भारतीय प्रौद्योगिकी संस्थान भुवनेश्वर

INDIAN INSTITUTE OF TECHNOLOGY BHUBANESWAR

School of Infrastructure

Curriculum and Syllabus for

M. Tech. (Geotechnical Engineering)

Preceding Degree:

B.E / B.Tech or equivalent degree in Civil Engineering

Intake per year: 15 students

Compliance Report of M. Tech. (Geotechnical Engineering) Curriculum

Components	**Subjects**	**As per 64th Senate**		**Proposed Credit Structure for M.Tech (Geotechnical Engineering)**	
		Nos.	**Credits**	**Nos.**	**Credits**
Theory	Total	9 to 10 Nos.	-	9 Nos.	31-36
	Departmental Core courses	-	-	4	16
	Electives	-	-	5	15-20
Labs		3 to 4 Nos.	-	3 Nos.	6
Seminar		-	-	1 No.	1
Thesis		3 Parts	2+14+14	3 Parts	30
Total Credits			65-74		69-74

Curriculum for M.Tech. (Geotechnical Engineering)

M.Tech. Curriculum					
Subject Name	**Course Code**	**Type**	**L-T-P**	**Credit**	**Contact Hours**
Semester-1					
Applied Soil Mechanics	CE6L201	DC	3-1-0	4	4
Computational Geomechanics	CE6L202	DC	3-1-0	4	4
Department elective 1/ Open elective 1	CE6LXXX	DE1/OE1	3-0-0 / 3-1-0	3 / 4	3 / 4
Department elective 2/ Open elective 2	CE6LXXX	DE2/OE2	3-0-0 / 3-1-0	3 / 4	3 / 4
Department elective 3/ Open elective 3	CE6LXXX	DE3/OE3	3-0-0 / 3-1-0	3 / 4	3 / 4
Seminar and Technical Writing	CE6S201	Seminar	0-0-2	1	2
Geotechnical Engineering Laboratory	CE6P201	Lab	0-0-3	2	3
			Total	**20 / 23**	**22 / 25**
Semester-2					
Foundation Analysis and Design	CE6L203	DC	3-1-0	4	4
Soil Dynamics	CE6L204	DC	3-1-0	4	4
Department elective 4/ Open elective 4	CE6LXXX	DE4/OE4	3-0-0 / 3-1-0	3 / 4	3 / 4
Department elective 5/ Open elective 5	CE6LXXX	DE5/OE5	3-0-0 / 3-1-0	3 / 4	3 / 4
Geosynthetics and In-situ Testing of Soils Laboratory	CE6P202	Lab	0-0-3	2	3
Computational Geomechanics Laboratory	CE6P203	Lab	0-0-3	2	3
Thesis Part 1	CE6D201	Thesis Part - 1	-	2	-
			Total	**20 / 22**	**20 / 22**

Industrial Internship (Optional)*

Semester-3					
Thesis Part 2	CE6D202	MTP	-	14	-
			Total	**14**	
Semester-4					
Thesis Part 3	CE6D203	MTP	-	14	-
			Total	**14**	
			Total Credits:	**68/73**	

*Industrial internship is an optional subject included in the curriculum for the benefit of the student and does not carry any credit. The duration of this internship shall be a maximum of six months. The student is permitted to go for an industrial internship based on the consent from the allotted supervisor after the completion of the second semester from the month of May, which shall continue up to the month of October. Students opting for six-month internship after second semester (May to October) have to compensate the same during the following winter (December) and summer (May to July) breaks.

Tentative plan for the M.Tech thesis evaluation.

M.Tech Thesis	M.Tech Student (With no industrial internship)	M.Tech Student (With industrial internship)
Part-I	During the second semester	During the second semester
Part-II	November or December (Autumn)	Jan or Feb (Spring)
Part-III	April or May (Spring)	June or July (During summer vacation)

