CURRICULUM

M. TECH.
in
GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING

(July 2019 admission onwards)

APPROVED BY

BOARD OF STUDIES (BOS)
12th MEETING, February 20, 2019

DEPARTMENT OF CIVIL ENGINEERING

Dr B R AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY,

Jalandhar

Teaching Scheme

Semester – I*

Course No.	Course Title	Periods			Credits
		L	T	P/D	
CE	Course - I	3	0	0	3
CE	Course - II	3	0	0	3
CE	Course - III	3	0	0	3
CE	Course - IV	3	0	0	3
CE	Course - V	3	0	0	3
CE	Lab-I	0	0	3	2
CE	Lab-II	0	0	3	2

Semester - II

Course No.	Course Title	Periods			Credits
		L	T	P/D	
CE	Course - VI	3	0	0	3
CE	Course - VII	3	0	0	3
CE	Course - VIII	3	0	0	3
CE	Course - IX	3	0	0	3
CE	Course - X	3	0	0	3
CE	Lab-III	0	0	3	2
CE	Lab-IV	0	0	3	2
Total					19

Semester – III*

Course No.	Course Title	Periods			Credits
		L	T	P/D	
CE	Course - XI	3	0	0	3
CE	Course - XII	3	0	0	3
CE	Independent Study	0	0	6	3
CE	Dissertation Part I	0	0	12	6*
Total					**15**

Note: 8 Core courses excluding Independent Study and Dissertations and 4 Elective courses need to be completed for the degree. ***Only Elective Courses will be offered in the 3rd Semester.***

Semester – IV[@]

Course No.	Course Title	Periods			Credits
		L	T	P/D	
CE	Dissertation Part II	0	0	24	12*
Total		0	0	24	**12**

[@]*The result of Dissertation Part I & II shall be forwarded cumulatively after evaluation of dissertation*

Grand Total of Credits = 65

List Of Core Courses For M.Tech Geotechnical And Geoenvironmental Engineering

S. No.	Course Code	Course Title	Hrs/Week			Credits
			L	T	P	
1.	CE-539	Engineering Behaviour Of Soils	3	0	0	3
2.	CE-551	Design Of Substructures	3	0	0	3
3.	CE-552	Soil Dynamics And Earthquake Engineering	3	0	0	3
4.	CE-531	Geoenvironmental Engineering	3	0	0	3
5.	CE-533	Solid And Hazardous Waste Management	3	0	0	3
6.	CE-513	Advanced Numerical Methods	3	0	0	3
7.	CE-553	Environmental Risk Assessment	3	0	0	3
8.	CE-554	Finite Element Method in Geotechnical Engineering	3	0	0	3
9.	CE-601	Independent Study	0	0	6	3
10.	CE-600	Dissertation Part-I Dissertation Part-II	0	0	30	6+12

List Of Laboratory Courses For M.Tech Geotechnical And Geoenvironmental Engineering

S. No.	Course Code	Course Title	Hrs/Week			Credits
			L	T	P	
1.	CE-561	Materials Testing And Characterization Laboratory	0	0	3	2
2.	CE-562	Soil Engineering Laboratory	0	0	3	2
3.	CE-563	Advanced Water And Wastewater Laboratory	0	0	3	2
4.	CE-564	Simulation Laboratory	0	0	3	2

List Of Elective Courses For M.Tech Geotechnical and Geoenvironmental Engineering

S. No.	Course Code	Course Title	Hrs/Week			Credits
			L	T	P	
1.	CE-501	Advanced Solid Mechanics	3	0	0	3
2.	CE-540	Geosynthetics	3	0	0	3
3.	CE-532	Landfills And Ashponds	3	0	0	3
4.	CE-555	Subsurface Hydrology	3	0	0	3
5.	CE-556	Mechanics of Sediment Transport	3	0	0	3
6.	CE-557	Water Resources Systems	3	0	0	3
7.	CE-558	Geotechnical Investigations and Ground Improvement	3	0	0	3
8.	CE-559	Earth Dams and Stability Of Slopes	3	0	0	3
9.	CE-560	Emerging Topics In Geotechnical Engineering	3	0	0	3
10.	CE-566	Pavement Geotechnics and Material	3	0	0	3
11.	CE-567	Rock Mechanics	3	0	0	3
12.	CE-568	Engineering Geology	3	0	0	3
13.	CE-569	Environmental Impact Assessment	3	0	0	3
14.	CE-570	Environmental System Analysis	3	0	0	3
15.	CE-571	Risk and Reliability in Geotechnical Engineering	3	0	0	3
16.	CE-572	Constitutive Models for Soil	3	0	0	3

17.	CE-573	Natural Treatment Systems	3	0	0	3
18.	CE-541	Pavement Analysis, Design and Construction	3	0	0	3
19.	CE-574	Watershed Management and Remote Sensing Applications	3	0	0	3
20.	CE-590	Modelling and Research Methodology	3	0	0	3

SYLLABUS

CE 539 Engineering Behaviour of Soils (3-0-0)

Course Objectives

- To understand the mechanical stress, strain and strength of soil
- To understand the critical state soil mechanics
- Apply fundamental knowledge of the behaviour of soil as an engineering material in Civil Engineering Projects
- Analyse and solve a range of soil-related problems, especially those involving water flow and soil settlement

Course Syllabus

Origin, nature and distribution of soils. Description of individual particle. Clay mineralogy, clay-water-electrolytes. Soil fabric and structure.
Effective stress principle. Steady state flow in soils. Effect of flow on effective stress. Determination of coefficient of permeability.
Consolidation, one, two, three and radial consolidation. Variation of effective stress during consolidation. Various consolidation tests and determination of parameters.
Stress-path. Triaxial and direct shear tests. Shear behaviour of granular soils. Factors affecting shear beahviour. Determination of parameters.
Shear behaviour of fine grained soils. Porepressure parameters. UU, CU, CD tests. Total and effective stress-strength parameters. Total and effective stress-paths. Water content contours.
Factors affecting strength : stress history, rate of testing, structure and temperature.
Anisotropy of strength, thixotropy, creep. Determination of in-situ undrained strength.
Stress-strain characteristics of soils. Determination modulus values.
Critical state model. Engineering Behaviour of soils of India : Black cotton soils, alluvial silts and sands, laterites, collapsible and sensitive soils, aeolin deposits.

Course outcomes

- Students will be able to determine the stress, strain of soil, critical state of soil
- Students will have knowledge regarding the behaviour of soil as an engineering material in Civil Engineering Projects
- Students will learn to analyse and solve a range of soil-related problems, especially those involving water flow and soil settlement

Text and Reference Books:

1. Mitchell, J. K., 1993. Fundamentals of soil Behaviour. Edition, John Wiley and sons, New York
2. Das, B.M., 1997. Advanced soil Mechanics. Taylor and Francis.
3. Lambe, T.W. and Whitman, R.V., 1987. Soil Mechanics. John Wiley and Sons
4. Gulhati, S. K. and Datta M. 2008. Geotechnical Engineering. Tata Mcgraw-Hill Company Ltd.

5. Coduto, D. P. 2002. Geotechnical Engineering, Principles and Practices. Pearson Education International, New Jersey.

CE 551 Design of Substructures (3-0-0)

Course Objectives:

- To be able to develop deeper understanding of shallow and deep foundations
- To be able to develop understanding of different design parameters
- To be able to design reinforced retaining wall

Course Syllabus:

Shallow Foundations: Depth, Spacing of footings, Erosion problems, Water table effects, foundations on sands, Silts, Clays, landfills (qualitative treatment only). Introduction to design of Spread footings, Rectangular footings, and Eccentrically loaded spread footings, Basics of beams on elastic foundation and Ring foundations.

Mat Foundations: Types, Bearing capacity, Settlements, Sub grade reaction, Design guidelines.

Deep Foundations: Tension piles, Negative skin friction, and under-reamed piles. Guidelines for design of pile caps, Batter piles, Laterally loaded piles- Ultimate capacity of laterally loaded piles. Drilled piers – Uses, load carrying capacity, Settlements.

