Master of Technology

In

Civil Engineering (Geotechnical)

Course Structure & Syllabus

Department of Civil Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) - 177005, India

SEMESTER-I

S No.	Course No.	Course Name	L	P	Hours/ week	Credit
1	CE-631	Advanced Soil Mechanics	4	0	4	4
2	CE-632	Advanced Foundation Engineering	4	0	4	4
3	CE-633	Geotechnical Earthquake Engineering	4	0	4	4
4	CE-634	Advanced Geotechnical Engineering Lab.	0	4	4	2
5	CE-7MN	Program Elective-I	4	0	4	4
6	CE-7MN	Program Elective-II	4	0	4	4
	Total		**20**	**4**	**24**	**22**

Program Elective-I & II: Any course listed in Annexure-I (List of Electives)

SEMESTER-II

S No.	Course No.	Course Name	L	P	Hours/ week	Credit
1	CE-641	Underground Excavation in Rocks	4	0	4	4
2	CE-642	Design of Sub-Structures	4	0	4	4
3	CE-643	Soil Dynamics and Machine Foundation	4	0	4	4
4	CE-644	Numerical Modeling in Geotechnical Engineering Lab.	0	4	4	2
5	CE-7MN	Program Elective-III	4	0	4	4
6	CE-70N	Institute Elective	4	0	4	4
	Total		**20**	**4**	**24**	**22**

Program Elective–III: Any course listed in Annexure-I (List of Electives)

SEMESTER-III

S No.	Course No.	Course Name	Hours/week	Credit
1	CE-798	M Tech Dissertation	--	18
	Total			**18**

SEMESTER-IV

S No.	Course No.	Course Name	Hours/week	Credit
1	CE-799	M Tech Dissertation	--	18
	Total		**--**	**18**

Total Credits of the Program: 80

Annexure I: List of Program Elective Courses

	Course No	Course Title
Program Electives	CE-711	Geo-Environmental Engineering
	CE-712	Ground Improvement Techniques
	CE-713	Forensic Geotechnical Engineering
	CE-737	Finite Element Method
	CE-714	Granular Mechanics
	CE-715	Rock Mechanics
	CE-716	Application of Neuro-Fuzzy and Artificial Intelligence in Civil Engineering
	CE-717	Soil-Structure Interaction
	CE-718	Design of Earth Retaining Structures
	CE-719	Rock Slope Engineering
	CE-720	Reinforced Soil Structures and Nanomaterial
	CE-721	Earth and Rockfill Dams

Annexure II: List of Institute Elective Courses

	Course No	Course Title
Institute Electives	CE-701	Project Management
	CE-702	Disaster Management
	CE-703	Environmental Impact Assessment
	CE-704	Remote Sensing & GIS
	CE-705	Engineering Seismology

Course Name: **Advanced Soil Mechanics**
Course Code: **CE-631**
Course Type: **Core**

Contact Hours/Week: **4** Course Credits: **4**

Course Objectives:

- Equip the students with advanced soil mechanics concepts to analyse complex geotechnical problems.
- Impart knowledge about the concepts of critical soil mechanics.

Course Content

Introduction: Fundamental aspects of soil mechanics, classification of soil, clay mineralogy. Basic concepts from solid mechanics: Basic definition and sign conventions for stresses, equations of static equilibrium, concept of strain, idealized stress–strain response and yielding, generalized Hooke's law, plane strain problems, axisymmetric problems, plane stress problems, compatibility equation, equations of compatibility for three-dimensional problems, stress and stress transformation, stress invariants, strain invariants, total and effective stresses in soils. Permeability and Seepage : Darcy's law, determination of the coefficient of permeability, modified Kozeny–Carman equation for practical application, electroosmosis, flow nets: calculation of seepage from a flow net under a hydraulic structure, hydraulic uplift force under a structure, flow nets in anisotropic material, flow nets for hydraulic structures on non-homogeneous soil, numerical analysis of seepage, safety of hydraulic structures against piping, filter design, flow net construction for earth dams. Consolidation: Primary and secondary consolidation settlement, typical void ratio-pressure relationships for sands and clays - normally consolidated and over consolidated clays. reconstruction of field virgin compression curve for NC & OC clays - Schmertmann's correction, time rate of consolidation settlement, coefficient of consolidation, radial consolidation, three-dimensional consolidation, methods for accelerating consolidation settlement-preloading, sand drains, wick drain, PVDs. numerical solution for one-dimensional consolidation, numerical solution for radial drainage. Shear Strength of Soils: Models for Interpreting the Shear Strength of Soils- Coulomb's, Taylor's, Mohr–Coulomb, Tresca Failure Criterion. triaxial tests, energy correction, drainage conditions and strength parameters, Hvorslev strength parameters, critical void ratio, effect of dilation in sands, different dilation models, unconfined compression test, modulus of elasticity and Poisson's ratio from triaxial tests, stress path- Lambe's and Rendulic - Henkel unique stress paths & their characteristics. plotting of stress path using stress invariants, pore water pressure due to undrained loading- determination of A and B parameter, pore water pressure due to uniaxial loading, directional variation of A_f, pore water pressure under triaxial test conditions, pore water pressure due to one-dimensional strain loading, Critical State Soil Mechanics: Definitions of key terms, basic concepts, elements of the critical state model, failure stresses from the critical state model, modifications of CSM and their practical implications, relationships from CSM that are of practical, significance, soil stiffness, strains from the critical state model, stress–strain response, application of CSM to cemented soils.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Apply advanced soil mechanics theories to solve real-world geotechnical problems.

