NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF CIVIL ENGINEERING

Revised Curriculum and Syllabi

Program Name
Master of Technology in Geotechnical Engineering
Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 12.07.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

CURRICULUM

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	CE1011	Foundation Engineering	3-1-0	4
2	CE1012	Advanced Soil Mechanics	3-1-0	4
3	CE1013	Geotechnical Earthquake Engineering	3-1-0	4
4	CE9061-CE9067	Specialization Elective I	3-0-0	3
5		Specialization Elective II	3-0-0	3
6	CE1061	Geotechnical Lab-I	0-0-4	2
7	CE1062	Computational Lab	0-0-4	2
TOTAL			15-3-8	**22**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	CE2011	Ground Improvement	3-1-0	4
2	CE9081-CE9090	Specialization Elective III	3-0-0	3
3		Specialization Elective IV	3-0-0	3
4		Specialization Elective V	3-0-0	3
5	CE9095-CE9097	Specialization Elective VI	3-0-0	3
6	CE2061	Geotechnical Lab-II	0-0-4	2
7	CE2062	Mini Project with Seminar	0-0-8	4
TOTAL			**15-1-12**	**22**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	XX907X	Audit Lectures/Workshops	0-0-2	0
2	CE3061	Dissertation-I	0-0-24	12
3	CE3062	Seminar - Non-Project / Evaluation of Summer Training	0-0-4	2
TOTAL			0-0-30	**14**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credits
1	CE4061	Dissertation - II / Industrial Project	0-0-24	12
2	CE4062	Project Seminar	0-0-4	2
TOTAL			0-028	**14**

CREDIT UNIT OF THE PROGRAM:

Semester	I	II	III	IV	TOTAL
Credit Unit	22	22	14	14	72
Contact Hours	26	28	30	28	112

Sub Discipline: DEPTH ELECTIVES

FIRST SEMESTER: Specialization Elective-I & II

SL. NO.	SUBJECT CODE	SUBJECTS
1	CE9061	Applied Probability and Statistics in Civil Engineering
2	CE9062	Geo-environmental Engineering
3	CE9063	Groundwater Hydrology
4	CE9064	Finite Element Method
5	CE9065	Offshore Geotechnical Engineering
6	CE9066	Design of Reinforced Concrete Foundation
7	CE9067	Advanced Analysis of Structures

SECOND SEMESTER: Specialization Elective-III to V

SL. NO.	SUBJECT CODE	SUBJECTS
1	CE9081	Soil Dynamics and Machine Foundation
2	CE9082	Soil Structure Interaction
3	CE9083	Constitutive Modelling in Soil Mechanics
4	CE9084	Rock Mechanics
5	CE9085	Slope Stability and Earth Dams
6	CE9086	Pavement Analysis and Design
7	CE9087	Reinforced Earth and Geotextiles
8	CE9088	Remote Sensing and GIS
9	CE9089	Forensic Geotechnical Engineering
10	CE9090	Tunnelling Technology

Specialization Elective-VI

SL. NO.	SUBJECT CODE	SUBJECTS
1	CE9095	Applied Numerical Methods
2	CE9096	Machine Learning in Civil Engineering
3	CE9097	Modelling, Simulations and Computer Applications in Geotechnical Engineering

Specialization specific faculty and their specializations

S.No.	Name	Qualification	Specialization	Research Area	(Reg / Temp. / Adjunct)
1.	Dr. K. Bhattacharya	BE, M. Tech., Ph.D.	Geotechnical Engineering	Geotechnical Earthquake Engg., Machine Foundation, Soil dynamics	Regular
2	Dr. V.K. Dwivedi	BE, M. Tech., Ph.D.	Water Resources Engineering	Water Resources and Highway Engineering	Regular
3	Dr. A. K. Samanta	BCE, MCE, Ph.D.	Structural Engineering	Structural Damage, Residual life, Soil-Structure Interaction	Regular
4	Dr. A. K. Banik	BE, M. Tech, Ph.D.	Structural Engineering	Offshore Structure, Soil-Structure Interaction	Regular
5	Dr. R. P. Nanda	BE, M. Tech, Ph.D	Structural Engineering	Geotechnical Earthquake Engineering	Regular
6	Dr. D. Das	BE, M. Tech., Ph.D.	Structural Engineering	Dynamics of structures, Fluid-Soil-structure Interaction	Regular
7	Dr. S. Pal	BE, MCE, Ph.D.	Geotechnical Engineering	Gr Improvement & Geo-environmental Engineering	Regular
8	Dr. P. Roy	BE, M. Tech., Ph.D.	Structural Engineering	Reliability Engg. Machine Learning in Structural & Geotechnical Applications.	Regular

Program Outcomes (POs):

PO1: **A**bility to independently carry out research /investigation and development work to solve practical problems

PO2: 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

PO4: Ability to work in inter-disciplinary engineering teams with social responsibility and ethical values and pursue lifelong learning.

NB.: COs (preferably 4 to 5 nos) will be as per the faculty concerned… and the Correlation Level of Co vs PO as below

"1" – Slight (Low) Correlation
"2" – Moderate (Medium) Correlation
"3" – Substantial (High) Correlation

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 1011	FOUNDATION ENGINEERING	PCR	3	1	0	4	4
Pre-requisites		Soil Mechanics					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Interpret field and laboratory data and prepare soil investigation report. • CO2: Analyze bearing capacity and settlement of foundations. • CO3: Design shallow and deep foundations. • CO4: Analyze and suggest remedial measures against foundation failures.
Topics Covered	**Shear strength:** Basic concepts, Shear strength characteristics of cohesive and cohesionless soils under drained, undrained and partially drained conditions, Mohr-Coulomb theory, Mohr's circle (4) **Soil Exploration:** Exploration Methods; Planning the Exploration Program; Boring and Sampling; In Situ Tests: Standard Penetration Tests, Field Vane & Borehole shear tests, Rock Sampling, Core Recovery, RQD; Geophysical Exploration; Plate Load Test, Static Cone Penetration Test. Preparation of Soil Report. (8) **Shallow Foundations:** Bearing Capacity: - Bearing capacity of foundation based on in-situ tests. Bearing capacity for foundation on slope, design of mat foundations including floating raft, Effect of Water Table; Footings with Eccentric or Inclined Loads, on Layered Soils. (10) **Deep Foundations:** Mechanics of load transfer in piles, load carrying capacity, pile load test, Vertically loaded piles, Static capacity, Bearing Resistance of Piles on Rock; Uplift Resistance; Laterally Loaded Piles –Ultimate Lateral Resistance; Negative Skin Friction; Under Reamed Piles; Ultimate Capacity of Pile Groups in Compression, Pullout & Lateral Load; Efficiency; Settlements of Pile Groups. (10) **Sheet piles:** Design of anchored sheet piles: Free Earth Support Method, Fixed Earth Support Method, Problems. (6) **Coffer Dams:** Cellular cofferdams- Circular and Diaphragm type, Merits and demerits, Deign of circular type cofferdams, practice problems. (6) **Braced Cuts:** Pressure envelope for Braced – Cut design, Pressure envelope for cuts in layered soil, Design of various components of a braced cut, Bottom heave of cut in clay, Stability of the bottom of cut in sand.(4)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Design Aids in Soil Mechanics and Foundation Engineering S.R. Kaniraj 2. Foundation Engineering by V.N.S Murthy **REFERENCE BOOKS:** 3. Foundation Engineering by B.M.Das 4. Foundation Engineering By J.E. Bowles 5. Design of Pile Foundation By Tomlinsion.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2	3	--	1
CO2	3	1	2	--
CO3	3	2	3	---
CO4	2	--	3	--

