M. Tech. Course Structure for Geotechnical Engineering
(Modified for July 2011 Onwards)

SEMESTER-1		
Course No.	**Course Name**	**L – T – P – C**
CE 531	Advanced Soil Mechanics	3 – 0 – 2 – 8
CE 532	Dynamics of Soil and Foundations	3 – 1 – 0 – 8
CE xxx	Elective I	3 – 0 – 0 – 6
CE xxx	Elective II	3 – 0 – 0 – 6
	Total Credits in First Semester	12– 1 – 2 – 28 Contact Hours 15
SEMESTER-2		
CE 533	Advanced Foundation Engineering	3 – 1 – 0 – 8
CE 534	Seminar	0 – 0 – 2 – 2
CE xxx	Elective III	3 – 0 – 0 – 6
CE xxx	Elective IV	3 – 0 – 0 – 6
CE xxx	Elective V	3 – 0 – 0 – 6
	Total Credits in Second Semester	12– 1 – 2 – 28 Contact Hours 15
SEMESTER-3		
CE 549	Project and Thesis Phase-I	0 – 0 – 24 – 24
SEMESTER-4		
CE 550	Project and Thesis Phase-II	0 – 0 – 24 – 24
	Total Credits	24– 2 – 52 – 104

NB: Students can opt for any approved course as elective provided there is no clash with the time-table slots.

ELECTIVES

CE 601	Numerical Methods	3	0	0	6
CE 602	Optimization Methods	3	0	0	6
CE 603	Fuzzy logic and Artificial intelligence in Civil Engineering Applications	3	0	0	6
CE 605	Computer Aided Design	3	0	0	6
CE 606	Earthquake Engineering	3	0	0	6
CE 607	Random Vibration	3	0	0	6
CE 610	Finite Element Analysis	3	0	0	6
CE 611	Computational Plasticity	3	0	0	6
CE 583	Pavement Analysis and Design	3	0	0	6
CE 641	Reinforced Soil Structures	3	0	0	6
CE 642	Subsurface Investigation and Instrumentation	3	0	0	6
CE 643	Earthquake Geotechnical Engineering	3	0	0	6
CE 644	Elastic Analysis in Geotechnical Engineering	3	0	0	6
CE 645	Soil-Structure Interaction	3	0	0	6
CE 646	Rock Mechanics	3	0	0	6
CE 647	Environmental Geotechnology	3	0	0	6
CE 648	Applied Soil Mechanics	3	0	0	6
CE 649	Ground Improvement Techniques	3	0	0	6
CE 650	Geotechnical Practice for Waste Disposal	3	0	0	6

SYLLABUS

CE 531 ADVANCED SOIL MECHANICS 3 0 2 8

Pre-requisites: Nil

Introduction to stress-strain behavior of soils; Mohr Circle of Stress; Principal Stresses. Shear strength of cohesive and cohesion less soils; drained and undrained shear strength of soils, Significance of pore pressure parameters; Determination of shear strength; Interpretation of triaxial test results.

Stress path; Drained and undrained stress path; Stress path with respect to different initial state of the soil; Stress path for different practical situations.

Critical state soil mechanics; Critical state parameters; Critical state for normally consolidated and over consolidated soil; Significance of Roscoe and Hvorslev state boundary surface; drained and undrained plane.

Behavior of sands; Critical void ratio; Effect of dilation in sands; Different dilation models.

Elastic and plastic deformations: elastic wall; introduction to yielding and hardening; yield curve and yield surface.

Textbooks/References

1. Atkinson, J.H. and Bransby, P.L, **The Mechanics of Soils: An introduction to critical soil mechanics**, McGraw Hill, 1978.
2. Atkinson J.H, **An introduction to the Mechanics of soils and Foundation**, McGraw- Hill Co., 1993.
3. Das, B.M., **Advanced Soil Mechanics**, Taylor and Francis, 2nd Edition, 1997
4. Wood, D.M., **Soil Behavior and Critical State Soil Mechanics**, Cambridge University Press, 1990.
5. Craig, R.F., **Soil Mechanics**, Van Nostrand Reinhold Co. Ltd., 1987.
6. Terzaghi, K., and Peck, R.B., **Soil Mechanics in Engineering Practice**, John Wiley & Sons, 1967.
7. Lambe, T.W. and Whitman, R.V., **Soil Mechanics**, John Wiley & Sons, 1979.

