engineering projects**
CLO2	**To perform parameter estimation and hypothesis testing relevant to geotechnical data**
CLO3	**To assess the uncertainty in soil properties measured from field and laboratory tests and interpret techniques considering spatial variability.**
CLO4	**To develop probabilistic models for groundwater flow through earth dams and conduct slope stability analysis incorporating uncertainty.**

CLO5	**To design shallow and deep foundations using reliability-based methods and create fragility curves for evaluating geotechnical systems under various risk scenarios**

Course Content

Introduction: Sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic methods and reliability-based analysis in geotechnical engineering.

Review of probability and statistics: Discrete and continuous random variables, parameter estimation, testing of hypothesis, regression analysis Fundamentals of reliability analysis: First Order Second Moment (FOSM) method, First Order Reliability Method (FORM), Second Order Reliability Method (SORM), Monte Carlo simulation Application towards geotechnical problems:

Characterization of uncertainty in field-measured and laboratory-measured soil properties, uncertainty in interpretation techniques, Spatial variability of soil properties, and scale of fluctuations.

Estimation of autocorrelation and auto covariance Probabilistic groundwater modeling, flow through earth dams Probabilistic slope stability analysis.

Fundamentals of LRFD design methodology, reliability-based design of shallow and deep foundations, settlement analysis Reliability based liquefaction analysis, lateral spreading Development of fragility curves
for geotechnical problems for geotechnical problems

References

1.	**Baecher, G. B., & Christian, J. T. (2005). Reliability and statistics in geotechnical engineering. John Wiley & Sons.**
2.	**Fenton, G. A., & Griffiths, D. V. (2008). Risk assessment in geotechnical engineering (Vol. 461). New York: John Wiley & Sons.**
3.	**Phoon, K. K., & Ching, J. (Eds.). (2015). Risk and reliability in geotechnical engineering (Vol. 651). Boca Raton, FL, USA: CRC Press.**
4.	**Phoon, K. K. (2016). Reliability of geotechnical structures. Japanese Geotechnical Society Special Publication, 2(1), 1-9.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**Understand the sources and types of uncertainties in geotechnical engineering and the importance of probabilistic methods and reliability-based analysis**
CO2	**Apply statistical methods such as parameter estimation, hypothesis testing, and regression analysis to geotechnical problems**

CO3	**Characterize and analyze uncertainty in field-measured and laboratory-measured soil properties and interpret techniques considering spatial variability and scale of fluctuations.**
CO4	**Perform probabilistic groundwater modeling, flow analysis through earth dams, and slope stability analysis using techniques like autocorrelation and autocovariance.**
CO5	**Implement LRFD design methodology and conduct reliability-based design and analysis for shallow and deep foundations, settlement, liquefaction, and develop fragility curves for geotechnical problems.**

Course Code	**:**	CE831
Course Title	**:**	**GEOTECHNOLOGY OF WASTE DISPOSAL FACILITIES**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To understand the fundamentals of waste disposal**
CLO2	**To analyze geotechnical properties of waste from different sources**
CLO3	**To understand the waste containment system design**
CLO4	**To learn remediation techniques for contaminated sites**
CLO5	**To explore sustainable waste management practices**

Course Content

Waste management - types of waste - sources and generation - principles of waste management - regulations and guidelines - environmental impact of waste disposal - role of geotechnology in waste management

Geotechnical characterization of waste - physical, chemical, and biological characteristics - soil-waste interaction - leachate generation and composition - gas production in waste

Design and construction of waste containment systems – landfills - design principles, site selection, and layout - design and construction of liner and cover systems - leachate management - gas management systems - stability and settlement of landfills - disposal of nuclear waste - tailing dams for disposal of fly ash, coal, copper, iron and other metal wastes. Introduction to nuclear waste repositories.

Remediation of contaminated sites - site assessment and characterization - remediation technologies – Vertical barriers - geotechnical aspects of remediation - stabilization and solidification, encapsulation, and soil washing - case studies

Sustainable waste management - geosynthetics in waste management - climate change and waste disposal - innovative technologies - waste-to-energy technologies - smart waste management systems

