DEPARTMENT OF CIVIL ENGINEERING

Course Structure and Syllabi

for

2-Year M.Tech. Course on Geotechnical Engineering
(Effective from AY 2019-2020)

INDIAN INSTITUTE OF TECHNOLOGY (ISM), DHANBAD
Dhanbad-826004, Jharkhand
March 2019

Highlights of the Course

The programme began in Monsoon semester of the session 2018-19 with student strength of the 12. The programme provides a strong theoretical/practical background necessary in the analysis and design of geotechnical systems. The programme imparts basic and advanced knowledge of soil mechanics, foundation engineering, rock engineering, slopes and retaining structures with specialized courses like, geotechnical earthquake engineering, geoenvironmental engineering, ground improvement techniques, soil-structure interaction, railway geotechnics etc. in line with the vision of the department. The department is also equipped with equipments for laboratory and in-situ tests. On successful completion of the course, students are expected to gain knowledge and confidence to tackle challenging infrastructure problems and be motivated towards innovative research problems.

Importance of the Course

Geotechnical engineering is one of the very basic courses in the domain of Civil Engineering with its applications also in Mining Engineering. The programme is expected to serve the societal need of good geotechnical practitioner for various challenging problems of infrastructural projects and mining industries.

Placement Opportunity

The students are expected to get absorbed in various private/public sector units handling various infrastructure projects, mining industries, thermal power plants, nuclear power plants, hydro projects etc. There is also a great opportunity towards career in research.

Future/Recent Areas of Prominence

1. Geotechnics for sustainable mining
2. Waste containment system
3. Seismic microzonation
4. Energy geotechnics
5. Underground mining/tunnelling
6. Geotechnics for high speed corridors

Programme Objectives

- Imparting specialized knowledge on various areas of geotechnical engineering among the students.
- Training of the students on professional geotechnical engineering and preparing them for various challenges of the field.
- Enhancement of problem solving skills of students by covering basic concepts with advanced topics through theoretical/practical course works.
- Development and transfer of innovative technology based on dissertation works of the students for benefit of the society.

Strength of the Programme

- Faculty members having basic exposure to the emerging fields.

Weakness of the Programme

- Advanced geotechnical facilities for research is not fully developed.

COURSE STRUCTURE

Course No.	Course Name	L	T	P	C
Semester - 1					
DC XXX	***Core Course 1***: Advanced Soil Mechanics	3	0	0	9
DC XXX	***Core Course 2***: Advanced Foundation Engineering	3	0	0	9
DC XXX	***Core Course 3*: Numerical Methods** Numerical Methods in Civil Engineering	3	0	0	9
DC XXX	***Core Course 4***: Geoenvironmental Engineering	3	0	0	9
DC XXX	***Core Course 5***: Soil Dynamics and Machine Foundation	3	0	0	9
DC XXX	***Practical 1****:* Experimental Geotechnics I: Laboratory Testing	0	0	3	3
DC XXX	***Practical 2****:* Experimental Geotechnics II: In-situ Testing	0	0	2	2
	Total	**15**	**0**	**5**	**50**

Course No.	Course Name	L	T	P	C
Semester -2					
DE XXX	***Departmental Elective 1***	3	0	0	9
DE XXX	***Departmental Elective 2***	3	0	0	9
DE XXX	***Departmental Elective 3***	3	0	0	9
OE XXX	***Open Elective 1***	3	0	0	9
OE XXX	***Open Elective 2***	3	0	0	9
DC XXX	***Practical 3****:* Computer Modelling of Geotechnical Systems	0	0	3	3
DC XXX	***Practical 4****:* Term Project	0	0	2	2
	Total	**15**	**0**	**5**	**50**

Course No.	Course Name	L	T	P	C
Semester - 3					
DC XXX	Thesis Unit 1	0	0	0	9
DC XXX	Thesis Unit 2	0	0	0	9
DC XXX	Thesis Unit 3	0	0	0	9
DC XXX	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Course No.	Course Name	L	T	P	C
Semester - 4					
DC XXX	Thesis Unit 5	0	0	0	9
DC XXX	Thesis Unit 6	0	0	0	9
DE XXX/ OE XXX	***Departmental Elective 4/*** ***Open Elective 3***	3	0	0	9
DE XXX/ OE XXX	***Departmental Elective 5/*** ***Open Elective 4***	3	0	0	9
	Total	**0**	**0**	**0**	**36**

LIST OF DEPARTMENTAL CORE SUBJECTS FOR MONSOON SEMESTER

Course No.	Course Name	L	T	P	C
DC XXX	Advanced Soil Mechanics	3	0	0	9
DC XXX	Advanced Foundation Engineering	3	0	0	9
DC XXX	Numerical Methods in Civil Engineering	3	0	0	9
DC XXX	Geoenvironmental Engineering	3	0	0	9
DC XXX	Soil Dynamics and Machine Foundations	3	0	0	9

LIST OF DEPARTMENTAL PRACTICAL SUBJECTS FOR MONSOON SEMESTER

Course No.	Course Name	L	T	P	C
DC XXX	Experimental Geotechnics I: Laboratory Testing	0	0	3	3
DC XXX	Experimental Geotechnics II: In-situ Testing	0	0	2	2