List of Electives (I to IV)				
Sl. No.	**Subject Code**	**Name**	**L-T-P**	**Credit**
1	CE6L205	Theoretical Soil Mechanics	3-0-0	3
2	CE6L206	Rock Mechanics	3-0-0	3
3	CE6L207	Transportation Geotechnics	3-0-0	3
4	CE6L208	Soil Structure Interaction	3-0-0	3
5	CE6L209	Geotechnical Earthquake Engineering	3-0-0	3
6	CE6L210	Geotechnical Risk and Reliability	3-0-0	3
7	CE6L211	Ground Water Seepage and Earth Dams	3-0-0	3
8	CE6L212	Ground Improvement	3-0-0	3
9	CE6L213	Geosynthetic Engineering	3-0-0	3
10	CE6L214	Dynamics of Soil and Foundations	3-0-0	3
11	CE6L215	Foundations of Offshore Structures	3-0-0	3
12	CE6L216	Geotechnics of Polluted Sites	3-0-0	3
13	CE6L217	Geotechnics of Waste and Waste Containment	3-0-0	3
14	CE6L218	Soil Exploration and In-situ Testing	3-0-0	3
15	CE6L219	Unsaturated Soil Mechanics	3-0-0	3
16	CE6LXX	Fundamentals of Underground Infrastructure	3-0-0	3
17	CE6L222	Environmental Geotechnology	3-0-0	3

CORE SUBJECTS

Subject Code: CE6L201	**Name: Applied Soil Mechanics**	**L-T-P: 3-1-0**	**Credits: 4**

Prerequisite: None

Shear Strength: Shear strength of cohesive and cohesionless soils; Stress paths in p-q space; Triaxial behavior: stress states and analysis of UCS, UU, CU, CD, and other special tests, stress paths in triaxial testing, porewater pressure parameters.

Stability of slopes: introduction, stability of infinite and finite slopes, different methods of analysis, mass procedures, method of slices, method of slices for steady state seepage, slopes under rapid drawdown condition, fluctuation of factor of safety of slopes, end-of-construction and long-term stability, embankments and dams.

Theory of arching in soils and its applications; Sheet pile walls.

Text/Reference Book:

- Das, B. M. Fundamentals of Geotechnical Engineering, Chris Carson Publishers, Spain.
- Bowles, J. E. (1996). Foundation Analysis and Design, McGraw-Hill, Singapore.
- Budhu, M. (2000) Soil Mechanics and Foundations, John Wiley & Sons Inc., New York, N.Y.
- Coduto, D. P. (2001). Foundation Design Principles and Practices, Prentice Hall, Upper Saddle River, New Jersey.

- Das, B. M. (2011). Principles of Geotechnical Engineering, Cengage Learing, USA. ,
- T. W. Lambe and R. W. Whitman, Soil Mechanics, John Wiley & Sons, New York, 1969.
- Ranjan, G. and Rao, A. S. R. (2000). Basic and Applied Soil Mechanics, New Age International (P) Ltd., New Delhi.
- Terzaghi, K., Peck, R. B. and Mesri, G. (1996). Soil Mechanics in Engineering Practice, John Wiley and Sons, New York.

Subject Code: CE6L202	**Name: Computational Geomechanics**	**L-T-P: 3-1-0**	**Credits: 4**

Prerequisite: None

Numerical modelling, constitutive modelling of soils and rock, continuum and discrete element modelling; Concept of stress and strain, principal stresses and strains; Octahedral stresses and strains, finite element discretization of a continuum, geomechanics problems of plane strain and axisymmetric problem; Finite elements for non-linear material problems in soil mechanics computational procedures; Finite difference approach; application in soil-structure interaction, consolidation, bearing capacity and slope stability problems using numerical approaches.

Text/Reference Book:

- Chandrakant S. Desai and J.T. Christian Numerical Methods in Geotechnical Engineering, McGraw-Hill Publishers.
- Plasticity and Geomechanics by R. O. Davis, A. P. S. Selvadurai, Cambridge University Press.
- Finite Element Analysis in Geotechnical Engineering: Theory and Application Author: David M. Potts and Lidija Zdravkovic (January 1, 2001).
- John T. Christian, Numerical Methods in Geotechnical Engineering, McGraw-Hill Publishers.
- Computational Geomechanics with Special Reference to Earthquake Engineering by O. C. Zienkiewicz, A. H. C. Chan, M. Pastor, and B. A. Schrefler (Hardcover - May 11, 1999), Publisher: Wiley.
- Potts and Zdravkonics (1999) Finite element analysis in geotechnical engineering: Part-I Theory & part-II Applications, Thomas Telford Publishers.

