SOIL STRUCTURE AND FUNDAMENTALS OF SOIL BEHAVIOUR			
Course Code	**1MCGT201**	**Scheme**	**2026**
Type of Course	Integrated Professional Core Courses (IPCC)	**Semester**	II
Teaching Hours/Week (L:T:P)	**70 (3:0:2)**	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	**120 (42:0:28:50)**	**SEE Marks**	50
Credits	4	**Total Marks**	100
Type of Examination (IPCC)	Theory – CIE + SEE, and Lab – CIE only	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1 L2** – Understand soil structure, mineralogy, soil fabric, and physicochemical characteristics influencing soil behaviour.
2. **CO2 L3** – Apply concepts of soil–water interaction, index properties, permeability, and stress–strain relationships in geotechnical engineering.
3. **CO3 L3** – Apply laboratory and analytical methods to evaluate consolidation, permeability, and shear strength characteristics of soils.
4. **CO4 L4** – Analyze advanced soil behaviour including critical state soil mechanics, constitutive modelling, and seepage under various field conditions.
5. **CO5 L5** – Evaluate analytical and numerical models for predicting field behaviour of soils and solving complex geotechnical engineering problems.

Module-1

Soil Structure and Mineralogy:

- Fundamentals of soil formation, soil classification, and engineering significance of different soil types.
- Clay mineralogy including kaolinite, Illite, montmorillonite, and their influence on soil behaviour.
- Soil fabric, particle arrangement, interparticle bonding, and structural characteristics of soils.
- Interparticle forces, diffuse double layer theory, and physicochemical behaviour of fine-grained soils.
- Sensitivity, thixotropy, and engineering behaviour of cohesive soils under different loading conditions.

Linked COs: CO1, CO2 **Number of Hours: 08**

Module-2

Soil–Water Interaction and Index Behaviour:

- Phase relationships, engineering index properties, and consistency limits of soils.
- Capillary action, soil suction, matric suction, and Soil–Water Characteristic Curve (SWCC) concepts.
- Behaviour of unsaturated soils, including swelling and shrinkage characteristics of expansive soils.
- Fundamentals of permeability, seepage through soils, and Darcy's law with its assumptions and limitations.
- Factors affecting permeability and engineering applications of seepage analysis in geotechnical engineering.

Linked COs: CO1, CO2 **Number of Hours: 10**

Module-3

Stress–Strain Behaviour of Soils:

- Fundamentals of stress paths, stress history, and Mohr–Coulomb failure criterion for soils.
- Drained and undrained behaviour of soils, including shear failure mechanisms and strength characteristics.
- Triaxial compression tests and determination of shear strength parameters for engineering analysis.
- Dilatancy, volume change behaviour, strain hardening, and strain softening characteristics of soils.
- Introduction to Critical State Soil Mechanics and its applications in geotechnical engineering.

Linked COs: CO2, CO3 **Number of Hours: 08**

Module-4

Consolidation and Seepage Analysis:

- One-dimensional consolidation theory, primary and secondary consolidation, and settlement behaviour of soils.
- Estimation of settlement for shallow and deep foundations under different loading conditions.
- Fundamentals of permeability, seepage, and effective stress principle in saturated soils.
- Flow net construction, seepage through isotropic and anisotropic soils, and engineering applications.
- Practical problems involving consolidation, seepage analysis, and groundwater flow in geotechnical projects.

Linked COs: CO3, CO4 **Number of Hours: 08**

Module-5

Advanced Soil Behaviour Models

- Fundamentals of Critical State Soil Mechanics and constitutive modelling concepts in geotechnical engineering.
- Cam Clay models and elastic–elasto-plastic behaviour of soils under different loading conditions.
- Behaviour of soils under cyclic loading, repeated loading, and time-dependent creep effects.
- Numerical modelling techniques for predicting stress–strain behaviour and deformation of soils.
- Engineering applications of advanced constitutive models in foundation, embankment, and earth structure design.

Linked COs: CO4, CO5 **Number of Hours: 08**

PRACTICAL COMPONENTS OF IPCC

PART – A: FIXED SET OF EXPERIMENTS **LI: 20 hrs**

Students shall perform **6–8 laboratory experiments** related to the fundamental and advanced behaviour of soils using standard laboratory equipment and analysis techniques.