LIST OF DEPARTMENTAL ELECTIVE SUBJECTS FOR WINTER SEMESTER

Course No.	Course Name	L	T	P	C
DE XXX	Rock Engineering	3	0	0	9
DE XXX	Continuum Geomechanics	3	0	0	9
DE XXX	Ground Improvement and Geosynthetics	3	0	0	9
DE XXX	Railway Geotechnics	3	0	0	9
DE XXX	Slope and Retaining Structures	3	0	0	9
DE XXX	Soil-Structure Interaction	3	0	0	9
DE XXX	Geotechnical Earthquake Engineering	3	0	0	9

LIST OF OPEN ELECTIVE SUBJECTS FOR WINTER SEMESTER

Course No.	Course Name	L	T	P	C
OE XXX	Reliability and Risk Assessment	3	0	0	9
OE XXX	Optimization Methods	3	0	0	9

LIST OF DEPARTMENTAL PRACTICAL SUBJECTS FOR WINTER SEMESTER

Course No.	Course Name	L	T	P	C
DC XXX	Computer Modelling of Geotechnical Systems	0	0	3	3
DC XXX	Term Project	0	0	2	2

SYLLABI OF DEPARTMENTAL CORE SUBJECTS OF

MONSOON SEMESTER

DC XXX	Advanced Soil Mechanics	3-0-0

Course Philosophy:

- To develop thorough understanding of basics and advanced topics of soil behaviour and the underlying mechanics involved

Learning Outcome:

- Students will be able to understand various parameters of soil and their applications
- The course will provide a solid background for analysis and design of geotechnical systems

Unit-I: Advanced Theories of Consolidation **[10L]**

One, two, three dimensional and radial consolidation, Determination of consolidation parameters, Numerical solution for consolidation theories, Preloading.

Unit-II: Shear Strength of Soils **[8L]**

Shear strength of cohesive and cohesionless soils, Drained and undrained shear strength of soils, Significance of pore pressure parameters; Determination of shear strength, Stress path, Stress path for different field problems.

Unit-III: Critical State Soil Mechanics **[10L]**

Introduction to critical state soil mechanics, Critical state parameters, Critical state for normally consolidated and over consolidated soil, Roscoe and Hvorslev state boundary surface, Cam clay soil model, Stress path for Cam clay soil model.

Unit-IV: Flow through Porous Media **[8L]**

Equation of continuity, Numerical solution of seepage problems, Effective stress for steady state and transient flow.

Unit-V: Case Studies **[3L]**

Seepage analysis of earthen/tailing dams and retaining structures, Ground water analysis in deep excavation.

Recommended Text Books:

1. Das, B.M. (2013). Advanced Soil Mechanics, 4th Edition, CRC Press.
2. Budhu, M. (2010). Soil Mechanics and Foundations, 3rd Edition, Wiley.

Recommended References:

1. Wood, D.M. (1990). Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, USA.
2. Craig, R.F. (1983). Soil Mechanics, 3rd Edition, ELBS.
3. Lambe, T.W. and Whitman, R.V. (2008). Soil Mechanics, SI version, Wiley India.

DC XXX	Advanced Foundation Engineering	3-0-0

Course Philosophy:

- To develop deeper understanding of foundation analyses, choice of design parameters, advanced topics of foundation design and analyses.

Learning Outcome:

- The students will be able to identify a suitable foundation system for various structures and will be capable of analysing and designing of the same.

UNIT-I: Subsurface Exploration **[4L]**

Boring, Sampling, SPT, CPT, Geophysical methods, Bore log and soil report.

UNIT -II: Shallow Foundations **[15L]**

Bearing capacity, Terzaghi and Meyerhoff theories, based on SPT, layered soils, eccentric and inclined loads. Bearing capacity of foundation on slopes, Foundation settlements Design of combined footings and rafts by Conventional and elastic line methods.

UNIT-III: Deep Foundations **[14L]**

Pile foundations, construction methods, Load transfer mechanism, Pile capacity in various soil types, negative skin friction, group action, settlements, laterally loaded vertical piles, load test on piles, codal provisions. Micro-pile, Anchor pile. Well foundations, Bearing capacity of well foundations

UNIT-IV: Advanced Foundation Systems and Case Studies **[6L]**

Combined piled raft foundation: Bearing capacity and deformation behavior, Analysis methods and design guidelines. Case studies

Recommended Text Books:

1. Murthy, V.N.S. (2010). Advanced Foundation Engineering, CBS Publisher.
2. Das, B.M. (2011). Principle of Foundation Engineering, 7th Edition, Cengage Learning, USA.

Recommended References:

1. Bowles, J.E. (1996). Foundation Analysis and Design, McGraw Hill Education, New Delhi, India.
2. Katzenbach, R., Leppla, S. and Choudhury, D. (2017). Foundation Systems for High-Rise Structures, CRC Press, New York.

DC XXX	Numerical Methods in Civil Engineering	3-0-0

Course Philosophy:

- This course deals with the solution procedures to linear and nonlinear systems, partial differential equations and integral equations.

Learning Outcome:

- Comprehend the fundamental principles of estimating errors and solving linear and nonlinear systems, partial differential equations and integral equations.
- Learn the computer-based techniques to utilize numerical methods in civil engineering applications.

UNIT-I: [**5L**]

Sources of Errors, Truncation Error, Round-off Error, Order of Accuracy, Taylor series expansion.

UNIT-II: [**10L**]

Gauss Elimination, Gauss Jordan Elimination, Pivoting, Factorization, Cholesky Decomposition, Jacobi Iteration, Gauss Seidel Iteration, Newton Raphson Iterations, Newton Iterations, Quasi Newton Iterations, Convergence Criteria.