CO2: Determine consolidation characteristics and shear strength parameters.

CO3: Apply critical soil mechanics concepts to solve practical problems.

Books and References:

1. Das, B. M., Advanced Soil Mechanics, Taylor and Francis
2. Budhu, M (2002). Soil Mechanics and Foundations, John Wiley & Sons.
3. Budhu, M. Soil Mechanics and Foundations, John Wiley & Sons.

Course Name: **Advanced Foundation Engineering**
Course Code: **CE-632**
Course Type: **Core**

Contact Hours/Week: **4**
Course Credits: **4**

Course Objectives:

- To impart knowledge of methods of analysis and design of various foundations.
- Understand the methods of foundation in expansive soil.

Course Content

Introduction: Selection of foundation type, general requirement, data required, penetration tests, geophysical methods, field vane shear test, field permeability tests. Shallow foundations: Estimation of bearing capacity using Terzaghi's , Meyerhof's, Hansen's, Vesics's, IS code methods. bearing capacity and settlement from filed tests - standard penetration test, cone penetration test, plate load test, pressuremeter test. footings with eccentric and/or inclined loadings, bearing capacity of footings on layered soil, bearing capacity of footings on slopes, bearing capacity with uplift or tension forces, computation of immediate settlements of footings, differential settlement, allowable bearing capacity of raft foundation, settlement of raft foundation, floating raft, modulus of subgrade reaction, beams on elastic foundation. Pile foundations: Ultimate bearing capacity of driven pile, bored and cast-in-situ pile, driven and cast-in-situ pile in cohesionless and cohesive soils, ultimate bearing capacity of pile in c-φ soils, static and lateral pile load tests, Coyle and Reese (1966) method of estimating load settlement behaviour of piles, negative skin friction in single pile and pile groups, vertical pile subjected to lateral loads, batter piles under lateral loads, uplift capacity of piles, bearing capacity and settlement of pile group in cohesive and cohesionless soil, ultimate lateral resistance of pile group, distribution of load between vertical piles of a pile group subjected to eccentric loading distribution of load between vertical and batter piles of a pile group, distribution of lateral load in a pile group, Hrennikoff s method. Caissons: Types of caissons and their advantages and disadvantages, forces acting on well foundations, factors governing depth, load carrying capacity of wells in sands and clays, stability of Well foundation using elastic theory and ultimate resistance methods (IS and IRC codal provisions). Foundations in expansive soils: Identification of expansive soils, expansive soils in India, methods of foundation in expansive soils, replacement of soils and CNS concept, underreamed pile foundations, remedial measures for cranked buildings.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Assess the bearing capacity of the shallow foundation on various types of soil conditions.
CO2: Evaluate the load carrying capacity of deep foundations.
CO3: Evaluate bearing capacity of foundation in expansive soil.

Books and References:

1 Bowles, Joseph E., "Foundation Analysis and Design", Mc-Graw Hill.
2. Das, Braja M., "Principles of Foundation Engineering", PWS Publishing.
3. Som, N, N. and Das S. C., "Theory and Practice of Foundation Design",Prentice Hall.
4. Saran, S., "Analysis and Design of Substructures", Oxford and IBH.

Course Name: **Geotechnical Earthquake Engineering**
Course Code: **CE-633**
Course Type: **Core**

Contact Hours/Week: **4** Course Credits: **4**

Course Objectives:

1. To impart knowledge about earthquakes, various types of vibrations and vibration measuring instruments.
3. To enable the students to understand local site effects and seismic hazard analysis.
3. To enable the students to evaluate wave propagation velocity, dynamic soil properties, liquefaction potential.
4. To impart knowledge about ground response analysis.

Course Content

Introduction: Importance of Geotechnical Earthquake Engineering, seismic hazards, significant historical earthquakes. Engineering Seismology: Basic Seismology, earthquake, types of seismic waves, causes of earthquakes, sources of earthquake data, elastic rebound theory, faults, continental drift and plate tectonics, size of earthquakes, strong-motion measurements, ground motion parameters, estimation of ground motion parameters. local site effects: effect of local site conditions on ground motion, design parameters and development, development of ground motion time history. Seismic hazard analysis: Identification and evaluation of earthquake sources, deterministic seismic hazard analysis, probabilistic seismic hazard analysis-earthquake source characterization, predictive relationships, temporal uncertainty, probability computations. Theory of vibrations: Concept of dynamic load, damped and undamped systems, single, two and multiple degree of freedom systems, determination of damping ratio, vibration isolation, vibration absorbers, vibration measuring instruments, Response spectra. Wave propagation: Waves in unbounded media-1D, 3D, waves in semi-infinite body, attenuation of stress waves. Dynamic Soil Properties: Stress path, measurement of dynamic soil properties by field and laboratory tests, stress-strain behavior of cyclic loaded soil. Ground Response analysis: One dimensional ground response analysis by linear and non-linear approaches, two and three dimensional ground response analysis by equivalent linear and non-linear approaches. Liquefaction: Liquefaction, mechanism, factors affecting, studies by dynamic tri-axial testing, shake table test, assessment of liquefaction potential by field methods, effects of liquefaction.

