M. Tech.

in

Geotechnical Engineering

CURRICULUM
(For students admitted in 2020-21)

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015, TAMIL NADU, 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)

PEO 1	Graduates of the programme will possess the ability to provide solutions to Geotechnical Engineering problems with the highest standards economically, socially and ethically.
PEO 2	Graduates of the programme will become Geotechnical Engineers in government, public and private sector industries and work for the betterment of the global community.
PEO 3	Graduates of the programme will continue their lifelong learning to remain effective professionals to maintain and enhance technical and professional growth.

PROGRAMME OUTCOMES (POs)

Graduates of the Geotechnical Engineering Programme will be able:

a. To acquire in-depth knowledge of Geotechnical engineering, with an ability to understand, evaluate and analyse existing techniques and establish new techniques and integrate them for the betterment of the field.
b. To analyse Geotechnical Engineering problems critically and apply independent judgment to come up with advanced and reliable solutions.
c. To develop original and unique concepts to solve Geotechnical Engineering issues and evaluate and compare existing concepts in order to provide solutions that are economically and technically feasible with highest standards of professionalism.
d. To conduct thorough literature survey on trending problems of Geotechnical Engineering and adopt appropriate research methodology to conduct experiments and analyse the obtained results and apply it to develop technical knowledge and publish in the corresponding domains of Geotechnical Engineering.
e. To use computer based modelling and numerical analysis of Geotechnical Engineering problems in various platforms based on Finite element methods and understand the significance of such modelling techniques and their applicability in real-time scenarios.
f. To possess knowledge and understanding of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.
g. To demonstrate knowledge and understanding of Geotechnical Engineering and Management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently after consideration of economic and financial factors.
h. To communicate with the Engineering community, and with society at large, regarding complex Geotechnical engineering activities confidently and effectively,

such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

i. To recognize the need for, and have the preparation and ability to engage in life-long learning, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
j. To acquire professional and intellectual integrity, professional ethics and code of conduct, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the society for sustainable development.
k. To observe and examine critically the outcomes of one's actions in addressing Geotechnical Engineering problems and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

GRADUATE ATTRIBUTES (GA)

1. Scholarship of Knowledge
2. Critical Thinking
3. Problem Solving
4. Research Skill
5. Usage of modern tools
6. Collaborative and Multidisciplinary work
7. Project Management and Finance
8. Communication
9. Life-long Learning
10. Ethical Practices and Social Responsibility
11. Independent and Reflective Learning

GA AND PO MAPPING

The Programme Outcomes have been derived from the Graduate Attributes. Hence, they are aligned to each other one to one as indicated below:

Graduate Attributes	Programme Outcomes										
	a	b	c	d	e	f	g	h	i	j	k
1	√										
2		√									
3			√								
4				√							
5					√						
6						√					
7							√				
8								√			
9									√		
10										√	
11											√

CORRELATION BETWEEN THE POs AND THE PEOs

Three levels of correlation have been identified between the POs and the PEOs, viz, High, Medium and Low. The correlation matrix is given below:

PEOs		Programme Outcomes (POs)										
		a	b	c	d	e	f	g	h	i	j	K
Programme Educational Objectives	1	H	H	H	M	M	H	M	M	M	H	H
	2	M	M	H	L	L	M	H	H	M	H	M
	3	M	M	M	L	L	H	L	H	H	M	M

Note: H - High; M - Medium; L - Low

CURRICULUM

The total minimum credits for completing the M. Tech. Programme in Geotechnical Engineering is 66.

SEMESTER I

Code	Course of Study	Credit
MA602	Applied Mathematics	4
CE801	Geomechanics - Theory and Applications	3
CE803	Soil Properties and Behaviour	3
	Elective I	3
	Elective II	3
	Elective III	3
CE809	Advanced Geotechnical Engineering Laboratory	2
	TOTAL	**21**

SEMESTER II

Code	Course of Study	Credit
CE802	Foundation Analysis and Design	4
CE804	Earth Retaining Structures	3
CE806	Dynamics of Soils and Foundations	3
	Elective IV	3
	Elective V	3
	Elective VI	3
CE810	Geotechnical Design Studio	2
	TOTAL	**21**

SUMMER TERM

Code	Course of Study	Credit
	Practical Training (4 Weeks)	-

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

PROGRAMME ELECTIVES

Sl. No.	Code	Course of Study	Credit
1.	CE811	Linear Algebra and Differential Equations	3
2.	CE812	Soil Exploration and Field Testing	3
3.	CE813	Applied Soil Mechanics	3
4.	CE814	Slope Stability and Earth Dams	3
5.	CE815	Ground Improvement Techniques	3
6.	CE816	Analysis of Deep Foundations	3
7.	CE817	Machine Foundations	3
8.	CE818	Marine Foundations	3
9.	CE819	Soil-Structure Interaction	3
10.	CE820	Offshore Geotechnical Engineering	3
11.	CE821	Rock Mechanics	3
12.	CE822	Unsaturated Soil Mechanics	3
13.	CE823	Analysis and Design of Deep Excavations	3
14.	CE824	Geotechnical Earthquake Engineering	3
15.	CE825	Geoenvironmental 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

OPEN ELECTIVES

Sl. No.	Code	Course of Study	Credit
1.	CE812	Soil Exploration and Field Testing	3
2.	CE815	Ground Improvement Techniques	3
3.	CE816	Analysis of Deep Foundations	3
4.	CE819	Soil-Structure Interaction	3
5.	CE825	Geoenvironmental Engineering	3

Course Code	**:**	MA602
Course Title	**:**	**APPLIED MATHEMATICS**
Number of Credits	**:**	4
Course Type	**:**	Core

Course Learning Objectives:

1. To develop students with knowledge in Laplace and Fourier transform.
2. To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications.
3. To expose the students to calculus of variation, conformal mappings and tensor analysis.
4. To familiarize students in the field of bilinear transformations.
5. 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.