UNIT-III: [**10L**]

First and Second Order Equations, Examples, Strong and Weak form of differential equations, Galerkin method, Interpolation Functions, Lagrange Polynomials, Numerical Quadrature, Numerical Stability.

UNIT-IV: [**8L**]

Difference Operators, Stability and Accuracy of Solutions, Finite Difference Operators to solve Initial and Boundary Value Problems, Fredholm Integral Equations, Fredholm's Alternative theorem, Newmark's Method, Wilson-theta.

UNIT-V: [**6L**]

Programming-based Application of Numerical Methods in Civil Engineering Case Studies.

Recommended Text Books:

1. G. Dahlquist and A. Bork, Numerical Methods, Prentice-Hall, Englewood Cliffs.

Recommended References:

1. S.C. Chhapra, Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw Hill Education.
2. J.H. Mathews and K.D. Fink, Numerical Methods using MATLAB, Pearson Publishing.

DC XXX	Geoenvironmental Engineering	3-0-0

Course Philosophy:

- To develop capability of identifying, preventing and solving geoenvironmental problems for sustainable mining and industries.

Learning Outcome:

- Students will be able to understand geo-environmental challenges and corresponding design such as landfill designs, contaminant transport, barrier design etc.

Unit-I: Scope **[6L]**

Scope of geoenvironmental engineering. Importance of soil physics, soil chemistry, hydrogeology and biological process. Role of thermal, electrical and hydraulic conductivity of soil.

Unit-II: Sustainable Geomaterial **[6L]**

Characterization of industrial and mine waste: Fly ash, red mud, GGBS and mine tailings.

Unit-III: Soil Contamination **[7L]**

Sources and type of ground contamination, ground water flow and contaminant transport, contaminated site characterization, impact of ground contamination on geoenvironment.

Unit-IV: Waste Containment System **[10L]**

Design of various land fill components such as liners, covers, leachate collection and removal. Slurry walls and barrier systems, design and construction. Geoenvironmental issues related to mine tailings and industrial wastes.

Unit-V: Stability of Tailing Dam and Dump Slopes **[6L]**

Stability analysis of ash dykes, tailing dams and dump slope. Rehabilitation of mines and industrial waste dump sites.

Unit-VI: Case Studies **[4L]**

Design of ash dyke, mine tailing dam, waste containment system.

Recommended Text Books:

1. Sharma, H.D. and Reddy, K. (2004). Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, Wiley.
2. Reddi, L.N. and Inyang, H.I. (2000). Geoenvironmental Engineering: Principles and Applications, CRC Press.

Recommended References:

1. Fang, H.Y. and Chaney, R.C. (2016). Introduction to Environmental Geotechnology, 2nd Edition, CRC Press.
2. Singh, D.N. and Asadi, A. (2018). Environmental Geotechnology: Meeting Challenges Through Need-based Instrumentation, World Scientific Publishing Company.
3. Yong, R.N., Mulligan, C.N. and Fukue, M. (2017). Sustainable Practices in Geoenvironmental Engineering, 2nd Edition, CRC Press.

DC XXX	Soil Dynamics and Machine Foundation	3-0-0

Course Philosophy:

- Basics and evaluation methodology of dynamic parameters of soil.
- Design and analysis of machine foundation.

Learning Outcome:

- Thorough understanding of dynamic parameters to be adopted for design of suitable foundation systems under dynamic loading
- Knowhow of use of dynamic parameters in analyses.

Unit-I: Introduction to Dynamics **[5L]**

Introduction to dynamics of SDOF and MDOF system.

Unit-II: Seismic Waves **[7L]**

Waves in Semi-Infinite Media: One, two and three dimensional wave propagation; Attenuation of stress waves, Dispersion, Waves in layered medium.

Unit-III: Stress-Strain Behaviour of Cyclically Loaded Soils **[8L]**

Equivalent linear model, Cyclic nonlinear model, Hyperbolic and Ramberg-Osgood stress-strain models, Evaluation of damping and elastic coefficients.

Unit-IV: Evaluation of Dynamic Properties of Soil **[7L]**

Field tests: Reflection test, Refraction test, SASW test, Cross-hole test; Laboratory test: Resonant column test, Bender element test, Cyclic shear and triaxial test; Dilatancy of sand subjected to cyclic drained shear; Dilatancy under cyclic loading.

Unit-V: Machine Foundation **[8L]**

Free and forced vibration with and without damping, Elastic half space for rigid footings. Vibration analysis of foundations subjected to vertical, sliding and rocking modes, Foundations under reciprocating machine, Design criteria for machine foundations.

Unit-VI: Case Study **[3L]**

Behaviour of mine tailing materials under dynamic loading, Modeling of soil considering dynamic properties by using software.

Recommended Text Books:

1. Das, B.M. and Ramana, G.V. (2014). Principles of Soil Dynamics, Cengage Learning, USA.
2. Srbulov, M. (2011). Practical Soil Dynamics, Springer, Dordrecht Heidelberg London New York.

Recommended References:

1. Ishihara, K. (1996). Soil Behaviour in Earthquake Geotechnics, Oxford University Press.
2. Barkan, D.D. (1952). Dynamics of Bases and Foundations, McGraw-Hill, New York.
3. Kramer, S.L. (1996).Geotechnical Earthquake Engineering,1st Edition, Pearson India Education Services Pvt. Ltd., Noida, India.