Course Outcomes:

Upon successful completion of the course, the students will be able

CO1: To know basics of earthquake, various types of vibrations and vibrations measuring instruments.
CO2: To study the local site effect and to analyse the seismic hazards.
CO3: To assess the prorogation of waves through different media.
CO4: To evaluate dynamic soil parameters.
CO5: To interpret the liquefaction characteristics of soil in laboratory and in the field.
CO6: To determine ground response analysis and local site effects.

Books and References:

1. Shamsher Prakash,"Soil Dynamics", McGraw-Hill Book Company.
2. Steven L.Kramer,"Geotechnical Earthquake Engineering",Prentice Hall Inc.
3. Robert W. Day,"Geotechnical Earthquake Engineering Handbook", McGraw Hill, New York.
4. Structure Dynamics by A.K. Chopra
5. IS 1893 (part 1):2016, Indian Standard Criteria for earthquake resistant Design of Structures.

Course Name: **Advanced Geotechnical Engineering Lab**
Course Code: **CE-634**
Course Type: **Practical**

Contact Hours/Week: **4**
Course Credits: **2**

Course Objectives:

- To train the students for collection of soil and rock specimens for testing in the laboratory.
- To provide skills for determining soil and rock properties in laboratory and in the field.
- To enable the students to assess design soil and rock parameters.
- To make the students determine the safe bearing capacity of soil and rock.

Course Content

Basic index property tests, Determination of consolidation properties of the given clay sample, Laboratory vane shear test on given soil sample and in- situ vane shear test, Unconsolidated undrained (UU), consolidated undrained (CU) and consolidated drained (CD) triaxial shear test on the given soil sample, Determination of free swell index and swelling pressure of given clay sample, Brazilian test on rock core, Point load test on rock core, Unconfined compressive strength test on rock core. Bearing capacity of soil using plate load test, Pressure meter test on given soil sample, Soil exploration by sounding techniques, Exposure to live site problems in Geotechnical engineering, Testing of geosynthetics

Note: The concerned course coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list

Course Outcomes:

Upon successful completion of the course, the students will be able to
CO1: Determine consolidation characteristics of soil.
CO2: Interpret settlement, shear strength and swell characteristics of soil.
CO3: Assess the strength parameters of rock.

Books and References:

1. Advanced Geotechnical Engineering Lab Manual by Akash Gupta et al, Academic Guru Publishing House.
2. Soil Testing for Engineers by S Mittal, Khanna Publishers; Limited Edition

Course Name: **Underground Excavation in Rocks**
Course Code: **CE-641**
Course Type: **Core**

Contact Hours/Week: **4**
Course Credits: **4**

Course Objectives:

1. Make theoretical calculations and engineering assessments of in situ and induced stresses before and after opening formation.
2. Understand the practical approaches in designing support system for underground openings
3. Analyze the tunnel face stability.
4. Learn about the design procedures for dealing with structurally controlled instabilities in underground openings.
5. Impart knowledge of instrumentation and monitoring of underground excavations.

Course Content

Basics of rock mechanics: Rock mass classification, rock properties, stresses in rocks, failure theories. Overview of Underground Structures: Planning of and exploration for various underground construction projects, Stereographic projection method, principle and its application in underground excavation design. Stress Distribution in Underground openings: Stresses distribution around single openings, Stress distribution around multiple openings, Stresses and deformations around tunnels and galleries with composite lining due to internal pressure, rock mass-tunnel support interaction analysis, ground response and support reaction curves, Ladanyi's elasto-plastic analysis of tunnels. Design of Underground Openings and support system: Underground openings, size and shapes, support systems, Ground conditions in tunneling, analysis of underground openings in squeezing and swelling ground, design of various support systems including concrete and shotcrete linings, steel sets, rock bolting and rock anchoring, combined support systems. Field Tests: Estimation of load carrying capacity of rock bolts, estimation of elastic modulus and modulus of deformation of rocks; uniaxial jacking / plate jacking tests, radial jacking and Goodman jacking tests. Tunnelling Methods: Long term behaviour of tunnels and caverns, Norwegian Tunneling Method (NTM), Observational method- NATM, Convergence-confinement method, construction dewatering. Tunnel Face Stability Analysis: Key block analysis, Stability of excavation face and Tunnel portals. Instrumentation and monitoring of underground excavations, during and after construction, various case studies.

Course Outcomes:

Upon successful completion of the course, the students will be able to
CO1: Learn the basics of underground openings and support system.
CO2: Learn the design of underground openings in varying ground conditions.
CO3: Learn the tunnelling methods in varying ground conditions.

Books and References:

1. Underground excavation in rock by Hoek and Brown, E & FN Spon.
2. Introduction to Rock Mechanics by Richard E. Goodman, John Wiley & Sons Inc.
3. Engineering Rock Mechanics: An Introduction to the Principles by J. A. Hudson & J.P. Harrison, Elsevier Science & Technology.

Course Name: **Design of Sub-Structures**
Course Code: **CE-642**
Course Type: **Core**

Contact Hours/Week: **4**
Course Credits: **4**

Course Objectives:

- To impart knowledge about limit state design of foundations.
- To introduce the analysis and concepts of shallow and pile foundations.
- To enable the students to design shallow, pile and bridge substructure.