Subject Code: CE6L203	**Name: Foundation Analysis and Design**	**L-T-P: 3-1-0**	**Credits: 4**

Prerequisite: None

Settlement and bearing capacity: shallow spread footings, mat or raft foundations, deep foundations; Analysis of Elastic settlement; Special cases of shallow foundation; Contact pressure distribution for footings, rafts; Retaining Structures: braced excavation, sheet pile wall; Drilled shafts; Pile Foundations; Laterally loaded piles; Well foundation/Ring Foundation

Text/Reference Book:

- Das, B. M. Principles of Foundation Engineering, Cengage Learning.
- Budhu, M., Soil mechanics and foundations, Wiley Publishers, New Delhi.
- Coduto, D.P., Foundation design: Principles and Practices, Prentice Hill Publishers.
- Holts R.D. and Kovacs, W.D. An introduction Geotechnical Engineering, Prentice Hall.
- Das, B.M. Shallow Foundations: Bearing Capacity and Settlement, CRC Press.
- Tomilson, M.J. Foundation Design and Construction, Pearson Publishers.
- Poulos, H.G. and Davis E.H. Pile Foundation Analysis and Design.
- Salgado, R. The engineering of foundations. Tata Mc.Graw Hill Edu. Pvt. Ltd. New Delhi. 2011

Subject Code: CE6L204	**Name: Soil Dynamics**	**L-T-P: 3-1-0**	**Credits: 4**

Prerequisite: None

Introduction (Dynamic properties of geomaterials, design criteria related to applied loads and material properties, vibration tolerances); Vibration of elementary systems; Transient vibrations; Analysis of earthquake and blast loadings; Liquefaction of soils; Laboratory and field evaluation of soil properties as per IS Codes; Analysis and design of foundations for hammers,

reciprocating engines and turbogenerators; Vibration isolation and damping; Propagation of elastic waves in soils; Waves in layered and saturated soils; Theories for vibration of foundations on elastic media; Design procedures for dynamically loaded foundations and constructional features; Interaction of soils and foundations under dynamic loadings.

Text/Reference Book:

- Braja Das, G.V. Ramana, Principles of Soil Dynamics, Cengage Learning, USA.
- Prasad Bharat Bhushan, Fundamentals of Soil Dynamics and Earthquake Engineering, PHI Publisher, New Delhi.
- Milutin Srbulov, Practical Soil Dynamics: Case Studies in Earthquake and Geotechnical Engineering, Springer link Publishers.

LABORATORY COURSES

Subject Code: CE4P001	**Name: CAD Laboratory**	**L-T-P: 0-0-3**	**Credits: 2**

Prerequisite: None

Exposure to commercial software tools for analysis, design and research in civil engineering.

Subject Code: CE6P201	**Name: Geotechnical Engineering Laboratory**	**L-T-P: 0-0-3**	**Credits: 2**

Prerequisite: None

Consolidation, Pocket penetrometer, Static and Cyclic triaxial testing, Model studies using centrifuge.

Rock testing: Compressive strength, Indirect tensile strength test by Brazilian testing, Point load strength index testing, Sonic velocity: P-and S-waves, Schmidt rebound hammer test, Slake durability index.

Subject Code: CE6P202	**Name: Geosynthetics and In-situ Testing Laboratory**	**L-T-P: 0-0-3**	**Credits: 2**

Prerequisite: CE6P201

GPR, Shear wave velocity of soils, Packer test for in-situ permeability, In-situ/field density test, Drilling techniques, In-situ testing (SPT, cone penetration test, pressure meter test), Resistivity testing.

Geosynthetics testing: Specific gravity, Mass per unit area, Thickness, Permeability: in-plane and cross plane, Cone drop test, Tensile strength, Impact tests, CBR Puncture tests, Friction behavior, Pullout tests.

Subject Code: CE6P203	**Name: Computational Geomechanics Laboratory**	**L-T-P: 0-0-3**	**Credits: 2**

Prerequisite: CE6L202

Static and dynamic analysis of foundations; Analysis of retaining walls and slopes; Finite element modelling of geotechnical structures; Seismic ground response analysis; Usage of software's for geotechnical structure analysis.

ELECTIVE SUBJECTS (PG level)

Subject Code: CE6L205	**Name: Theoretical Soil Mechanics**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Compressibility and rate of consolidation, one, two, and three dimensional consolidation theories; Mohr's circles; Critical state soil mechanics: Critical State Line, Hvorslev Surface, Yield Surfaces: Modified Cam-clay and Original Cam-clay; Elastic and plastic analysis of soil; Constitutive relationships of soil; failure theories; Limit analysis, limit equilibrium methods.

Text/Reference Book:

- Das, B M Advanced Soil Mechanics, Taylor and Francis
- Scott, R F Principles of Soil Mechanics, Addison & Wesley.
- Davis R.O. and Selvadurai, A.P.S., Elasticity and Geomechanics, Cambridge University Press, New York.
- Mitchell, James K, Fundamentals of Soil Behaviour, John Wiley and Sons.
- Wood, D.M. Soil Behaviour and Critical State Soil Mechanics, University of Glasgow.
- Schofield, A. N.; Wroth, C. P., Critical State Soil Mechanics, McGraw-HillPractice, John Wiley and Sons, New York.
- Wai-fai Chen, Limit Analysis and Soil plasticity, J Ross Publishing Classics.