Retaining Walls, MSE Walls, Sheet Piles, Well Foundations, Cofferdams

Course Outcomes:

- Students should be able to design shallow and deep foundations
- Students should be able to determine different design parameters
- Students should be able to design reinforced retaining wall

Text and Reference Books:

1. Das, B.M., 1999. Principles of Foundation Engineering. Cengage Learning, Singapore.
2. Bowles, J. E. 1988. Foundation Analysis and Design. Mc Graw Hill, New York.
3. Swami, S., 2009. Analysis and Design of Substructures. Oxford & IBH Publishing Company Pvt. Ltd.

CE 552 Soil Dynamics And Earthquake Engineering (3-0-0)

Course Objectives:

1. Identification of dynamic loads and their characteristic.
2. To apply theories of vibrations.
3. Able to determine dynamic soil parameters.
4. Understand the concept of Vibration isolation and screening.

Course Syllabus:

Nature of dynamic loads, stress conditions on Soil elements under E.Q. loading,
Theory of vibrations, Behaviour of retaining walls during earthquakes, modification of Coulomb's theory, Modified Culmann's construction,
Analytic solution for C- ϕ soils, Indian Standard Code of Practice, General, Failure Zones & ult. B.C. criteria for satisfactory action of a footing, Earthquakes loads on footings.
Dynamic analysis for vertical loads, Theory, criterion of liquefaction, factor affecting, Laboratory studies on liquefaction in Triaxial shear and Oscillatory simple shear, Evaluation of Liquefaction Potential, Vibration table studies,Liquefaction behaviour of Dense sands,

Introduction, Seismology and earthquakes, continental drift and plate tectonics, elastic Rebound theory, location and size of earthquakes. Ground motion parameters & their estimation, Seismic Hazard Analysis - Deterministic and Probabilistic. Wave Propagation,
Ground Response Analysis - one, two and three dimensional ground response analysis.

Introduction, Criteria for a satisfactory M/C foundation, Methods of analysis, Degrees of freedom of a Block foundation, soil spring stiffness, vibrations of a block I.S. for design of reciprocation M/c design procedure for Block Foundation, Vibration Isolation & Screening of Waves.

Course Outcomes:

- Students will learn the basics of dynamic loads and their characteristics, apply theories of vibrations

- Students will be able to determine the dynamic soil parameters and understand the concept of vibration isolation.

Text and Reference Books:

1. Barken, D. D.,1962. Dynamics of bases and foundations. McGraw Hill, New York.
2. Saran, S., 1999. Soil Dynamics and Machine Foundations. Galogotia Publications Pvt. Ltd, New Delhi.
3. Rao, N. D. V. K., 1998. Vibration Analysis and Foundation Dynamics. Wheeler Publishing Div. of A. H. Wheeler & Co. Ltd. New Delhi.
4. Krammer, S., 2003. Geotechnical Earthquake Engineering. Pearson Education Pvt. Ltd. New Delhi.
5. Prakash, S., 1981. Soil Dynamics. McGraw Hill Book Company, New York.

CE 531 Geoenvironmental Engineering (3-0-0)

Course Objectives:

1. To make students aware about subsurface contamination and its sources
2. To make students learn about geotechnical aspects of planning and design of facilities for disposal of different kinds of solid waste
3. To make students learn about detection & monitoring of subsurface contamination and control & remediation of contaminated sites.
4. To make students learn about rehabilitation of waste dumps and geotechnical re-use of waste.

Course Syllabus:

Sources and effects of subsurface contamination; Physical, Chemical and biological characteristics of solid wastes; Soil-waste interaction; Contaminant transport; Laboratory and field evaluation of permeability; Factors affecting permeability;

Waste disposal on land. Types of landfills : Sitting criteria; waste containment principles; Types of barrier materials; Planning and design aspects relating to waste disposal in landfills, in ash ponds and tailing ponds, and in rocks.

Environmental monitoring around landfills; Detection, control and remediation of subsurface contamination; Engineering properties and geotechnical reuse of waste, demolition waste dumps; Regulations; Case studies.

Course Outcomes:

Students will be to

- plan and design the facilities for disposal of different kinds of solid waste
- plan the detection and monitoring of subsurface contamination

Text and Reference Books:

1. Sharma, H. and Reddy, K.R., 2004. Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies. Wiley.
2. Daniel, D.E., 1993. Geotechnical Practice for waste disposal. Chapman and Hall, London
3. Koerner, R.M., 2005. Designing with Geosynthetics. Prentice Hall, New Jersey
4. Reddi, L.N. and Inyang H.I., 2000. Geoenvironmental Engineering: Principles and Applications, Marcel Dekker Inc Publication

CE -533 Solid And Hazardous Waste Management (3-0-0)

Course Objectives

- To make students understand the components of solid waste management system
- To make students learn about recycling, reuse and reclamation of solid wastes

Course Content

Municipal Solid Waste : Generation, Rate Variation, characteristics (Physical, Biological and Chemical); Management Options for Solid Waste, Waste Reduction at the Source, Collection techniques, Materials and Resources Recovery / Recycling. Transport of Municipal Solid Waste, Routing and Scheduling, Treatment, Transformations and Disposal Techniques (Composting, Vermi Composting, Incineration, Refuse Derived fuels, Landfilling). Norms, Rules and Regulations. Economics of the on-site v/s off site waste management options. Integrated waste management.

Course outcomes

After this course student will be able to:

- To review the components of solid waste management system
- Appreciate the significance of recycling, reuse and reclamation of solid wastes
- develop an insight into the collection, transfer, and transport of municipal solid waste
- understand the importance and operation of a various facilities for resource recovery and waste disposal

Text and Reference Books:

1) Tchobanoglous, G., Vigil, S.A. and Theisen, H.,1993. Integrated Solid Waste Management: Engineering Principles and Management Issues, Mc-Graw Hill.
2) Pichtel, J., 2005. Waste Management Practices – Municipal, Hazardous and Industrial, CRC Press.
3) Vesilind, P.A., 2008. Solid Waste Engineering, Thomson Learning Inc.
4) Vesilind, P.A., Worrell, P.A., Reinhart, D., 2001. Solid Waste Engineering, Nelson Engineering.
5) Peavy, H.S., Rowe, D.R., Tchobanoglous, G., Environmental Engg, McGraw Hill, International Edition.

CE 513 Advanced Numerical Methods (3-0-0)

Course Objective:

- To understand the different numerical methods
- To be able to use different numerical methods for solving various geotechnical problems

Course Syllabus:

Introduction Solutions to linear equations, properties of matrices, Eigen values and Eigen vectors, solutions of linear systems; direct methods and iterative methods, Computation of Eigen values, solutions to the problems using programming languages (C, C++, FORTRAN, MATLAB)

Solutions of non linear equations, importance of non linear equations, different numerical techniques to solve non-linear equations (Newton Raphson method, secant method, Aitken method)

Approximation of functions. Introduction, Taylor series, least squares, legendre polynomials, regression analysis

Numerical differentiation and integration, ODE and PDE, truncation errors

Course Outcomes:

- Student should be able to use different numerical methods for solving various geotechnical problems

Text and Reference Books:

1. Chapra, S. C. and Canale R. P., 2003. Numerical Methods for Engineers. Tata McGraw Hill
2. Carnahan, B., Luther, H. A. and Wilkes, J. O., 1969. Applied Numerical Methods", John Wiley
3. Heath, M. T., 1997. Scientific Computing : An Introductory Survey. McGraw Hill
4. Rajasekaran, S., 1999. Numerical Methods in Science and Engineering. S. Chand

CE 501 Advanced Solid Mechanics (3-0-0)

Course Objectives:

Course Syllabus:

State of stress in a body. Tensor notations, Differential equations of equilibrium, Invariants of the stress tensor, Theory of strain, Displacement components, strain components and relation between them, Generalised Hooke's law, Solution of the elasticity problem in terms of displacements, Basic equations of the theory of elasticity, Lame's equations, Plane problem in cartesian co-ordinates, Plane problem in polar co-ordinates, Shrink fits, Rotating disks with uniform thickness, Plate with hole, Torsion in prismatic bars, Saint Venant's method, Solution of torsion problem in terms of stresses Strain energy, Elastic plastic behaviour, Design philosophy, Linear elastic and plastic behaviour, Tresca and Von Mises yield criteria, Visco-elastic behaviour.