CE 532 DYNAMICS OF SOILS AND FOUNDATIONS 3 1 0 8

Pre-requisites: Nil

Fundamentals of vibration-Response of SDOF systems: Free vibration, Experimental determination of natural frequency and damping, Forced vibration, Base excitation, Vibration measuring instruments and Response of 2DOF systems.

Wave propagation: Elastic rods, elastic continuum medium and semi-infinite elastic

continuum medium. Stress-strain behavior of cyclically loaded soils, Strength of cyclically loaded soils, Dynamic soil properties - Laboratory and field testing techniques, Selection of design values.

Liquefaction of soils: An introduction and evaluation using simple methods. Dynamic stiffness and damping constants of shallow foundation-Circular rigid mat foundation on elastic half space excited vertically, laterally, torsion or rocking, Effective stiffness and damping of such systems, Modeling of soil medium by frequency dependent and frequency independent elements. Design of machine foundations.

Dynamic stiffness and damping constants of single pile and pile group-Analysis for vertical, lateral, rocking modes of vibration.

Vibration absorption and isolation techniques.

Textbooks/References

1. Arya S.D, O'Neil, M. and Pincus, G., **Design of structures and foundations for vibrating machines**, Gulf Publishing Co., 1979.
2. Prakash, S. and Puri, V.K., **Foundation for machines: Analysis and Design**, John Wiley & Sons, 1998
3. Prakash, S., Soil Dynamics, McGraw Hill, 1981.
4. Kameswara Rao, N.S.V., **Vibration analysis and foundation dynamics**, Wheeler Publication Ltd., 1998.
5. Major, A., **Dynamics in Civil Engineering: Analysis and Design Vol. I-III**, Akademiai Kiado, 1980.
6. Richart, F.E. Hall J.R and Woods R.D., **Vibrations of Soils and Foundations**, Prentice Hall Inc., 1970.

CE 533 ADVANCED FOUNDATION ENGINEERING **3 1 0 8**

Pre-requisites: Nil

Foundation classification, choice of foundations, bearing capacity theories and settlement analysis of shallow foundations, bearing capacity theory for special cases of shallow foundations. Deep foundation. Pile design for compressive load, uplift, lateral load, design of pile groups, concept of negative skin friction. Soil structure interaction: an introduction.

Textbooks/References

1. Bowles. J.E., **Foundation Analysis and Design**, Tata McGraw-Hill International Edition, 5th Edn, 1997.
2. Das B.M., **Shallow Foundations: Bearing capacity and settlement**, CRC Press, 1999.
3. Tomlinson M.J., **Pile design and construction Practice**, Chapman and Hall Publication, 1994.

4. Peck, R.B., Hanson, W.E. and Thornburn, T.H., **Foundation Engineering**, Wiley Eastern Ltd., 2nd Edn., 1980.
5. Kurian, N.P. **Design of Foundation Systems - Principles and Practices**, Narosa Publishing House, 2nd Edn., 1994.
6. Prakash, S. and Sharma, H.D., **Pile Foundations in Engineering Practice**, John Wiley & Sons Inc., 1990.
7. Teng, W.C., **Foundation Design**, Prentice-Hall of India (Pvt) Ltd., 1965.
8. Tomlinson, M.J., **Foundation Design and Construction**, English Language Book Society, Longman Group Ltd., 5th Edn.,1986.
9. Winterkorn, H.F. and Fang, H., **Foundation Engineering Handbook**, Van Nostrand Reinhold Company, 1975.

CE 601 NUMERICAL METHODS **3 0 0 6**

Pre-requisites: Nil

Linear equations and eigen value problems, Accuracy of approximate calculations, Nonlinear equations, interpolation, differentiation and evaluation of single and multiple integrals, initial and boundary value problems by finite difference method, Newton's method, variation and weighted residual methods, introduction to finite element methods, fundamental of statistical distribution.

Textbooks/References

1. Scarborough, J.B., **Numerical mathematical analysis**, Oxford & IBH Publishing CO Pvt., 2000
2. Jain, K.K., Iyengar, S.R.K and Jain, R.K., **Numerical methods-problem and solutions**, Wiley eastern limited, 2001
3. Hamming, R.W., **Numerical methods for scientist and engineers**, McGraw Hill, 1998.
4. Mathews, J.H. and Fink, K.D., **Numerical methods using MATLAB**, Pearson Education, 2004
5. Hayter, A.J., **Probability and statistics**, Duxbury, 2002.