Course Content

Introduction: Limit state design of reinforced concrete foundations, computation of loads, design steps, soil pressure for structural design. Design of shallow foundations: Conventional structural design of isolated footings, continuous footings, combined footings, strap footings, raft footings, soil structure interaction and 'flexible' approach to the design of foundations. Design of Pile foundations: Structural design of piles including pile caps, design of under-reamed piles, design of pile-raft foundation. Design of Bridge Substructures: Elements of a bridge substructures, determination of maximum flood discharge, discharge for design of foundations, determination of the maximum depth of scour, depth of foundation, allowable bearing pressure, loads to be considered, lateral stability of well foundation, design of pier, sinking stresses in wells, design of well foundation.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: To know about the general requirements, loads imposed and limit state design of foundations.
CO2: To learn the analysis of foundations.
CO3: To perform structural design of different types of footings.
CO4: To design pile foundations.
CO5: To envisage the structural design of bridge substructures.

Books and References:

1. Analysis & Design of Substructures by Swami saran, Oxford & Ibh Publishing Co. Pvt Ltd.
2. Bowles, Joseph E., "Foundation Analysis and Design", Mc-Graw Hill.
3. IS 456 : 2000 (Reaffirmed in 2021)

Course Name: **Soil Dynamics and Machine Foundation**
Course Code: **CE-643**
Course Type: **Core**

Contact Hours/Week: **4** Course Credits: **4**

Course Objectives:

- To study the concept for determining dynamic bearing capacity of shallow and pile foundation.
- To study the seismic analysis of slope and retaining walls.
- To impart knowledge about analysis and design of machine foundation.

Course Content

Introduction: Nature and types of dynamic loading; importance of soil dynamics, equivalent dynamic load to an earthquake load, seismic force for pseudo-static analysis. Shallow Foundations: Dynamic bearing capacity of shallow foundation by pseudo-static analysis, settlement, tilt, and horizontal displacement, Dynamic analysis of footings under transient loads-Triandafilidis's solution, Wallace's solution, Chummar's solution. Pile Foundations: Pseudo-static analysis, single pile under vertical and lateral vibrations, group action under dynamic loading. Seismic Analysis of Retaining Walls: Seismic slope stability analysis by pseudo-static method, Newmark sliding block method, dynamic response of retaining walls by Mononobe-Okabe method, effect of water on wall pressure, seismic displacement of retaining walls by Richards-Elms and Whiteman-Liao method. Machine foundations: Types and basic requirements, general requirement, modes of vibration of a rigid foundation block, analysis and design of foundations for reciprocating machine by linear elastic weightless spring method and elastic half space method, effect of footing shape on vibratory response, dynamic response of embedded block foundation, soil mass participating in vibrations, design procedure for block foundation, analysis and design of impact type machines, design of T.G. Foundations.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Calculate dynamics bearing capacity of shallow and pile foundation.
CO2: Evaluate seismic slope stability and dynamic earth pressure.
CO3: Design various types of machine foundations.

Books and References:

1. Saran S. (2006), “Soil Dynamics & Machine Foundation”, Galgotia Pub. Pvt. Ltd, New Delhi.
2. Prakash S. (1981), "Soil Dynamics", McGraw-Hill Company, New York
3. Kramer S.L. (1996), “Geotechnical-Earthquake Engineering”, Pearson Education Pvt. Ltd., Singapore
4. Day R.W. (2001), “Geotechnical Earthquake Engineering Handbook”, McGraw-Hill Company, New York
5. Ranjan G. and Rao A.S.R. (2004), “Basic and Applied Soil Mechanics”, New Age Int. Ltd., New Delhi.
6. Towhata I. (2008), “Geotechnical-Earthquake Engineering”, Springer Series in Geomechanics and Geoengineering
7. Analysis and design of foundations for machines by Shamsher Prakash and V K Puri

Course Name: **Numerical Modeling in Geotechnical Engineering Lab**
Course Code: **CE-644**
Course Type: **Core**

Contact Hours/Week: **4**
Course Credits: **2**

Course Objectives:

- To provide basic knowledge on how to implement software for solving practical and research problems related to geotechnical engineering.
- To provide skills for writing program and using PLAXIS/ GEO5/ ABAQUS.

Course Content

Introduction to PLAXIS 2D and PLAXIS 3D/ GEO5/ ABAQUS, Basics of numerical modeling and mesh generation, Slope stability analysis, Analysis of foundations and tunnels, Numerical analysis of geotechnical structures subjected to dynamic loading.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list of software*

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the basics of numerical modelling.

CO2: Perform numerical modeling with PLAXIS 2D/PLAXIS 3D/ GEO5/ ABAQUS.

CO3: Analyse of geotechnical structure.

Books and References:

1. Neuro-Fuzzy and Soft Computing by J.S.R.Jang, C.T.Sun and E.Mizutani, Pearson Education.
2. User manuals of PLAXIS/ GEO5/ ABAQUS softwares.