Course Outcomes:

Text and Reference Books:

1. Timoshenko S P and Goodier J N "Theory of Elasticity" McGraw Hill, New York, 2002.
2. Housner G W and Vreeland J R "The Analysis of Stress and Deformation" Mcmillan London, 1998.
3. Srinath L S "Advanced Mechanics of Solids" Tata Mcgraw Hill, New Delhi, 2000.
4. Westergaard H M "Theory of Elasticity and Plasticity" Harvard University Press,

Cambridge, 1998.
5. Kazimi S M A “Solid Mechanics” Tata McGraw Hill, New Delhi, 1999.

CE -532 Landfills And Ashponds (3-0-0)

Course Objectives

- To make students learn about design of waste disposal facilities
- To make students learn about the construction and operation of waste disposal facilities

Course Content

Integrated solid waste management of municipal solid waste, hazardous waste, coal ash and other wastes; Landfilling practice for different types of solid wastes; Municipal solid waste landfills: acceptability of waste; planning, design, construction, operation and closure including management of leachate and gas. Hazardous waste landfills: waste compatibility and acceptability; planning, design, construction, operation, closure and environmental monitoring. Ash ponds: Slurry disposal versus dry disposal; Engineering properties of bottom ash, fly ash and pond ash; planning and design; incremental raising of height by upstream and downstream methods; closure and reclamation.

Course outcomes

The student will be able to:

- To design the waste disposal facilities
- To contribute in construction and operation of the waste disposal facilities
- To plan the environmental monitoring around the waste disposal facilities.

Text and Reference Books:

1. Datta, M., 1998. Waste disposal in Engineered landfills, Narosa Publishers.
2. Reddy, L.N. and Inyang. H. I., 2000. Geoenvironmental Engineering –Principles and Applications, Marcel Dekker, Inc., New York
3. Powell, J., Jain, P., Xu, Q., Tolaymat, T., and Townsend, T. G., 2015. Sustainable Practices for Landfill Design and Operation. Springer.

CE 540 Geosynthetics (3-0-0)

Course Objectives:

- Understand different the basics of Geosynthetics
- Identify the geosynthetic materials and its applications.
- To get familiar with using different geosynthetics for improvement of bearing capacity and soil texture

Course Syllabus:

Geosynthetics and Reinforced Soil Structures:
Types and functions; Materials and manufacturing processes; Testing and evaluations; Principles of soil reinforcement; Design and construction of geosynthetic reinforced soil retaining structures - walls and slopes; Codal provisions; Bearing capacity improvement; embankments on soft soils; Indian experiences.
Geosynthetics in Pavements:
Geosynthetics in roads and railways; separations, drainage and filtering in road pavements and railway tracks; overlay design and construction; AASHTO and other relevant guidelines; trench drains.
Geosynthetics in Environmental Control:
Liners for ponds and canals; covers and liners for landfills - material aspects and stability considerations; Landslides - occurrences and methods of mitigation; Erosion - causes and techniques for control.

Course Outcomes:

- Students should be able to distinguish between different geosynthetics
- Students should be able to determine the properties of geosynthetics
- Students should be able to determine the bearing capacity of soil after introducing geosynthetics

Text and Reference Books:

1. Shukla, S. K. and Yin, J. H., 2006. Fundamentals of Geosynthetics Engineering. Taylor and Francis.
2. Shukla, S. K., 2002. Geosynthetics and their Applications. Thomson Telford.
3. Han, J.,1964. Principles and Practices of Ground Improvement. John Wiley & Sons, Inc., New Jersey.
4. Rao, G. V. and Raju, S., 1990. Engineering with Geosynthetics. Tata McGraw-Hill Publishing Company Ltd., New Delhi.
5. Koerner, R. M., 1986. Designing with Geosynthetics. Prentice-Hall, N. J., U.S.A.
6. Saran, S., 2006. Reinforced soil and its Engineering Applications. I.K. International Pvt. Ltd.

CE 553 Environmental Risk Assessment (3-0-0)

Course Objectives

- To introduce concepts of environmental risk assessment to the students
- To teach mathematical approaches to quantify different risk assessment components.

Course Content

Basic concepts of environmental risk and definitions; Human health risk and ecologial risk assessment framework; Hazard identification procedures and hazard prioritization; Environmental risk zonation; Consequence analysis and modelling (discharge models, dispersion models, fire and explosion models, effect models etc). Estimation of incident frequencies from historical data, frequency modelling techniques e.g., Fault tree analysis (FTA) and Event tree analysis (ETA), Reliability block diagram. Case Studies. Human factors in risk analysis; Risk management & communication. Rules, regulations and conventions.

Course outcomes

The student will be able to:

- To understand the concept of environment risk assessment.
- To implement mathematical tools to assess environmental risk .

Text and Reference Books:

1. Devore, J.L., Probability and Statistics for Engineering and the Science. Latest edition, Thomson Learning Inc.
2. Kammen, D.M., and Hassenzahal, D.M., Should we risk it?: Exploring environmental, health, and technological problem solving. Latest edition, Princeton University Press.
3. DeGroot, M.H. and Schervish, M.J. Probability and Statistics. Latest edition, Addison-Wesley.
4. Johnston, J. and DiNardo, J., Econometric methods. Latest edition, The McGraw-Hill Companies, Inc.

CE 554 Finite Element Method in Geotechnical Engineering (3-1-0)

Course Objectives:

- To implement the basics of FEM to relate stresses and strains.
- To solve one, two and three dimensional and dynamic problems using Finite Element Analysis.
- To develop the ability to generate the governing FE equations for systems governed by partial differential equations;
- To understand the use of the basic finite elements for structural applications using truss, beam, frame, and plane elements;
- To develop proficiency in the application of the finite element method (modeling, analysis, and interpretation of results) to realistic engineering problems through the use of a major commercial general-purpose finite element code.

Course Syllabus:

Structural stiffness analysis, Introduction, Matrix Algebra and Gaussian Elimination, The structural element, One Dimensional Problems, Trusses, Assembly and analysis of a structure; Transformation of co-ordinates. Finite elements of a column, Element characteristics, Two Dimensional Problems, Plane stress and plane strain, Interpolation Functions, Numerical Integration and Modelling Considerations, Element characteristics, Two Dimensional Isoparametric Elements, Assessment of accuracy, Some practical applications. Axi-Symmetric stress analysis, Some improved elements in two dimensional problems, Beams and Frames, Bending of plates, Techniques for Nonlinear Analysis, Three Dimensional Problems in Stress Analysis, Heat Conduction and Seepage Problems

Course Outcome:

- Implement numerical methods to solve mechanics of solids problems.
- Formulate and Solve axially loaded bar Problems.
- Formulate and analyze truss and beam problems.
- Implement the formulation techniques to solve two-dimensional problems using triangle and quadrilateral elements.
- Formulate and solve Axi-symmetric and heat transfer problems.

Text and Reference Books:

1. Zienkiewiez O. C., 1991. The Finite Element Method. Mcgraw Hill, London.
2. Abel, J. F. and Desai, C. A., 2004. Finite Element Method. Van Nostrand Reinhold, New York.
3. Reddy, J.N., 2003. An Introduction to the Finite Element Method. Tata McGraw Hill, New Delhi.
4. Bathe, K. J. 1997. Finite Element Procedures. Prentice Hall of India Private Limited, New Delhi.
5. Chandrupatla, T. R. and Belegundu, A. D. 1997. Introduction to Finite Elements in Engineering" Prentice Hall of India Private Limited, New Delhi.