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 1012	ADVANCED SOIL MECHANICS	PCR	3	1	0	4	4
Pre-requisites		Soil Mechanics					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Analyse effective stress for different field conditions • CO2: Calculate settlement of soils using one dimensional and three dimensional consolidation theories. • CO3: Calculate seepage through soil. • CO4: Develop stress path diagrams for different load conditions.
Topics Covered	**Stresses, Strains, and Deformations of Soils** Stresses and strains, Idealized stress-strain response and yielding, Generalized Hooke's Law, Plane strain and axial symmetric conditions, Anisotropy and cross anisotropy, Total and Effective stresses, Lateral Earth pressure at rest, stresses in soil from surface loads, octahedral stresses, stress and strain invariants, stress paths, plastic analysis of soil: Yielding and failure of particulate materials, Constitutive relationships of soil, practical example. (15) **One-Dimensional Consolidation Settlement of Fine-Grained Soils** Basic concepts, calculation of primary consolidation settlement, One-Dimensional Consolidation Theory, Secondary Compression settlement, One-Dimensional Consolidation Laboratory Test, Relationship between laboratory and field consolidation, Typical values of consolidation settlement parameters and empirical relationships, Preconsolidation of soils using wick Drains, practical example. (12) **Two-Dimensional flow of water through soils** Two-Dimensional flow of water through porous media, Flow net sketching, interpretation of Flow net, Finite difference solution for Two-Dimensional flow, Flow through Earth Dams, Soil filtration, practical example. (13)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Braja M.Das, "Advanced Soil Mechanics" Tata Mc.- Grawhill 2. M. Budhu, "Soil Mechanics and Foundations", Wiley India Pvt. Ltd., New Delhi **REFERENCE BOOKS:** 1. R.O. Davis and A.P.S. Selvadurai, "Elasticity and Geomechanics, Cambridge University Press, New York.

	2. R F Scott, “Principles of Soil Mechanics”, Addison & Wesley

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2	--	3	--
CO2	3	2	3	--
CO3	3	2	3	---
CO4	3	2	3	1

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 1013	GEOTECHNICAL EARTHQUAKE ENGINEERING	PCR	3	1	0	4	4
Pre-requisites		SOIL MECHANICS AND DYNAMICS OF SYSTEM					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Determine size of earthquake and strong ground motion parameters from a recorded seismogram or accelerogram. • CO2: Carry out deterministic seismic hazard analysis considering the different soil properties and site conditions. • CO3: Principles of Dynamics of Soil-Structures. • CO4: Design earthquake resistant geotechnical structures like retaining walls, slopes
Topics Covered	**Introduction to Geotechnical Earthquake Engineering:** Scope and objective; ground shaking, liquefaction, land slide, tsunami. (2) **Fundamentals of Vibration,** Free and Steady State Forced vibration of Damped SDF system, Impulsive Loading and Duhamel's Integral, System with Two Degree Freedom, Coupled Translation and Rotational Motion. Multi-degree Freedom system, Normal Coordinates, Generalized Mass, Stiffness and Damping Matrices. Newmark's Direct Integration Method (8) **Waves in Elastic Medium**, Stress and Strain, Hook's Law, Longitudinal Elastic Waves in Bar, Stress Waves in Elastic Infinite Medium. (4) **Engineering seismology:** Seismic waves, faults, Plate boundaries, Elastic Rebound Theory, Strong ground motion, effect of local site condition on ground motion. Intensity and Magnitude. Different Magnitude Scale: Richter magnitude, Moment magnitude Surface wave magnitude, Seismic energy, Spatial Variability of Ground Motion, Correlation between Magnitude and Energy released. Earthquake measuring instruments, Site specific response spectra; development and utility (8) **Characteristics of Rock Motion During Earthquake,** Vibration of Horizontal Soil Layers with Linearly Elastic Properties. Dynamic Soil Properties under Large Shear strain (6) **Development of Spectra**: Peak Acceleration, Peak Velocity, Peak Displacement, Frequency Content and duration, Attenuation Relationships, Development of response spectra, (4) **Liquefaction of Soils,** Dynamic Triaxial Tests, Cyclic Simple Shear Test, Rate of Excess Pore Pressure Increase, Assessment of liquefaction potential from insitu tests (SPT and CPT). (6) **Use of response spectra:** Retaining wall and Earthen dams with and Without Seepage. Examples. (7)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Geotechnical Earthquake Engineering, Steven L. Kramer 2. Principles of Soil Dynamics, B.M. Das and G.V. Ramana **3.** EARTHQUAKE RESISTNT DESIGN OF STRUCTURES, Pankaj Agarwal, M.Shrikende **4.** Elements Of Earthquake Engineering, A.R. Chandrasekharan, Jai Krishna,

	5. Geotechnical Earthquake Engineering Handbook, Roobert W. Day **REFERENCE BOOKS:** 1. Dynamics of Structures. Prof. Madhujit Mukhopadhyay. 2. Earthquake Engineering. Anil K. Chopra

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	2	--	--
CO2	2	--	3	1
CO3	3		1	--
CO4	3	2	3	--

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 2011	Ground Improvement	PCR	3	1	0	4	4
Pre-requisites		Soil Mechanics					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: understand how to improve the geotechnical properties of soft soil by different techniques. • CO2: identify ground conditions and suggest method of improvement • CO3: understand the principles of soil reinforcement and confinement in engineering constructions. • CO4: Promote wider use of techno – economical construction techniques such as Reinforced soil structures, Stone columns.
Topics Covered	**Introduction:** Formation of soil, major soil type, collapsible soil, expansive soil, reclaimed soil,sanitary land fill, ground improvements; objective, potential. (06) **General Principal of Compaction:** Mechanics , field procedure, quality control in field. (06) **Ground Improvement in Granular Soil:** In place densification by (i) Vibrofloatation (ii)Compaction pile (iii) Vibro Compaction Piles (iv) Dynamic Compaction (v) Blasting. (10) **Ground Improvement in Cohesive Soil:** Preloading with and without vertical drains.Compressibility, vertical and radial consolidation, preloading methods. Types of Drains, Design of vertical Drains, construction techniques. Stone Column: Function Design principles, load carrying capacity, construction techniques, settlement of stone column foundation. (10) **Ground Improvement by Grouting and Soil Reinforcement:** Grouting in soil, types of grout,desirable characteristics, grouting pressure, grouting methods. Soil Reinforcement: Mechanism,Types of reinforcing elements, reinforcement-soil interaction, Reinforcement of soil beneath the roads. (08) **Drainage & Dewatering in soils (**04) **Liquefaction Potential and Measures to prevent liquefaction (**02)
Text Books, and/or reference material	**TEXT BOOKS:** 1. M.P.Mosely, "Ground Improvement" CRC Press, Inc. 2. N.N.Som & S.C.Das, " Theory and Practice of Foundation Design", PHI Learning Pvt. Ltd., New Delhi. **REFERENCE BOOKS:** 1. K.B. Woods, D.S. Berry and W.H. Goetz, "Highway Engineering Handbook", 1960. 2. Winterkorn& Fang, "Foundation Engineering Hand book", Galgotia Publishing House . 3. Jie Han: Principles and practice of ground improvement, John Wiley and Sons Inc.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	--	1	--
CO2	2	3	--	1
CO3	2	--	3	--
CO4	1	--	2	3

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total of contact hours				Credit
			L	T	P	H	
CE 9061	**Applied Probability and Statistics in Civil Engineering**	**PEL**	**3**	**0**	**0**	**3**	**3**
Pre-requisites		Course Assessment methods					
Engineering Mathematics		Continuous (CT) and end assessment (EA). CT+EA					

Course Outcomes

- CO1: understand the basic of probability and statistics
- CO2: understand the random variables, different distributions of random variables, functions of random variable, joint distribution, sampling distributions, estimation theory, testing of hypothesis and goodness of fit tests.
- CO3: solve different engineering problems applying the theory of probability and statistics.
- CO4: apply the theories of probability and statistics to analyse data which is important for design of civil engineering structures and foundations.