SYLLABI OF DEPARTMENTAL PRACTICAL SUBJECTS OF MONSOON SEMESTER

DC XXX	Experimental Geotechnics-I (Laboratory Testing)	0-0-3

Course Philosophy:

- To evaluate the engineering characteristics of soil, rock and waste materials by laboratory procedures.

Learning Outcome:

- Students will be able to conduct the tests in laboratory and get exposure to advanced apparatus in the field of geotechnical engineering.

EXPERIMENT-1 **[1P]**
Introduction to soil testing equipments, Preparation of samples: sand, clay and rock

EXPERIMENT-2 **[1P]**
Consolidation/Oedometer test

EXPERIMENT-3 **[1P]**
Direct shear test

EXPERIMENT-4 **[1P]**
Interface Tests (Large direst shear test)

EXPERIMENT-5 **[1P]**
Unconsolidated undrained triaxial test

EXPERIMENT-6 **[1P]**
Consolidated undrained triaxial test

EXPERIMENT-7 **[1P]**
Consolidated drained triaxial test

EXPERIMENT-8 **[1P]**
Cyclic triaxial shear test

EXPERIMENT-9 **[1P]**
Bender element/ Resonant column test

EXPERIMENT-10 **[1P]**
Uniaxial compression test of rock samples

EXPERIMENT-11 **[1P]**
Split tensile and Point load test of rock samples

Revision and Evaluation **[2P]**

Recommended References:

1. Respective Bureau of Indian Standard/ International Standard Codes of Practices.
2. Bowles, J.E. (2012). Engineering Properties of Soil and their Measurement, 4th Edition, McGraw Hill (India) Publishers.
3. Mandal, J.N. and Divshikar, D.G. (1994). Soil Testing in Civil Engineering, Oxford & IBH Publishing Company Pvt. Ltd., New Delhi, India.
4. Sivakugan, N., Arulrajah, A. and Bo, M.W. (2011). Laboratory Testing of Soils, Rocks and Aggregates, J.Ross Publishing.

DC XXX	Experimental Geotechnics-II (In-Situ Testing)	0-0-2

Course Philosophy:

- To demonstrate the engineering behaviour of Soil in the field and to teach various properties of Geosynthetic materials by experimentally.

Learning Outcome:

- Students will be able to conduct the tests in field and predict the geotechnical engineering properties of soil and also get exposure to different geosynthetic materials and its properties.

EXPERIMENT-1 **[1P]**
Standard penetration test
EXPERIMENT-2 **[1P]**
Static cone penetration test
EXPERIMENT-3 **[1P]**
Dynamic cone penetration test
EXPERIMENT-4 **[1P]**
Plate load test
EXPERIMENT-5 **[1P]**
Pressuremeter Test
EXPERIMENT-6 **[1P]**
Field permeability test
EXPERIMENT-7 **[1P]**
Multichannel analysis of surface waves
EXPERIMENT-8 **[1P]**
Block vibration test
EXPERIMENT-9 **[1P]**
Physical (e.g. Thickness, AOS, Stiffness, Specific gravity etc) properties testing of geosynthetics
EXPERIMENT-10 **[1P]**
Hydraulic (e.g. permittivity) properties testing of geosynthetics
EXPERIMENT-11 **[1P]**
Mechanical (e.g. Wide width tensile strength) properties testing of Geosynthetics
Revision and Evaluation **[2P]**

Recommended References:

1. Respective Bureau of Indian Standard/ International Standard Codes of Practices.
2. Bowles, J.E. (2012). Engineering Properties of Soil and their Measurement, 4th Edition, McGraw Hill (India) Publishers.
3. Mandal, J.N. and Divshikar, D.G. (1994). Soil Testing in Civil Engineering, Oxford & IBH Publishing Company Pvt. Ltd., New Delhi, India.
4. Sivakugan, N., Arulrajah, A. and Bo, M.W. (2011). Laboratory Testing of Soils, Rocks and Aggregates, J.Ross Publishing.

SYLLABI OF DEPARTMENTAL ELECTIVE SUBJECTS OF

WINTER SEMESTER

DE XXX	Rock Engineering	3-0-0

Course Philosophy:

- To provide comprehensive knowledge to the rock engineering subject and understand the principles and applications for design aspects of various structures in/on rock like tunnels, rock slopes, foundation on rocks, etc

Learning Outcome:

- Students will have exposure to in-depth analysis of rock properties, rock masses, strength and deformability of rock joints. Also learn advance topics like rock yielding criteria, analysis of rock slope stability, foundation on rocks and rock tunneling and bolting.

Unit-I: Introduction and Physico-Mechanical Properties [5L]

Introduction to rock engineering, its development, Problems and application areas, Rock coring and logging, Physical and mechanical properties, Various laboratory tests, In-situ tests in rock mass, Geophysical investigations.

Unit-II: Planes of Weakness in Rocks [4L]

Rock discontinuities, Geometrical characteristics of rock joints: joint sets, persistence, orientation, spacing, frequency, block size, wall strength, surface roughness, matching, aperture, filling.

Unit-III: Rock Mass Classification [6L]

Rock mass classification methods

Unit-IV: Stresses in Rocks [4L]

In-situ stress, Measurement of in-situ stresses and deformation, Hydrofracturing technique, Flat jack technique. Stresses in rock near underground openings: Elastic and elasto-plastic approach.

Unit-V: Strength and Failure Criteria of Rock Material [8L]

Rock strength behaviour in uniaxial compression, tension and triaxial state. Fracture strength of jointed rock mass, Shear strength of rock joints, Deformability of rock joints, Concept of joint compliance. Failure criteria for rock and rock masses.