CE 555 Subsurface Hydrology (3-0-0)

Course Objectives:

- To understand the mechanism of ground water flow
- To get familiar with transport processes in porous media
- To identify the sources of ground water

Course Syllabus:

Fundamentals of subsurface flow and transport, role of groundwater in the hydrologic cycle, the relation of groundwater flow to geologic structure, and the management of contaminated

groundwater. Darcy equation, flow nets, mass conservation, the aquifer flow equation, heterogeneity and anisotropy, storage properties, regional circulation, unsaturated flow, recharge, stream-aquifer interaction, well hydraulics, flow through fractured rock, numerical models, groundwater quality, contaminant transport processes, dispersion, decay, and adsorption. Groundwater recharge, water logging and salinity; infiltration and exfiltration from soils in absence and presence of a water table; modelling contaminant transport through porous media: dispersion, adsorption and decay, volatilization; applications of numerical models (GMS, FEFLOW, PMWIN, etc.) in hydrogeology; model conceptualization, discretization and calibration, initial and exit boundary conditions.

Text and Reference Books:

1. Bear, J., Dynamics of Fluids in porous Media, Dover Publications, 1972.
2. Fetter, C.W., Contaminant Hydrogeology, Prentice Hall, 1999.
3. Bear, J. and Verruijt, A., Modelling Groundwater Flow and Pollution, Reidel Publishing Company, 1990.
4. Fetter, C.W., Applied Geohydrology, Prentice Hall, 2001.

Course Outcomes:

- Students should be able to distinguish amongst ground water and surface water
- Students should be able to quantify the flow in groundwater in different saturated zones.
- Students should be able to determine the quality and quantity of ground water and its sources.

CE 556 Mechanics of Sediment Transport (3-0-0)

Course Objectives:

- To understand the mechanism of sediment transport
- To get familiar with the dynamics of natural streams
- To know about behaviour and maintenance of open channels

Course Syllabus:

Fluvial sediments; transportation and entrainment; physical & chemical characteristics; grain size distribution;

Introduction to sediment: Physical properties of fluid and sediment, origin and properties of sediments, nature of problems.

Fluvial hydraulics: Scour criteria and problems: regimes of flow, Shields curve, incipient motion of sediment particles, terminal fall velocity of sediment in fluid, alluvial bed forms and Resistance to flow.

Sediment transport: Bed load, suspended load and total load transport, Meyer-Peter approach, du Boys' approach, Einstein's approach, Engelund and Fredsøe's approach, sediment samplers, design of stable channels, alluvial stream and their hydraulic geometry.

Turbulent Fluvial Flows: Decomposition and averaging procedure, equation of motion (Reynolds equations), Prandtl's mixing length theory, hypothesis of von Kármán, velocity distribution, the linear law in viscous sub-layer, the logarithmic law in turbulent wall shear layer, law in buffer layer, log-wake law and velocity defect law, turbulence intensity, calculation of bed shear stress using bed slope, velocity distribution, average velocity, Reynolds shear stress distribution, turbulent kinetic energy distribution.

River Training Works: Objectives, classification of river training works, design of guide banks, groynes or spurs their design and classification ISI Recommendations of approach embankments and afflux embankments, pitched islands, artificial cut-offs, objects and design considerations, river control-objectives and methods.

Sediment control: Silt management, management of canal in Punjab, Bhakra calal, delta formation.

Text and Reference Books:

Dey, Subhasish, "Fluvial Hydrodynamics" 2014, Springer, India

Garde, R.J., Raju, K.G.R, "Mechanics of Sediment Transportation and Alluvial Stream Problems" 1985, Wiley Eastern Ltd.

Yang, C.T., "Sediment Transport: Theory and Practice." 1996, McGraw-Hill, USA.

Yalin, M.S., "Mechanics of Sediment Transport" 1977, Pergamon Press, Oxford.

Course Outcomes:

- Students should be able to evaluate the quantity of sediment transport in alluvial channels
- Students should be able to analyse the flow structure on deformable boundaries
- Students should be able to take initiative to protect the rivers by erosion and deposition

CE 557 Water Resources Systems (3-0-0)

Course Objectives:

- To understand the complex water resources processes
- To get familiar optimization techniques and algorithm in reservoir operation
- To analyse the economics and social impact of water resources projects

Course Syllabus:

Basic concepts of systems, need for systems approach in water resources, system design techniques, problem formulation; optimization techniques, LP, NLP, dynamic programming, genetic algorithm, sensitivity analysis, capacity expansion; reservoir operation problems, simulation, case studies; planning, role of a planner, National water policies, public involvement, social impact, economic analysis.

Text and Reference Books:

1. Loucks, D.P., Stedinger, P.J.R., Haith, D.A., Water Resources Systems Planning and Management, Prentice Hall, New Jersy, 1987.

2. Hall, K., A and Draoup, J.A., Water Resources Systems Engineering, Tata McGraw Hill, 1970.

3. Neil, G.S., Water Resources Planning, McGraw Hill, 1985.

4. National Water Policy, Ministry of Water Resources, Government of India, 1987.

Course Outcomes:

- Students should be able to understand the water resources system and its management
- Students should be able to evaluate the quantity of water in various resources of water
- Students should be able to optimize the use of water for different purposes
- Students should be able to carry out the sensitivity, economic and social impact analysis of water projects.

CE 558 Geotechnical Investigations And Ground Improvement (3-0-0)

Course Objectives:

- Understand the basic principles, techniques of soil stabilization.
- Knowledge of different methods of soil stabilization.
- Identify the geosynthetic materials and its applications.
- To get familiar with different techniques of improvement of bearing capacity.

Course Syllabus:

Site Investigations: Planning of investigation programmes, Information required for planning different stages of investigations. Geophysical methods: electrical resistivity, and seismic

refraction methods. Methods of site investigations: Direct methods, semi-direct methods and indirect methods, Drilling methods. Boring in soils and rocks, methods of stabilizing the bore holes, measurement of water table, field record. Field tests: In-situ shear test, in-situ permeability test, SPT, DCPT, SCPT, in-situ vane shear test, pressure meter test, plate load test. Codal provisions.
Sampling techniques, Sampling disturbances, storage, labeling and transportation of samples, sampler design, influence on properties.
Report writing. Safety measures.
Geotechnical Processes:
Principles of compaction, Laboratory compaction, Engineering behaviour of compacted clays, field compaction techniques- static, vibratory, impact, Earth moving machinery, Compaction control.
Shallow Stabilization with additives: Lime, flyash, cement and other chemicals and bitumen.
Deep Stabilization: sand column, stone column, sand drains, prefabricated drains, electroosmosis,
lime column. soil-lime column. Grouting : permeation, compaction and jet. Vibrofloatation, dynamic compaction, thermal, freezing. Dewatering systems

Course Outcomes:

- Students will learn the basics of stabilization and different techniques and materials used for stabilization
- Students will learn about geosynthetics and their properties
- Students will learn to design the foundations on stabilized soils and will be able to compare the results with not stabilized soils

Text and Reference Books:

1. Peck, R. B., Hanson, W. B. and Thornburn, T. H., 1974. Foundation Engineering. John Wiley and Sons Inc, New York.
2. Teng, W. C. 1977. Foundation Design. Prentice Hall of India Pvt. Ltd., New Delhi.
3. Schnaid, F., 2009. In Situ Testing in Geomechanics. Taylor and Francis.
3. Bowles, J. E., 1982. Foundation Analysis and Design. McGraw Hill, New York.
4. Coduto, D. P., 2001. Foundation Design. Pearson Education International, New Jersey.

CE 559 Earth Dams And Stability of Slopes (3-0-0)

Course Objectives:

Have an understanding of seismic design concepts and current practices for earth dams and other similar structures to enable them to plan and direct the construction activity appropriately.

Understand the soil dynamic testing procedure and methodology of seismic design to be able to execute a proper design.
Have a clear understanding of design methodology and the interpretation in the seismic codes.

Course Syllabus:

Earth and Rockfill Dams: Selection Criteria, Classification, Causes of failure, Instrumentation, Stress Measurements
Nature and Importance of failure, Piping through embankment, design of filters, Types of failure, Rockfill dams

Course Outcomes:

At the end of the course, the student will be able to:
Describe the behaviour of natural and engineered soil / rock slopes under various weather and engineering conditions.
Explain the factors that may affect the stability of slopes.
Select an appropriate slope stability analysis method subject to geometry of slope, material properties, and uncertainty of observations.
Assess the potential landslide risk of slopes.