Topics Covered

Probability: Axiomatic definitions of probability, addition rule and conditional probability, multiplication rule, total probability, Bayes' Theorem and independence, CE problems. (5)
Random Variables: Discrete, continuous random variables, probability mass, probability density and cumulative distribution functions, mathematical expectation, moments, probability and moment generating function, Markov inequality, Chebyshev's inequality problems. (6)
Special Distributions: Discrete uniform, binomial, geometric, negative binomial, hypergeometric, Poisson, continuous uniform, exponential, gamma, Weibull, beta, normal, lognormal, civil engineering problems. (8)
Function of a random variable: Different functions of a random variable. (2)
Joint Distributions: Joint, marginal and conditional distributions, product moments, correlation and regression, independence of random variables, bivariate normal distribution. (4)
Sampling Distributions: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Chi-Square, t and F distributions, problem (3)
Estimation: Unbiasedness, consistency, the method of moments and the method of maximum likelihood estimation, confidence intervals for parameters in one sample and two sample problems of normal populations, confidence intervals for proportions. (6)
Testing of Hypotheses: Null and alternative hypotheses, the critical and acceptance regions, power of the test, the most powerful test and Neyman-Pearson Fundamental Lemma, tests for one sample and two sample problems for normal populations, tests for proportion. (8)
Goodness of fit tests: Chisquare goodness of fit test and its applications, civil engineering problems. (2)

Text Books, and/or reference material

TEXT BOOKS:

1. Ang, A. H. S. and Tang, W. H. 1975. Probability Concepts in Engineering Planning and Design: Volume 1, Basic Principles, Wiley.
2. Ang, A. H.-S. and Tang, W. H. 1984. Probability Concepts in Engineering Planning and Design: Volume 2 Decision, Risk and Reliability, Wiley, New York.
3. Ross, S, 1998. A First Course in Probability, Prentice Hall, NJ.
4. Montgomery, D.C. and Runger, G.C. 1998. Applied Statistics and Probability for Engineers, Wiley, New York.

REFERENCE BOOKS:

1. Speiegel M. R., Schiller, J.J. and Srinivasan, R. A. 2010. Probability and Statistics, Tata- Mcgraw-Hill, New Delhi.
1. Papoulis, A. 1991. Probability. Random variable and Stochastic process, McGraw-Hill, New York.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5
CO1	2	-	-	-	-
CO2	2	-	-	-	-
CO3	-	-	3	-	-
CO4	-	-	-	3	-

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9062	GEOENVIRONMENTAL ENGINEERING	PEL	3	0	0	3	3
Pre-requisites		Soil Mechanics, Environmental Engineering					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Identify contaminant transport mechanisms in soils • CO2: Design of suitable liner for landfills. • CO3: Apply suitable in-situ remediation techniques to decontaminate polluted sites
Topics Covered	**Sources and Site Characterization:** Scope of Geoenvironmental Engineering, Various Sources of Contaminations, Need for contaminated site characterization; and Characterization methods. (6) **Soil properties:** Geotechnical properties, Chemical properties. (6) **Pollution in Groundwater:** Introduction, Advection and dispersion of pollutants in groundwater environment, Solute transport modelling by the finite element method. (8) **Contaminant Transport and Fate:** Transport process, Mass-transfer process, Modeling, Advection-Dispersion equation for modelling of contaminant transport in porous media. (12) **Remediation Techniques:** Objectives of site remediation, various active and passive methods, remediation NAPL sites, Emerging Remediation Technologies. (6) **Landfills:** Types of landfills, Site Selection, Waste Containment Liners, Leachate collection system, Cover system, Gas collection system. (6)

Text Books, and/or reference material	**TEXT BOOKS:** 1. Daniel, D.E., "Geotechnical practice for waste disposal", Chapman and Hall, London. 2. H.D. Sharma &K.R.Reddy, " Geoenvironmental Engineering: Site remediation, waste containment and emerging waste management technologies" John Wiely& Sons, INC. **REFERENCE BOOKS:** 1. Sincero and Sincero, "Environmental Engineering: A Design Approach", Prentice Hall of India (P) Ltd. New Delhi. 2. Kays, W.B., "Construction of Linings for reservoirs, Tanks and Pollution control facilities".

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3		1	
CO2	3	2	3	
CO3	2		3	1

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9063	GROUND WATER HYDROLOGY	PEL	3	0	0	3	3
Pre-requisites		Hydrology & Irrigation Engineering, Soil Mechanics					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Interpret aquifer characteristics for availability of groundwater • CO2: Estimate characteristic feature of geo-hydrology • CO3: Estimate storage and yield and quality of ground water from the aquifer • CO4: Manage and develop ground water for sustainable use						

Topics Covered	**Fundamentals of ground water** Introduction – Characteristic of Ground water – Distribution of water - ground water column –Permeability - Darcy's Law - Types of aquifers – Hydro-geological Cycle – water level fluctuations. (6) **Hydraulics of flow** Storage coefficient - Specific field - Heterogeneity and Anisotropy -Transmissivity– Governing equations of ground water flow - Steady state flow – DupuitForchheimer assumptions – Velocity potential - Flow nets (6) **Estimation of parameters** Transmissivity and Storavity – Pumping test - Unsteady state flow - Thiess method – Jacob method - Image well theory – Effect of partial penetrations of wells - Collectors wells. (6) **Ground water development** Infiltration gallery - Conjunctive use - Artificial Recharge, Rainwater harvesting - Safe yield –Yield test – Geophysical methods – Selection of pumps. (6) **Water quality** Ground water chemistry - Origin, movement and quality - Water quality standards – Saltwater intrusion –Environmental concern (6) **Groundwater management** Ground water basin management; concepts of conjunction use (4)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Raghunath H.M., "Ground Water Hydrology", Wiley Eastern Ltd., 2000. 2. Todd D.K., "Ground Water Hydrology", John Wiley and Sons, 2000. **REFERENCE BOOKS:** 1. Bawvwr, Ground Water, John Wiley & Sons

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2	3	3	3
CO2	2	3	3	3
CO3	3	3	3	3
CO4	3	3	3	3

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9064	FINITE ELEMENT METHOD	PEL	3	0	0	3	3
Pre-requisites		Matrix Method of Analysis. Engineering Mechanics.					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Understand the concept of finite element method for solving geotechnical engineering problems						

	• CO2: Develop algorithms and write FE code for solving simple design problems and understand the use of commercial packages for complex problems • CO3: Apply finite element method for analysing behaviour of geotechnical structures.
Topics Covered	**Introduction:** Basics of FE, discretization, nodes, elements, mesh, stiffness, degrees of freedom, element stiffness matrix, element load vector, element displacement vector, assembly procedure, global stiffness matrix global load vector, global displacement vector, stresses and strains, types of elements and properties, interpolation functions. Difference between linear and quadratic elements (6) **Different formulations:** Galarkine's Residual Model, Virtual Work Model, Energy Principal etc. and derivation of shape functions in light of above of beam element. (6) **Triangular and Rectangular Element**: Formulation by basic method of displacement function with nodal variables. Examples. (8) **Introduction of Isoparametric Elements**: Plane stress and plane strain. Concept of Integration points, Jacobian matrix. Application in Geotechnical Engineering.Example. (6) **3D elements:** Formulation as Iso-parametric element. Application in Geotechnical Engineering. Example. (6) Programming on Simple Element Formulation (6)
Text Books, and/or reference material	**TEXT BOOKS:** 1 Finite Element Analysis (Theory and Programming). C.S. Krishnamurthy. Tata McGrew Hills 2 Finite Element Methods. Dhanraj Nair. Oxford **REFERENCE BOOKS:** 1. Problems in Structural Analysis by Matrix method. P. Bhatt. Wheelers.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	--	--	--
CO2	--	--	3	2
CO3	3		3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9065	OFFSHORE GEOTECHNICAL ENGINEERING	PEL	3	0	0	3	3
Pre-requisites		Solid Mechanics, Structural Analysis					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: CO1: Enable the students to learn basics of marine soil behavior. CO2: Design of offshore foundations, seabed anchors, and submarine pipelines. CO3 Implement in-situ testing procedures for determining the properties of marine clays.						