1. Determine the **Atterberg Limits** (Liquid Limit, Plastic Limit, and Shrinkage Limit) of cohesive soils and interpret their engineering significance.
2. Perform **grain size distribution analysis** using sieve analysis and hydrometer analysis for classification of soils.
3. Conduct **constant head and falling head permeability tests** to determine the coefficient of permeability of different soil types.
4. Perform a **one-dimensional consolidation test** on clayey soil and determine compression index, coefficient of consolidation, and settlement characteristics.
5. Conduct a **direct shear test** to determine shear strength parameters (cohesion and angle of internal friction).
6. Perform a **triaxial compression test** and interpret stress-strain behaviour under drained and undrained loading conditions.
7. Study the influence of **soil structure and moisture variation** on engineering properties.
8. Compare laboratory results with theoretical predictions and engineering applications.

Suggested Learning Resources: Text Books

1. Braja M. Das and Michael T. Sobhan, *Principles of Geotechnical Engineering*, Cengage Learning.
2. V. N. S. Murthy, *Soil Mechanics and Foundation Engineering*, CBS Publishers & Distributors.
3. K. R. Arora, *Soil Mechanics and Foundation Engineering*, Standard Publishers Distributors.
4. B. C. Punmia, Ashok Kumar Jain and Arun Kumar Jain, *Soil Mechanics and Foundations*, Laxmi Publications.
5. Gopal Ranjan and A. S. R. Rao, *Basic and Applied Soil Mechanics*, New Age International Publishers.

Reference Books / Manuals

1. Andrew N. Schofield and Peter Wroth, *Critical State Soil Mechanics*, McGraw-Hill.
2. J. H. Atkinson, *The Mechanics of Soils and Foundations*, CRC Press.
3. D. G. Fredlund and H. Rahardjo, *Soil Mechanics for Unsaturated Soils*, Wiley.
4. Jean-Louis Briaud, *Geotechnical Engineering: Unsaturated and Saturated Soils*, Wiley.
5. T. William Lambe and Robert V. Whitman, *Soil Mechanics*, Wiley.

Web links and Video Lectures (e-Resources) & Software tools:

- NPTEL lectures on Soil Mechanics, Advanced Geotechnical Engineering, and Foundation Engineering.
- SWAYAM courses related to Soil Behaviour,
- Geotechnical Engineering, and Ground Improvement Techniques.
- PLAXIS tutorial videos and learning resources.
- GeoStudio learning modules and numerical modelling tutorials.
- Indian Geotechnical Society (IGS) webinars and technical lectures.
- Virtual geotechnical laboratory demonstrations available through IITs and other academic platforms.

Software Tools:

- **PLAXIS 2D / 3D**
- **GeoStudio**
- **Geo5**
- **MATLAB**
- **Python** (for numerical modelling and data analysis)
- **Microsoft Excel** (for laboratory data analysis and plotting)
- **AutoCAD Civil 3D** (basic geotechnical applications)

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to): • Flipped Classroom

- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

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A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only

he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest thre

modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks. (ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment of regular laboratory classwork as per the rubrics listed in Table - ICs/IPCCs1.

The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table – ICs/IPCCs 1.

To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 13 marks out of 25 in the C theory component, and at least 12 marks in the CIE Practical component.

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Table – ICs/IPCCs 1 Distribution of marks corresponding to laboratory component		
Component	Description	Marks
Allotment of marks for regular classwork		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
Subtotal		15
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
Subtotal		10
Total		25

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-70 hour) and Teamwork/ Self learning (TW/Sl-50 hours). Hence, students must complete minimum of two actives as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW-1:Three-phase relationships and index calculations** Task: Given experimental data (mass, volumes, water content), students compute void ratio, degree of saturation, unit weights, and relative density for different soils.	24
2	**TW-2: Particle size distribution and gradation interpretation** Task: Provide sieve/hydrometer data; students plot grain size distribution curves, compute C_u, C_c, and comment on gradation and engineering significance	24
3	**TW-3: Soil structure sketching and description** Task: Students draw and label typical fabric for single-grained sand, flocculated clay, dispersed clay, and composite structures, and relate to field behaviour (settlement, compressibility)	24
4	**TW-4: Consistency limits and "activity of clays" (data-based)** Task: Using given liquid limit, plastic limit, and plasticity index data, students: • Plot LL–PI on plasticity chart to infer soil type. • Compute activity $A = PI/\%$clayfor different soils and comment on swelling tendency.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL-1: Field soil profile and structure observation** Task: Students visit a nearby excavation/site or roadside cutting, photograph soil layers, note colour, texture, visible structure (blocky, granular, laminar) and presence of roots/cracks. They prepare a brief note relating observed features to formation and expected behaviour (drainage, stability)	24
2	**SL-2: Simple jar test for texture and structure** Task: At home/lab, students collect soil, perform a basic sedimentation jar test (water + soil + dispersant), record settling pattern and layer thickness, and infer relative sand, silt, clay fractions qualitatively	24