CE 602 OPTIMIZATION METHODS **3 0 0 6**

Pre-requisites: Nil

Basics of engineering analysis and design, Need for optimal design, formulation of optimal design problems, basic difficulties associated with solution of optimal problems, Classical optimization methods, Necessary and sufficient optimality criteria for unconstrained and constrained problems, Kuhn-Tucker conditions, Global optimality and convex analysis,

Linear optimal problems, Simplex method, Introduction to Karmarkar's algorithm. Numerical methods for nonlinear unconstrained and constrained problems, sensitivity analysis, Linear post optimal analysis, sensitivity analysis of discrete and distributed systems. Introduction to variational methods of sensitivity analysis, shape sensitivity, Introduction to integer programming, dynamic programming, stochastic programming and geometric programming, Introduction to genetic algorithm and simulated annealing.

Textbooks/References

1. Deb. K., **Optimization for engineering design: Algorithms and examples**, PHI Pvt Ltd., 1998.
2. Arora., J.S., **Introduction to optimum design**, McGraw Hill International edition, 1989.
3. Hafta, R.T. and Gurdal. Z., **Elements of structural optimization**, Kluwer academic publishers, Third revised and expanded edition, 1996.

CE 603 FUZZY LOGIC AND ARTIFICIAL INTELLIGENCE IN CIVIL ENGINEERING APPLICATIONS 3 0 0 6

Pre-requisites: Nil

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. Fuzzy logic-basic concepts-problem formulation using fuzzy logic-applications.

Textbooks/References

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

CE 605 COMPUTER AIDED DESIGN 3 0 0 6

Pre-requisites: Nil

Principles of computer aided design, computer configuration for CAD applications, Computer peripherals for CAD. Computer graphics fundamentals, points and lines, Three-dimensional transformations and projections, plane curve, space curves surface descriptions and generation. Hidden line algorithms for wire-frame modeling, Surface modeling, Solid modeling, Representation of 3D objects. B-rep solid modelers and constructive solid

geometry, CAD system utilization and application Hidden surface algorithms and Shading, Finite element systems, Computer aided drafting system.

Textbooks/References

1. Rogers, D.F., **Mathematical elements for computer graphics**, McGraw Hill, 1990.
2. Rogers, D.F., **Elements of computer graphics**, McGraw Hill International edition, 1998
3. Mortenson, M.E., **Geometric modelling**, John Wiley and Sons, 1989.

CE 606 EARTHQUAKE ENGINEERING **3 0 0 6**

Pre-requisites: Structural Dynamics (CE504)

Earthquakes: Causes, Magnitude and Intensity, Ground Motions, Site effects, Sensors; Response spectrum: Construction, Characteristics, Design Response spectrum; Linear Earthquake analysis: Idealization of structures, Response spectrum analysis, Torsionally coupled systems, Frequency domain analysis, Time domain analysis; Nonlinear Earthquake analysis: Force-deformation relationships, Equation of motion, Controlling parameters, Ductility demand, Allowable ductility; Earthquake resistance design: philosophy ductility based design, Detailing provisions, Codal Provisions, Concepts of passive controls; Geotechnical aspects: Dynamic properties of soil, dynamic earth pressures, Liquefaction and ground improvement techniques; Retrofitting and strengthening of Buildings and Bridges.

Textbooks/References

1. R. W. Clough and J. Penzien, **Dynamics of Structures**, McGraw Hill International edition, Second edition ,1993.
2. M. Paz, **Dynamics of Structures**, CBS Pub, 1987.
3. A.K. Chopra, **Dynamics of Structures-Theory and application to Earthquake Engineering**, PHI,1997.
4. T. Pauley and M.S.N. Priestly, **Seismic design of reinforced concrete and masonry buildings**, John Wiley and Sons,1992.
5. M.N.S. Priestly, F. Seible and G.M. Calvi, **Seismic design and retrofit of bridges**, John Wiley and Sons,1996.
6. D.J. Dowrick, **Earthquake Resistant Design: for engineers and architects**, John Wiley and Sons,1987.