Subject Code: CE6L206	**Name: Rock Mechanics**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Geological survey and rock exploration; Physical and Mechanical properties of Rocks; Rock Testing: Laboratory and Field tests; Discontinuities in Rock Masses; classification of intact rock and rock masses; Stereographic Projection; Analysis of Stresses and Strains; Stress-Strain Relationships; Rock Strength and Failure Criteria: Mohr-Coulomb, Griffith, Drucker-Prager, Hoek-Brown, Alternative Criteria and Other Empirical Failure Criteria; Rock slope stability; Rock foundations; Rock mass stabilization.

Text/Reference Book:

- Deb, D. and Verma, A.K., "Fundamentals and Applications of Rock Mechanics", PHI Learning Private Limited, 2016
- Verma, B. P., "Rock Mechanics for Engineers" Khanna Publishers.
- ·Singh, B. and Goel, R. K. "Rock Mass Classification Systems – A Practical Approach in Civil Engineering "Elsevier Publisher.
- Hoek, E. and Brown, E. T. "Underground Excavations ", Span Press.
- Hoek, E. and Bray, J D., "Rock Slope Engineering ", Span Press.
- Brown, E.T., "Rock Characterisation, Testing and Monitoring", Pergamon Press, London, U.K.
- Farmer, W. Engineering Behavior of Rocks, Chapman and Hall Ltd.
- Goodman, R. E. Introduction to Rock Mechanics.
- Sheorey, P.R. Empirical Rock Failure Criteria, Balkema, Rotterdam, 1997.

Subject Code: CE6L207	**Name: Transportation Geotechnics**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Subgrade Soil: Classification, desirable properties, determination of soil strength characteristics; Road aggregates: classification, properties of aggregates, design of aggregate gradation; Cyclic response of soils, resilient and plastic behaviour of soils and aggregates, Effects of traffic loads, natural forces, and material quality.

Current design practices; Principles and theoretical concepts of rigid and flexible pavements for highways and airfields; Pavement evaluation and performance; Utilization of recycled materials for

sustainable pavements; Life cycle cost analysis. Highway embankments; Design and construction of embankments; Stage construction; Introduction to reinforced earth design and construction.

Text/Reference Book:

- Papagiannakis A. T. and Masad, E. A. Pavement Design and Materials
- Shell Bitumen, The Shell Bitumen Handbook
- Asphalt Institute, MS-26 Asphalt Binder Handbook
- Rajib B. Mallick, Tahar El-Korchi, Pavement Engineering: Principles and Practice.
- Chakraborty P. and Das, A. Principles of Transportation Engg., PHI Publication, 1st Edition 2005.
- Rao, G.V. Principles of Transportation and Highway Engineering, Tata Mc. Graw Hill, 1st Ed. 1995

Subject Code: CE6L208	**Name: Soil Structure Interaction**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction to soil foundation interaction problems, soil behaviour, foundation behaviour, interface behaviour, concept of subgrade modulus, effects/parameters influencing subgrade modulus soil foundation interaction analysis, Winkler, elastic continuum, two parameter elastic model, Elastic Plastic behaviour, time dependent behaviour, elastic analysis of single pile, theoretical solutions for settlement and load distributions, analysis of pile group, interaction analysis, Load deflection prediction for laterally loaded piles, other applications.

Text/Reference Book:

- Selvadurai, A.P.S., Elastic analysis of soil foundation interaction. Elsevier Science Ltd.
- Plasticity and Geomechanics by R. O. Davis, A. P. S. Selvadurai, Cambridge University Press
- R.O. Davis and A.P.S. Selvadurai, Elasticity and Geomechanics, Cambridge University Press, New York.
- Poulos, H.G. and Davis E.H. Pile Foundation Analysis and Design.
- Soil structure interaction: numerical analysis and modelling / edited by John W. Bull. London, New York : E & FN Spon, 1994

Subject Code: CE6L209	**Name: Geotechnical Earthquake Engineering**	**L-T-P: 3-0-0**	**Credits: 0**

Prerequisite: None

Introduction, engineering seismology, plate tectonics, earthquake magnitude, ground motion characteristics, effect of local soil conditions on ground motion, dynamic behaviour of soils, analysis of seismic site response. Liquefaction analysis of soil, laboratory and in-situ testing for seismic loading, analysis and design of slopes, embankments, foundations and earth retaining structures for seismic loading, computer-aided analysis.