Reference

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:

At the end of the course student will be able

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

Course Code	**:**	CE801
Course Title	**:**	**GEOMECHANICS -THEORY AND APPLICATIONS**
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives

1. To define the advanced theories of elasticity employed in Geomechanics.
2. To classify the yield concept and failure criterion to solve problems associated with stability.
3. To correlate the soil response with constitutive relationships.
4. To perform plane deformation analysis in slopes, retaining walls and footings.
5. To describe theories accounting for strain hardening.

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. *Jean-Louis Briaud, Geotechnical Engineering: Unsaturated and Saturated Soils, John Wiley & Sons, Inc., New Jersey, 2013.*
2. *Aysen, A., Problem solving in Soil Mechanics, Taylor & Francis, London, First Indian Print, 2011.*
3. *Chowdhury, I., Dasgupta S.P., Dynamics of Structure and Foundations, Taylor & Francis Group, London, 2009.*
4. *Bolton, M.D; A Guide to Soil Mechanics, University press (India) Pvt. Ltd., 2009*
5. *Renato Lancellotta, Geotechnical Engineering (2nd Edition), Taylor & Francis, 2009.*

Course Outcomes

At the end of the course students will be able
1. To understand the various elastic problems in geomechanics.
2. To conceive the failure and yield mechanism of soil.
3. To understand the elasto-plastic deformation of soil slopes and slope stability concepts.
4. To understand the soil behaviour based on the theories accounting for strain hardening in soil.

Course Code	**:**	CE803
Course Title	**:**	**SOIL PROPERTIES AND BEHAVIOUR**
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives:

1. To understand the identification and classification of soil deposits.
2. To comprehend the principle of the physio-chemical behaviour of soil.
3. To study the causes and consequences of problems associated with the behaviour of soils.
4. To understand the various engineering properties of soil and its

significance.
5. To comprehend the suitability of soils for various geotechnical applications.

Course Content:

Introduction – formation of soils – different soil deposits and their engineering properties – Genesis of clay minerals –identification and classification – Anion and cation exchange capacity of clays – specific surface area – bonding in clays.

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, thixotrophy of soils – soil suction – soil compaction – factors affecting soil compaction.

Compressibility, shear strength and permeability behaviour of fine and coarse grained soils – mechanisms and factors influencing engineering properties – liquefaction potential – causes and consequences.

Conduction in soils – hydraulic, electrical, chemical and thermal flows in soils – applications - coupled flows – Electro-kinetic process – thermo osmosis - electro osmosis – prediction of engineering behaviour of soils using index properties – empirical equations and their applicability.

References

1. *Mitchell, J.K., Fundamentals of Soil Behaviour, John Wiley, New York, 1993.*
2. *Yong, R.N. and Warkentin, B.P., Introduction to Soil Behaviour, Macmillan, Limited, London, 1979.*
3. *Coduto, D.P., Geotechnical Engineering – Principles and practices, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.*
4. *Das, B.M.,Principles of Geotechnical Engg, PWS Publishing Comp, Boston, 1998*
5. *McCarthy D.F., Essentials of Soil Mechanics & Foundations, Prentice-Hall, 2002.*

Course Outcomes:

At the end of the course student will be able
1. To identify and classify soil deposits.
2. To comprehend the principle of the physio-chemical behaviour of soil.
3. To reason the causes for the problems associated with the behaviour of soils.
4. To derive the various engineering properties of soil.

5. To comprehend the suitability of soils for various geotechnical applications.

Course Code	**:**	CE802
Course Title	**:**	**FOUNDATION ANALYSIS AND DESIGN**
Number of Credits	**:**	4
Course Type	**:**	Core

Course Learning Objectives

1. To analyse the load bearing capacity of soil.
2. To design shallow and deep foundations in soil.
3. To estimate the settlement of foundations.
4. To understand the concept of special foundations considering theory of vibration.

Course Content

Types of foundations – Types of shallow foundation – Design concept - General requirements - Additional consideration - selection of type of foundation - hostile environment.

Bearing capacity of shallow foundations - Homogeneous - Layered soils - Soft and Hard Rocks - Evaluation of bearing capacity from insitu tests - partial safety factor approach – Codal recommendations.

Analysis of foundation - isolated - strip - combined footings - Flat raft – Stiffened raft foundations - Conventional - elastic approach - Soil Structure Interaction Principles – Winkler foundation – Elastic half space approach – Structural design of Shallow foundation – Codal provisions.

Allowable load evaluation of piles and pile groups – Static method – cohesive – cohesion less soil – time effects – Dynamic method – pile driving formulae – Wave equation application – modeling – theoretical analysis – Interpretation of field test results and pile load test results – Introduction to lateral loaded piles - Settlement of Piles and Pile groups.

Introduction to special foundations - Foundation design in relation to ground movements - Foundation on recent refuse fills - Design of Foundation for seismic forces - Codal recommendations - Introduction to theory of vibration - Design of Block foundation - Codal recommendations.