CE 607 RANDOM VIBRATIONS **3 0 0 6**

Pre-requisites: Nil

Concepts of probability, random variables, theory of random process, stationary and non-stationary process, Expected values, moments, spectral properties of random process, Response of linear systems to random excitations, SDF and MDF discrete systems, Continuous systems, Response of nonlinear systems to random excitations. Fokker-plank equations, Markov vector approach, statistical linearization and perturbation techniques. Level crossing, Peaks envelops and First passage time, Mone-Carlo simulation.

Textbooks/References

1. N.C. Nigam, **Introduction to random vibration**, MIT Cambridge, 1983.
2. Y.K. Lin, **Probabilistic theory of structural dynamics**, McGraw Hill, 1967.
3. D.E. Newland, **Random vibration and spectral analysis**, Longman, 1984.

CE 610 FINITE ELEMENT ANALYSIS **3 0 0 6**

Pre-requisites: Nil

Principles of discretization, element stiffness and mass formulation based on direct, variational and weighted residual techniques and displacements approach, Shape functions and numerical integrations, convergence, Displacement formulation for rectangular, triangular and isoparametric elements for two dimensional and axisymmetric stress analysis. Thin and thick plates and shells. Semi-analytical formulations, Three-dimensional elements and degenerated forms. Stiffener elements and modifications such as use of different coordinate systems, use of non-conforming modes and penalty functions. FEM in incompressible and compressible fluid, applications of FEM in thermal problems.

Textbooks/References

1. O.C. Zienkiewicz and R.L. Taylor, **Finite element methods Vol I & Vol II**, McGraw Hill,1989,1992.
2. K.J. Bathe, **Finite element procedures**, PHI Ltd., 1996.
3. R.D. Cook, D.S. Malkus. and M.E. Plesha, **Concepts and applications of finite element analysis**, John Wiley and Sons, Third edition, 1989.

CE 611 COMPUTATIONAL PLASTICITY **3 0 0 6**

Pre-requisites: Nil

Experimental behavior of metals and other materials under monotonic and cyclic loading, One-dimensional mathematical modeling and its computational implementation, Yield criteria for different materials in multi-axial conditions, Elastoplastic boundary value problem. Finite element analysis of elastoplastic boundary value problems, Integration of constitutive relations. Consistent tangent modulus, Kinematics of plastic deformation at finite strain. Finite element formulation at large strain, Recent development in cyclic plasticity and its computational implementation.

Textbooks/References

1. J.C. Simo and T.J.R. Hughes, **Computational Inelasticity**, Springer, 1998
2. J. Lemaitre and Chaboche, **Mechanics of Solid Materials**, Cambridge university Press, Cambridge 1990.
3. A.S. Khan and S. Huang, **Continuum Theory of Plasticity**, John Wiley & sons Inc., 1995.
4. I.H. Shames and F.A. Cozzarelli, **Elastic and Inelastic Stress Analysis**, Prentice hall, 1992.

CE 583 PAVEMENT ANALYSIS AND DESIGN **3 0 0 6**

Pre-requisites: Nil

Philosophy of design of flexible and rigid pavements, analysis of pavements using different analytical methods, selection of pavement design input parameters – traffic loading and volume, material characterization, drainage, failure criteria, reliability, design of flexible and rigid pavements using different methods, comparison of different pavement design approaches, design of overlays and drainage system.

Textbooks/References

1. Yang and H. Huang, **Pavement Analysis and Design**, Pearson Prentice Hall, 2004.
2. Yoder and Witzech, **Pavement Design**, McGraw-Hill, 1982.
3. Sharma and Sharma, **Principles and Practice of Highway Engg**., Asia Publishing House, 1980.
4. Teng, **Functional Designing of Pavements**, McGraw- Hill, 1980.

CE 641 REINFORCED SOIL STRUCTURES **3 0 0 6**

Pre-requisites: Nil

Historical background; Principles, concepts and mechanism of reinforced earth; Design consideration for reinforced earth and reinforced soil structures; Geosynthetics-their composition, manufacture, properties, functions, testing and applications in reinforced earth structures; Design of reinforced soil structures like retaining walls, embankments, foundation beds etc.; Designing for Separation, Filtration, Drainage and Roadway Applications; Designing for Landfill Liners and Barrier Applications; Case histories of applications.