Course Name: **Geo-Environmental Engineering** Course Code: **CE-711** Course Type: **Program Elective**
Contact Hours/Week: **4** Course Credits: **4**
Course Objectives: • Familiarize with the geo-environmental issues at global, regional, and local levels • Landfill design and considerations • Geosynthetics and natural geotextiles and their role in geo-environmental engineering • Understand the usage of different industrial waste products
Course Content
Introduction: Introduction to Geo environmental engineering, environmental cycle, sources, production and classification of waste, causes of soil pollution, factors governing soil-pollutant interaction, Safe disposal of waste. Contaminant Transport: Contaminant transport in sub surface, advection, diffusion, dispersion, governing equations, contaminant transformation, sorption, biodegradation and ion exchange. Landfill design and Considerations: Precipitation, hydrological consideration in land fill design, site selection for landfills, characterization of land fill sites, waste characterization, stability of landfills, current practice of waste disposal, different components of landfill, landfill closure and post closure plan. Geosynthetics in Geo-environmental Engineering: Application of geo synthetics in solid waste management, rigid or flexible liners, bearing capacity of compacted fills, foundation for waste fill ground. Utilization of Industrial Wastes: Geotechnical properties of different industrial wastes, problems in utilization, present status and future need for bulk utilization of different industrial wastes, case studies.
Course Outcomes: Upon successful completion of the course, the students will be able to CO1: Learn the design of landfills CO2: Understand the usage of different industrial wastes. CO3: Handle the geo-environmental problem in actual practice.
Books and References: 1. Waste disposal in engineered landfills by Manoj Dutta, Narosa Publishing House. 2. Geoenvironmental Engineering by Abdel M.O. Mohamed and Hogan E. Antia, Elsevier. 3. Solid Waste Management: Principles and Practice by Ramesha Chandrappa & Diganta Bhusan Das, Springer. 4. Geotechnical Engineering - C. Venkatramaiah.

Course Name: **Ground Improvement Techniques**
Course Code: **CE-712**
Course Type: **Program Elective**

Contact Hours/Week: **4**
Course Credits: **4**

Course Objectives:

- To Know the methods of ground improvement techniques required for the actual field situation
- To design the optimum ground improvement technique

Course Content

Introduction: Need and objectives of ground improvement, emerging trends in ground improvement, methods of de-watering, horizontal wells-foundation drains-blanket drains, criteria for selection of fill material around drains, electro-osmosis. Compaction: Principles of compaction, laboratory compaction, engineering behavior of compacted clays, field compaction techniques- static, vibratory, impact, Earth moving machinery, compaction control, compaction using vibratory probes, vibro techniques, vibro equipment, vibro systems and liquefaction, soil improvement by thermal treatment, preloading techniques, vibro floatation, dynamic compaction, introduction to biotechnical stabilization. Shallow stabilization: Shallow Stabilization with additives such as lime, fly ash, cement and other chemicals and bitumen. Deep stabilization: Sand column, stone column, sand drains, prefabricated drains, electro-osmosis, lime column, soil-lime column. Grouting: Chemical grouting, commonly used chemicals, grouting systems, jet grouting, jet grouting process, permeation, grouting, thermal, freezing, dewatering systems.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the concept of the various ground improvement techniques.

CO2: Understand the concept of compaction and its application in the field.

CO3: Choose the right kind of ground improvement techniques required for the actual field situation.

Books and References:

1. Ground Improvement Techniques by P. Purushothama Raj, Laxmi Publications.
2. Ground Improvement by M.P. Moseley and K. Kirsch, Spon Press.
3. Ground Control and Improvement by Petros P Xanthakos, Lee W Abramson and Donald A Bruce, Wiley Interscience.

Course Name: **Forensic Geotechnical Engineering**
Course Code: **CE-713**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

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

Course Content

Concept of Forensic Investigation, Necessity, Objectives of Forensic Geotechnical Investigation, Methods of Forensic Investigation. Types of Damage, Planning the Investigation, Investigation Methodology, Collection of Data, Distress Characterization, Development of Failure, Hypothesis, Diagnostic Tests, Back Analysis, Technical Shortcomings. 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 failures 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. Legal Issues Reliability Aspects, Legal conflict of geotechnical failures, sanctions in the legal code of construction, geotechnical work for documentation of forensic cases; case studies of legal conflict of prominent structures (such as landslides, deep excavations, unexpected settlements of oil tanks, distress in soil walls, failure due to slow creep of hills, etc.). Development of codal provisions and performance-based analysis procedures.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Predict the failure modes in geotechnical engineering before the construction of structures.

CO2: Design the structures to overcome failure in geotechnical engineering by understanding the behavior of soils.

CO3: Frame the guidelines for avoiding the legal aspects of geotechnical failures by predicting and understanding the failure mechanism, and their remedial measures before the construction of the foundations.

Books and References:

1. Robert W. Day, Forensic Geotechnical and Foundation Engineering, Mc Graw Hill.
2. Rao V.V.S and Sivakumar Babu G.L, Forensic Geotechnical Engineering, Springer New Delhi

Course Name: **Finite Element Method**
Course Code: **CE-737**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

- To provide a framework for developing computational models for solving engineering problems.

Course Content

Approximate methods of Analysis, Introduction, Steps in finite element, Different approaches in FEM- Direct, Variational, Energy, Weighted residual,1-D FE Analysis- bar element, truss element, Beam element and Frame element, 2-D FE Analysis-CST element for plane stress and plane strain, Axis symmetry case,4-node rectangular element, Langrangian interpolation function, 3-D FE Analysis- brick element, Assembling, iso-parametric formulations, Use of Symmetric and anti-symmetric condition.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the concepts of various approaches in FEM.