References

1. *Poulos H.G, Tall Building Foundation Design (1st Edition), CRC Press, London, 2017.*
2. *Rodrigo Salgado, The Engineering of Foundations, McGraw-Hill, New York, 2006.*

3. *Tomlinson, M.J. Foundation engineering, ELBS, Longman Group, U.K. Ltd., England, 1995.*
4. *Michael Tomlinson and John Woodward, Pile design and construction practice, Taylor & Francis Group, London & New York, 2008.*
5. *Bowles, J.E., Foundation Analysis and Design, Fifth Edition, McGraw Hill, New York, 1996.*

Course outcomes

At the end of the course students will be able

1. To analyse the load carrying capacity of soil.
2. To design shallow and deep foundations on various ground conditions.
3. To calculate the settlement of foundations.
4. To understand the basic concepts of special foundations considering theory of vibrations.

Course Code	**:**	CE804
Course Title	**:**	**EARTH RETAINING STRUCTURES**
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives

1. To identify the types, advantages, and disadvantages of the different earth retaining systems
2. To quantify the lateral earth pressures associated with different earth retaining systems.
3. To gain knowledge on analysis and design of retaining structures.
4. To evaluate the stability of retaining structures under regular and earthquake forces.

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.*

Course Outcomes

At the end of the course students will be able

1. To calculate earth pressure on various earth retaining structures such as retaining walls, sheet piles, bulkheads, bracing/struts and coffer dams.
2. To design a relevant earth retaining structure for given soil condition.
3. To design sheet pile with and without anchors.
4. To analyse earth pressures on shafts, conduits and tunnels.

Course Code	**:**	CE806
Course Title	**:**	**DYNAMICS OF SOILS AND FOUNDATIONS**
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives

1. To interpret the concept of dynamics in Geotechnical Engineering.
2. To predict liquefaction and suggest mitigation.
3. To recognize the significance of soil-structure interaction.
4. To apply the principles of dynamics for the design of machine foundation.

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.

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.*

Course Outcomes

At the end of the course students will be able

1. To interpret the principles of dynamics in Geotechnical Engineering.
2. To predict liquefaction and suggest measures for its mitigation.
3. To reason the response of any soil-structure system.
4. To apply the principles of soil dynamics.

PROGRAMME ELECTIVES

Course Code	**:**	CE811
Course Title	**:**	**LINEAR ALGEBRA AND DIFFERENTIAL EQUATIONS**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives:

1. To gain an understanding of statistical methods relevant to upper division interdisciplinary courses
2. To study the concepts of both discrete and continuous probability distribution
3. To calculate the confidence intervals for various population parameters
4. To analyze the problems using Linear programming approach

Course Content:

Linear System - Gaussian Elimination and Gauss - Jordan Methods - Matrix Inversion - Gauss Seidel Method - Nonlinear Equations - Regula Falsi and Newton - Raphson Methods - Interpolation - Newton's and Lagrange's Interpolation.

Linear Programming - Graphical and Simplex methods - Big-M method - Two phase method - Dual simplex method - Dual theory - Sensitivity analysis - Integer programming – applications - Random Variable - Two Dimensional Random Variables - Standard Probability Distributions - Binomial Poisson and Normal Distributions - Moment Generating Function - Sampling Distributions - Confidence Interval Estimation of Population Parameters - Testing of Hypotheses.

Large Sample Tests for Mean and Proportion – t - Test, F-Test and Chi-Square Test - Curve Fitting - Method of Least Squares.

Regression and Correlation - Rank Correlation - Multiple and Partial Correlation - Analysis of Variance - One Way and Two Way Classifications - Experimental Design - Latin Square Design - Time Series Analysis.

References

1. *Bowker and Liberman, Engineering Statistics, Prentice-Hall, 1972.*
2. *Venkatraman, M. K., Numerical Methods in Science and Engineering, National Publisher Company, 5th Edition, 1999.*
3. *M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for scientific and engineering computation, 6th edition, New Age International (p) Limited, 2007*

4. *Operations Research: An introduction, Hamdy A. Taha, 10th edition Pearson Prentice Hall, 2007.*
5. *S. C. Gupta, Fundamentals of Statistics, Himalaya Publishing House, 7th Revised and Enlarged Edition, 2014.*
6. *S.C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2014.*

Course Outcomes

At the end of the course students will be able
1. To distinguish the concepts of linear and nonlinear systems
2. To solve the problems through linear programming approaches
3. To correlate any results using statistical methods
4. To develop statistical models between variables

Course Code	**:**	CE812
Course Title	**:**	**SOIL EXPLORATION AND FIELD TESTING**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To recall the various soil investigation techniques.
2. To identify the appropriate technique for soil exploration.
3. To classify soil strata using direct and in direct methods.
4. To interpret the investigated data to design suitable foundation system.

Course Content

Scope and objectives - planning an exploration program - methods of exploration - exploration for preliminary and detailed design - spacing and depth of bores - data presentation - Geophysical exploration and interpretation - seismic and electrical methods - cross bore hole, single bore hole – up hole - down hole methods.

Methods of boring and drilling - non-displacement and displacement methods - drilling in difficult subsoil conditions - limitations of various drilling techniques, stabilization of boreholes - bore logs.

Sampling Techniques – quality of samples – factors influencing sample quality - disturbed and undisturbed soil sampling advanced sampling techniques, offshore sampling, shallow penetration samplers, preservation and handling of samples.

Field tests - penetration tests - Field vane shear - Insitu shear and bore hole shear test - pressuremeter test - dilatometer test - plate load test – monotonic and cyclic; field permeability tests – block vibration test – Procedure – limitations - correction and data interpretation of all methods.