Unit-VI: Rock Slope Stability [4L]

Stability of rock slopes, Modes of failure, Analysis of Plane failure, Wedge failure, Circular failure, Toppling failure.

Unit-VII: Foundations on Rocks [4L]

Foundation types, Bearing capacity estimation, Stress distribution in rocks, Settlement and Design requirements.

Unit-VIII: Tunneling and Bolting in Rocks [4L]

Introduction to tunneling in rocks, Rock improvement by bolting

Recommended Text Books:

1. Goodman, R.E. (1989). Introduction to Rock Mechanics, 2nd Edition, Wiley, Canada.
2. Deb, D., and Verma, A. K. (2016). Fundamentals and Applications of Rock Mechanics, 1st Edition, PHI Learning Pvt. Ltd., India.
3. Ramamurthy, T. (2014). Engineering in Rocks for Slopes, Foundation and Tunnels, 1st Edition, PHI Learning Pvt. Ltd., India.

Recommended References:

1. Goel, R.K. and Singh, B. (2011). Engineering Rock Mass Classifications: Tunnelling, Foundations and Landslides, Elsevier, USA.
2. Jaegar, J.C., Cook, N.G.W. and Zimmerman, R.W. (2012). Fundamentals of Rock Mechanics, 4th Edition, Wiley India Pvt. Ltd., India.
3. Hoek, E. and Bray, J. (1999). Rock Slope Engineering. Taylor and Francis.
4. Sivakugan, N., Das, B.M. and Shukla, S.K. (2013). Rock Mechanics: An Introduction. CRC Press.

DE XXX	Continuum Geomechanics	3-0-0

Course Philosophy:

- The course broadly encompasses various constitutive relationships of geomaterials covering elastic to plastic range and discusses in detail various analytical and numerical methods. The course provides a comprehensive approach towards modelling of cohesive/granular material.

Learning Outcome:

- The student will acquire information and knowledge on elastic and plastic equilibrium in soils through constitutive relations, analytical and numerical techniques thereby enabling them to gain confidence on analysis and modeling the behavior of soils.

Unit-I: Introduction and basic review [3L]

Review of basic concepts of continuum mechanics: Constitutive relations, Stress functions, Stress and displacement formulations.

Unit-II: Theory of plasticity [9L]

Theory of plasticity: Yield criterion, Plastic potential and plastic flow rule, Principle of maximum plastic work, Strain hardening and Perfect plasticity, Isotropic and Kinematic hardening, General stress strain relations; Perfect plasticity constitutive relations: elastic models, plasticity models for cohesive and frictional soils.

Unit-III: Method of stress characteristics [8L]

Method of stress characteristics or slip line method: Theorem, Formulation for stress characteristics, Application to different geotechnical structures such as foundation problem, retaining wall problem, slope stability, etc.

Unit-IV: Lower and Upper Bound Methods [9L]

Limit analysis: Lower and upper bound theorem of plastic collapse, Lower and upper bound limit analysis, Lower and upper bound analysis using linear programming, Application to different geotechnical structures such as foundation problem, retaining wall problem, slope stability etc.

Unit-V: Finite Difference and Finite Element Method [8L]

Introduction to finite difference and finite element methods, Application to different geotechnical structures such as foundation problem, retaining wall problem, slope stability etc.

Recommended Text Books:

1. Chen, W.F. and Baladi, G.Y. (1985). Soil Plasticity, 1st Edition, Elsevier.
2. Srinath, L.S. (2010). Advanced Mechanics of Solids, 3rd Edition, McGraw Hill publications.

Recommended References:

1. Chen, W.F. (1975). Limit Analysis and Soil Plasticity, 1st Edition, Elsevier.
2. Wood, D.M. (1990). Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, USA.
3. Desai, C.S. and Abel. J.F. (2005). Introduction to the Finite Element Method: A Numerical Method for Engineering Analysis, 1st Edition, CBS Publisher.
4. Bowles, J.E. (1996). Foundation Analysis and Design, 5th Edition, McGraw Hill Publications.

DE XXX	Ground Improvement and Geosynthetics	3-0-0

Course Philosophy:

- To understand various ground improvement techniques along with principles, design and construction procedures for the construction sites which are not suitable for supporting any physical infrastructure.

Learning Outcome:

- Student will learn about various ground improvement techniques, their design and field implementation along with various case studies where ground failures were resolved using ground improvement techniques and the application of geosynthetics for ground improvement and containment purpose.

UNIT-I: Introduction [**2L]**

Need for ground improvement, Different types of problematic soils, Classification of ground improvement techniques, Emerging trends in ground improvement.

UNIT-II: Mechanical Stabilization [**5L]**

Shallow and Deep Compaction: Conventional and Intelligent compaction, Deep dynamic and Rapid impact compaction, Vibro compaction, Blasting densification. Deep Replacement: Stone Columns, Vibro concrete columns. Design and Construction Methods

UNIT-III: Hydraulic Modification [**5L]**

Drainage and Dewatering System: Dewatering methods, Design of dewatering systems, Prefabricated vertical drains, Vacuum consolidation, Electro-kinetic dewatering, Design and construction methods.

UNIT- IV: Chemical and Thermal Modification [**5L]**

Modification by Admixtures: Lime and Cement columns, Admixtures in Pavement design, Stabilization of Industrial Waste. Modification by Grouting: Different Types of grouting, Grouting techniques and control. Thermal Modification: Heat Treatment of Soils, Ground Freezing, Design and construction methods

UNIT-V: Modification by Inclusions and Confinement [**6L]**

Soil nailing: Stabilization using soil nailing, Types, design and construction methods. Anchors: Design and construction methods, Soil Confinement by form work.