	CO4 Analyze behavior of marine soil deposits under repetitive loading conditions.
Topics Covered	**Submarine soils:** Origin, nature and distribution. Terrigenic and pelagic soils. Submarine soils of India. 4 **Engineering behaviour of submarine soils:** under-consolidated soils, calcareous soils, cemented soils, corals. 4 **Offshore site investigations:** sampling and sampling disturbance, insitu testing, wireline technology. 8 Offshore pile foundations for jacket type structures. 6 Foundations of gravity structures; Foundations for jackup rigs. 6 Anchors and breakout forces; anchor systems for floating structures. 6 Stability of submarine slopes. 4 Installation and stability of submarine pipelines. 4
Text Books, and/or reference material	**TEXT BOOKS:** 1. E.T. Richard Dean. Offshore Geotechnical Engineering, ICE, UK, London, 2009. 2. Mark Randolph and Susan Gourvenec. Offshore Geotechnical Engineering, CRC Press, 2011. 3. H. G. Poulos. Marine Geotechnics, Unwin Hyman, 1988. **REFERENCE BOOKS:** 1. Susan Gourvenec and Mark Cassidy. Frontiers in Offshore Geotechnics,Taylor & Francis, 2005. 2. William O. McCarron. Deepwater Foundations and Pipeline Geomechanics, J. Ross Publishing, 2011. 3. Hydrodynamics of Offshore Structures, S.K. Chakrabarti, WIT Press / Computational Mechanics

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2	1	2	--
CO2	3	3	3	2
CO3	3	1	2	--
CO4	3	--	2	--

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9066	DESIGN OF REINFORCED CONCRETE FOUNDATION	PEL	3	0	0	3	3
Pre-requisites		RC and Steel Structure Design					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Learn basic concept of RC design to solve geotechnical engineering problems • CO2: Design shallow and deep foundation for structures • CO2: Design earth and water retaining structures
Topics Covered	Refreshers course on RC Design-Beam, Column, Slab (8) Design of Mat foundation (Flexible & Rigid) (12) Design of Pile foundation (8) Design of sheet pile wall (8) Design of retaining wall (4) Design of Brace-cut (4)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Foundation design by B.M. Das 2. Foundation Engineering by J.E.Bowles 3. Foundation Engineering by P.C. Varghese **REFERENCE BOOKS:** 1. Design of R.C Structure, Mallik& Gupta 2. Design of Foundation Systems: Principles and Practices by Nainan P Kurian

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3			1
CO2	3	2	3	
CO3	3	2	3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			L	T	P	H	
CE 9067	**Advanced Analysis of Structures**	**PEL**	**3**	**0**	**0**	**3**	**3**

Pre-requisite(s)	Course Assessment methods
Engineering Mechanics, Solids Mechanics, Structural Analysis	Continuous (CT) and end assessment (EA). CT+EA

Course Outcomes (COs) :

- CO1: Model and analyse different structural systems by matrix method of analysis using displacement/ stiffness method
- CO2: Develop introductory understanding of the fundamental concepts of force/ flexibility method and finite element method
- CO3: : Develop basic understanding of elastic instability, second-order effects and nonlinearity on structures and introductory dynamic analysis.

Topics Covered (Hrs)

Part-I :

Recapitulation of basic theories/ theorems, fundamental concepts of analysis of Truss /Frames /structures, basic concepts of force and displacement methods, statical and kinematic indeterminacies, Consistent Deformation method, Slope-Deflection method. [6]

Stiffness / Displacement Method: Element stiffness matrix, load vector, transformation matrices, assembling, global stiffness matrix, solution. [10]

Flexibility/ Force Method: Element flexibility matrix, load vector, transformation matrix, assembling, global flexibility matrix, solution. [6]

Part-II :

Introduction to Elastic instability and second-order effects on simple structure **[10]**

Introduction to nonlinear analysis: Geometric and material nonlinearity [4]

Introduction to Structural Dynamics: Vibration and Oscillation, Degree of freedom, Free body diagram, D'Alembert's principle, Free and forced vibration, Damping, Dynamic loading, Free and forced vibration of undamped and viscously damped SDOF & MDOF system [8]

Text Books, and/or reference material(s)

Text Books:

1. Intermediate Structural Analysis by C.K. Wang, McGraw-Hill Education
2. Structural Analysis by L.S. Negi & R.S. Jangid, Tata McGraw-Hill Publishing Company Limited
3. Structural Analysis: A Unified Classical and Matrix Approach, Amin Ghali, Adam M. Neville by E & FN SPON 4th Ed.
4. Stability Analysis and Design of Structure by M. L. Gambhir, Springer 2004 edition
5. Structural Dynamics: Theory and Computation by Mario Paz, Kluwer Academic Publishers

Reference Books:

1. Structural Analysis: A Matrix Approach by G.S. Pandit & S.P. Gupta, Tata McGraw-Hill Publishing Company Limited

1. Dynamics of Structures by Ray Clough (Author), Joseph Penzien, McGraw-Hill Education; 2nd edition (31 May 1993)

Mapping of Course Outcomes Cos→POs (mentioning Correlation Level)

	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	-
CO2	2	-	1	1	1
CO3	-	-	3	2	-