CO2: Identify the application and characteristics of FEA elements such as bars, beams, plane and isoparametric elements, and 3-D element

CO3: Apply FEM in different fields like, seepage proble, heat transfer etc.

CO4: Develop element level equation and generate global stiffness equation for the engineering problem

Books and References:

1. O.C. Zienkiewicz and K. Morgan "Finite Elements and Approximation",John Wiley & Sons, Inc., Chichester
2. J.N. Reddy " Finite Element Method", 2nd edition, McGraw-Hill Book Company, New York
3. K.-J. Bathe "Finite Element Procedures", 2nd edition, PHI Learning Pvt. Ltd.,
4. J.O. Dow. "A Unified Approach to the Finite Element Method and Error Analysis Procedures", Elsevier
5. R.D. Cook, D. Malkus, M. Plesha and J. Witt. "Concepts and Applications of Finite Element Method", 4th edition, John Wiley & Sons
6. J.E. Akin. "Finite Element Analysis with Error Estimators", Elsevier

Course Name: **Granular Mechanics**
Course Code: **CE-714**
Course Type: **Program Elective**

Contact Hours/Week: **4** Course Credits: **4**

Course Objectives:

- Introduce students to granular mechanics principles and computational methods for understanding and analyzing granular materials behavior in various flow regimes.

Course Content

Introduction: Granular materials and their occurrence. Description of typical operations. Basics characterisation of granular materials. Particle-particle interactions: Friction, Collisions, Deformation, Cohesion. Angles of repose. Characteristics of flowing and static granular materials, flow regimes. Tools – Vectors and tensors: algebra, differential operations. Numerical methods: Discrete element method for granular simulations, Hard particle simulations, Soft particle simulations. Introduction to LAMMPS, solution of example problems, Examples of some fundamental insights obtained from DEM; Limitation of DEM simulations. Quasi-static flows: Mohr-Coulomb theory, critical state theory. Analysis of bins and hoppers. Microscopic analysis: force chains. Rapid flows: Bagnold theory, Granular kinetic theory. Applications. Dense flows – Empirical models: μ-I model, applications. Surface flows: Avalanches, chute flows, heap flows, prorating cylinder flow. Depth averaged equations. Applications. Mixing and segregation: Self-diffusion of tracers. Mixing in tumblers. Segregation phenomena. Applications.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand granular materials and their operations.

CO2: Characterize particle interactions and flow regimes.

CO3: Apply numerical methods for granular simulations.

CO4: Analyze quasi-static and rapid flows, including microscopic analysis.

CO5: Investigate mixing, segregation phenomena, and their applications.

Books and References:

1. An introduction to granular flow by K. Kesava Rao and Prabhu R. Nott (Cambridge Univ. Press, 2008).
2. Sands, Powders, and Grains: An Introduction to the Physics of Granular Materials (Partially Ordered Systems) by Jacques Duran (Springer Verlag; March 2000)
3. Pattern Formation in Granular Materials (Springer Tracts in Modern Physics, 164) by Gerald H. Ristow (Springer Verlag; December 1999)
4. Processing of Particulate Solids by J. P. K. Seville, U. Tuzun and R. Clift (Blackie Academic 1997)

Course Name: **Rock Mechanics**
Course Code: **CE-715**
Course Type: **Program Elective**

Contact Hours/Week: **4**
Course Credits: **4**

Course Objectives:

- To understand the classification of rock mass.
- Impart knowledge rock properties.
- To study the various types of stresses in rock mass.
- To impart knowledge about basic concept of failure theories for rock and rock mass.
- To study the various types of foundation on rocks.

Course Content

Classification: Rock Mechanics and its relationship with soil mechanics and engineering geology, application of rock mechanics to civil engineering problems, Lithological classification, engineering classification of rocks, classification based on wave velocity ratio, R.Q.D. Classification of rock masses i.e. RMR and Q systems. Rock Properties: Laboratory test, compression, tensile, void index, permeability and shear, effects of size of specimen, rate of testing, confining pressure etc. Stress strain curves of typical rocks, strength of intact and fissured rocks, effects of anisotropy, saturation and temperature effects, shear strength of jointed rock mass, Uniaxial tests in tunnels and open excavations, shear test, pressures tunnel tests etc. Stresses in rocks: State of stress in the ground, In-situ stress, various methods of stress measurement, Hydro-fracturing technique, Flat jack technique, Overcoring technique. Failure Theories: Failure criteria for rock and rock masses, Mohr-Coulomb Yield Criterion, Hoek-Brown Criterion, Griffith's (1924), Mcclintock and Walsh (1962), empirical failure criteria by Bieniawski (1974), Ramamurthy (1993), Singh and Singh (2005), Tensile Yield Criterion, Strength of discontinuities. Foundation on Rocks: Stress distribution in foundation, methods of determination of bearing capacity of rocks, improvement of rock properties, pressure grouting for tunnels and dams, dental concreting, shear zone treatment.

Course Outcomes:

Upon successful completion of the course, the students will be able to
CO1: Classify the rock mass.
CO2: Determine the properties of rock mass.
CO3: Determine the stresses in rock.
CO4: Understand the failure theories in rock and rock mass.
CO5: Determine the bearing capacity of rock mass.