Textbooks/References

1. Clayton, C.R.I., Milititsky, J. and Woods, R.I., **Earth Pressure and Earth Retaining Structures**, Blackie Academic & Professional, 1993.
2. Ingold, T, **Reinforced Earth**, Thomas Telford Ltd., 1982.
3. Jones, C.J.F.P, **Earth Reinforcement and Soil Structures**, Butterworth, 1985.
4. Koerner, R.M, **Designing with Geosynthetics**, Prentice Hall, 1993.

CE 642 SUBSURFACE INVESTIGATION AND INSTRUMENTATION **3 0 0 6**

Pre-requisites: Nil

Problems and phases of foundation investigations. Geophysical, sounding, drilling and accessible explorations. Sample requirements, sampling methods and equipment. Handling, preservation and transportation of samples. Sample preparation, laboratory tests, analysis of results and interpretation, importance of in-situ testing. Performing various in situ tests. Precautions and interpretation. Field Instrumentation; Investigation below sea/river bed; offshore investigation; Site evaluation and reporting.

Textbooks/References

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

CE 643 EARTHQUAKE GEOTEHCNICAL ENGINEERING 3 0 0 6

Pre-requisites: Dynaimcs of Soils and Foundations (CE532)/ Structural Dynamics (CE504)

Earthquake seismology – Causes of earthquake, Plate tectonics, Earthquake fault sources, Seismic waves, Elastic rebound theory, Quantification of earthquake, Intensity and magnitudes, Earthquake source models.

Earthquake ground motion – Seismograph, Characteristics of ground motion, Effect of local site conditions on ground motions, Design earthquake, Design spectra, Development of site specification and code-based design.

Ground response analysis – One-dimensional ground response analysis: Linear approaches, Equivalent linear approximation of non-linear approaches, Computer code "SHAKE".

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

Seismic design of foundations, Seismic slope stability analysis: Internal stability and weakening instability and Seismic design of retaining walls.

Textbooks/References

1. Kramer S.L., **Geotechnical Earthquake Engineering**, Prentice Hall, 1996.
2. Day, R.W., **Geotechnical Earthquake Engineering Handbook**, McGraw-Hill, 2002.
3. Seco e Pinto, P., **Seismic behaviour of ground and Geotechnical structure**, A. A. Balkema, 1997.
4. Naeim, F., **The Seismic Design Handbook**, Kluwer Academic Publication, 2nd Edition, 2001.
5. Bolt, B.A, **Earthquakes**, W. H. Freeman and Company, 4th Edition, 1999.
6. Lourie, W., **Fundamentals of geophysics**, Cambridge University press, 1997.
7. Wang J.G.Z.Q and Law, J.K.T., **Siting in Earthquake zones**, A. A. Balkema, 1994.
8. Ferrito, J.M, **Seismic design criteria for soil liquefaction**, Tech. Report of Naval Facilities service centre, Port Hueneme, 1997.

CE 644 ELASTIC ANALYSIS IN GEOTECHNICAL ENGINEERING

3 0 0 6

Pre-requisites: Nil

Concepts of stress and strain; Principal stresses and strains; Invariants; Octahedral stresses and strains; Mohr's diagrams; Plane state of stress and Plane state of strain; Stress strain relations for linearly elastic solids; Stresses and displacements in soil, Basic solutions of Boussinesq, Cerutti, Mindlin and Westergaard. Application of fundamental solutions for problems of practical interest in geotechnical engineering: foundations, stress applied to surface of a circular opening, Inclusions in infinite regions, surface loads in a semi-infinite region. Elastic solutions for layered soil systems, settlement and contact stress under rigid and flexible foundations, Computation of immediate settlements for shallow and deep foundations.

Textbooks/References

1. Harr, M.E, **Foundations of Theoretical Soil Mechanics**, McGraw-Hill Inc., 1996.
2. Das, B.M, **Advanced Soil Mechanics**, McGraw-Hill Book Co., 1987.
3. Poulos, H.G. and Davis, E.H, **Elastic Solutions for Soil and Rock Mechanics**, Wiley, 1974.

CE 645 SOIL-STRUCTURE INTERACTION

3 0 0 6

Pre-requisites: Nil

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

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.