3	**SL-3: Micro-project on local problematic soil** Task: Each student/group selects a local soil problem (e.g., coastal loose sand, laterite, black cotton soil) and prepares a 3–4 page brief: origin, structure, mineralogy (where known), typical behaviour, and common engineering treatments used locally.	24

Sample Rubrics for TW Activities

Criteria	4 – Excellent	3 – Good	2 – Satisfactory	1 – Needs Improvement
Concept Understanding	Demonstrates excellent understanding of advanced soil mechanics concepts, laboratory principles, and engineering applications.	Shows good understanding with minor conceptual gaps.	Basic understanding with limited clarity.	Understanding is weak or incorrect.
Task Completion	Activity is completed fully, correctly, and submitted on time.	Mostly completed with minor omissions.	Partially completed.	Incomplete or missing.
Technical Accuracy	Experimental procedures, calculations, modelling, and interpretations are technically accurate and properly justified.	Mostly correct with few technical errors.	Contains noticeable errors but demonstrates partial correctness.	Major technical errors or no meaningful attempt.
Data Handling and Analysis	Experimental observations, calculations, graphs, and analysis are systematic, accurate, and well organized.	Data handling is good with minor gaps.	Workflow is partially organized.	Poor data handling and analysis.
Engineering Interpretation	Provides excellent interpretation of soil behaviour with appropriate engineering conclusions and recommendations.	Good interpretation with some analysis.	Limited interpretation.	Interpretation is absent or incorrect.
Presentation and Documentation	Report is well organized with proper tables, graphs, calculations, references, and engineering conclusions.	Well presented with minor formatting issues.	Acceptable presentation with several deficiencies.	Poor presentation and documentation.

Suggested Rubrics for Practical Continuous Assessment

Performance Indicators	Excellent	Very Good	Good	Satisfactory

Fundamental Knowledge (4) (PO1)	Student demonstrates in-depth knowledge of soil mineralogy, soil behaviour, consolidation, permeability, constitutive modelling, and advanced geotechnical engineering concepts. **(4)**	Student has good knowledge of most advanced soil mechanics concepts. **(3)**	Student understands the concepts but lacks depth. **(2)**	Student has limited understanding of the subject. **(1)**
Design of Experiment (5) (PO2 & PO3)	Student can design multiple laboratory or numerical investigations, compare approaches, and justify the most appropriate methodology. **(5)**	Student discusses several approaches with reasonable justification. **(4)**	Student explains one suitable experimental approach. **(3)**	Student has only partial understanding of experimental design. **(1–2)**
Implementation (8) (PO3 & PO8)	Student accurately performs laboratory testing, data acquisition, numerical modelling, calculations, and engineering interpretation using systematic procedures. **(7–8)**	Student performs experiments with minor procedural gaps. **(5–6)**	Student completes experiments with partial explanation. **(3–4)**	Student performs only limited parts of the experiment. **(1–2)**
Results and Analysis (5) (PO4)	Student accurately analyses laboratory/numerical results, compares theoretical and experimental behaviour, and provides meaningful engineering conclusions. **(5)**	Student analyses most experimental results correctly. **(4)**	Student performs basic analysis with limited interpretation. **(3)**	Student reports observations but cannot analyse results effectively. **(1–2)**
Demonstration (8) (PO9)	Laboratory record/portfolio is comprehensive with objectives, theory, procedure, observations, calculations, graphs, numerical results, discussions, engineering conclusions, and references. **(7–8)**	Portfolio is well organized with minor omissions. **(5–6)**	Portfolio contains incomplete documentation. **(3–4)**	Poorly maintained laboratory record with missing sections. **(1–2)**

ADVANCED GEOTECHNICAL ENGINEERING			
Course Code	**1MCGT202**	**Scheme**	**2026**
Type of Course	Professional Core Course (PCC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain advanced concepts of soil behaviour, stress distribution, and constitutive relationships in geotechnical engineering.
2. **CO2:** Analyze shear strength, consolidation characteristics, and stress–strain behaviour of soils under different loading conditions.
3. **CO3:** Evaluate the stability and performance of shallow and deep foundations, retaining structures, and slopes using advanced analytical methods.
4. **CO4:** Apply numerical and analytical techniques to solve complex geotechnical engineering problems using modern computational tools.
5. **CO5:** Design suitable ground improvement measures considering field conditions and engineering requirements.
6. **CO6:** Critically evaluate geotechnical systems and recommend sustainable engineering solutions for foundation, slope, and soil improvement projects.