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9081	SOIL DYNAMICS AND MACHINE FOUNDATION	PEL	3	0	0	3	3
Pre-requisites		Geotechnique					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Apply theory of vibrations to solve dynamic soil problems • CO2: Analyze and design behaviour of a machine foundation resting on the surface, embedded foundation and foundations on piles by Soil as Spring and Elastic Half Space. • CO3: Analyze and design vibration isolation systems						
Topics Covered	Introduction to machine foundation. (2) General theory: Theory of SDF and MDF system, damping of single and two degree freedom system, transient response and periodic response. Coupled Translation and Rotational Motion (8) Design parameters: Dynamic soil parameters under compression, bending yawing etc, Evaluation of elastic base theory: BARKAN'S METHOD. Codal Methods of Dynamic Soil Properties Determination. (6) Elastics Half Space Theory and Application. (6) Block foundation: Mode of vibration, theoretical and recommended methods of dynamic analysis, design of reciprocating machine foundation. (8) Hammer foundation (8) Turbogenerator foundation: Special consideration in planning and design, design data recommended, dynamic analysis and design. (2)						
Text Books, and/or reference material	**TEXT BOOKS:** 1. Handbook of Machine Foundation. By.: C.V. Vaidyanathan and P. Srinivashalu 2. Design Aids in Soil Mechanics and Foundation Engineering S.R. Kaniraj **REFERENCE BOOKS:** 1. Dynamics of Structures by Madhujit Mukhopadyay 2. IS 5249:1992: Determination of dynamic properties of soil- Method of test 3. IS 2974 (Part 1) 1982: Code of practice for design and construction of machine foundation (Reciprocating type of machine)						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3		2	
CO2		2	3	1
CO3	3		3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9082	SOIL STRUCTURE INTERACTION	PEL	3	0	0	3	3
Pre-requisites		Soil Mechanics. Engineering Mechanics					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: understand the basis of soil-structure interaction • CO2: understand various soil models like beams on elastic foundation (Winkler beam model), infinite beam, finite beam models. • CO3: apply soil-structure interaction models to different type of foundations like pile, sheet pile walls (cantilever and anchored sheet pile walls). • CO4: analyse the foundation of different civil structures with considering soil-structure interaction in static as well as dynamic conditions.
Topics Covered	**Part I:** Introduction, Superstructure-foundation interaction, static soil-structure interaction.(4) Non-uniform contact pressure, Interaction problems of shallow foundation, Combined footing, Rigid method, Flexible method. (6) **Various Soil Models:** Beams on elastic foundation, Infinite beam, Finite beam, Modulus of subgrade reaction. (10) Sheet pile wall, Cantilever and anchored sheet pile wall, Fixed earth support, Free earth support. (4) Piles under different loading conditions, Analysis under lateral load, Different approaches, Mechanism of failure, Ultimate load, Deflections, Elastic continuum approach, Design, Analysis. (8) **Part-II:**Introduction to Dynamic Soil Structure interaction. (2) Estimations of damping ratio of DSSI. (6) Geotechnical consideration of DSSI (2)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Advanced GEOTECHNICAL Engineering soil-structure Interaction using Computer and Material Models by C.S.Desai, Musharraf Zaman. 2. Foundation analysis and Design by J.E.Bowles **REFERENCE BOOKS:** 1. Soil-Structure Interaction Numerical Analysis and Modelling by J. W. Bull. 2. Advanced Soil Mechanics B.M. Das, McGraw Hills Publishers. 3. Dynamic Soil-Structure Interaction, John. P. Wolf, Prentice Hall Inc.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3			
CO2	3			
CO3		3		
CO4		3		

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9083	CONSTITUTIVE MODELING IN SOIL MECHANICS	PEL	3	0	0	3	3
Pre-requisites		Soil Mechanics, Engineering Mechanics.					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Understand theory of plasticity and various yield criteria and flow rule • CO2: Apply critical state concept to consolidation and triaxial soil behaviour • CO3: Learn the theory of propagation of waves through elastic medium						
Topics Covered	Mechanics of continua (Stress and strain, Concept of strain, Displacement field, Concept of small domain, Body undergoing small deformation, Strain tensor, Derivative of a vector fixed in a moving reference, Physical interpretation of strain tensor, Cubical dilatation, Transformation of strains, Equations of compatibility, Stresses, Concept of stress, Principal stresses and strains, Invariants, Cauchy's stress quadric and Mohr diagram, Octahedral stresses and strains, Spherical and deviatoric stress components, Constitutive relations.(16) Equations of equilibrium (Some useful expressions, Differential equations at a point (general), Differential equations at a point (in terms of stresses), Differential equations at a point (in terms of displacements), General solution, Two-dimensional cases, Theorems of elasticity, Principles of superposition, Strain energy, Virtual work. (12) Development of soil dynamics to the present state of art, One-dimensional propagation of wave through an elastic medium, Three-dimensional propagation of waves in an infinite elastic medium , Propagation of waves in polar co-ordinates, Reflection/Refraction, Some background on integral transforms and other mathematical theorems, Lamb's solution for two-dimensionalproblem. (16)						
Text Books, and/or reference material	**TEXT BOOKS:** 1. Theory of Elasticity by Timoshenko and Goodier. McGrew Hills **REFERENCE BOOKS:** 1. Foundation Engineering by J.E. Bowles. McGrew Hills						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2		2	
CO2	3		3	
CO3			2	1

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9084	ROCK MECHANICS	PEL	3	0	0	3	3
Pre-requisites		Geotechnique.					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Choose appropriate methods to improve stability of rock mass • CO2: Estimate foundation capacity of rock mass. • CO3: Design of tunnel excavation and support systems.
Topics Covered	**Engineering Classification of Rocks:** Classification of intact rocks, Rock mass classifications, Rock Quality Designation (RQD), Rock Structure Rating (RSR), Rock Mass Rating (RMR), Strength and modulus from classifications, Classification based on strength & modulus and strength and fracture strain, Geoengineering classification. (10) **Stability of Rock Slopes and Foundations on Rocks:** Rock slopes, Modes of failure, Rotational failure, Plane failure, Design charts, Wedge method of analysis, Buckling failure, Toppling failure, Improvement of slope stability and protection. Foundations on Rock: Introduction, Estimation of bearing capacity, Stress distribution, Sliding stability of dam foundations, strengthening measures, Settlements in rocks, Bearing capacity of pile/pier in rock, Remedial measures, Foundations located on edge of jointed slope. (22) **Tunnels:** Rock stresses and deformation around tunnels, Rock support interaction, Tunnel driving methods, Design of tunnel lining.
Text Books, and/or reference material	**TEXT BOOKS:** 1. Jaeger, J.C., Cook, N.G.W., Zimmerman, R.W., "Fundamentals of Rock Mechanics", 4th Edition, Blackwell Publishing. 2. Mogi Kiyoo, "Experimental Rock Mechanics", Taylor & Francis. **REFERENCE BOOKS:** 3.Obert and Duvall, "Rock Mechanics and Design of Structures", John Willey & Sons.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3		3	
CO2	2	3		
CO3	3	2	3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9085	SLOPE STABILITY AND EARTH DAMS	PEL	3	0	0	3	3
Pre-requisites		Geotechnique					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Application of the principles and basic of soil and rock mechanics in the analysis of slope stability of dams. • CO2: Able to check the stability of earthen dams, and the safety measures to be undertaken to prevent the instability of slopes, earthen dams and embankments
Topics Covered	**Slope Stability Analysis:** Types of Failure: Failure surfaces - Planar surfaces, Circular surfaces, Non-circular surfaces, Limit equilibrium methods, Total stress analysis versus effective Stress analysis, Use of Bishop's pore pressure parameters, Short term and Long term stability in slopes.(12) **Methods of Slope Stability:**TaylorCharts,Effect of Tension Cracks, Vertical Cuts. Bishop's Analysis, Bishop and Morgenstern Analysis, Noncircular Failure Surfaces: Morgenstern and Price Analysis, Janbu Analysis, Sliding Block Analysis,Seismicstability,Stabilization of slopes: Drainage measures, Soil reinforcement (geosynthetics/soil nailing/micro piles etc), soil treatment (cement/lime/thermal treatment), surface protection (vegetation/erosion control mats/shotcrete). (16) **Earth and Rockfill Dams:** General features, Selection of site; Merits and demerits of the earth and rock fill dams, Classification of earth dams, Materials of construction and requirements, Causes of failure, Safe design criteria. Instrumentation in earth dams: Pore pressure measurements, Settlement gauges, Inclinometers, Stress measurements, Seismic measurements.(16)
Text Books, and/or reference material	**TEXT BOOKS:** 1) Christian Kutzner, "Earth & Rock fill dams – Principles of design and construction",Published Oxford and IBH 2) Bharat Singh, "Earth and Rock fill dams" **REFERENCE BOOKS:** 1. . USIBR, "Design of small dams" Oxford and IBH Publishing Company