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. *Bowles, J.E, Physical and Geotechnical Properties of Soil, McGraw-Hill Book Company,1985.*
2. *Bowles, J.E, Foundation Analysis and Design, McGraw-Hill International edition, 1997.*
3. *Dunnicliff, J. and Green, G.E, Geotechnical Instrumentation for Monitoring Field Performance, John Wiley & Sons, 1982.*
4. *GopalRanjan and Rao, A.S.R, Basic and Applied Soil Mechanics, Wiley Eastern Limited,1991.*
5. *Lunne, T., Robertson, P.K. and Powell, J.J.M, Cone Penetration Testing in Geotechnical Practice, Blackie Academic & Professional, 1997.*
6. *Compendium of Indian Standards on Soil Engineering Parts 1 and II 1987 – 1988*
7. *All related ASTM codes and Eurocode 7 - Part 2.*

Course Outcomes

At the end of the course students will be able

1. To understand the significance of understanding the soil properties at a site conduct a sequential soil exploration according to the site.
2. To extract samples as per requirement and perform field and laboratory tests.
3. To understand the practical significance of the results obtained from field and laboratory tests.
4. To clearly report the conclusions based on the conducted soil exploration and tests.

Course Code	**:**	CE813
Course Title	**:**	**APPLIED SOIL MECHANICS**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the concept of effective stress in different field conditions.
2. To be able to estimate the settlement of soils using one-dimensional and three-dimensional consolidation theories.
3. To understand the shear strength of saturated and partially saturated soils.
4. To understand the concept of stress path diagrams for various load conditions.

Course Content

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 - shear parameters under different drainage conditions construction - pore pressure in saturated and unsaturated soils -analytical predictions of pore water pressures - stress dilatancy theory – results of plain strain shear tests -forces on shear parameters.

Mechanics of consolidation: phenomenon of consolidation -Terzaghi's theory of unidimensional consolidation - methods to determine precompression history - 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.

References

1. *Scott R F, "Principles of Soil Mechanics", Addition Wesley Publishing Co. Inc., 1988.*
2. *Bowles, J.E, Physical and Geotechnical Properties of Soil, McGraw-Hill Book Company,1985.*
3. *Terzaghi , Peck .and Mesri " Soil Mechanics in Engineering Practice " 1996.*
4. *Gopal Ranjan and Rao, A.S.R, Basic and Applied Soil Mechanics, Wiley Eastern Limited,1991.*
5. *Richard Handy and Merlin Spangler. "Geotechnical Engineering: Soil and Foundation Principles and Practice (5th Edition)", McGraw-Hill, 2007.*

Course Outcomes

At the end of the course students will be able

1. To analyse effective stress for different field conditions.
2. To calculate the settlement of soils using one-dimensional and three-dimensional consolidation theories.
3. To estimate shear strength of saturated and partially saturated soils.
4. To develop stress path diagrams for different load conditions.

Course Code	**:**	CE814
Course Title	**:**	**SLOPE STABILITY AND EARTH DAMS**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To identify the types, advantages, and disadvantages of the different earth retaining systems.
2. To quantify the lateral earth pressures associated with different earth retaining systems.
3. To evaluate the mechanical properties of geosynthetics used for soil reinforcement.
4. To study the stability and seepage in earth dams.

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.

Each pressure due to earthquake forces – Stability of retaining structure - Retaining structure - Selection of soil parameters – Analysis and design of cantilever and anchored sheet pile walls. Deadman and continuous anchor - Diaphragm and bored pile walls – Design requirements. Lateral pressure on sheeting in braced excavation, stability against piping and bottom heaving - Earth pressure around tunnel lining, shaft and silos.

Reinforced earth retaining wall – principles, Concepts and mechanism of reinforced Earth – Design consideration of reinforced earth – Materials used in reinforced earth - Geotextile – Geogrids, Metal strips, facing elements.

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, 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.

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.

References

1. *Duncan J.M., Wright S.G., and Brandon.T.L,"Soil Strength and Slope Stability (2nd Edition),Wiley, 2014.*
2. *Militisky.J and Woods.R, "Earth and Earth retaining structures", Routledge, 1992*
3. *McCarthy, D.F., Essentials of Soil Mechanics and Foundations: Basic Geotechnics,Sixth Edition, Prentice Hall, 2002.*
4. *Chowdhury R, Flentje P and Bhattacharya G, "Geotechnical Slope Analysis",CRC Press, 2019.*
5. *Sherard, J.L., Woodward, R.J., Gizienski, R.J. and Clevenger, W.A., Earth and Earth rock dam, John Wiley, 1963.*

Course Outcomes

At the end of the course students will be able

1. To study the stability of an excavation, cut or natural slope.
2. To analyse slopes using different methods of slope stability analysis.
3. To study the stability and seepage in earth dams.
4. To design earth dams considering the hydraulic forces.

Course Code	**:**	CE815
Course Title	**:**	**GROUND IMPROVEMENT TECHNIQUES**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To summarize the engineering properties of soil and problems associated with weak deposit.
2. To familiarize with the need for ground improvements.
3. To define the concept of soil stabilization.
4. To recall soil reinforcement techniques and geo-synthetics.

Course Content

Introduction - Engineering properties of soft–weak and compressible deposits – problems associated with weak deposit – Requirements of ground improvements – introduction to engineering ground modification, need, objectives and outcomes.

Soil Stabilization - Science of soil stabilization – Mechanical modification – Hydraulic modification – Dewatering systems – Chemical modification – Modification by admixtures like lime, Cement, Bitumen etc – Grouting – Deep jet mixing methods.