Module-1

Advanced Soil Behaviour and Stress Distribution

- Soil structure and fabric, engineering properties of soils, and influence of particle arrangement on soil behaviour.
- Stress distribution, stress paths, stress–strain relationships, and behaviour of soils under different loading conditions.
- Elastic and plastic behaviour of soils, yielding mechanisms, and deformation characteristics.
- Critical State Soil Mechanics concepts, yield criteria, and applications in geotechnical engineering.
- Pore water pressure parameters, anisotropic behaviour of soils, and their influence on strength, settlement, and stability.

Linked COs: CO1 **Number of Hours: 10 hrs**

Module-2

Advanced Shear Strength and Consolidation

- Shear strength theories, drained and undrained shear behaviour, and failure criteria of soils.
- Laboratory evaluation of shear strength using triaxial compression tests and stress path testing.
- Consolidation theory, primary consolidation, settlement analysis, and prediction of soil compressibility.
- Secondary consolidation, radial consolidation, and consolidation behaviour under variable loading conditions.
- Engineering applications of consolidation in foundation design, embankments, and ground improvement projects. .

Linked COs: CO2 **Number of Hours: 8 hrs**

Module-3

Advanced Foundation Engineering

- Bearing capacity analysis under vertical, inclined, eccentric, and combined loading conditions.
- Settlement analysis of shallow and deep foundations considering immediate, consolidation, and differential settlements.
- Design principles and behaviour of raft foundations, pile foundations, pile groups, and laterally loaded piles.

- Machine foundations subjected to dynamic loading, vibration analysis, and design considerations.
- Soil–structure interaction concepts, foundation flexibility, and load transfer mechanisms in foundation systems.

Linked COs: CO3 **Number of Hours: 8 hrs**

Module-4

Slope Stability and Earth Retaining Structures

- Stability analysis of finite slopes using limit equilibrium methods and methods of slices.
- Stability of slopes under seepage, rapid drawdown, and seismic loading conditions.
- Earth pressure theories, retaining walls, reinforced soil structures, and braced excavations.
- Ground improvement methods for slope stabilization, including drainage, reinforcement, grouting, and soil stabilization.
- Engineering applications and case studies on retaining structures, excavations, and slope stabilization techniques.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Numerical Methods and Ground Improvement Techniques

- Finite Element Method (FEM), Finite Difference Method (FDM), constitutive modelling, and numerical analysis in geotechnical engineering.
- Introduction to PLAXIS and GeoStudio for modelling foundations, slopes, excavations, and seepage problems.
- Soil stabilization methods, grouting techniques, vibro-compaction, and stone columns for ground improvement.
- Geosynthetics, reinforced earth systems, and soil reinforcement techniques for geotechnical applications.
- Selection and application of numerical modelling and ground improvement techniques for solving complex geotechnical engineering problems.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Braja M. Das, Principles of Geotechnical Engineering, Cengage Learning, 10th Edition, 2022.
2. V. N. S. Murthy, Textbook of Soil Mechanics and Foundation Engineering (Geotechnical Engineering Series), CBS Publishers & Distributors Pvt. Ltd. (CBSPD), 2nd Edition (Paperback), 2021.
3. Gopal Ranjan, A. S. R. Rao, Basic and Applied Soil Mechanics, New Age International (P) Ltd., New Delhi, 5th Edition, 2024.
4. Braja M. Das, Nagaratnam Sivakugan, Principles of Foundation Engineering, Cengage Learning, 9th Edition, 2019.
5. Donald P. Coduto, Man-chu Ronald Yeung, William A. Kitch, Geotechnical Engineering: Principles and Practices, Pearson Education (Prentice Hall), 2nd Edition, 2011.

Reference Books

1. Karl Terzaghi, Ralph B. Peck, Gholamreza Mesri, Soil Mechanics in Engineering Practice, John Wiley & Sons, 3rd Edition, 1996.
2. J. E. Bowles, Foundation Analysis and Design, McGraw-Hill Education, 5th Edition, 1996 (International Student Edition).
3. R. F. Craig, Jonathan Knappett, Craig's Soil Mechanics, CRC Press (Taylor & Francis Group), 9th Edition, 2019.
4. Nagaratnam Sivakugan, Braja M. Das, Principles of Foundation Engineering, Cengage Learning, 9th Edition (SI Edition), 2019.
5. IS 6403:1981 (Reaffirmed 2021), Code of practice for determination of bearing capacity of shallow foundations, Bureau of Indian Standards.
6. IS 8009 (relevant parts, latest active revisions) – Code of practice for calculation of settlements and other aspects of foundation design on soils (Bureau of Indian Standards). [Title phrased generically here; specific

part numbers and years can be slotted as per BIS access for your course file).