Text and Reference Books:

1. Hoek, E. and Bray, J.W., 1981. Rock Slope Engineering. Institution of Mining Engineering
2. Giani, G.P.,1992. Rock Slope Stability Analysis. A A Balkema
3. Wyllie, D. C. and Christofer, W. M., 2004. Rock Slope Engineering. Taylor and Francis.
4. Singh, B. and Goel, R.K., 2002. Software for Engineering Control of Landslides and Tunneling Hazards. A A Balkema.
5. Harr, M.E., 1962. Ground Water and Seepage. McGraw Hill.
6. Chowdhary, R. and Chowdhary, I., 2009. Geotechnical Slope Analysis. CRC Press.

CE 560 Emerging Topics In Geotechnical Engineering (3-0-0)

Course Objectives:

- To provide the idea of old and new techniques, new machinery and construction equipments
- To discuss about different trends in laboratory testing, soil behaviour, construction techniques

Course Syllabus:

A course which will vary from year to year to study new and exicting developments in the broad spectrum of Geotechnical and Geoenvironmental Engineering. The course will also focus on new offshoots of Geotechnical and Geoenvironmental Engineering.
Trends in Site investigation, laboratory testing, design and analysis, ground improvement, underground structures, soil behaviour, construction techniques

Course Outcomes:

- Students should be able to decide on the techniques, machinery and equipments which will be economical as well as beneficial to carry out the required tasks

Text and Reference Books:

1. Mitchell, J. K., 1993. Fundamentals of soil Behaviour. Edition, John Wiley and sons, New York
2. Das, B.M., 1997. Advanced soil Mechanics. Taylor and Francis.
3. Lambe, T.W. and Whitman, R.V., 1987. Soil Mechanics. John Wiley and Sons
4. Gulhati, S. K. and Datta M. 2008. Geotechnical Engineering. Tata Mcgraw-Hill Company Ltd.
5. Coduto, D. P. 2002. Geotechnical Engineering, Principles and Practices. Pearson Education International, New Jersey.
6. Shukla, S. K. and Yin, J. H., 2006. Fundamentals of Geosynthetics Engineering. Taylor and Francis.
7. Schnaid, F., 2009. In Situ Testing in Geomechanics. Taylor and Francis.

Along with the books, reference to different journals, conferences, workshop notes, magazones to be referred which highlight the new trends in geotechnical engineering

CE 566 Pavement Geotechnics and Material

Course Objectives

1. To study the significance of soil subgrade along with its functions, desirable properties of soil as a highway material, soil classification for highway engineering purpose as per different classification system and evaluation of properties.
2. To understand the concept of the mechanics of stresses in soils and characterization of the important properties of the soil to be used in the design.
3. To know the functions of sub-base, base and surface courses of the pavement and understand the geotechnical properties and behaviour of the different geomaterials including stabilized geomaterials, bituminous materials.
4. To know the various ground improvement techniques in the highway construction.
5. To know the significance of the highway / storm water drainage in the network of highway in rural and urban area including hilly region.

Course Syllabus

Subgrade: Functions, importance of subgrade soil properties, subgrade soil classification for highway engineering purpose, evaluation of properties, compaction system.

Stresses in soils: Theories and elastic and plastic behaviour of soils, methods of reducing settlement, estimation of rate of settlement due to consolidation; foundation of road embankment, static and cyclic triaxial test on subgrade soils. Resilient deformation, resilient strain, resilient modulus, CBR test, effect of lateral confinement on CBR and E value of subgrade soil; static and cyclic plate bearing test, estimation of modulus of subgrade reaction, correction for plate size, correction for worst moisture contents, etc.

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

Aggregates: Different types, desirable properties, various tests for evaluation of these properties, recommended values as per specification.

Bituminous Materials: Different grades, types of bituminous surfaces, desirable properties and tests for evaluating these properties, Marshall's stability test, bituminous mix design.

Ground Improvement Techniques: Different methods of soil stabilization, use of geosynthetics and fibers, etc. in the highway subgrade and highway construction, other ground improvement techniques (sand drains, band drains, stone columns, gabions, etc.) in the context of highway construction, reinforced earth.

Highway Drainage: General principles, significance, different drainage systems (surface/ sub-surface), drainage systems in the hilly areas, pumping systems, water body, holding ponds, frost action, frost susceptible soils, depth of frost penetration, loss of strength during frost melting, etc., design of drainage systems.

Course Outcomes

On successful completion of the course, the learner shall be able to:

1. Understand the soil classification in accordance with various prevailing classification system and evaluate the ability of the soil as a subgrade material.

2. Understand the requirements and desirable properties of the various materials to be used in the construction of pavements.
3. Understand the characterization of different paving materials along with the tests to be conducted on these materials.
4. Understand the basic deficiencies in the soils to be used as a highway materials and various ways and means of improving the soil and implementing the techniques of ground improvement.
5. Understand the implications of appropriate drainage system for the appropriate performance of the roads, various drainage systems in rural, urban and hilly regions and design the drainage system.

Books Recommended:

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

11. Chakraborty, P. and Das, A., 2013. , Principles of Transportation Engineering, Prentice Hall India Learning Pvt. Ltd., New Delhi (Eighth Printing: January 2013).
10 Khanna, S.K., Justo, C.E.G. and Veeraraghavan, A., 2013. Highway Material and Pavement Testing; Nem Chand and Bros., Roorkee, India.

Reference Books

11. Yoder E.J. and Witzack M.W. ,1991. Principles of Pavement Design; John Wiley and Sons, New York.
12. Kandhal, Prithvi Singh , 2014. Bituminous Road Construction in India; PHI Learning Pvt. Ltd., Delhi
13. Delattee, Norbert J., 2017. Concrete Pavement: Design, Construction and Performance (Second Edition)
14. Mallick, Rajib B. and Korchi, Tahar El, 2017. Pavement Engineering: Principles and Practice, CRC Press, Taylor and Francis Group (Third Edition)
15. Nikolaides, A., 2017. Highway Engineering: Pavement Materials and Control of Quality, CRC Press, taylors and Francis Group.

Additional Reading

Relevant specifications of Bureau of Indian Standards for Highway Material Testing, Indian Roads Congress (IRC) and Ministry of Road Transport and Highways (MoRTH) w.r.t. / Pavement Design and Highway Construction revised time to time shall be referred to, e.g.:

IRC: 37-2012. “Tentative Guidelines for the Design of Flexible Pavements,” Indian Road Congress, Delhi.
IRC: 58-2011. “Tentative Guidelines for the Design of Rigid Pavements,” Indian Road Congress, Delhi.
IRC: 81-2012. “Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique,” Indian Road Congress, Delhi
IRC: SP: 76-2008. “Tentative Guidelines for Conventional, Thin and Ultra-Thin White-topping,” Indian Road Congress, Delhi.

Note: Some of the recent specifications may not have been incorporated in few books authored by Indian Authors. For this, titles of multiple books are given in the list of the Recommended Books. The latest editions shall be used. In addition to this, relevant specifications/ codes with the latest revisions thereof shall be referred to.

CE 567 Rock Mechanics (3-0-0)

Course Objectives:

- To impart to students the knowledge of the basic mechanics which governs the behaviour of rocks and rock masses so that they can understand the mechanics of structures constructed in/on them.

Course Syllabus:

Definition, Application of Rock Mechanics, Stress and Strain in Rock, Physico - mechanical Properties of Rock, Dynamic Properties of Rock and Rockmass, Time Dependent Properties of Rock, Behaviour of Rockmass, Failure Criteria for Rock and Rockmass, Pre-mining State of Stress

Course Outcomes:

- Students will be able to distinguish between different rocks, kind of failure in rocks, different types of tests in rocks and the bearing capacity of rocks

Text and Reference Books:

1. Hudson, J.A. and Harrison, J. P., 2000. Engineering Rock Mechanics- An Introduction to the Principles. Elsevier
2. Jaeger, J.C. and Cook, N.G.W., 1979. Fundamentals of Rock Mechanics. Mathew & Co. Ltd.
3. Singh, B. and Goel, R.K., 2006. Rock Mass Classification- A Practical Engineering Approach. Elsevier.
4. Hoek, E., 2000. Practical Rock Engineering. Rock Science.
5. Ramamurthy, T., 2008. Engineering in Rocks. PHI Learning Pvt. Ltd.