Text/Reference Book:

- Kramer, S.L., Geotechnical Earthquake Engineering, Pearson Education.
- Day, R.W., Geotechnical Earthquake Engineering Handbook, McGraw Hill.

Subject Code: CE6L210	**Name: Geotechnical Risk and Reliability**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction to probabilistic geotechnical engineering, variability measures, random variables, probability mass and density functions, moments of distribution, modelling of uncertainty, engineering judgment, spatial variability of soil, autocovariance functions, functions of random fields, levels of reliability, loads and resistances, reliability methods, first order second moment (FOSM) method, Hasofer-Lind approach, Response Surface Method, Monte Carlo simulations.

Text/Reference Book:

- Achintya Haldar and Sankaran Mahadevan, Probability, Reliability, and Statistical Methods in Engineering Design, John Wiley and Sons
- Gregory Baecher and John Christian, Reliability and Statistics in Geotechnical Engineering, John Wiely and Sons, Inc.

- Alfredo Hua-Sing Ang and Wilson H. Tang, Probability Concepts in Engineering Planning and Design: Basic Principles (Vol. I), John Wiely and Sons, Inc.
- Alfredo Hua-Sing Ang and Wilson H. Tang, Probability Concepts in Engineering Planning and Design: Decision, Risk, and Reliability (Vol. II), John Wiely and Sons, Inc.
- Alfredo Hua-sing Ang, Wilson H. Tang, Probability Concepts In Engineering: Emphasis On Applications In Civil & Environmental Engineering, Publisher: Wiley
- Robert E. Melchers, Structural Reliability Analysis and Prediction, John Wiley and Sons.
- Andrzej S Nowak and Kevin R. Collins, Reliability of Structures
- Erik Vanmarcke, Random Fields: Analysis and Synthesis, The MIT Press, Cambridge, Massachusetts.

Subject Code: CE6L212	**Name: Ground Improvement**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction, ground improvements schemes for cohesive soil sites (preloading, staged construction, accelerated consolidation with prefabricated drains, granular columns, lime columns, electro-osmosis, compaction piles, deep mixing, and vibro-replacement), ground improvement schemes for cohesionless soil sites (deep dynamic compaction, vibro-compaction, blast densification, grouting, and jet grouting), mechanically stabilized earthwork, soil nailing, ground anchors, light weight fill, and monitoring and quality control in ground improvement projects.

Text/Reference Book:

- P. Puroshothama Raju, Ground Improvement Techniques, Laxmi Publications, New Delhi.
- M.P. Moseley and K. Kirsch, Ground Improvement, Spon Press, Taylor and Francis Group.
- B. M. Das, Principles of Foundation Engineering, Cengage Learning.
- Buddhima Indraratna and Jian J Chu, Ground Improvement: Case Histories, Elsevier.
- Chris A. Raison, Ground and Soil Improvement, Thomas telford, UK.
- Robert M. Koerner., Designing with Geosynthetics, Pearson Prentice Hall.

Subject Code: CE6L213	**Name: Geosynthetic Engineering**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction to Geosynthetics; Basic description of geosynthetics; Types and functions of geosynthetics; Engineering properties of geosynthetics and their evaluation; Testing of geosynthetic materials; Design methodologies with geosynthetics; Geotechnical applications: bearing capacity, settlement, stability analysis, retaining walls, embankments; Geoenvironmental applications: covers and liners of landfills; Hydraulic applications: liners for ponds, canals, reservoirs; Transportation applications: separator, drainage and filtering in road pavement, strength improvement in base, sub-base and subgrade layers; Mining, agriculture and aquaculture applications: containment, filtration; Case studies.