7. IS 2911 (Part 1 to Part 4) latest revisions (e.g., IS 2911: Part 3:2021, Design and construction of pile foundations — Code of practice: Under-reamed piles), Bureau of Indian Standards.
8. IS 1904:1986 (with latest reaffirmation), Code of practice for design and construction of shallow foundations, Bureau of Indian Standards.
9. IS 456:2000 (with latest amendments), Plain and Reinforced Concrete — Code of Practice, Bureau of Indian Standards. (Latest status to be confirmed from BIS portal when you freeze the syllabus document.)

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Advanced Geotechnical Engineering.
2. SWAYAM courses on Soil Mechanics and Foundation Engineering.
3. PLAXIS official tutorials and user manuals.
4. GeoStudio learning resources and webinars.
5. BIS Indian Standards related to Foundation Engineering and Soil Mechanics.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*
- *Partial Delivery of course by Industry expert/ industrial visits*
- *ICT-Enabled Teaching*
- *Role Play*

	using PLAXIS/GeoStudio	
3	Geotechnical investigation and interpretation of soil parameters for a selected site	*24*
4	Ground improvement design assignment using grouting, stone columns or geosynthetics	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete a MOOC (NPTEL/SWAYAM) on Advanced Geotechnical Engineering	*24*
2	Review and summarize a recent research paper on foundation engineering or ground improvement	*24*
3	Learn PLAXIS or GeoStudio through online tutorials and prepare a software application report	*24*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Advanced geotechnical case study on foundation or slope failure and remediation techniques	*24*
2	Numerical modelling of foundations, retaining walls or slopes	*24*

Sample

rubrics for TW activities:

Criteria	*4 – Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*
Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*
Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

DYNAMICS OF SOILS AND FOUNDATIONS			
Course Code	**1MCGT203**	**Scheme**	**2026**
Type of Course	Professional Core Course (PCC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the principles of vibration theory and analyze the dynamic response of single and multidegree freedom systems subjected to different dynamic loads.
2. **CO2:** Evaluate dynamic soil properties using laboratory and field testing methods and interpret soil behaviour under cyclic loading.
3. **CO3:** Analyze and design foundations for reciprocating machines considering dynamic soil–structure interaction effects.
4. **CO4:** Design foundations for impact and rotary machines using dynamic analysis principles and relevant codal provisions.
5. **CO5:** Assess liquefaction potential and apply vibration isolation, screening, and remedial techniques for machine foundation systems.
6. **CO6:** Critically evaluate dynamic soil–foundation systems and recommend appropriate engineering solutions for vibration control and safe foundation performance.

Module-1

Theory of Vibration:

- *Fundamentals of dynamic loads, vibration concepts, Single Degree of Freedom (SDOF) systems, and equations of motion.*
- *Free and forced vibrations, natural frequency, resonance, and dynamic amplification of spring–mass systems.*
- *Viscous damping, damping ratio, transmissibility, amplitude ratio, and vibration isolation principles.*
- *Vibration measurement using displacement, velocity, and acceleration sensors for dynamic response evaluation.*
- *Introduction to transient and pulsating loads, Multi-Degree of Freedom (MDOF) systems, and modal analysis.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Dynamic Soil Properties and Behaviour

Dynamic stress–strain behaviour of soils under cyclic loading and factors influencing soil response.

Dynamic soil properties including shear modulus, damping ratio, modulus degradation, and engineering significance.

Laboratory and field methods for determining dynamic soil properties using resonant column, cyclic triaxial, SPT, CPT, and seismic tests.

Dynamic bearing capacity, earth pressure, and soil behaviour under dynamic loading conditions.

Soil–structure interaction concepts and interpretation of dynamic soil properties for engineering applications.