CE 568 Engineering Geology (3-0-0)

Course Objectives

- Awareness about earth resources and processes to be considered in various facets of civil engineering

- Appreciation of surface of earth as the fundamental foundation structure and the natural phenomena that influence its stability

Course Syllabus:

Relevance of geology in Civil Engineering. Subdivisions of Geology. Interior of the earth. Weathering, its engineering significance and laboratory tests used in civil engineering. Soil profile. Hydrogeology-occurrence of groundwater, Types of aquifers and their properties. Engineering significance of subsurface water in construction. Methods to control of subsurface water. Minerals- Properties that affect the strength of minerals. Physical properties and chemical composition of common rock forming minerals Earth quakes- in relation to internal structure of earth and plate tectonics Types of rocks. Brief account of selected rocks. Rock features that influence the strength of rocks as construction material. Rock types of Kerala. Engineering properties of rocks. Attitude of geological structures- strike and dip. Deformation structures and their engineering significance. Geological factors considered in the construction of engineering structures. Introduction to natural hazards and their management. Coastal Processes and protection strategies. Soil erosion and conservation measures.

Course Outcomes:

- The course would help the student to understand of the factors that determine the stability of earth's surface
- The student would comprehend better the earth resources used as building materials

Text and Reference Books:

1. Duggal, S.K., Rawal, N. and Pandey, H.K., 2014. Engineering Geology, McGraw Hill Education, New Delhi.
2. Garg, S.K., 2012. Introduction to Physical and Engineering Geology, Khanna Publishers, New Delhi.
3. Gokhale, K.V.G.K., 2010. Principles of Engineering Geology, BS Publications, Hyderabad 4. Kanithi, V., 2012. Engineering Geology, Universities Press (India) Ltd., Hyderabad
5. Singh, P., 2004. Engineering and General Geology, S. K. Kataria and Sons, New Delhi
6. Bennison, G.M., Olver, P.A. and Moseley, K.A., 2013. An introduction to geological structures and maps, Routledge, London
7. Gokhale, N.W., 1987. Manual of geological maps, CBS Publishers, New Delhi

CE 569 Environmental Impact Assessment

Course Objectives

- To expose the students with the methods of qualitative and quantitative assessment of environmental impacts due to developmental activities.

- To make the students learn planning for mitigation of adverse impact on environment.
- To expose students to the analysis of case studies on environmental impact assessment

Course Content

The Need for EIA, Indian Policies Requiring EIA, The EIA Cycle and Procedures, Screening, Scoping, Baseline Data, Impact Prediction, Assessment of Alternatives, Delineation of Mitigation Measure and EIA Report, Public Hearing, Decision Making, Monitoring the Clearance Conditions, Components of EIA. List of projects requiring Environmental clearance, Application form, Composition of Expert Committee, Ecological sensitive places, International agreements. Identifying the Key Issues.

EIA Methodologies: Criteria for the selection of EIA methodology, impact identification, impact measurement, impact interpretation & Evaluation, impact communication, Methods-Adhoc methods, Checklists methods, Matrices methods, Networks methods, Overlays methods, Environmental index using factor analysis, Cost/benefit analysis, Predictive or Simulation methods.

Reviewing the EIA Report: Scope, Baseline Conditions, Site and Process alternatives, Public hearing. Construction Stage Impacts, Project Resource Requirements and Related Impacts, Prediction of Environmental Media Quality, Socio-economic Impacts, Ecological Impacts, Occupational Health Impact, Major Hazard/ Risk Assessment, Impact on Transport System, Integrated Impact Assessment.

Review of Environmental Management Plan and Monitoring. Case Studies.

Course outcome

The student will be able to:

- To review the key concepts of environmental impact assessment and the current legislation covering it
- To prediction and assess the impact from an activity /project on land, water, air, flora and fauna

Text and Reference Books:

1. Sadler, B. and McCabe, M., 2002. Environmental Impact Assessment: Training Resource Manual. UNEP.
2. Rau J. G. and Wooten D. C., 1980. Environmental Impact Analysis Handbook, Tata McGraw-Hill.

3. MOEF, India, EIA manual. Ministry of Environment and Forests, Government of India (http://www.envfor.nic.in/legis/eia/so195.pdf).

4. Canter, R. L., Environmental Impact Assessment, Tata McGraw-Hill (1981).

CE 570 Environmental System Analysis

Course Objectives

- To expose students to a systems approach based mathematical framework for addressing environmental problems.
- To train students in defining systems and their boundaries, apply appropriate algorithms and optimize systems for a set of constraints and objectives.

Course Content

Introduction to natural and man-made systems. Systems modeling as applied to environmental systems. Nature of environmental systems, the model building process addressing to specific environmental problems. Strategies for analyzing and using environmental systems models. Fate and transport models for contaminants in air, water, and soil. Optimization methods (search techniques, linear programming, non-linear programming, dynamic programming) to evaluate alternatives for solid-waste management and water and air pollution control. Optimization over time. Integrated environmental management strategies addressing multi-objective and multi-stakeholder planning.

Course outcomes

The student will be able to:

- To describe and use different environmental system analysis tools.
- To assess strengths and weaknesses for different tools
- To present and critically discuss the results from an environmental system analysis perspective.

Text and Reference Books:

1. Sven E. Jorgensen, 1999. A Systems Approach to the Environmental Analysis of Pollution Minimization. CRC Press.
2. Tanimoto, Jun. 2014. Mathematical Analysis of Environmental System. Springer, 2014
3. Haith, D. A., 1982. Environmental Systems Optimization. John Wiley & Sons, New York, NY.

CE 571 Risk and Reliability in Geotechnical Engineering (3-0-0)

Course Objectives:

- To introduce graduate students the concepts and application of risk and reliability
- To be able to compute first- and second-order estimates of failure probabilities of engineered systems
- To be able to update reliability estimates based on new observational data
- To be able to identify the relative advantages and disadvantages of various analytical reliability methods, as well as Monte Carlo simulation

Course Syllabus:

Introduction: Sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic methods and reliability based analysis in geotechnical engineering Review of probability and statistics: Discrete and continuous random variables, parameter estimation, testing of hypothesis, regression analysis Fundamentals of reliability analysis: First Order Second Moment (FOSM) method, First Order Reliability Method (FORM), Second Order Reliability Method (SORM), Monte Carlo simulation Application towards geotechnical problems: Characterization of uncertainty in field measured and laboratory measured soil properties, uncertainty in interpretation techniques Spatial variability of soil properties, scale of fluctuations, estimation of auto correlation and auto covariance Probabilistic groundwater modeling, flow through earth dams Probabilistic slope stability analysis Fundamentals of LRFD design methodology, reliability based design of shallow and deep foundations, settlement analysis Reliability based liquefaction analysis, lateral spreading Development of fragility curves for geotechnical problems

Course Outcomes:

- Students will be able to compute first- and second-order estimates of failure probabilities of engineered systems
- Students will be able to measure the relative importance of the random variables associated with a system;
- Students will be able to update reliability estimates based on new observational data
- Students will be able to identify the relative advantages and disadvantages of various analytical reliability methods, as well as Monte Carlo simulation

Text and Reference Books:

1. Phoon, K. and Ching, J., 2015. Risk and Reliability in Geotechnical Engineering. Taylor and Francis, New York.
2. Baecher, G.B. and Christian, J.T., 2003. Reliability and Statistics in Geotechnical Engineering. John Wiley and Sons, Sussex, England
3. Modarres, M., Kaminskiy, M. and Krivtsov, V. 1999. Reliability Engineering and Risk Analysis - A Practical Guide. Marcel Dekker Inc, Basel, New York.
4. Halder, A. and Mahadevan, S., 2000. Probability, Reliability, and Statistical Methods in Engineering Design. John Wiley.
5. Ang, A.H.S. and Tang, W. H., 1975. Probability Concepts in Engineering Planning and Design. Wiley.