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3		1	
CO2	2	1	3	

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CE 9086</td><td>PAVEMENT ANALYSIS AND DESIGN</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Highway Engineering</td></tr>
<tr><td colspan="2"></td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Decide factor affecting selection of type of pavement to be constructed
• CO2: Identify the material to be used for pavement construction
• CO3: Design low volume as well as regular flexible pavement, rigid pavement
• CO4: Determine the quality of the constructed flexible as well as rigid pavement</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Characterization of Sub-Grade Soil and Mineral Aggregates – Introduction, particle size analysis of sols, soil gradation, moisture content, consistency test of soil, methods of soil classification, composition of soil mass, determination of soil compaction, strength determination of soils, strength properties of mineral aggregates (8)
Bituminous Materials – Introduction, desirable properties of bitumen, tests on bituminous materials, other binders, engineering properties of bituminous materials, mix design. (8)
Design of Cement Concrete Mixes for Pavements – Introduction, cement, properties of cement, mineral aggregates, water, admixtures, properties of fresh concrete, test on hardened concrete, design of cement concrete mix, factors considered for durable concrete, the Bureau of Indian Standards Method of Cement Concrete Mix Design, Indian Road Congress Method of Cement Concrete Mix Design (IRC : 44-2008), Dry Lean Cement Concrete (MORTH 201), Concrete Mix Design for Rural Roads (IRC :SP:62-2004) (8)
Factors Affecting Pavement Design – Types of pavements, factors affecting design of pavements (4)
Analysis and Design of Flexible Pavements – Stress analysis of flexible pavements, flexible pavement design methods, benefits of pavement design based on M-E method, test roads, design methods of flexible pavements (4)
Structural Evaluation of Pavements – Purpose, types, and methods of structural evaluation, structural evaluation by static loading, structural evaluation by steady – state Vibratory Loading, structural evaluation by impulse lading, Models of Falling Weight Deflectometer, structural evaluation of flexible pavement using FWD, back calculation of Layer Moduli from FWD Test data, uses of Back-calculated Pavement Layer Moduli, Structural Evaluation of Rigid Pavement using FWD. (8)
Structural Evaluation of Unbound Granular and Sub-Grade Layers using Dynamic Cone Penetrometer (DCP) – Development of DCP Test, The Dynamic Cone Penetrometer, material testing with DCP, determination of DCP index values, factors affecting DCP test results, correlation of DCP index values with other standard test values, application of DCP test data, limitation of DCP. (8)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">TEXT BOOKS:
1. Highway Engineering by R. Srinivas Kumar
REFERENCE BOOKS:
2.Principles of Pavement Engineering by Nick Tom</td></tr>
</table>

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2	3	3	3
CO2	2	3	3	3
CO3	3	3	3	3
CO4	3	3	3	3

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9087	REINFORCED EARTH AND GEOTEXTILES	PEL	3	0	0	3	3
Pre-requisites		Geotechnique					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Explain the significance of Geosynthetics, Properties of Geotextiles and its application • CO2: Design the Reinforced Earth Retaining Walls, Reinforced Pavements, and Landfills. • CO3: Apply geocomposite systems to solve contemporary geotechnical problems
Topics Covered	Introduction to Geosynthetics - Types – Geotextiles - polymer type geotextiles –woven and non-woven geotextiles, geogrids, geo membranes and geocomposites, functions and mechanisms in reinforcement, filtration, drainage, liquid barrier, multiple functions - Materials and manufacturing processes - Mechanical, endurance, hydraulic and degradation properties - Testing and evaluation. (8) Principles of soil reinforcement - load transfer mechanism and strength development -Design and construction of geosynthetic reinforced soil retaining structures – walls and slopes, Codal provisions, Soil Bearing capacity improvement using reinforcing elements. (14) Geosynthetics in pavements- Advantages and disadvantages of placing geosynthetics in surfacing, base, sub base and sub grade layers, Embankments on soft soils, Geosynthetics in roads and railways, separators, drainage and filtering in road pavements, railway tracks, overlay design and constructions, trench drains . (8) Geosynthetics in Environmental control, liners for ponds and canals, covers and liners for landfills, material aspects and stability considerations, landslides - occurrences andmethods of mitigation, Erosion causes, control and construction techniques. (10)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Swami Saran, “Reinforced Soil & it’s Engineering Applications” 2. R. A. Jewel, “Soil Reinforcement with Geotextiles”, Construction Industry Research & Information Association (CIRIA) Thomas Telford. **REFERENCE BOOKS:** 3. Koerner, R. M, “Designing with Geosynthetics”, Prentice Hall, NJ.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1		3		1
CO2	2	2	3	
CO3		2	3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9088	REMOTE SENSING AND GIS	PEL	3	0	0	3	3
Pre-requisites		None					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Learn about basic items, parameters & concepts related with remote sensing. • CO2: Apply techniques of visual image interpretation and digital image processing. • CO3: Use GIS and its components for applications in Geo-Environmental engineering.						
Topics Covered	**Remote Sensing –** History, Physical basis, Electromagnetic spectrum, Spectral reflectance curves, Spectral signatures, Resolutions, Passive & active remote sensing, Remote sensing platforms. (10) **Sensors** – Different types, Satellite band designations & principal applications, FCC, Aerial photography & its interpretation.(10) **Digital image processing** – Pixels & DN values, Digital image formats, Image processing functions – Image enhancement, Image transformation, Image classification & analysis.(10) **Geographic Information System** – Introduction, GIS components – hardware, software & infrastructure, GIS data types, Data input & processing, Preparation of thematic map from RS data.(10) Integration of RS & GIS techniques and its applications in the fields of Geo- Environmental engineering.(5)						
Text Books, and/or reference material	**TEXT BOOKS:** 1. B. Bhatta, *Remote Sensing & GIS*, Oxford University Press. **REFERENCE BOOKS:** 1. T.M. Lillesand and R.W. Kiefer, *Remote Sensing and Image Interpretation*, John Wiley & Sons. 2. C.P. Lo & A.K.W. Yeung, *Concepts & Techniques of Geographic Information Systems*, PHI.						

Mapping of course outcomes with program outcomes

M. TECH. IN GEOTECHNICAL ENGINEERING				
Course Outcome	PO1	PO2	PO3	PO4
CO1	2			
CO2	2	1	3	
CO3		1	3	2

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9089	FORENSIC GEOTECHNICAL ENGINEERING	PEL	3	0	0	3	3
Pre-requisites		Soil Mechanics					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Explain the need of Forensic Geotechnical investigation. • CO2: Learn the concept of Back Analysis. • CO3: Outline the Instrumentation, Monitoring and Case studies in Forensic Geotechnical Investigation.
Topics Covered	Concept of Forensic Investigation, Necessity, Objectives of Forensic Geotechnical Investigation, Methods of Forensic Investigation. (6) Project reconnaissance and characterization of the distress, including document search such as plans, codes, and other technical specifications followed in the original design. (8) Diagnostic tests – Analysis of field data – selection of laboratory tests based on actual field parameters to evaluate the behavior of soil/ground. Scope and extent of application of Forensic Engineering techniques in geotechnical and foundation failure investigations, settlement of structures, expansive soils, lateral movement, other geotechnical and foundation problems, groundwater and moisture problems., Case studies (12) Back analysis: Selection of theoretical model - methods of analysis, Instrumentation and Monitoring, Development of the most probable failure hypothesis - cross-check with original design. (8) Performing reliability checks, Legal issues involving jurisprudence system, insurance, repairs, reducing potential liability, responsibility of geotechnical engineers and contractors.(8)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Forensic Geotechnical and Foundation Engineering. Robert W. Day. 2. A Guide to Soil Mechanics. Malcolm D. Bolton **REFERENCE BOOKS:** 1. Saxena, D.S., "Technical, Ethical, and Legal Issues with Forensic Geotechnical Engineering - A Case History", Proceedings, 13th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, Kolkata, India, 11 Dec-ember 2007