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Foundations for Reciprocating Machines

- *Types of machines, design requirements, and vibration modes of rigid machine foundations.*
- *Dynamic analysis of machine foundations using block method, linear elastic spring method, and elastic half-space theory.*
- *Soil–structure interaction and analogue models for evaluating foundation response under dynamic loading.*
- *Design principles of block foundations for reciprocating machines considering vibration criteria.*
- *Codal provisions, design recommendations, and practical considerations for reciprocating machine foundations.*

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Foundations for Impact and Rotary Machines

- *Dynamic analysis and design of foundations for impact machines, including hammer foundations.*
- *Design principles of rotary machine foundations, turbo-generator foundations, and vibration control measures.*
- *Dynamic loads, vibration characteristics, and soil–structure interaction in machine foundations.*
- *Application of vibration absorbers and codal recommendations for machine foundation design.*
- *Analytical methods and practical design considerations for impact and rotary machine foundations.*

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Influence of Vibration and Remediation

- *Mechanism of liquefaction, susceptibility factors, and evaluation using SPT-based methods.*
- *Principles of force isolation, motion isolation, and vibration control techniques for machine foundations.*
- *Use of spring and damping materials, retrofitting methods, and vibration mitigation measures.*
- *Vibration screening using trenches, pile barriers, and other isolation systems for dynamic loading.*
- *Construction practices, maintenance, and performance assessment of machine foundations under vibration.*

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Swami Saran, *Soil Dynamics and Machine Foundations*, Galgotia Publications, New Delhi.
2. Braja M. Das and Zhe Luo, *Principles of Soil Dynamics*, Cengage Learning.
3. Shamsher Prakash and Vijay K. Puri, *Foundations for Machines: Analysis and Design*, John Wiley & Sons.
4. Anil K. Chopra, *Dynamics of Structures: Theory and Applications to Earthquake Engineering*, Pearson Education.
5. Joseph E. Bowles, *Foundation Analysis and Design*, McGraw-Hill. **Reference Books**

1. IS 2974 (Part I–IV): *Code of Practice for Design and Construction of Machine Foundations*, Bureau of Indian Standards.
2. Richart, Hall and Woods, *Vibrations of Soils and Foundations*, latest edition.
3. Arya, O'Neill and Pincus, *Design of Structures and Foundations for Vibrating Machines*, latest edition.
4. Kramer, S. L., *Geotechnical Earthquake Engineering*, latest edition.
5. Recent journal articles on soil dynamics, machine foundations and vibration control.

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Soil Dynamics and Machine Foundations.
2. IIT Kharagpur and IIT Madras Geotechnical Engineering lecture series.

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3. BIS Standards related to Machine Foundations.
4. SWAYAM online courses on Geotechnical Engineering.
5. Technical tutorials on vibration analysis and dynamic foundation design.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*
- *Partial Delivery of course by Industry expert/ industrial visits*
- *ICT-Enabled Teaching*
- *Role Play*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Dynamic analysis of machine foundations by evaluating vibration characteristics and soil dynamic properties for a selected industrial application.	*24*
2	Case study on soil dynamics, liquefaction, or machine foundation performance with recommendations for vibration mitigation.	*24*
3	Software-based dynamic analysis of soil–foundation systems using PLAXIS, ANSYS or MATLAB and interpretation of results.	*24*

	Structural Dynamics or Machine Foundations.	
2	Review recent research papers on liquefaction, vibration control or machine foundation design.	*24*
3	Study IS 2974 and other relevant standards related to dynamic foundation design and prepare a technical report.	*24*
4	Design assignment on reciprocating, rotary or impact machine foundations considering soil–structure interaction and codal provisions.	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Complete a MOOC (NPTEL/SWAYAM) on Soil Dynamics,	*24*

3 **Sample rubrics for TW activities:**

Criteria	*4 - Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*

Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*
Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

GROUND IMPROVEMENT TECHNIQUES			
Course Code	**1MCGT204**	**Scheme**	**2026**
Type of Course	Professional Core Course (PCC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** Explain the principles of ground improvement and identify problematic soil conditions requiring suitable improvement techniques.
2. **CO2:** Analyze and design dewatering, drainage and preloading systems for improving soil behaviour under various field conditions.
3. **CO3:** Apply densification methods such as compaction, sand piles, stone columns and lime piles to improve the engineering properties of soils.
4. **CO4:** Evaluate and design grouting and soil stabilization techniques for enhancing the performance of geotechnical systems.
5. **CO5:** Recommend technically feasible and economical ground improvement solutions for practical geotechnical engineering projects.
6. **CO6:** Critically evaluate ground improvement alternatives and propose sustainable solutions considering engineering, environmental and construction aspects.