CE 572 Constitutive Models for Soil (3-0-0)

Course Objectives:

- To introduce fundamentals of constitutive modelling of soils
- Students will learn elastic, viscoelastic, plastic, viscoplastic material responses and continuum damage mechanics
- Students will learn how microstructural mechanisms influence the macroscopic mechanical behavior in different materials

Course Syllabus:

Stress strain relationships. Definition of stress and strain tensors. Elasticity. Linear Elasticity. Generalized Hooke's law. Field equations in linear elasticity.

Linear elasticity and incrementally non-linear elastic formulation. Stress-strain relationships, strength and volumetric response. Evaluation of model parameters. Incremental finite element analyses.

Plasticity theory. Incrementally linearized elasto-plastic formulation. Linear elastic-perfectly plastic. Critical state soil mechanics framework (Cam-clay and modified cam-clay models). Drained and undrained response of clays. Effects of consolidation stress history.

Compressibility of soils. Yielding for soils. Stress and strain history. Plastic hardening. Evolving anisotropy. Small strain non-linear "elastic" response. Hysteretic response. Large strain failure criteria: Von Mises, Drucker-Prager, Mohr Coulomb.

Course Outcomes:

- Students will learn the fundamentals of constitutive models
- Students will learn various kinds of elastic and inelastic, e.g, plastic, viscoplastic, viscoelastic, material response
- Students should be able to develop constitutive models

Text and Reference Books:

1. Desai, C.S., 2000. Mechanics of Materials and Interfaces:The Disturbed State Concept. CRC Press LLC.
2. Desai, C.S. and Siriwardane, H. J., 1984. Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials. Prentice-Hall, Inc., New Jersey.
3. Hicher and Shao, 2008. Constitutive Modeling of Soils and Rocks. John Wiley
4. Potts, D. M. and Zdravkovic, L., 1999. Finite Element Analysis in Geotechnical Engineering Theory. Thomas Telford.
5. Selvadurai, A.P.S. and Boulon, M. J., 1995. Mechanics of Geomaterial Interfaces, Elsevier.

CE 573 Natural treatment Systems (3-0-0)

Course Objectives

- To provide knowledge regarding natural wastewater treating technologies
- To provide know-how for designing a low cost and sustainable wastewater treatment system

Course Content

Introduction: Natural wastewater treatment Systems (NWTS), Main Types Of NWTS, Advantages And Disadvantages Of NWTS, Flows And Loads, Preliminary Treatment.

Septic tanks, Waste stabilization ponds - Facultative Ponds, Maturation Ponds, Polishing Ponds, Physical Design, Sampling And Performance Evaluation, Operation And Maintenance, WSP Design Example, Case Study. Rock filters: Types Of Rock Filter, Un-aerated Rock filter for BOD And SS Removal, Aerated Rock filter for Ammonia Removal.

Constructed wetlands: Types Of Constructed Wetlands, Free-Water-Surface CW, Subsurface Horizontal-Flow CW, Vertical-Flow CW, Physical Design, Operation and Maintenance, Compact Vertical Flow-CW Treating Raw Wastewater, Nitrification, Denitrification, Phosphorous removal, heavy metal removal, CW Design Examples.

Application of Constructed wetlands for urban floods: Case studies and design examples.

NWTS technology selection: Comparative Costs, Technology Selection.

Course outcomes

The student will be able to:

- Design a low cost, sustainable wastewater treatment system.
- Practically implement NTS systems for field applications
- Appreciate wider applications of natural treatment systems

Text and Reference Books:

1. Kadlec, R.H., Wallace, S., 2008. Treatment Wetlands, CRC Press.
2. Peavy, H.S., Rowe, D.R., Tchobanoglous, G., Environmental Engg, McGraw Hill, International Edition.
3. Garg, S.K., Environmental Engineering (Vol. II), Khanna Publishers, Delhi.

4. Metcalf and Eddy, 2017. Wastewater Engineering: Treatment and Reuse, McGraw Hill Education.
5. IWA, 2017. Treatment Wetlands. IWA Publishing. https://doi.org/10.2166/9781780408774

CE 541 Pavement Analysis and Design (3-0-0)

Course Objectives

1. To study the different types of pavements depending upon the mode of transportation using it and further, depending upon the structural behaviour.
2. To understand the concept of consideration of wheel loads, axle loads, wheel –axle configuration and allied aspects as a pre-requisite in the analysis and design of the pavement.
3. To study the various types of structural responses (stresses and deformations) inducing in the pavements due to wheel load and other climatic variations.
4. To introduce the constructions of different types of highway pavements.
5. To study the different types of distresses in the pavement, evaluation of the existing pavements using different methods and rehabilitation of the distressed pavements.
6. To study the design methodology and construction technology w.r.t. low volume roads.

Course Syllabus

Introduction: Pavement structure and functional attributes, factors affecting pavement design, types of wheel loads for highway and airports, development of design methods for highways and airport pavements.

Analysis of Pavements: Stresses in flexible pavements- Single layer, Two layer and Three layer theories , ESWL, EWLF, etc.; Stresses in rigid pavements- Wheel load, temperature and combined stresses.

Flexible Pavement Design: Various approaches for designing the highway and airport pavements (empirical, semi-empirical, mechanistic empirical, etc.), methods falling under each

of these methods, overview of the revision of specifications pertaining to these methods, design of pavements using these methods.

Rigid Pavement Design: Various approaches for designing the pavements (highways and airports) and methods falling under each of these methods, overview of the revision of specifications pertaining to these methods, design of pavements using these methods, design of joints

Highway Constructions: Construction of water bound macadam, wet mix macadam roads, bituminous concrete Roads, bituminous surfacing and treatment, cement concrete roads, semi-rigid and composite pavements, pavement consruction using Pozzolanic and waste materials, roller compacted concrete pavement, fiber reinforced concrete pavements, quality control and quality assurance during constructions, etc.

Evaluation and Strengthening:

Distresses in flexible and rigid pavements, condition and evaluation surveys, present serviceability index, roughness measurement, pavement maintenance, Benkelman beam deflections, different methods of designing the overlays, overview of the revision of specifications pertaining to these methods, design of different overlays, skid resistance and measurement

Low Volume and Low Cost Roads: Classification of low cost roads, stabilization of subgrade, sub-base and base and its advantages, low cost materials and methods used for construction, design of low volume roads.

Course Outcomes

On successful completion of the course, the learner shall be able to:

1. Understand the structural actions involved in the pavement due to different types of load acting thereon and the various methods of analysis of these pavements.
2. Understand the application of analysis in the design of pavements using various methods of pavement designs along with the design of low volume roads.
3. Understand the various aspects of the construction of different types of roads including that of low volume roads.
4. Know the different types of failures occurring in the existing pavements and carry out the structural and functional evaluation of pavements;

5. To apply the knowledge gained in evaluating the pavements in pre-empting the failure and subsequently, in arriving upon the methodology of the rehabilitation of pavements.

Books Recommended:

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

Reference Books

16. Yoder E.J. and Witzack M.W., 1991. Principles of Pavement Design; John Wiley and Sons, New York.
17. Kandhal, Prithvi Singh , 2014. Bituminous Road Construction in India; PHI Learning Pvt. Ltd., Delhi

18. Delattee, Norbert J., 2017. Concrete Pavement: Design, Construction and Performance (Second Edition)
19. Mallick, Rajib B. and Korchi, Tahar El, 2017. Pavement Engineering: Principles and Practice, CRC Press, Taylor and Francis Group (Third Edition)
20. Nikolaides, A., 2017. Highway Engineering: Pavement Materials and Control of Quality, CRC Press, taylors and Francis Group.

Additional Reading

Relevant specifications of Bureau of Indian Standards for Highway Material Testing, Indian Roads Congress (IRC) and Ministry of Road Transport and Highways (MoRTH) w.r.t. / Pavement Design and Highway Construction revised time to time shall be referred to, e.g.:

IRC: 37-2012. "Tentative Guidelines for the Design of Flexible Pavements," Indian Road Congress, Delhi.
IRC: 58-2015. "Tentative Guidelines for the Design of Rigid Pavements," Indian Road Congress, Delhi.
IRC: 81-2012. "Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique," Indian Road Congress, Delhi
IRC: SP: 76-2008. "Tentative Guidelines for Conventional, Thin and Ultra-Thin White-topping," Indian Road Congress, Delhi.