Text/Reference Book:

- Sanjay Kumar Shukla and Jian-Hua Yin, Fundamentals of Geosynthetic Engineering, CRC Press.
- Moseley M.P. and Kirsch, K. Ground Improvement, Spon Press, Taylor and Francis Group.
- Robert M. Koerner., Designing with Geosynthetics, Pearson Prentice Hall.
- Rao G. V. and Rao, G. V. S. Text Book on Engineering with Geotextiles, Tata McGraw Hill.
- Jewell, R.A. (1996) Soil reinforcement with geotextiles, CIRIA & Thomas Telford, London, U.K.
- John, N.W.M. (1987) Geotextiles, Blackie & Son Ltd., London, UK.
- Jones, C.J.F.P. (2010) Earth Reinforcement and Soil Structures, Thomas Telford, London, U.K.
- Mandal, J.N and Divshikar, D.G. (2000) A guide to geotextile testing, New Age International Ltd., New Delhi.
- Saran, Swami (2006) Reinforced Soil and its Engineering Applications, I.K. International, New Delhi.
- Shukla, S.K. (2012) Handbook of Geosynthetic Engineering, 2nd Edition, ICE Publishing, London, U.K.
- Federal Highway Administration Guidelines for Mechanically Stabilised Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines, Report No. FHWA-NHI-00-0043, Washington, D.C. 2001

Subject Code: CE6L214	**Name: Dynamics of Soil and Foundations**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction, vibration theories, analysis of free and forced vibrations using spring dashpot model, single degree of freedom system, multi-degrees of freedom system, application of single and multi-degree of freedom systems, wave propagation in elastic media, laboratory and field evaluation of dynamic soil properties, seismic bearing capacity of shallow foundations, pile foundation under dynamic load, seismic earth pressures, seismic slope stability.

Text/Reference Book:

- Swami Saran, Soil Dynamics and Machine Foundations, Galgotia Publications.
- Braja M. Das and G. V. Ramana, Principles of Soil Dynamics, Publisher: CL-Engineering.
- Richart, F.E., Woods, R.D., and Hall, J.R., Vibrations of soils and foundations, Prentice Hall, 1970.
- Steven L. Kramer, Geotechnical Earthquake Engineering, 1996, Prentice Hall.

Subject Code: CE6L215	**Name: Foundations of Offshore Structures**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Basic Soil Mechanics: Basic soil properties, correlation between engineering parameters, geotechnical investigation, bore log.

Offshore site investigations, properties of marine soils; Soil behaviour under cyclic loading, design storm loading; Gravity structures; Dynamic response and cyclic displacements; Pile foundations for offshore structures, axial lateral and cyclic loads, types of foundation anchorage; Jack-up platforms; Rig foundations.

Pile foundation: Jacket main piles, skirt piles, driven piles, drilled and grouted piles, steel and concrete piles, axial capacity, point bearing and skin friction, factor of safety, lateral load on piles, p-y, t-z and q-z curves, pile group effect, scour around piles, seabed subsidence and design of piles against seabed movement, negative skin friction, cyclic degradation, main pile to jacket connections, skirt pile to jacket connections, API RP 2A provisions.

Pile Installation: Minimum pile wall thickness, pile handling stresses, static and dynamic stresses, pile stickup, stresses during stickup, wave and current loads, hammer selection, pile driving stresses, wave equation analysis, pile driving fatigue, API RP 2A guidelines.

Pile Testing: Working load test, ultimate load test, pile monitoring during driving, pile integrity testing, high strain dynamic testing, rebound method.

Text/Reference Book:

- S.K. Chakrabarti, Handbook of Offshore Engineering, Elsevier, 2005.
- Tomlinson, M. J. and Spon F.N. Pile Design and Construction, 1994.
- Bowles, J. E., Foundation analysis and design, McGraw-Hill, 1988
- Gerwick, B.C., Construction of Marine and Offshore Structures, CRC press
- Rowe R.K.," Geotechnical and Geoenvironmental Engineering Handbook" Kluwer Academic Publications, London, 2000.

Subject Code: CE6L216	**Name: Geotechnics of Polluted Sites**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Basic concepts related to soil pollution; Sources of pollution: industrial areas, agricultural, municipal, nuclear; types of contaminants; Role of physical and chemical properties of soil in

contamination; Factors effecting retention and transport of contaminants; Soil sampling collection and characterization: sampling of contaminated soil, site investigation and monitoring parameters, exploratory site investigation, methods of analysis/identification, sample handling, preservation, transportation and storage; Non-destructive techniques of site characterization: electrical and thermal properties, GPR; Soil and ground water remediation: conceptual approach to soil and ground water remediation, risk assessment, methodologies and selection of treatment models; Soil remediation: excavation, soil washing, stabilization/solidification; Soil vapor extraction, electrokinetic remediation, thermal desorption, vitrification; Bioremediation, phytoremediation, soil fracturing; Groundwater Remediation: selection of technique, pump and treat, in-situ flushing; Groundwater Remediation: permeable reactive barriers, in-situ air sparging, monitored natural attenuation, bioremediation; Green and sustainable remediation; Case studies on polluted sites and issues related to environment.