UNIT-VI: Geosynthetics [**14L]**

Overview of geosynthetics: Major application areas, Manufacturing and testing, Properties: Physical, Mechanical, Endurance and Degradation properties. Geosynthetics Types: Geotextile, Geogrid, Geonet, Geomembranes, Geocell and GCL etc. Designing for Functions: Reinforcement, Separation, Filtration and Drainage etc. Designing of Geosynthetics in Transportation Infrastructure and Reinforced Soil Structures: Overburden Mine Slopes reinforced with Geosynthetics, Pavements, Embankments etc. Geosynthetics Reinforcement in waste containment Applications: Liquid contaminant Liners (Design with Geomembranes), Solid Containment (Landfill Covers and Liner system), Design with Geocomposites.

UNIT-VII: Emerging and Innovative Topics [**2L]**

Microbial and Nano-Technology in site remediation, Energy Geotechnology, Recent developments and Case studies of ground improvement projects.

Recommended Text Books:

1. Hausmann, M.R. (1990). Engineering principles of ground modification, McGraw Hill.
2. Koerner, R.M. (2012). Designing with geosynthetics: Vol. 1 & 2, 6thEdition, Xlibris.
3. Babu, G.L.S. (2005). An introduction to soil reinforcement and geosynthetics, 1st Edition, Universities Press, India.

Recommended References:

1. Han, J. (2015). Principles and practice of ground improvement, 1stEdition, Wiley.
2. Van Impe W.F., Soil improvement techniques and their evolution, Balkema, 1989.
3. Moseley, M.P. and Kirsch K. (1993). Ground improvement, Taylor and Francis.
4. Shukla, S.K. and Yin, J.H. (2006). Fundamentals of geosynthetic engineering, Taylor and Francis, UK.

DE XXX	Railway Geotechnics	3-0-0

Course Philosophy:

- To learn the geotechnical aspects of railway engineering for the design, construction and management of multi-layered railway track substructure.

Learning Outcome:

- Students will be able to learn and demonstrate about the load environment, mechanics, design, construction, measurements and cost-effective management of a multi-layered railway track substructure. From the case studies, students shall also able to learn about the engineering behavior of track substructure, causes of track substructure instability and the cost-benefit trade- offs of potential remedial options.

UNIT-I: Track Structure and Loading [**2L]**

Introduction to the railroad industry, Types of track structure, Component descriptions and functions, Track forces and Load transfer mechanism.

UNIT-II: Ballast and Sub-ballast [**6L]**

Factors governing ballast behaviour: Particle and aggregate characteristics, Effect of particle characteristics on behavior, Ballast degradation and particle breakage. Sub-ballast requirements: Stress reduction, Subgrade attrition prevention, Drainage and filtration, Recycle and reuse of solid waste materials (eg. mine overburden waste) as sub-ballast layer.

UNIT-III: Subgrade [**6L]**

Subgrade behavior: Subsurface investigation, Resilient modulus, Subgrade failure
Track bearing capacity: Meyerhof and Hanna Method, Slope stability method.

UNIT-IV: Mechanics and Design [**7L]**

Required ballast/Sub-ballast Depth: North America, British Railways, European Multi-layer Elastic methods etc. Design of Tracks: Threshold stress concept, Displacement based design, ORE method etc.

UNIT-V: Track Modelling [**6L]**

Constitutive model for ballast: Plastic deformation models, Modelling of particle breakage. Computer models: ILLITRACK, GEOTRACK, KENTRACK, FEM and DEM modeling of track components, Modelling seepage from subgrade

UNIT-VI: Retrofitting in Tracks [**6L]**

Subgrade improvement alternatives: Altering properties in Place, Reconstruction and replacement, Asphalt concrete application etc. Heavy axle and high-speed trains: Retrofitting techniques for improving the existing tracks, Railway bridges and tunnels. Geosynthetic application in tracks: Geotextiles/geogrid in the role of sub-ballast, Bituminous spray alternatives.

UNIT-VII: Track Construction, Rehabilitation and Maintenance [**3L]**

Track drainage: Importance and drainage methods, Sub-ballast design and permeability. Track maintenance: Ballast fouling, Track settlement, Track geometry, Mechanics base maintenance model, Cost analysis.

UNIT-VIII: Case Studies [**3L]**

Recent developments and case studies in the field of track geotechnology.

Recommended Text Books:

1. Selig, E.T. and Waters, J.M. (1994). Track Geotechnology and Substructure Management,1 Edition, ICE Publishing, UK.

Recommended References:

1. Indraratna, B., Salim,W. and Rujikiatkamjorn, C. (2018). Advanced Rail Geotechnology Ballasted Track, 1st Edition, CRC Press.
2. Li, D, Hyslip, J and Sussmann, T. (2015). Railway Geotechnics, CRC Press

DE XXX	Slope and Retaining Structures	3-0-0

Course Philosophy:

- To provide knowledge of slope stability analyses and earth pressure problems in retaining structures.

Learning Outcome:

- Students will be able to evaluate earth pressures on retaining structures, stability of slopes and earthen dams for earthquake forces, and design of braced excavation for deep cuts and excavation in ground.

UNIT-I: Slope Stability **[12L]**

Infinite and Finite slopes analysis, Conditions of analysis: steady state, End of construction and sudden draw down, Reinforcement on slope stability.