Books and References:

1. Introduction to Rock Mechanics by Richard E. Goodman, John Wiley & Sons Inc.
2. Underground excavation in rock by Hoek and Brown, E & FN Spon.
3. Engineering Rock Mechanics: An Introduction to the Principles by J. A. Hudson & J.P. Harrison, Elsevier Science & Technology.

Course Name: **Application of Neuro-Fuzzy and Artificial Intelligence in Civil Engineering**
Course Code: **CE-716**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

Impart knowledge of application of various artificial techniques used for modeling of data sets to the various civil engineering problems.

Pre-requisite: Knowledge of basics of Civil Engineering

Course Content

Introduction: Classification of artificial intelligence-expert systems-artificial neural networks-basic concepts-uses in functional approximation and optimization-applications in the design and analysis, building construction. Introduction to Artificial Neural Network: Feed-forward and Feed-Backward -work. Neural network learning rules. Linear separability of training patterns, Perceptron learning Algorithms. Multilayer Networks: Exact and approximate representation using feed forward net-works, Fixed Multilayer feed forward Network Training by Back propagation. Recurrent Network: Symmetric networks and Associative Memory, Bi-directional Associative Memory. Analog Hopfield networks, simulated Annealing in optimization. Case studies for modeling using ANN and Fuzzy. Introduction to Fuzzy logic: Statistics and random Processes, Uncertainty in information. Classical Sets and Fuzzy Sets: Classical sets, operations on classical sets, properties of classical sets. Mapping of classical sets to functions, Fuzzy sets, fuzzy set operations, properties of Fuzzy sets. Classical Relations and Fuzzy Relations: Cartesian product, crisp, relations, cardinality of crisp relations, operations on crisp relation, properties of crisp relations. Composition, fuzzy relations. Cardinality of Fuzzy relations, operations on Fuzzy relations. Properties of Fuzzy relations. Membership Functions: Fuzzification, Membership value assignment. Fuzzy-to-crisp Conversions: Defuzzification Methods.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Know basic concept of neural network models and fuzzy logic-based models.
CO2: Develop different types of neural network models.
CO3: Apply fuzzy reasoning and fuzzy inference to solve civil engineering problems.
CO4: Ability to apply neuro-fuzzy computing in hydrologic modelling.

Books and References:

1. D.E. Rumelhart, J.L. McClelland, Parallel distributed processing Vol 1, M I T Press England 1986.
2. Fuzzy logic implementation and applications, M.J. patyra, Mlynek, Wiley Teubner 1996.

Course Name: **Soil-Structure Interaction**
Course Code: **CE-717**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

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

Course Outcomes:

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

Books and References:

1. Soil-Structure Interaction by A. S. Cakmak, Elsevier
2. Soil-Structure Interaction: Numerical Analysis and Modelling by J.W. Bull, CRC Press.
3. Principles of Geotechnical Engineering by Braja M. Das, Thomson

Course Name: **Design of Earth Retaining Structures**
Course Code: **CE-718**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

- To identify the types, advantages, and disadvantages of the different earth-retaining systems.
- To gain knowledge on analysis and design of retaining structures.
- To design f retaining structures under regular and earthquake forces.

Course Content

Introduction: Dynamic earth pressure, dynamic active earth pressure for c-φ soil, point of application, Theory of arching, practical utility. Rigid Retaining Walls: Common proportioning of retaining wall, stability of retaining wall, structural design of retaining walls, backfill drainage, back anchorage of retaining walls. SHEET PILE WALLS: Types of sheet pile structures, design of cantilever sheet pile wall in granular and cohesive soils , design of anchored bulkheads, anchorage methods, Rowe's theory of moment reduction, design of anchors, diaphragm walls – construction, trench cutter, design of braced sheeting in cuts, design of cellular cofferdams. Underground conduits: Types, loads on underground conduits, surface loads

Course Outcomes:

Upon successful completion of the course, the students will be able to
CO1: Design retaining walls under static and dynamic loads.
CO2: Design sheet pile wall, anchored bulkhead and braces sheeting.
CO3: Understand the concept of underground conduits.

Books and References:

1. Saran, S., "Analysis and Design of Substructures", Oxford and IBH.
2. Earth pressure and earth retaining structures by Clayton, Milititski and Woods, Taylor & Francis Group, London.
3. Principles of Geotechnical Engineering by Braja M. Das, Thomson
4. Soil Mechanics and Foundation Engineering by Dr. K. R. Arora, Standard Publisher Dist
5. Foundations and Earth Retaining Structures, Muni Budhu, Wiley, 2010
6. Earth pressure and retaining structures by W C Huntington
7. Bowles, Joseph E., "Foundation Analysis and Design", Mc-Graw Hill

Course Name: **Rock Slope Engineering**
Course Code: **CE-719**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

1. Analyze the stability of rock slopes.
2. Learn about the stabilisation of rock slopes.
3. Learn about the design procedures for dealing with structurally controlled instabilities in rock slope engineering.