References

1.	**H.D. Sharma and S.P. Lewis, Waste Containment Systems, Waste Stabilization and Landfills: Design and Evaluation, John Wiley & Sons Inc., 1994**
2.	**D.E. Daniel, Geotechnical Practice for Waste Disposal, Chapman and Hall, 1993**
3.	**Qian, X., Koerner, R., and Gray, D.H., Geotechnical aspects of landfill design and construction, Prentice Hall, 2002.**
4.	**D.E. Daniel and R.M. Koerner, Waste Containment Facilities, ASCE, 2nd Ed, 2007.**
5.	**A.M.O. Mohamed and H.E. Antia, Geo-Environmental Engineering, Elsevier, 1998**
6.	**R.K. Rowe, R.M. Quigley and C. Booker, Clay Barrier Systems for Waste Disposal Facilities, J. R., E and FN Spon, 1995.**
7.	**L.N. Reddi and H.F. Inyang, Geoenvironmental Engineering: Principles and Applications, Marcel Dekker Inc, 2000**
8.	**Vick, S.G., Planning, analysis and design of tailings dams, John Wiley & Sons, 1970**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To demonstrate comprehensive knowledge of waste management**
CO2	**To evaluate geotechnical properties and interactions of waste**
CO3	**To apply design principles for waste containment systems**
CO4	**To implement effective remediation techniques**
CO5	**To enhance knowledge in sustainable waste management**

LABORATORY COURSES

Course Code	**:**	CE807
Course Title	**:**	**ADVANCED GEOTECHNICAL ENGINEERING LABORATORY**
Type of Course	**:**	Laboratory
Prerequisites	**:**	NIL
Contact Hours	**:**	
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To perform basic tests on soil to identify its index properties**
CLO2	**To carry out advanced laboratory tests to identify the engineering properties of soil.**

Course Content

Sieve Analysis – Hydrometer Analysis – Atterberg limits – Specific gravity – Standard proctor compaction – Field density – Free swell index – California bearing ratio – Permeability.
Unconfined compression test – Direct shear test - Triaxial test – Consolidation test.
Cyclic Triaxial test – Bender element test - Large scale direct shear test .

References

1.	**Alam Singh and Chowdary, G.R., "Soil Engineering in Theory and Practice (Vol.2) Geotechnical Testing and Instrumentation, CBS Publishers and Distributors, New Delhi,2006.**
2.	**I.S. Code of Practice (2720): Relevant Parts, as amended from time to time.**
3.	**Bowles, J.E., Engineering properties of soils and their measurements, McGraw Hill, 1992.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To perform basic tests on soil to identify its index properties**
CO2	**To carry out advanced laboratory tests to identify the engineering properties of soil.**

Course Code	**:**	CE808
Course Title	**:**	**GEOSYNTHETICS AND FIELD TESTING LABORATORY**
Type of Course	**:**	LABORATORY
Prerequisites	**:**	NIL
Contact Hours	**:**	
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To perform various field tests in soils**

CLO2	**To perform tests on geosynthetics in laboratory**

Course Content

Disturbed and undisturbed Sampling; Standard Penetration test; Static Cone Penetration test; Plate load test; Unconfined Compression test on rock specimens, field vane shear test, resistivity test, GPR, pile integrity test, pile load test, Soil response characteristics.

Physical Properties: Introduction; Types of Geosynthetics; Functions; Mass per unit area, thickness,
Mechanical Properties, Tensile strength and trapezoidal tear strength; Tensile Modulus. Grab strength; Sewn seam strength test.

Permittivity, % Opening size of geogrid, Interface Shear Test

Tests on Geofoam: Density of geofoam, Water absorption test, Compressive strength

References

1.	**I.S. Code of Practice Relevant Parts, as amended from time to time.**
3.	**Mandal, J.N. and Divshikar, D.G. (1994). A Guide To Geotextile Testing, Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.**
4.	**ASTM Standards on Geosynthetics Mandal, J. N. (2017). Geosynthetics Engineering : In theory and practice. Research Publishing, Singapore.**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To be able to conduct various field tests in soils**
CO2	**To understand the properties of geosynthetics from laboratory test**

Course Code	**:**	CE810
Course Title	**:**	**GEOTECHNICAL DESIGN STUDIO**
Type of Course	**:**	Laboratory
Prerequisites	**:**	NIL
Contact Hours	**:**	
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To understand the concept of software based numerical modelling.**
CLO2	**To learn and carry out basic numerical modelling on using different Geotechnical softwares.**

Course Content

Engineering aspect of finite element method - Basic tools of the design software – Different soil models – modelling of substructure and loading conditions – analysis of the response of the different geotechnical problems.

References

1.	**PLAXIS 2D & 3D manuals.**
2.	**FLAC3D User guide.**
3.	**OASYS Geotechnical software user manual**

Course Outcomes (CO)

At the end of the course student will be able

CO1	**To understand the concept of software based numerical modelling.**
CO2	**To carry out basic numerical modelling for practical Geotechnical issues on different Geotechnical software.**