UNIT-II: Earth Pressure **[14L]**

Rankine's theory and Coulomb's theory, Linear and composite failure surfaces, Effects due to wall friction and wall inclination, Graphical methods. Earth pressure determination under seismic condition. Rigid retaining structures: Types, Stability analysis

UNIT-III: Flexible Retaining Structures **[10L]**

Types, Cantilever sheet piles, Anchored bulkheads- free earth method, Fixed earth method, Moment reduction factors, Anchorage.

UNIT-IV: Braced Excavation **[3L]**

Construction methods; Pressure distribution in sands and clays; Stability-bottom heave, Seepage, Ground deformation.

Recommended Text Books:

1. Das, B.M. (2011). Principle of Foundation Engineering, 7th Edition, Cengage Learning, USA.

Recommended References:

1. Cheng, Y.M. and Lau, C.K. (2017).Slope Stability Analysis and Stabilization: New Methods an Insight, 2nd Edition, CRC Press.
2. Clayton, C.R.I., Woods, R.I., Bond, A.J. and Milititsky, J. (2014). Earth Pressure and Earth Retaining Structures, 3rd Edition, CRC Press.

DE XXX	Soil-Structure Interaction	3-0-0

Course Philosophy:

- To provide basic concepts of soil-structure interaction and develop understanding of effectively simulating the soil-structure interaction problems.

Learning Outcome:

- Understanding of coupled behaviour of soil and structure systems under static and dynamic loading.
- Capability of analyses of SSI problems for practical cases such as building, bridges, nuclear reactor structures etc.

Unit-I: Introduction **[3L]**

Objectives, Practical significance, Structures on soft ground, Consideration of unbounded media

Unit-II: Static SSI **[14L]**

Discrete model: Winkler, Pasternak, Filoneko-Borodich, Hetenyi, Kerr, Rhines; Continuum model: Vlazov, Reissner, Biots, Gorbunov and Posadov, Modeling of boundaries. Beams and plates resting on elastic foundation and subjected to various loading conditions.

Unit-III: Dynamic SSI **[12L]**

Rational methods of analysis of substructure, Equation of motion for flexible and rigid base, Kinematic interaction, Inertial interaction and Modeling of unbounded domain, Effect of embedment, Dynamic stiffness of Surface foundation, Embedded foundation, Shallow (strip) foundation and Deep foundations.

Unit-IV: Nonlinear SSI Problems **[6L]**

Material nonlinearity of soil, Geometrical nonlinearity, Nonlinear soil-pile structure interaction problems, Liquefaction in soil structure interaction problems.

Unit-V: Application of SSI **[4L]**

Engineering applications of dynamic soil-structure interaction: Shallow footing, Concrete gravity dam, Soil-pile-structure interaction problem.

Recommended Text Books:

1. Hetenyi, M. (1979). Beams on Elastic Foundation: Theory with Applications in the Fields of Civil and Mechanical Engineering, The University of Michigan Press.
2. Wolf, J.P. (1985).Dynamic Soil-Structure Interaction,1st Edition, Prentice Hall, USA.

Recommended References:

1. Chowdhury, I. and Dasgupta, S.P. (2008). Dynamics of Structure and Foundation: A Unified Approach, Vol. 1 and 2, CRC Press.
2. Selvadurai, A.P.S. (1979). Elastic Analysis of Soil-Foundation Interaction, Elsevier Science.

DE XXX	Geotechnical Earthquake Engineering	3-0-0

Course Philosophy:

- Imparting knowledge of fundamentals for evaluation of seismic hazard, liquefaction, dynamic analyses of slopes and retaining walls

Learning Outcome:

- Assessment of seismic hazard for a given site for important projects like bridges, nuclear power plants etc
- Evaluation of liquefaction potential for any project sites
- Assessment of slope stability under dynamic loading and seismic design of retaining wall

Unit-I: Seismic Hazard Analysis **[12L]**

Basic seismology, Strong motion measurement, Ground motion parameters, Deterministic and probabilistic seismic hazard analyses, Ground response analyses

Unit-II: Liquefaction **[10L]**

Flow liquefaction and cyclic mobility, Liquefaction susceptibility; CVR line, Evaluation of liquefaction potential: Characterization of earthquake loading and liquefaction resistance, Cyclic stress ratio, Seed and Idriss method.

Unit-III: Seismic Analysis of Footing **[5L]**

Seismic analysis of footings, Force based pseudo-static pseudo-dynamic analysis.

Unit-IV: Dynamic Slope Stability **[7L]**

Earthquake induced landslides, Evaluation of slope stability, Seismic slope stability analysis, Behaviour of reinforced slope; Dump slope stability of mine overburden considering earthquake and blast forces.

Unit-V: Practical Design Application **[5L]**

Seismic hazard analysis for a particular site, Soil improvement for remediation of seismic hazards, Recommendations of seismic design codes related to geotechnical earthquake engineering.

Recommended Text Books:

1. Kramer, S.L. (1996).Geotechnical Earthquake Engineering,1st Edition, Pearson India Education Services Pvt. Ltd., Noida, India.
2. Prakash, S. (1981). Soil Dynamics, McGraw Hill Higher Education, India.

Recommended References:

1. Ishihara, K. (1996). Soil Behaviour in Earthquake Geotechnics, Oxford University Press.
2. Towhata, I. (2008). Geotechnical Earthquake Engineering, 1st Edition, Springer-Verlag Berlin Heidelberg.