Note: Some of the recent specifications may not have been incorporated in few books authored by Indian Authors. For this, titles of multiple books are given in the list of the Recommended Books. The latest editions shall be used. In addition to this, relevant specifications/ codes with the latest revisions thereof shall be referred to.

CE 574 Watershed Management and Remote Sensing Applications (3-0-0)

Course Objectives:

- To understand the catchment management system
- To get familiar with remote sensing and their link with surface properties
- To identify the satellite and their use in Civil Engineering Profession

Principles of watershed management, soil water conservation practices, integrated planning, multi-disciplinary approach, management of agricultural lands - structural and non-structural measures, forest and grass land management, erosion problems and controlling techniques, gully control, landslide and correction techniques, soil water plant relationships, watershed modeling.

Remote sensing: fundamentals – physics of remote sensing – electromagnetic radiation,interaction of ENR with atmosphere, earth surface, soils, water and vegetation. Data acquisition, photographic system and imaging systems, single vertical photographs, visible and near infrared imagery, photo interpretation, visual analysis, spectral properties of water, photogrammetry, stereoscopic viewing, application to water resources mapping, area assessment and watershed management – satellite data – geo-coding – GPS and GIS utilities – classification using imageries – applications in water resources and watershed management – case studies.

Text and Reference Books:

1. Lillesand, K., Remote Sensing and Image Interpretation, John Wiley & Sons, 1979.

2. Tideman, E.M., Watershed Management – Guidelines for Indian Conditions, Omega Scientific Publishers, New Delhi, 1996.

3. FAO Watershed management and Field manual, 13/1, 13/2,13/3,13/4,13/5 FAO, UN, Rome, 1988.

4. Reeves, R.G., Manual of Remote Sensing, Volume I and II, American Society of Photogrammetr, Falls Church, 1975.

Course Outcomes:

1. Introduction to basis of GIS and watershed management includes conservation soil.
2. Understand the mapping process and geographical coordinate system of earth.
3. Able to do vector based and raster based data processing.
4. Knowledge of remote sensing and its components.
5. To apply integration of remote sensing and GIS.

LABORATORY

CE 561 Materials Testing And Characterization Laboratory (0-0-3)

Course Objectives

- The objective is to characterize the geosynthetics and waste materials used in construction industry

List of Experiments

- Specific gravity of available waste material
- Shear tests of waste material and geosynthetics, stress paths
- Hydrometer analysis of waste materials

Course Outcomes

- Students should be able to perform the various tests on geosynthetics as well as waste materials

CE 562 Soil Engineering Laboratory (0-0-3)

Course Objectives:

- The objective is to learn to perform basic tests on soil and determine the properties of various soils

List of Experiments

- Determination of relative density
- Vane shear test
- Consolidation tests
- Direct shear and tri-axial compression test – UU, CU, CD tests ,Influence of strain rate, Stress path testing etc.
- Standard penetration tests 5. Dynamic cone penetration tests
- Plate load tests
- Hydrometer Test

Course Outcomes

- Students should be able to perform different tests on soils

|CE 563 Advanced Water and Wastewater Laboratory (0-0-3)

Course Objectives

- To enable the students in analysing the physical and chemical characteristics of water and wastewater
- To familiarize the students with the methods to estimate the organic strength of wastewater

Course Content

Principles of instrumentation and application for water quality parameters measurements.
Indicative list of experiments:
Physical and Chemical Characteristics of Water - pH, Electrical Conductivity, Turbidity, Alkalinity, Acidity, Hardness, Sulphates, Fluorides, Nitrates; Estimation of Solids (TSS, TDS, VSS, FSS); Estimation of Nitrogen (Ammonical Nitrogen, Nitrite, Nitrate, TKN); Estimation of Phosphates and Sulphates; Determination of heavy metals using AAS; Determination of COD using spectrophotometer; Ambient Air Quality Analysis - Determination of SPM, CO, NO_X and $SO_{X;}$ Soil Analysis - pH, Conductivity, Cation Exchange Capacity, Sodium Adsorption Ratio.

Course Outcomes

Students will be able to

- To conduct experiments as per standard methods of sampling and analysis.
- To demonstrate the expertise to characterize water and wastewater samples.
- To understand the importance of laboratory analysis as a controlling factor in the treatment of water and wastewater**.**

Text and Reference Books:

1. Sawyer,C.N., McCarty, P.L. and Parkin,G.F., (2002). Chemistry for Environmental Engineering and Science. 5th edition, McGraw-Hill Publishing Company.
2. Standard methods for the examination of water and wastewater, 21st Edition, Washington: APHA., 2012.

CE 564 Simulation Laboratory (0-0-3)

Course Objectives

- To be able to write a computer code for different numerical methods

List of Experiments

- Introductory exercises on MATLAB and other software
- Simulation using MATLAB – an exercise on a simulation method
- Development of algorithms/codes by considering different methods for: roots of equations
- Solution of simultaneous equation (linear-nonlinear),
- Eigen value and Eigen vectors
- Numerical integration
- Solution of differential equation

Course Outcomes

- Students should be able to write basic codes for different numerical methods and apply the codes for problems in geotechnical engineering

CE 590 Modelling and Research Methodology

Course Objectives

1. Learn the research types, methodology and formulation.
2. Know the sources of literature, survey, review and quality journals.
3. Understand the research design for collection of research data.
4. Understand the research data analysis, writing of research report and grant proposal.

Course Outcomes

1. Differentiate the research types and methodology.
2. Able to do literature survey using quality journals.
3. Able to collect research data.
4. Process research data to write research report for grant proposal.

Course Syllabus

UNIT –I Research methodology

Meaning, Objectives and Characteristics of research - Research methods Vs Methodology - Types of research - Descriptive Vs. Analytical, Applied Vs. Fundamental, Quantitative Vs. Qualitative, Conceptual Vs. Empirical - Research process - Criteria of good research - Developing a research plan.

UNIT –II Literature survey

Importance of literature survey -Sources of information -Assessment of quality of journals and articles -Information through internet. Literature review: Need of review -Guidelines for review - Record of research review.

UNIT –III Research design

Meaning of research design -Need of research design -Feature of a good design -Important concepts related to research design -Different research designs -Basic principles of experimental design -Developing a research plan -Design of experimental set-up -Use of standards and codes of Civil Engineering.

UNIT –IV Data collection and analysis:

Collection of primary data and Secondary data of different Civil Engineering fields -Data organization -Methods of data grouping -Diagrammatic representation of data -Graphic representation of data -Sample design -Need for sampling -Some important sampling definitions -Estimation of population -Role of statistics for data analysis -Parametric vs. non parametric methods -Descriptive statistics -Measures of central tendency and dispersion -Hypothesis testing -Use of statistical softwares. Data Analysis: Deterministic and random data -Uncertainty analysis

-Tests for significance -Chi-square -Student's t-test -Regression modeling -Direct and interaction effects –ANOVA-F-test -Time series analysis -Autocorrelation and autoregressive modeling.

UNIT –V Research report writing: Format of the research report –Synopsis –Dissertation -Thesis -Its differentiation –References –Bibliography -Technical paper writing -Journal report writing -Making presentation -Use of visual aids. Research proposal preparation: Writing a research proposal and research report -Writing research grant proposal.

Text and Reference Books:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K. 2002. An introduction to research methodology, RBSA Publishers.
2. Kothari, C.R, 2004. Research methodology, methods & technique, New Age International Publishers, New Delhi.
3. Ganesan, R. 2015. Research methodology for engineers, MJP Publishers, Chennai.
4. Khananabis, Ratan and Saha, Suvasis 2015. Research methodology, Universities Press, Hyderabad.
5. Agarwal,Y.P. 2004. Statistical Methods: concepts, application and computation, Sterling Publishing Pvt. Ltd., New Delhi.
6. Upagade, Vijay and Shende, Aravind 2009. Research methodology, S. Chand & Company Ltd., New Delhi.
7. Nageswara Rao, G. 2012. Research methodology and quantitative methods, BS Publications, Hyderabad.