Recent Ground improvement techniques - stabilization using industrial waste – modification by inclusion and confinement – soil nailing – stone column –

compaction piles – dynamic compaction – prefabricated vertical drains – preloading – electro-osmosis – soil freezing vacuum consolidation – deep explosion – dry powdered polymers – enzymes.

Soil reinforcement - Historical background, RCC – Vidalean concept of reinforced earth – Mechanisms – Types of reinforcements – Soil–Reinforcement – Interaction studies – Internal and External stability criteria – Design Principles of steep reinforced soil slopes – pavements – Embankments on soft soils.

Geo-Synthetics - Geo-synthetic clay liner – Construction details – Geo Synthetic Materials – Functions – Property characterization – Testing Methods for Geo-Synthetics – Recent research and Developments - Control of Improvement – Field Instrumentation – design and analysis for bearing capacity and settlement of improved deposits.

References

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

Course outcomes

At the end of the course students will be able

1. To understand the engineering properties of soil and problems associated with weak deposit.
2. To reason the need for the implementation of ground improvement techniques.
3. To be understand the concept of soil stabilization.
4. To be utilize soil reinforcement techniques and geo-synthetics.

Course Code	**:**	CE816
Course Title	**:**	**ANALYSIS OF DEEP FOUNDATION**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To familiarize different types of deep foundation and their significance.
2. To explain how pile classification is done based on its functions and how to estimate pile capacity based on static and dynamic approach as per codes.
3. To explain how to select soil design parameters for pile capacity analysis and role of geotechnical investigation in the pile capacity analysis.
4. To explain pile group failures under varies conditions and the importance of group action in pile group capacity.
5. To explain how lateral pile capacity analysis is done under various pile failure mode.

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.

Reference Books

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

At the end of the course students will be able

1. To select appropriate foundation type based on available soil conditions.
2. To determine the load carrying capacity of pile foundation.
3. To gain thorough knowledge about the design of pile foundations.
4. To understand the importance of deep foundation in civil engineering construction field and they could able to select appropriate pile system based on the site conditions.
5. To do pile capacity (static, dynamic, lateral and group capacity) analysis as per code and they will understand the complete physics of pile and pile group failure mode under various circumstances.

Course Code	**:**	CE817
Course Title	**:**	**MACHINE FOUNDATION**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To estimate the dynamic properties of soils required for analysis and design of machine foundations.
2. To understand the behaviour of different types of machine foundations.
3. To analyse and design different types of machine foundations.
4. To analyse and design vibration isolation systems.

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 - 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 - active and passive isolation - transmissibility - methods of isolation in 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

At the end of the course students will be able

1. To estimate the dynamic properties of soils required for analysis and design of machine foundations.
2. To define the behaviour of different types of machine foundations.
3. To analyse and design different types of machine foundations.
4. To analyse and design vibration isolation systems.

Course Code	**:**	CE818
Course Title	**:**	**MARINE FOUNDATION**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To emphasize the importance of offshore soil investigations for offshore structures
2. To analysis the response of foundations of gravity structures under offshore environmental loading
3. To analysis the foundation response of jacket and jack-up platforms under static and dynamic loading
4. 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 – lateral load deformation behaviour of piles – calculation of bearing capacity of piles- design of piles subjected to lateral loads – Reese-Matlock method and p-y curves method.

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) – geotechnical aspects in the design and installation of sea bed anchors, moorings, submarine pipelines etc.

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*

Course Outcomes

At the end of the course students will be able

1. To analyse the behaviour of marine soil deposits under repetitive loading conditions.
2. To understand the suitable offshore investigation techniques in the proposed project.
3. To perform foundation analysis for gravity structures, jacket and jack-up kind of offshore structures.

4. To analyse suitable anchor system for mooring structures and foundation system for offshore pipeline

Course Code	**:**	CE819
Course Title	**:**	**SOIL STRUCTURE INTERACTION**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To make students understand soil foundation interaction and its importance.
2. To familiarize students with model analysis, Winkler model for soil structure interaction analysis.
3. To expose students to beams and plates on elastic foundation.
4. To enable students to carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction.
5. 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.

Elastic Analysis of Pile: Elastic analysis of single pile, Theoretical solutions for settlement and load distributions, Analysis of pile group, Interaction analysis, 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 - An introduction to soil-foundation interaction under dynamic loads.

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.*

Course outcomes

At the end of the course students will be able

1. To understand soil foundation interaction and its importance.
2. To be familiar with model analysis, Winkler model for soil structure interaction analysis.
3. To be exposed to beams and plates on elastic foundation.
4. To carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction.
5. To better understand the concepts of laterally loaded pile.

Course Code	**:**	CE820
Course Title	**:**	**OFFSHORE GEOTECHNICAL ENGINEERING**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To analyse index and engineering properties of marine clays.
2. To adopt suitable investigation method and sampling techniques for these marine deposits
3. To analyse loads on offshore structures and select appropriate foundation for these structures.
4. To implement required ground improvement technique for these structures

Course Content

Identify and describe key challenges of offshore engineering design - describe the aspects of the marine environment that feed into offshore engineering design.

Describe the main components of an offshore site investigation; Interpret selected geotechnical site investigation data - Identify the main types of offshore foundation systems and describe the drivers during foundation design, perform selected foundation design calculations to illustrate the interplaying mechanisms.

Identify key aspects of geotechnical pipeline design and perform selected design calculations to illustrate the interplaying mechanisms - determine the loads acting on the offshore structures.