SYLLABI OF OPEN ELECTIVE SUBJECTS OF

WINTER SEMESTER

OE XXX	Reliability and Risk Assessment	3-0-0

Course Philosophy:

- To provide the students a thorough understanding of the key concepts behind reliability and risk analyses of engineering structures.

Learning Outcome:

- Knowledge of risk assessment methods for decision making under uncertain conditions.

UNIT-I: **[4L]**

Sources of uncertainty in Geotechnical design parameters, In-situ soil characterization, Sensitivity analysis, Modelling of uncertainty

UNIT -II: **[12L]**

Fragility curves, Probability of failure, FORM, Monte Carlo Simulation Techniques, Response Surface Method, Parallel and series systems. Explicit and implicit functions, Target reliability index, LRFD approach

UNIT-III: **[8L]**

Applications to shallow and deep foundations, landslides and embankments, liquefaction behavior of soils.

UNIT-IV: **[15L]**

Concept of risk, objective and scope of risk assessment, Probabilistic risk, Risk perception and acceptability, Quantitative aspects of risk. Three levels of risk quantification, PRA management, Preliminary hazard analysis.

Recommended Text Books:

1. Baechaer, G. and Christian, J. (2005). Reliability and Statistics in Geotechnical Engineering, Wiley Publications.
2. Griffiths, D.V. and Fenton, G.A. (2007). Probabilistic Methods in Geotechnical Engineering, Springer.

Recommended References:

1. Haldar, A. and Mahadevan, S. (2000). Probability, Reliability and Statistical Methods in Engineering Design, Wiley.
2. Phoon, K.K. (2008). Reliability based Design in Geotechnical Engineering: Computations and Applications, Taylor and Francis.

OE XXX	Optimization Methods	3-0-0

Course Philosophy:

- To make students acquainted with basics of linear and non-linear optimization methods.

Learning Outcome:

- The students will have ability to apply the optimization methods for the solution of engineering problems.

UNIT-I: Introduction to Optimization Problems [4L]

Basics of engineering analysis and design, Need for optimal design, formulation of optimal design problems, basic difficulties associated with solution of optimal problems

UNIT -II: Analytical Methods of Nonlinear Optimization Problems [12L]

Classical optimization methods, Necessary and sufficient optimality criteria for unconstrained and constrained problems, Kuhn-Tucker conditions, Global optimality and convex analysis.

UNIT-III: Formulation and Solution of Linear Optimization Problems [7L]

Linear optimal problems, Simplex method, Introduction to Karmarkar's algorithm.

UNIT-IV: Numerical Methods of Nonlinear Optimization Problems [12L]

Numerical methods for nonlinear unconstrained and constrained problems, sensitivity analysis.

UNIT-V: Introduction to Evolutionary Methods of Optimization [4L]

Introduction to evolutionary methods: Genetic algorithm and simulated annealing.

Recommended Text Books:

1. Deb, K. (1998). Optimization for engineering design: Algorithms and examples, PHI Pvt Ltd.
2. Arora, J.S. (1989). Introduction to optimum design, McGraw Hill International editions.

Recommended References:

1. Hafta, R.T. and Gurdal, Z. (1996) Elements of structural optimization, third revised an expanded edition. Kluwer academic publishers.
2. Rao, S.S. (1996). Engineering optimization theory and practice.

SYLLABI OF DEPARTMENTAL PRACTICAL SUBJECT OF

WINTER SEMESTER

DC XXX	Computer Modelling of Geotechnical Systems	0-0-3

Pre Requisite:

- Advanced Geotechnical Engineering
- Advanced Foundation Engineering

Course Philosophy:

- Exposure to modelling of geotechnical systems using analytical and numerical modelling techniques via software.

Learning Outcome:

- Students will develop the skill modeling of various geotechnical systems through software packages. Further, will gain ability to model and analyze the advanced problems for carrying out the thesis.

Unit-I: Stresses in soil **[1P]**

Stresses in soil caused by a point load, line load, strip load, uniformly loaded rectangular area: Analytical solutions via programming/software

Unit-II: Consolidation **[2P]**

1D and 2D finite element (FE)/finite difference (FD) analysis of consolidation problems

Unit-III: Shallow Foundations **[2P]**

Bearing capacity and settlement estimation of surface and embedded strip, square, rectangular, circular footings: Modelling and analysis using FE/FD software

Unit-IV: Lateral earth pressure and retaining walls **[2P]**

Active, passive and at rest lateral earth pressure calculations: Modelling and analysis using FE/FD software

Unit-V: Pile Foundations **[2P]**

Estimating the load capacity and settlement of single piles and pile groups: Modelling and analysis using FE/FD software.

Unit-VI: Slope Stability **[1P]**

Stability of slopes: Modelling and analysis using analytical, FE/FD software.

Unit-VII: Permeability and Seepage **[1P]**

Seepage analysis in soils: Analytical solutions via programming/software

Revision and Evaluation **[2P]**

Recommended Text Books:

1. Helwany, S. (2007). Applied soil mechanics with ABAQUS applications
2. Potts, D. M., and Zdravkovic, L. (1999). Finite element analysis in geotechnical engineering: Theory, Thomas Telford, London.
3. Potts, D. M., and Zdravkovic, L. (1999). Finite element analysis in geotechnical engineering: Application, Thomas Telford, London.

Recommended References:

1. Users' Manual of respective software packages.
2. Respective Bureau of Indian Standard/ International Standard Codes of Practices