	2. Forensic Geotechnical Engineering Developments in Geotechnical Engineering- V.V.S. Rao and G.L. Shivakumar Babu (eds) Springer India

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1		1		2
CO2	2	1	2	
CO3		2	3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9090	TUNNELLING TECHNOLOGY	PEL	3	0	0	3	3
Pre-requisites		Soil Mechanics					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: CO1: Select specific method of tunnel driving for a given ground condition CO2 Design tunnel excavation methods. CO3 Identify possible difficulties in different ground conditions. CO4 Select suitable tunnel support systems and its design.						
Topics Covered	Tunnels in Soils and Rocks: Benefits of tunnelling, Tunnels for different purposes, Site investigation and geophysical methods adopted for tunnelling purposes, Rock rating and classification, Instrumentation on tunnels 10 Tunnelling methods: Drill and blast method, Tunnel boring machine, NATM, Shield tunnelling, Earth pressure method, Application of compressed air 8 Tunnel lining and supports: Different types of support measures adopted in tunnelling, Analysis of stresses on the tunnel lining, Design of tunnel lining and support measures 12 Tunnelling Mechanics: Behaviour of soils and rocks, Stress and deformation fields around tunnels, Analytical equations used and derivations, Stability problems in tunnels 10 Numerical Analysis of Tunnelling: Finite element analysis of tunnelling process, Constitutive models used, Development of longitudinal displacement curves and ground reaction curves, Ground surface settlement due to tunnelling in soft grounds 10						
Text Books, and/or reference material	**TEXT BOOKS:** 1. D. Kolymbas, "Tunnelling and Tunnel Mechanics", A rational approach to tunnelling, Springer, 2005 2. B. Singh and R. K. Goel, "Tunelling through weak rocks", Elsevier, 2006						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	-	1	-
CO2	3	-	2	2
CO3	3	-	3	
CO4	3	-	3	2

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9095	APPLIED NUMERICAL METHODS	PEL	3	0	0	3	3
Pre-requisites		Mathematics at UG levels					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Assess the error involved in a numerical method • CO2: Solve problems in engineering and science with a required accuracy using appropriate numerical methods • CO3:Write algorithm for the numerical methods for efficient coding of program • CO4:Understand the mathematics concepts underlying the numerical methods
Topics Covered	**Fundamentals of numerical methods**, Elements of matrix algebra, Solution of Linear equations and eigenvalue problems; Solution of differential equationsError analysis and stability of algorithms. (2) **Nonlinear equations:** Newton Raphson method, Muller's method, system of non-linear equations. Roots of polynomial equations. (6) **Linear system of algebraic equations:** Gauss elimination method, LU decomposition method; matrix inversion, iterative methods, ill conditioned systems. Eigenvalue problems: Jacobi, Given's and Householder's methods for symmetric matrices, Power and inverse power methods. (8) **Interpolation and approximation**:Newton's, Lagrange and Hermite interpolating polynomials, cubic splines; least square and minimax approximations. (6) **Numerical differentiation and integration:** Newton-Cotes and Gaussian type quadrature methods. (6) **Ordinary differential equations:**Initial value problems: single step and multistep methods, stability and their convergence. Boundary value problems: functional approximation, finite difference method, finite element method. (8) **Partial Differential Equations:** Difference methods for solution of parabolic and hyperbolic equations in one and two-space dimensions, stability and their convergence, difference methods for elliptic equations. Computer oriented algorithms; Numerical solution of different problems. (6)

Text Books, and/or reference material	**TEXT BOOKS:** 1. Numerical Methods for Scientists and Engineers, R. W. Hamming, Dover Publications; 2 edition 2. Numerical Methods: Problems and Solutions, Mahinder Kumar Jain (Author), S.R.K. Iyengar (Author), R. K. Jain, New age publishers **REFERENCE BOOKS:** 3. Applied Numerical Methods for Engineers Using Matlab and C, Robert J. Schilling(Author), Sandra L. Harris, Nelson Engineering; Har/Cdr edition.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2	1		2
CO2	2	1	2	2
CO3	2	1	3	2
CO4	2	1		2

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9096	MACHINE LEARNING IN CIVIL ENGINEERING	PEL	3	0	0	3	3
Pre-requisites		Engineering Mathematics, Basic of Civil Engineering					
		CT+EA					
Course Outcomes	• CO1: understand the basic of machine learning • CO2: understand the theory of machine learning based on knowledge of probability statistics and linear algebra. • CO3: solve different engineering problems applying the machine learning methods. • CO4: apply the different software of machine learning to solve civil engineering problems						

Topics Covered	**Introduction to Machine Learning:** What is learning, What is machine learning, Machine learning activities, Basic types of data in machine learning. **(4 hours)** **Basis of Probability and Statistics:** Axiomatic definitions of probability, addition rule and conditional probability, multiplication rule, total probability, Bayes' theorem and independence, Random Variable , Few Distributions, Joint Distributions, Some Basic Statistics. **(4 hours)** **Linear Algebra:** Linear algebra and problem. **(2 hours)** **Artificial Neural Network:** Understanding biological neuron, artificial neuron, architectures of neural network, learning process of ANN. **(8 hours)** **Bayesian Learning**: Bayes theorem and concept learning. Naïve Bayes classifier. **(2 hours)** **Machine Learning:** Types of machine learning Approach: Supervised learning, Unsupervised learning and Reinforced learning, Applications of machine learning, usage of different software. **(6 hours)** **Supervised Learning:** (a) Supervised learning-classification- Basics of supervised learning classification, Decision tree, Support vector machine. **(10 hours)** (b) Supervised learning -Regression- Simple regression, Other regression techniques. **(4 hours)** **Applications of Machine Learning:** Apply machine learning methods to solve Civil Engineering problems using Python, TensorFlow. **(4 hours)**
Text Books, and/or reference material	**TEXT BOOKS:** 1.Goulet, James-A, Probabilistic Machine Learning for Civil Engineers, MIT Press. 2. Mitchell Tom M. Machine Learning, McGraw-Hill Education. **REFERENCE BOOKS:** 1. Dutta, Saikat, Chandramouli, Subramanian, Das, Amit Kumar, Machine Learning, Pearson 2. Marsland Stephen, Machine Learning, CRC Press. 3.Ang, A. H.-S. and Tang, W. H. 1984. Probability Concepts in Engineering Planning and Design: Volume 2 Decision, Risk and Reliability, Wiley, New York.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	1	-	-	-
CO2	3	-	-	-
CO3	-	-	3	-
CO4	-	-	-	3

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 9097	MODELLING, SIMULATION & COMPUTER APPLICATIONS IN GEOTECHNICAL ENGINEERING	PEL	3	0	0	3	3
Pre-requisites		Numerical Technique and Constitutive Modelling					
		CT+EA					