Textbooks/References

1. Selvadurai, A.P.S, **Elastic Analysis of Soil-Foundation Interaction**, Elsevier, 1979.
2. Poulos, H.G., and Davis, E.H., **Pile Foundation Analysis and Design**, John Wiley, 1980.
3. Scott, R.F., **Foundation Analysis**, Prentice Hall, 1981.
4. **Structure Soil Interaction - State of Art Report**, Institution of Structural Engineers, 1978.
5. ACI 336. (1988), **Suggested Analysis and Design Procedures for combined footings and Mats**, American Concrete Institute.

CE 646 ROCK MECHANICS **3 0 0 6**

Pre-requisites: Nil

Geological formation of rocks, Structural Geology, Classification of rocks, Physicomechanical properties of rocks, Laboratory and field tests, Stress-strain behaviour, Failure criteria for intact rock and rock masses, Fracture mechanism, Analysis and design of underground openings, Instrumentation in tunnels, Rock support and reinforcement, Foundations on rock, Rock blasting.

Textbooks/References

1. Mukerjee, P.K., **A text book of Geology**, World Press, 1995.
2. Brady, B.H.G. and Brown, E.T, **Rock Mechanics for Underground Mining**, Chapman & Hall, 1993.
3. Brown, E.T, **Rock Characterisation, Testing and Monitoring**, Pergamon Press, 1986.
4. Herget, G., **Stresses in Rock**, Balkema, 1988.
5. Hoek, E. and Brown, E.T., **Underground Excavation in Rock**, Institution of Mining and Metallurgy, 1982.
6. Goodman, R.E, **Introduction to Rock Mechanics**, John Wiley & Sons, 1989.
7. Bieniawski, Z.T, **Engineering Rock Mass Classification**, John Wiley and Sons, 1989.
8. Coates, D.F, **Rock Mechanics Principles**, Canada Centre for Mineral and Energy Technology, 1981.
9. Jaeger, J.C. and Cook, N.G.W, **Fundamentals of Rock Mechanics**, Chapman and Hall, 1976.
10. Wyllie, D.C., **Foundations on Rock**, E & FN Spon. 2nd Edition, 1992.

CE 647 ENVIRONMENTAL GEOTECHNOLOGY **3 0 0 6**

Pre-requisites: Nil

Soil as a multiphase system; Soil-environment interaction; Properties of water in relation to the porous media; Water cycle with special reference to soil medium.

Soil mineralogy; significance of mineralogy in determining soil behavior; Mineralogical characterization.

Mechanisms of soil-water interaction: Diffuse double layer models; Force of attraction and repulsion; Soil-water-contaminant interaction; Theories of ion exchange; Influence of organic and inorganic chemical interaction.

Introduction to unsaturated soil mechanics; water retention property and soil-water characteristic curve; flow of water in unsaturated soil.

Concepts of waste containment facilities; desirable properties of soil; contaminant transport and retention; contaminated site remediation.

Introduction to advanced soil characterization techniques; volumetric water content; gas permeation in soil; electrical and thermal properties; pore-size distribution; contaminant analysis.

Textbooks/References

1. Mitchell, J.K and Soga, K., **Fundamentals of Soil Behavior**, John Wiley and Sons Inc., 2005.
2. Fang, H-Y., **Introduction to Environmental Geotechnology**, CRC Press,1997.
3. Daniel, D.E, **Geotechnical Practice for Waste Disposal**, Chapman and Hall, 1993.
4. Rowe, R.K., Quigley, R.M. and Booker, J.R., **Clay Barrier Systems for Waste Disposal Facilities**, E & FN Spon, 1995.
5. Rowe, R.K, **Geotechnical and Geoenvironmental Engineering Handbook**, Kluwer Academic Publishers, 2001.
6. Reddi, L.N. and Inyang, H.F, **Geoenvironmental Engineering - Principles and Applications**, Marcel Dekker Inc, 2000.
7. Sharma, H.D. and Lewis, S.P, **Waste Containment Systems, Waste Stabilization and Landfills: Design and Evaluation**, John Wiley & Sons Inc., 1994.

CE 648 APPLIED SOIL MECHANICS **3 0 0 6**

Pre-requisites: Nil

Earth pressures and design of retaining walls: Lateral earth pressure coefficients; Rankine and Coulomb theories; Graphical constructions; Passive earth pressure with curved rupture surfaces.