Module-1

Introduction to Ground Improvement and Dewatering

- *Scope, necessity, philosophy, and applications of ground improvement in geotechnical engineering, including identification of problematic soils.*
- *Groundwater control methods and the importance of dewatering in construction and foundation engineering.*
- *Dewatering techniques including well point systems, deep well systems, and vacuum dewatering methods.*
- *Electro-osmotic dewatering principles, applications, and limitations in fine-grained soils.*
- *Selection of suitable dewatering and ground improvement techniques based on site conditions and engineering requirements.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Drainage and Preloading Techniques

- *Ground treatment methods including thermal treatment, artificial ground freezing, and preloading techniques.*
- *Principles and applications of vertical drainage systems for accelerating soil consolidation.*
- *Sand drains, fabric drains, wick drains, and theory of sand drains for soft ground improvement.*
- *Design considerations, installation methods, and performance of drainage and preloading systems.*
- *Comparative evaluation, advantages, limitations, and engineering applications of drainage techniques.*

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Soil Densification Techniques

- *In-situ densification methods for granular and cohesive soils, including shallow and deep compaction techniques.*
- *Ground improvement using sand piles, blasting, and dynamic consolidation methods.*
- *Stone columns, installation techniques, design principles, and applications in soft ground improvement.*
- *Lime piles, construction methods, estimation of load carrying capacity, and settlement reduction.*
- *Selection and performance evaluation of soil densification techniques for different field conditions.*

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Grouting Technology

- *Types of grouting methods, grout materials, and selection criteria for different geotechnical applications.*
- *Characteristics of suspension and solution grouts, and basic requirements of grout materials.*
- *Grouting equipment, principles of grout injection, and various injection techniques.*
- *Jet grouting, properties of treated ground, and engineering applications in foundation improvement.*

Grout quality control, monitoring techniques, and performance evaluation of grouted ground.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Soil Stabilization Techniques

- *Principles of soil stabilization and mechanical, chemical, thermal, and electro-chemical stabilization methods.*
- *Stabilization using cement, lime, and bituminous materials for improving engineering properties of soils.*
- *Stabilization techniques for expansive clays, collapsible soils, and other problematic ground conditions.*
- *Selection, design, and field application of suitable soil stabilization methods for geotechnical projects.*
- *Performance evaluation, sustainability considerations, and engineering applications of stabilized soils.*

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Purushothama Raj, *Ground Improvement Techniques*, Laxmi Publications.
2. R. M. Koerner, *Designing with Geosynthetics*, Pearson Education.
3. M. P. Moseley and K. Kirsch, *Ground Improvement*, CRC Press.
4. M. R. Hausmann, *Engineering Principles of Ground Modification*, McGraw-Hill.
5. P. P. Xanthakos, L. W. Abramson and D. A. Bruce, *Ground Control and Improvement*, Wiley.

Reference Books

1. Relevant IS Codes and IRC Guidelines related to Ground Improvement and Soil Stabilization.
2. Braja M. Das, *Principles of Foundation Engineering*, latest edition.
3. C. Venkatramaiah, *Geotechnical Engineering*, latest edition.
4. Donald P. Coduto, *Geotechnical Engineering: Principles and Practices*, latest edition.
5. Recent journal articles on ground improvement techniques and soil stabilization.

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Ground Improvement Techniques and Geotechnical Engineering.
2. IIT Madras and IIT Kharagpur Geotechnical Engineering lecture series.
3. SWAYAM online courses on Ground Improvement and Foundation Engineering.
4. BIS Codes and IRC publications related to soil stabilization and ground improvement.
5. Technical manuals and software tutorials for ground improvement design.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*
- *Partial Delivery of course by Industry expert/ industrial visits*
- *ICT-Enabled Teaching*
- *Role Play*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Analyze a problematic soil site and recommend suitable ground improvement techniques considering technical feasibility and cost-effectiveness.	*24*
2	Design a dewatering, preloading or drainage system for a selected geotechnical project and evaluate its performance.	*24*
3	Perform a design assignment on stone columns, lime piles, grouting or soil stabilization techniques using analytical methods or software.	*24*

4	Prepare a case study on ground improvement applications in foundations, embankments or infrastructure projects with recommendations for sustainable construction.	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Complete a MOOC (NPTEL/SWAYAM) on Ground Improvement Techniques, Soil Stabilization or Geotechnical Engineering.	*24*
2	Review recent research papers on ground improvement, grouting, soil stabilization or reinforcement techniques.	*24*
3	Study relevant IS Codes and IRC Guidelines related to ground improvement and prepare a technical report.	*24*

Sample rubrics for TW activities:

Criteria	*4 - Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*
Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*
Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

ROCK MECHANICS AND TUNNELLING			
Course Code	**1MCGT205A**	**Scheme**	**2026**
Type of Course	Professional Elective Course (PEC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** Explain the classification of rocks and evaluate their engineering properties through laboratory and field investigations.
2. **CO2:** Analyze the strength, deformation, permeability and stress–strain behaviour of rock masses for engineering applications.
3. **CO3:** Apply stress analysis principles to underground openings, tunnels and other rock engineering problems.
4. **CO4:** Evaluate the stability of rock slopes, foundations and underground excavations, and design suitable rock support systems.
5. **CO5:** Analyze tunnelling methods, construction techniques and groundwater problems associated with underground works.
6. **CO6:** Critically evaluate rock engineering and tunnelling projects, and recommend safe, economical and sustainable design and construction solutions.