Course Outcomes	• CO1: Solve linear and non-linear equations using numerical techniques. • CO2: Apply correlation and regression analysis for the geotechnical data • CO3: Solve problem of consolidation and flow through porous media using numerical technique. • CO4: apply probabilistic approach for selection of design parameters and compute their impact on risk assessment
Topics Covered	Systems and Models: Fundamentals of systemic approach, System modelling, Classification of models, Model structure, Linear, non-linear, time-invariant, time variant models, State-space models, Distributed parameter models, System Synthesis, Direct and Inverse Problems, Role of optimization, Role of computers. Examples from Civil Engineering. Preliminary Data Processing; Regression Analysis: Linear and Multiple Regression Analysis, Analysis of Residues, Tests of goodness of fit. (8) Parsimony criterion Spatial Distribution: Polynomial surfaces, Krigging, Spline functions, Cluster Analysis, Numerical Production of Contour Maps Time Series Analysis: Auto-cross correlation analysis, Identification of trend, Spectral analysis, Identification of dominant cycles, Smoothening techniques. Filters, Forecasting Model Building: Choice of Model Structure: A priori considerations, Selection based upon preliminary data analysis, comparing model structures Model Calibration: Role of historical data. Direct and Indirect methods of solving Inverse problem. (14) Validation Simulation: Random variables: Basic concepts, Probability density and distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, Covariance and correlation. (8) Commonly used theoretical Probability distributions (uniform, normal, binomial, Poisson's and negative exponential), Fitting distributions to raw data, Kolmogrov-Smirnov's tests of the goodness of fit, central limit theorem, various algorithms for generation of Random numbers. Queueing theory: Elements, Deterministic queues, Applications Monte Carlo simulation: Basic concepts, Generation of synthetic observations. Statistical interpretation of the output, Evaluation of definite integrals, Role in Civil Engineering, Examples. (10)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Desai, C.S. and Christian, J.T., "Numerical Methods on Geotechnical Engineering", McGraw Hill, New York, N.Y., USA. **REFERENCE BOOKS:** 2. Hornbeck, R.W., "Numerical Methods", Quantum Publishers, New York, USA. 3. Christian P. R., George C., "Monte Carlo statistical methods" Springer, 2004.

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	2		3	
CO2	3		3	
CO3		2	3	1
CO4	2		3	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 1061	GEOTECHNICAL LAB-I	PCR	0	0	4	4	2
Pre-requisites		Soil Mechanics					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Determine engineering properties of different soils and understand their behaviour • CO2: Gain basic knowledge towards soil specimen preparation and testing.						
Topics Covered	**Laboratory tests:** Tri-axial test, Consolidation test, CBR test, Light and heavy compaction test, Dynamic Cone Penetration Test, Point Load Test. (40)						
Text Books, and/or reference material	**TEXT BOOKS:** 1. SP 36 (Part I) 1987 Compendium of Indian Standards on soil Engineering: Part I Laboratory testing of soils for civil engineering purposes. **REFERENCE BOOKS:** 2. Departmental geotechnical lab manual						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	2		
CO2	2	1	2	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE1062	COMPUTATIONAL LAB	PCR	0	0	4	4	2
Pre-requisites		Basic Structural Analysis, Foundation Engineering					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: learn finite element software packages to solve real life problems in Geotechnical Engineering • CO2: Apply ABAQUS, Plaxis3D software tools to solve interdisciplinary problems in engineering
Topics Covered	Analysis of frame 2D & 3D: Introduction to ABAQUS. (3) Static Analysis of Plane frame: fixed base and on soil base (Plane stress) (6) Frequency analysis of Plane Frame with added mass. (3) Plane frame with Shear wall Interaction under Lateral Load. (3) Stress distribution in Soil under Line Load (3) Laterally Loaded Pile. (3) Seepage Through Earthen Dam (3) Slope Stability (3) Retaining wall on soil structure(Plane strain) (4) Consolidation problem 2D (8) Stress –strain analysis in soil subgrade under repetitive application of wheel load in flexible pavement. (2)
Text Books, and/or reference material	**TEXT BOOKS:** 1. Documentation of ABAQUS 2. Plaxis tutorial manual

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	1	2	
CO2	2	1	2	3

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Department of Civil Engineering
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE 2061	GEOTECHNICAL LAB-II	PCR	0	0	4	4	2
Pre-requisites		Soil Mechanics, Environmental Engineering					
		CT+EA					

Course Outcomes	At the end of the course, the student will be able to: • CO1: Determine geo-environmental properties of different soils and understand their behaviour • CO2: Gain basic knowledge towards soil specimen preparation and testing.
Topics Covered	**Laboratory tests:** Determination of porosity of soil, Hydraulic conductivity (vertical and horizontal direction), Adsorption test in soil (Batch test, column test, kinetic reaction studies), pH test, pHzpc, Organic carbon determination of soil. (40)
Text Books, and/or reference material	**TEXT BOOKS:** 1. SP 36 (Part I) 1987 Compendium of Indian Standards on soil Engineering: Part I Laboratory testing of soils for civil engineering purposes. 2. Departmental geotechnical lab manual **REFERENCE BOOKS:** 3. Sharma HD and Reddy KR, "Geoenvironmental Engineering: Site Remediation, Waste cont-ainment, and Emerging Waste Management Technologies" Wiely, 2004

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	2		
CO2	2	1	2	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE2062	Mini Project with Seminar	PCR	0	0	6	6	3
Pre-requisites		None					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Improve the communication skills and cultivate lifelong learning. • CO2: Broaden their knowledge about Geotechnical Engineering and its significance • CO3: Update their knowledge on the latest developments in geotechincal engineering. • CO4: Understand the environmental, safety, economical and sustainability aspects of any geotechnical engineering structure.						
Topics Covered	Each student has to select a topic and collect about 10 papers with at least 5 journal papers and prepare a report and give a seminar at the end the semester.						
Text Books, and/or reference material	Peer reviewed Journal and conference papers						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1				3
CO2			2	
CO3			2	
CO4				3

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE3061	Dissertation- I	PCR	0	0	24	24	12
Pre-requisites		None					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: Improve the skills of handling real life projects and cultivate lifelong learning. • CO2: identify real life projects problems in Geotechnical and Geoenvironmental engineering						
Topics Covered	Project problem Identification / Literature Review						
Text Books, and/or ref. material	Relevant books as per Supervisor direction Peer reviewed journal and conference papers						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	1			3
CO2	1	1	2	

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE3062	Seminar-Non Project/Evaluation of Summer Training	PCR	0	0	4	4	2
Pre-requisites		None					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: • CO1: solve practical problems in the field of Geotechnical and Geoenvironmental Engineering						
Topics Covered	Attempt for solution (Numerical /Experimental) & Progress						
Text Books, and/or ref material	Relevant books as per Supervisor direction Peer reviewed journal and conference papers						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	1	2	1

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE4061	Dissertation= II/ Industrial Project	PCR	0	0	24	24	12
Pre-requisites		None					
		CT+EA					
Course Outcomes	At the end of the course, the student will be able to: CO1: provide the solution of the problem and recommendations which can be used in real life or future researches.						
Topics Covered	Final reporting & Thesis submission						
Text Books, and/or reference material	Relevant books as per Supervisor direction Peer reviewed journal and conference papers						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1	3	1	2	1

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CE4062	Project Seminar	PCR	0	0	4	4	2
Pre-requisites		None					
		CT+EA					
Course Outcomes	• CO1: Improve the communication skills and cultivate lifelong learning. • CO2: Broaden their knowledge about real life Geotechnical Engineering problems • CO3: Update their knowledge on the latest developments in geotechnical engineering.						
Topics Covered	Each student has to review 40 technical papers in the area of the project topic with at least 30 journal papers and prepare a report and give a seminar at the end the semester.						
Text Books, and/or ref material	Relevant books as per Supervisor direction Peer reviewed journal and conference papers						

Mapping of course outcomes with program outcomes

Course Outcome	PO1	PO2	PO3	PO4
CO1				3
CO2			2	
CO3			2	