References

1. *Randolph M and Gourvene S, Offshore Geotechnical Engineering, CRC Press,2017.*
2. *Ben C. Gerwick, "Construction of Marine and Offshore Structures", CRC Press, 1999.*
3. *B. Gou, S. Song, J. Chacko and A. Ghalambor, "Offshore Pipelines", GPP Publishers, 2006.*
4. *S. K. Hakrabarti, "Handook of Offshore Engineering", Elsevier, 2005.*
5. *M. J. Tomlinson, "Pile Design and Construction", E and F Spon, 1994*

Course Outcomes

At the end of the course students will be able

1. To analyse index and engineering properties of marine clays.
2. To adopt suitable investigation method and sampling techniques for the marine deposits.
3. To analyse loads on offshore structures and select appropriate foundations for those.
4. To implement required ground improvement techniques for offshore structures.

Course Code	**:**	CE821
Course Title	**:**	**ROCK MECHANICS**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the behaviour, properties and to classify the rock mass.
2. To comprehend the models of failure of the rock.
3. To find the in-situ stresses in rock using their measurements.
4. To analyse the stability of rock in sloping ground and provide the remedial measures.

Course Content

Rocks of peninsular India and the Himalayas - Index properties and classification of rock masses, competent and incompetent rock - value of RMR and ratings in field estimations.

Behaviour of rock under hydrostatic compression and deviatory loading - Models of rock failure - planes of weakness and joint characteristics - joint testing, Mohr - Coulomb failure criterion and tension cut-off - Hook and Brown

Strength criteria for rocks with discontinuity sets.

In-situ stresses and their measurements, flat jack-over-under coring methods - stress around underground excavations - Design aspects of openings in rocks - case studies.

Rock slopes - role of discontinuities in slop failure, slope analysis and factor of safety - remedial measures for critical slopes - case studies - Reinforcement of fractured and joined rocks - shotcreting, bolting, installation methods - case studies.

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

At the end of the course students will be able
1. To conduct lab and field tests for given project.
2. To choose appropriate methods to improve stability of rock mass.
3. To estimate the foundation capacity of a rock mass.
4. To design a tunnel excavation and support systems.

Course Code	**:**	CE822
Course Title	**:**	**UNSATURATED SOIL MECHANICS**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the basic mechanisms of soil under specific conditions.
2. To enhance the ability of relating the basic mechanisms of soil to behaviour of the soil under various loading conditions.
3. To understand the application of the theory of elasticity and plasticity to characterize the soil behaviour.
4. To develop the understanding of soil behaviour and apply it to develop elasto-plastic models based on unsaturated soil conditions.

Course Content

Stresses and strains in soils - stress, strain paths invariants - one-dimensional and isotropic compression of soils and idealisation; state boundary of compression of soils; stress paths and soil tests; critical state line and Roscoe surface; Drained and undrained planes; Critical state line for sands; Behaviour of over-consolidated soils and Hvorslev surface;

Behaviour of soils before failure; Interpretation of index tests in the light of critical state concepts; Cam-clay models, Determination of critical state parameters.

Identification and classification of expansive and collapsing soils, effective stress concepts, matric and osmotic suction, collapse, heave and strength characteristics of unsaturated soils, flow through unsaturated soils.

Laboratory evaluation of swell pressure and swell potential, tests to evaluate collapse potential. Measurements of soil suction.

References

1. *Jean-Louis Briaud, Geotechnical Engineering: Unsaturated and Saturated Soils, John Wiley & Sons, Inc., New Jersey, 2013.*
2. *Murray E.J, Sivakumar V., Unsaturated Soils: A fundamental interpretation of Soil behaviour, Wiley-Blackwell, 2010.*
3. *Ng C.W.W and Menzies B, Advanced unsaturated soil mechanics and engineering, CRC Press, 2019.*
4. *Lu, N. and Likos, W.J., Unsaturated soil mechanics, Wiley, 2004 (2)*
5. *Fredlund, D. J., Rahardjo, R., and Fredlund, M.D. Unsaturated Soil Mechanics in Engineering Practice, Wiley, 2012.*

Course Outcomes

At the end of the course students will be able

1. To demonstrate basic mechanisms behind index properties and tests on soil
2. To relate behaviour of soils subjected to various loading and drainage conditions.
3. To apply theory of elasticity and plasticity to characterize the stress-strain behaviour of soils.
4. To formulate basic elasto-plastic model based on Unsaturated soil mechanics like cam-clay.

Course Code	**:**	CE823
Course Title	**:**	**ANALYSIS AND DESIGN OF DEEP EXCAVATIONS**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the requirements and principles of deep excavations
2. To understand the analysis and designing of deep excavations
3. To comprehend and apply the concepts of lateral earth pressure and retaining structures
4. To analyse the stress and deformation of deep excavations by various methods
5. To design supporting systems for a deep excavation

Course Content

Introduction to the analysis and design of excavation - Excavation methods and lateral supporting systems: retaining walls, strutting systems, factors influencing on the selection of the retaining strut system, case history.

Lateral earth pressure: Rankine's and Coulomb's earth pressure theory - earth pressure for design of excavation - Stability analysis: free and fixed earth support method - shear failure of strutted walls, push in, basal heave, upheaval, sand boiling.

Stress and deformation analysis of excavation: simplified method, beam on elastic foundation method, finite element method - Design of excavation supporting systems: design methods and factor of safety, structural components in braced excavations, strut systems, anchor systems, tests of anchors.