Course Content

Principles of rock slope design: Introduction, Socioeconomic consequences of slope failures, Principles of rock slope engineering, Open pit mining slope stability, Slope features and dimensions, Rock slope design methods such as Limit equilibrium analysis , Sensitivity analysis, Probabilistic design methods, Load and resistance factor design. Structural geology and data interpretation: Objectives of geological investigations, Mechanism of joint formation, Effects of discontinuities on slope stability, Orientation of discontinuities, Stereographic analysis of structural geology, Stereographic projection, Pole plots and contour plots, Pole density, Great circles, Lines of intersection, Identification of modes of slope instability, Kinematic analysis, Applications of kinematic analysis, site investigation and geological data collection Stability of Rock slopes: Plane failure, wedge failure, circular failure and toppling failure. Blasting and stabilization of rock slopes: Introduction, Mechanism of rock fracturing by explosives, Production blasting, Explosive properties, Bench height, Burden, Blast hole diameter, Nature of the rock, Sub-drill depth, Stemming, Hole spacing, Hole detonation sequence, Fragmentation, Evaluation of a blast, Controlled blasting to improve stability, -shearing and cushion blasting, Drilling, Explosive load, Stemming, Spacing and burden, Blast damage and its control , Damage from ground vibration, Control of flyrock , Control of air blast and noise and movement monitoring.

Course Outcomes:

CO1: Learn the failure mechanism of rock slope.
CO2: Determine the stability of the rock slopes.
CO3: Design of reinforcement for the rock slopes.

Books and References:

1. Rock Slope Engineering by Duncan C. Wyllie and Christopher W. Mah CRC Press.
2. Rock Slope Stability by Charles A. Kliche, Society for Mining Metallurgy.
3. Underground excavations in rock by Evert Hoek, CRC press.

Course Name: **Reinforced Soil Structures and Nanomaterial**
Course Code: **CE-720**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

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

Course Content

Introduction: Types and functions; Materials and manufacturing processes; Testing and evaluations. Principles of soil reinforcement: Principles of soil reinforcement; Design and construction of geosynthetic reinforced soil retaining structures – walls and slopes, Codal provisions. Applications: Bearing capacity improvement, embankments on soft soils, indian experiences, geosynthetics in abutments, pavements and railways serving different functions, overlay design, and construction. landslides – occurrences and methods of mitigation; erosion – causes and techniques for control. Nanomaterial - 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.

Course Outcomes:

Upon successful completion of the course, the students will be able

CO1: To understand the significance of Geosynthetics and classify them.
CO2: To classify Geosynthetics based on its manufacturing method and properties.
CO3: To recommend conventional and reinforced earth retaining structures.
CO4: To apply the design principles of Geosynthetics for Geotechnical applications.

Books and References:

1. Geosynthetics and Their Applications by S. K. Shukla and J.H Yin, CRC Press.
2. Reinforced Soil Engineering: Advances in Research and Practice by Hoe I. Ling, Dov Leshchinsky, Fumio Tatsuoka, Marcel Dekker, Inc.
3. Earth Reinforcement and Soil Structures by Colin John Francis Phillip Jones, Butterworths & Co.
4. Alternative Materials in Road Construction by P. T. Sherwood, Thomas Telford Publication, London, 1997.
5. Designing with Geosynthetics, Koerner, R. M., Prentice Hall, Englewood Cliffs, New Jersey, U.S.A.

Course Name: **Earth and Rockfill Dams**
Course Code: **CE-721**
Course Type: **Program Elective**

Contact Hours/Week: 4
Course Credits: **04**

Course Objectives:

- Analyze the given site for the construction of the earth dam
- Analyze the local material and design the earth dam by using the same
- Understand about the dam instrumentation for distress.
- Understand the dam distresses and its remedial measures

Course Content

Introduction: Introduction, Dam and its classification, Procedure of construction for earthen dam, Site selection and common problems faced, Case studies. Earthen Dams: Concept of earthen dam, height of the dam, design of the hearting and casing for zoned dam, number of hours, design of the various component parts of the dam: filter, cutoff wall, foundation, riprap, shear key etc. stability analysis & codel requirements. Rockfill dams: Rockfill dam’s types and height, rock material selection and techniques for its construction, design of the various component of the rock fill dams: zones, transition zone, riprap, filter etc, stability analysis and settlement, spill way, gate operations and flood routing. Health monitoring & Dam safety: Quality control of construction, instrumentation-necessity, pore pressure measurement, vertical movement devices, horizontal movement devices, choice of instrumentation, instrumentation problems, instrumentation for ambient measurements and its location. common distresses and its remedies, case studies, dam safety, gravity drainage, vacuum and osmotic drainage

Course Outcomes:

Upon successful completion of the course, the students will be able to
CO1: Design the earthen dams.
CO2: Design rock fill dams
CO3: Gain knowledge about health monitoring and dam safety.

Books and References:

1. Creager W. P. Engineering for dams, Wiley, 1967.
2. Singh, B. Earth and Rockfill dam, Sarita Prakashan, 1973.
3. Sowers G. I. Earth and Rockfill dam engineering, A. Earth Manual, USBR Publication.
4. Arcold - Volume on earth and rockfill dams.
5. Mistry J. F., Dams and Appurterant Works (Imp. Aspects of River valley projects), Mahajan Book Dist., 1998.
6. Sharma H. D., Embankment Dams, Oxford and IBH Pub., 1991.
7. Design of Small Dams, USDI, Oxford and IBH, 1976