Text/Reference Book:

- Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004, 992p. (ISBN: 0-471-21599-6).
- Reddy, K.R., and Cameselle, C. Editors, Electrochemical Remediation Technologies for Polluted Soils, Sediments and Groundwater, John Wiley & Sons, Inc., Hoboken, New Jersey, 2009, 760p. (ISBN: 0-470-38343-7).
- Reddy, K.R., and Adams, J.A., Sustainable Remediation of Contaminated Sites, Momentum Press, New York, December 2014 (ISBN: 9781606505205).

Subject Code: CE6L217	**Name: Geotechnics of Waste and Waste Containment**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Sources and types of wastes; Environmental and engineering properties of wastes; New and developing government policies; Beneficial re-use of wastes; Fundamentals of waste-soil interaction; Containment systems and basic principles; Lining and capping systems; Leachate and gas collection systems; Compacted soil liners; Admixed soil liners; Geosynthetic clay liners; Geomembranes; Drainage layers; Geosynthetic composites; Seepage flow; Contaminant transport; Landfill settlement; Landfill slope stability; Conventional caps, ET caps; Ground water monitoring; Landfill gas; Post-closure monitoring; Bioreactor landfills; Landfill mining; End-use of closed landfills; Impoundments; Integrated waste management and alternative landfills.

Text/Reference Book:

- Sharma H.D. and Reddy K.R., Geo-environmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley, New Jersey, 2004.
- Yong, R.N. Geoenvironmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation, Thomson Telford, 2000.
- Reddy L.N. and Inyang, H.I. Geoenvironmental Engineering: Principles and Applications, Marcel Dek, 2000.
- Raju, V.S., Datta, M., Seshadri, V., and Agarwal, V.K. (1996) (Eds.), "Ash Ponds and Ash Disposal Systems", Narosa Publishers, Delhi, 424 pages.
- Datta, M. (1997) (Ed.), "Waste Disposal in Engineered Landfills", Narosa Publishers, Delhi, 231 pages.
- Datta, M., Parida, B.P., Guha, B.K. and Sreekrishnan, T., (1999) (Eds.), "Industrial Solid Waste Management and Landfilling Practice", Narosa Publishers, Delhi, 204 pages.
- David E. Daniel, Geotechnical Practice for Waste Disposal, Published by Chapman & Hall, London, 1993.
- Bagchi, A., "Design of landfills and integrated solid waste management" John Wiley & Sons, Inc., USA, 2004.
- Qian, X., R. M. Koerner, and D. H. Gray. Geotechnical Aspects of Landfill Design and Construction. New Jersey: Prentice Hall, Upper Saddle River, 2002.

Subject Code: CE6L218	**Name: Soil Exploration and In-situ Testing**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction: Planning of Geotechnical exploration, methods of boring, types of samples & sampling, field tests, Geophysical exploration; standard penetration test, plate load test, cyclic plate load test, static and dynamic cone penetration test, pressure meter tests, dilatometer tests, in-situ permeability tests; Pile load tests; Presentation and processing of soil exploration data and its interpretation.

Types of field measurements; Principles of instrumentation; Settlement gauges, Piezometers, earth pressure cells and inclinometers; Planning of instrumentation; Vibration measurements.

Shallow foundations: Bearing capacity and settlement calculations from in-situ tests, empirical correlations.

Deep foundations: estimation of point load and side friction for in-situ tests, empirical correlations for single pile and pile groups, settlement calculations from empirical correlations.

Advanced topics on in-situ soil testing: SSAW, MSAW, GPR

Text/Reference Book:

- Das, B. M. Principles of Foundation Engineering, Thomson Brooks/Cole
- Bowles, J. E. Foundation Analysis and Design, McGraw-Hill Book.
- Kurien, N.P. Design of Foundation Systems: Principles & Practices, Narosa, New Delhi 1992.
- Ranjan G. and Rao, A.S.R. Basic and Applied Soil Mechanics, New Age
- international Publishers.
- Winterkorn H. F. and Fang, H Y. Foundation Engineering Hand Book, Galgotia Book source.
- John Dunnicliff, Geotechnical Instrumentation for Monitoring Field Performance, Wiley-Interscience Publishers, 1993.
- Coduto and Donald (2011). Geotechnical Engineering Principles and Practices. New Jersey: Pearson Higher Education

Subject Code: CE6L219	**Name: Unsaturated Soil Mechanics**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Introduction to unsaturated soil problems; Phase properties and relations; Effective stress concepts for unsaturated soils; Measurement of unsaturated soil properties; Flow of water in unsaturated soils; Steady state and transient flows; Soil water characteristic curve; Hydraulic conductivity-suction relations; Infiltration; Evaporation and drainage and applications to soil covers and earth dams; Mechanical behaviour of unsaturated soils; Pore pressure parameters; Volume change constitutive relations under drained and undrained loading.