References

1. *Y. O. Chang, Deep Excavation Theory and Practice, Taylor & Francis Group, London, UK, 2006.*
2. *R. D. Holtz & W. D. Kovaces, An Introduction to Geotechnical Engineering, Prentice -Hall, Inc., Englewood Cliffs, NJ, 1981.*
3. *R. B. Peck, W. E. Hanson & T. H. Thornburn, Foundation Engineering, John Wiley & Sons, New York,1977.*
4. *M. R. Hausman, Engineering Principles of Ground Modification, McGraw – Hill Publishing Company, New York, 1990.*
5. *Malcolm Puller, Deep Excavations: A practical manual (2nd Edition), ICE Publishing, 2003.*

Course Outcomes

At the end of the course students will be able

1. To understand the requirements and apply the principles of deep excavations
2. To analyse and design deep excavations
3. To apply the concepts of lateral earth pressure and retaining structures
4. To analyse the stress and deformation of deep excavations by various methods
5. To design supporting systems for a deep excavation

Course Code	**:**	CE824
Course Title	**:**	**GEOTECHNICAL EARTHQUAKE ENGINEERING**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To study the theory of vibration and mechanism of earthquake.
2. To understand the concept of ground motion and the process of estimating the frequency.
3. To analyse the seismic force and the foundation provided to resist that seismic forces.

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. Strong Motion Records - characteristics of ground motion - Factors influencing Ground motion - Estimation of frequency content parameters.

Seismic site investigations – Selected Case Studies - Evaluation of Dynamic soil properties – Codal Provisions.

Design Ground Motion - Developing Design Ground Motion-Codal recommendations.

Earthquake Resistant Design of foundation of buildings - Design considerations -. Earthquake Response of slopes - Evaluation of slope stability – Liquefaction Susceptibility - Liquefaction Resistance- Codal recommendations.

Risk mapping - Hazard assessment – Mitigation measures - Seismic micro zonation and its importance.

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.*

Course Outcomes

At the end of the course students will be able

1. To determine the strong ground parameters from a seismogram.
2. To carry out deterministic and probabilistic seismic hazard analysis considering different soil properties and site conditions.
3. To analyse liquefaction susceptibility of a site and determine a FOS against liquefaction.
4. To design earthquake resistant foundations, retaining walls, slopes etc.

Course Code	**:**	CE825
Course Title	**:**	**GEOENVIRONMENTAL ENGINEERING**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To identify the sources of soil contamination and its impact on geoenvironment.
2. To familiarize with the retention and flow behaviour of contaminants in soil.
3. To realize the significance of sampling techniques in geoenvironmental characterization.
4. To understand the state of the art methodologies for soil decontamination and containment.

Course Content

Basic concepts related to soil pollution - Sources of pollution- industrial, mining, agricultural, and municipal; types of contaminants - Impact of contamination - physical and chemical properties of soil - Retention behaviour - governing factors, sorption characteristics - isotherms.

Contaminant transport- saturated and unsaturated flow, pore size distribution characteristics - Site investigation - Soil sampling - sample handling, transportation, characterization, preservation and storage.

Non-destructive techniques - electromagnetic, thermal and seismic, Soil remediation - need and approach, Techniques - soil washing, permeable reactive barriers, solidification, vacuum extraction, electro-kinetic remediation, thermal desorption.

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

References

1. *Fang H.Y., Ronald.C.Chaney, "Introduction to Environmental Geotechnology (2nd Edition)", CRC Press, 2016.*
2. *Rowe R.K., "Geotechnical and Geoenvironmental Engineering Handbook" Kluwer Academic Publications, London, 2000.*
3. *Sarsby.R.W., "Environmental Geotechnics (2nd Edition)", ICE Publishing, 2012.*
4. *Reddi L.N. and Inyang, H. I., "Geoenvironmental Engineering, Principles and Applications" Marcel Dekker Inc. New York, 2000.*
5. *Yong, R. N., "Geoenvironmental Engineering, Contaminated Soils, Pollutant Fate, and Mitigation" CRC Press, New York, 2001.*
6. *Sharma H.D. and Reddy K.R., "Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies" John Wiley & Sons, Inc., USA, 2004.*

Course Outcomes

At the end of the course students will be able

1. To identify the origin, nature, and extent of contamination in field.
2. To predict the retention and flow properties of contaminants.
3. To adopt suitable sampling techniques for geoenvironmental characterization.
4. To suggest the remediation techniques for decontamination.

Course Code	**:**	CE826
Course Title	**:**	**GEOSYNTHETICS ENGINEERING**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To comprehend different types of Geosynthetics and their functions.
2. To compare the manufacturing methods and properties of Geosynthetics.
3. To compare conventional and reinforced earth retaining structures.
4. To apply design principles of Geosynthetics in Geotechnical applications.

Course Content

Background of reinforced earth, mechanism and concepts, Basics of reinforced earth wall design - Geosynthetics - classifications, functions, applications, raw materials used.

Different types of Geosynthetics, manufacturing, system, Design and sustainability - Various properties of Geosynthetics, physical properties, mechanical properties, hydraulic properties & endurance properties.

Nano material - Different types of facing elements, construction procedure, cost, design of Geosynthetics wrap around faced wall, geogrid reinforced soil walls, geocell wall, gabion wall - Model for single and multi-layer reinforced slopes, guidelines for design of reinforced slopes, Design of basal reinforced embankment, placement of Geosynthetics, construction procedure, widening of existing road embankments.

Consolidation techniques, Development of design chart for prefabricated vertical drains, ground instrumentation and monitoring, Design of encased stone columns, geocell/geofoam systems. Bearing capacity of Geosynthetics reinforced soil system; geocell reinforced sand overlaying soft clay.