Theory of arching in soils and its applications in tunnel, conduits, silos.

Braced excavations and open cuts, Sheet piles and Anchored bulkheads, Cofferdams and their design. Diaphragm walls, Bored pile walls and Prestressed ground anchors.

Stability analysis and design Earth dams and embankments.

Non-conventional retaining systems: Reinforced retaining walls and landfill systems.

Textbooks/References

1. Kurian, N.P, **Design of Foundation Systems – Principles and Practices**, New Delhi, Narosa publishing House, 2nd Edn., 1994.
2. Kurian, N.P., **Modern Foundations – Introduction to Advanced Techniques**, New Delhi, Tata McGraw-Hill Publishing Company Limited,1984.
3. Clayton, C.R.I., Milititsky, J. and Woods, R.I., **Earth Pressure and Earth Retaining Structures**, Blackie Academic & Professional, 1993.
4. Terzaghi, K., **Theoretical Soil Mechanics**, Wiley, 1965.
5. Terzaghi, K and Peck, R.B, **Soil Mechanics in Engineering Practice**, Asia Publishing House, 1960.
6. Teng, W.C, **Foundation Design**, Prentice-Hall of India Pvt. Ltd., 1965.
7. Bowles, J.W. **Analysis and Design of Foundations**, McGraw-Hill, 4th Ed., 1988.
8. Spangler, M.G and Handy, R.L, **Soil Engineering**, Harper & Row, 1982.

CE 649 GROUND IMPROVEMENT TECHNIQUES **3 0 0 6**

Pre-requisites: Nil

Site investigation and subsoil exploration; Methods of boring and sampling; Field tests; Engineering properties of soft, weak and compressible deposits; Principles of treatment; Methods of soil improvement; Dynamic compaction; Preloading; Vertical drains; Granular piles; Lime stabilization and injection; Grouting; Soil nailing; Anchors; Vacuum consolidation; Thermal, electrical and chemical methods; Case histories.

Textbooks/References

1. Bowles, J.E., **Foundation Analysis and Design**, McGraw-Hill International Edition, 1997.
2. Hausmann, M.R., **Engineering Principles of Ground Modification**, McGraw-Hill International Editions, 1990.
3. Yonekura, R., Terashi, M. and Shibazaki, M. (Eds.), **Grouting and Deep Mixing**, A.A. Balkema, 1966.
4. Moseley, M.P., **Ground Improvement**, Blackie Academic & Professional, 1993.
5. Xanthakos, P.P., Abramson, L.W. and Bruce, D.A., **Ground Control and Improvement**, John Wiley & Sons, 1994.

CE 650 GEOTECHNICAL PRACTICE FOR WASTE DISPOSAL 3 0 0 6

Pre-requisites: Nil

Introduction to waste containment, Soil system and soil-water pollution interaction, Structural components of clayey soils for landfill liner, Soil organic matter-soil minerals interaction, Site investigation at polluted sites (Geophysical techniques, Hydrological investigations etc.), Landfill liner system, Classification of liners and potential problems for clay barrier system, Leachate & gas collection and removal system, Leachate production and clay-leachate compatibility, Soil attenuation by biochemical, physical & chemical processes, Final covering system, Design of top & drainage layers, Monitoring in the saturated and unsaturated zone, Construction quality control and quality assessment, Challenges associated with landfill design & construction in tropical region.

Textbooks/References

1. D.E. Daniel and R.M. Koerner, **Waste Containment Facilities**, ASCE, 2nd Ed, 2007.
2. A.M.O. Mohamed and H.E. Antia, **Geo-Environmental Engineering**, Elsevier, 1998.
3. R.K. Rowe, R.M. Quigley and C. Booker, **Clay Barrier Systems for Waste Disposal Facilities**, J. R., E and FN Spon, 1995.
4. H.D. Sharma and S.P. Lewis, **Waste Containment Systems, Waste Stabilization and Landfills: Design and Evaluation**, John Wiley & Sons Inc., 1994.
5. D.E. Daniel, **Geotechnical Practice for Waste Disposal**, Chapman and Hall, 1993.
6. J.F. Crawford and G.S. Smith, **Landfill Technology**, Butterworths, 1985.
7. L.N. Reddi and H.F. Inyang, **Geoenvironmental Engineering : Principles and Applications**, Marcel Dekker Inc, 2000.