Text/Reference Book:

- Lu N. and Likos, W. J. Unsaturated Soil Mechanics, John Wiley & Sons, Inc., 2004
- Fredlund, D. G. Rahardjo, H. and Fredlund, M. D. Unsaturated Soil Mechanics in Engineering Practice.

Subject Code: CE6LXX	**Name: Fundamentals of Underground Infrastructure**	**L-T-P: 3-0-0**	**Credits: 3**

Prerequisite: None

Fundamentals of underground structures and rock mechanics - Overview of underground engineering and its significance, Applications in metro systems, pipelines, and energy projects, Field sensing technologies and safety measures, Introduction to rock mechanics and geological considerations, Rock properties, classifications, stress analysis and in-situ testing; Underground Excavation Techniques - Horizontal directional drilling, Auger boring, Pipe jacking, Microtunneling, Drill and blast, NATM, TBM; Tunneling Methods and Design - Overview of tunneling methods and techniques, Design principles for tunnels in different geologies, Case studies of metro tunnels and underground transportation systems; Caverns, silos, and shafts - Introduction to underground caverns, silos and shafts, Design considerations for storage and hydroelectric projects, Applications and case studies. Pipelines and CO_2 Sequestration - Design and installation of buried pipelines, Geotechnical challenges, Introduction to CO_2 sequestration and its underground applications, Sustainability and environmental impact; Geothermal energy systems - Introduction to geothermal energy and its potential, Integration with district heating and cooling systems, Energy tunnels, Environmental and societal benefits; Dynamic behaviour of underground structures - Response to blast-induced shock waves and seismic loading. Numerical Analysis of Underground Structures - Introduction and challenges in numerical modeling of underground structures.

Text/Reference Book:

- Underground Infrastructures: Planning, Design, and Construction by R. K. Goel, Bhawani Singh and Jian Zhao, Butterworth-Heinemann, 2012
- Guide to Cavern Engineering by Geotechnical Engineering Office, Civil Engineering and Development Department, the Government of the Hong Kong, Special Administrative Region, 2018
- CO2 Sequestration and Valorization by Claudia R. V. Morgado and Victor Esteves, IntechOpen, 2014
- Buried Pipe Design by A. P. Moser and Steven Folkman, Mc Graw Hill, 2008
- Engineering Rock Mass Classification, Tunneling, Foundations and Landslides by Bhawani Singh and R. K. Goel, Butterworth-Heinemann, Elsevier, 2011
- Geothermal Energy: Renewable Energy and the Environment by William E. Glassley, CRC press, Taylor & Francis group, 2014

Subject Code: CE6L222	**Subject Name: Environmental Geotechnology**	**L-T-P: 3-0-0**	**Credit: 3**

Scope of Environmental Geotechnology; Emergence of Environmental Geotechnology; Role of Geotechnical Engineers in Geoenvironmental Problems; Biogeochemistry; Subsurface Contamination and Contaminant Transport; Soil-Waste Interaction; Design Aspects of Landfills; Landfill Biocover; Geotechnical Re-use of Surplus Masses in the Circular Economy; Risk Assessment in Site Remediation Projects; Biogeotechnics; Soil Health Improvement; Sustainability in Geoenvironmental Engineering; Electrical, Thermal, and, Magnetic Properties of Soils

Sl. No.		**Year of Publication / Reprint**
Text Book		
1	Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004, 992p. (ISBN: 0-471-21599-6).	2004
Reference Books		
2	Tchobanoglous, G., Theisen, H. and Vigil, S.A., Integrated Solid Waste Management - Engineering Principles and Management Issues, McGraw Hill (1993).	1993
3	Gulhati, S.K. and Datta M., Geotechnical Engineering, Mcgraw Hill, 2005.	2005
4	Singh, D. N., Asadi, A., & Goli, V. S. N. S. (2022). Environmental geotechnology: Meeting challenges through needs-based instrumentation. World Scientific.	2022
5	Daniel, D. E. (Ed.). (2012). Geotechnical practice for waste disposal. Springer Science & Business Media.	2012
6	Qian, X., Koerner, R., and Gray, D.H., Geotechnical aspects of landfill design and construction, Prentice Hall, 2002.	2002