References

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

Course Outcomes

At the end of the course students will be able

1. To understand the significance of Geosynthetics and classify them.
2. To classify Geosynthetics based on its manufacturing method and properties.
3. To recommend conventional and reinforced earth retaining structures.
4. To apply the design principles of Geosynthetics for Geotechnical applications.

Course Code	**:**	CE827
Course Title	**:**	**FORENSIC GEOTECHNICAL ENGINEERING**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the roles and responsibilities of a forensic geotechnical engineer.
2. To understand the types of damages and investigation methods that can be adopted.
3. To understand and apply reverse-engineering of design and analysis to identify the cause of failure.
4. To inculcate the ability to write reports of the faults as deduced and suggest repair and rehabilitation measures.

Course Content

Types of Damage - Planning the Investigation - Investigation methodology, Collection of Data - Distress Characterization - Development of Failure, Hypothesis - Diagnostic Tests - Back Analysis - Technical Shortcomings, Legal Issues - Reliability Aspects.

Observation Method of Performance Evaluation - Case Histories related to settlement of Structures - lateral movement - backfill settlements - causes due to soil types such as collapsible soil, expansive soil, soluble soils, slope failures and landslides, debris flow, slope softening and creep, trench collapses, dam failures.

Foundation due to earthquakes, erosion, deterioration, tree roots, groundwater and moisture problems, groundwater problems, retaining failures problems, pavement failures and issues, failures in soil reinforcement and geosynthetics.

Development of codal provisions and performance based analysis procedures.

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

At the end of the course students will be able

1. To understand the roles of a Forensic Engineer.
2. To classify the types of damage and plan the investigation accordingly based on the knowledge obtained from case studies and relatable issues.
3. To apply design and analysis principles to investigate the cause of failure.
4. To suggest mitigation or rehabilitation measures according to the site conditions.

Course Code	**:**	CE828
Course Title	**:**	**GEOTECHNICS IN PRACTICE**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the application of geotechnical concepts to applying it in live practical issues.
2. To learn the procedural activities as part of a consultancy project.

3. To understand the limitations given by IS and IRC codes.
4. To comprehend to the quality requirements of any project.

Course Content

Geotechnical Interpretation Report (GIR) – deriving design parameters for a particular site – data analysis.

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.

Stepwise analysis of underground structures – Damage assessment of structures due to tunnelling - Empirical methods.

Elevated structures – foundation design – Shallow, Pile and Pile-raft – Geological considerations – 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.

References

1. *All relevant IS and IRC codes.*
2. *ISO 9001:2015.*
3. *All relevant ASTM and Euro codes.*

Course Outcomes

At the end of the course students will be able

1. To understand practical Geotechnical issues and apply appropriate engineering solutions.
2. To adopt the procedural activities as part of a consultancy project.
3. To follow and work according to the limitations given by IS and IRC codes.
4. To comprehend to the quality requirements of any project.

Course Code	**:**	CE829
Course Title	**:**	**PORTS AND HARBOUR STRUCTURES**
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To estimate the loading on port and harbour structures.

2. To gain knowledge of analysis and design of port and harbour structures.
3. To study concepts of shoreline evaluation, dredging etc.
4. To learn the concepts construction methodology, integrity monitoring, retrofitting and rehabilitation, according to codal requirements.
5. 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 Post Structures – Breakwaters, Jetties, Wharves, Quays, Diaphragm Walls, Slipways, Docks – Design of breakwaters - Dredging & methods of disposal - Offshore terminals and islands – fenders and Mooring Facilities.

Limit state and working stress method of design - crack width calculations. Integrity analysis of berthing structures - Case studies of breakwater failures and other types of structures - Partial safety Factors - Codal Requirements.

Soil-structure interaction – Pile load tests – ground improvement techniques – Design of piles – design and construction of diaphragm walls.

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.

Course Outcomes

At the end of the course students will be able

1. To estimate the loading on port and harbour structures.
2. To analyse and design any port and harbour structure.
3. To apply the concepts of shoreline evaluation, dredging etc.
4. To utilise the concepts construction methodology, integrity monitoring, retrofitting and rehabilitation, according to codal requirements.
5. To design piles and diaphragm walls for ports and harbours.

LABORATORY COURSES

Course Code	**:**	CE809
Course Title	**:**	**ADVANCED GEOTECHNICAL ENGINEERING LABORATORY**
Number of Credits	**:**	2
Course Type	**:**	Laboratory

Course Learning Objectives

1. To perform basic tests on soil to identify its index properties.
2. 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 – Soil resistivity meter – Soil response characteristics – Ground penetrating radar.

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

At the end of the course students will be able

1. To perform basic tests on soil to identify its index properties.
2. To carry out advanced laboratory tests to identify the engineering properties of soil.

Course Code	**:**	CE810
Course Title	**:**	**GEOTECHNICAL DESIGN STUDIO**
Number of Credits	**:**	2
Course Type	**:**	Laboratory

Course Learning Objectives

1. To understand the concept of software based numerical modelling.
2. To learn and carry out basic numerical modelling on PLAXIS 2D, 3D, FLAC3D v7.0 and OASYS Geotechnical software.

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 foundation under different loading conditions.

References

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

Course Outcomes

At the end of the course students will be able

1. To understand the concept of software based numerical modelling.
2. To carry out basic numerical modelling for practical Geotechnical issues on PLAXIS 2D, 3D, FLAC3D v7.0 and OASYS Geotechnical software.