Module-1

Fundamentals of Rock Mechanics and Rock Investigation

- *Introduction, objectives, scope, applications, and engineering significance of rock mechanics in civil engineering projects.*
- *Classification of rocks based on origin, lithology, engineering properties, and behaviour under loading conditions.*
- *Rock exploration techniques including drilling, rock coring, geological mapping, and geophysical investigation methods.*
- *Laboratory testing of rocks for compressive strength, tensile strength, flexural strength, and determination of engineering properties.*
- *Correlation between laboratory and field properties of rock masses for engineering analysis and design.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Strength, Deformation and Permeability Characteristics of Rocks

- *Strength and failure theories of rocks, including Griffith's theory, Coulomb's theory, and rheological behaviour of rock masses.*
- *In-situ testing methods, deformation characteristics, and instrumentation for monitoring rock mass behaviour.*
- *Permeability characteristics of intact and jointed rock masses, including flow through fractured rocks.*
- *Influence of interstitial water, seepage, and groundwater on the engineering behaviour of rock masses.*
- *Mechanical, thermal, and electrical properties of rocks and their applications in rock engineering.*

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Stress Analysis and Underground Openings in Rock

- *Stress analysis in rock masses using thick wall cylinder theory, Kirsch equations, and Greenspan method.*
- *Stress distribution around underground openings, tunnels, and excavations under different loading conditions.*
- *Development of plastic zones and stability considerations for underground excavations and pressure* **tunnels.**
- *Rock support requirements and design considerations for lined and unlined tunnels***.**
- *Subsidence problems, tunnel behaviour, and engineering applications of underground rock excavations.*

Linked COs: CO3 *Number of Hours: 9 hrs*

1

Module-4

Rock Engineering Applications and Rock Support Systems

- *Applications of rock mechanics in foundations, slopes, tunnels, dams, and other civil engineering structures.*
- *Bearing capacity of homogeneous and discontinuous rock masses, including joint behaviour and support pressure.*
- *Modes and mechanisms of rock failure, stability of unsupported spans, pillars, and underground openings.*
- *Rock slope stability analysis and reinforcement methods using rock bolting and anchoring systems.*
- *Fundamentals of plastic mechanics and design of rock support systems for engineering projects.*

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Tunnelling Engineering

- *Introduction, classification, shapes, and applications of tunnels in transportation, hydropower, and underground infrastructure.*
- *Conventional and modern tunnelling methods, construction procedures, and challenges in different geological conditions.*
- *Tunnelling through soils and rock masses, including groundwater problems and excavation control measures.*
- *Tunnel support systems, lining requirements, and stability considerations during construction.*
- *Case studies, engineering applications, and modern practices in tunnelling and underground construction.*

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Jaeger, J. C., Cook, N. G. W. and Zimmerman, R., *Fundamentals of Rock Mechanics*, 4th Edition, WileyBlackwell.
2. Bieniawski, Z. T., *Engineering Rock Mass Classifications: A Complete Manual for Engineers and Geologists in Mining, Civil and Petroleum Engineering*, John Wiley & Sons.
3. Brady, B. H. G. and Brown, E. T., *Rock Mechanics for Underground Mining*, 3rd Edition, Springer.
4. Jaeger, J. C. and Cook, N. G. W., *Fundamentals of Rock Mechanics*, Chapman and Hall.
5. Attewell, P. B. and Farmer, I. W., *Principles of Engineering Geology and Geotechnics*, 2nd Edition, Chapman and Hall.

Reference Books

1. Barton, N., Lien, R. and Lunde, J., *Engineering Classification of Rock Masses for the Design of Tunnel Support*, Norwegian Geotechnical Institute.
2. Relevant IS Codes related to Rock Engineering and Tunnelling (latest editions).
3. Hoek, E. and Brown, E. T., publications on rock engineering and underground excavations.
4. C. Jaeger and N. G. W. Cook, *Rock Mechanics for Engineering Practice*, latest edition.
5. Recent research papers on rock mechanics, underground excavations and tunnelling.

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Rock Mechanics.
2. NPTEL courses on Tunnelling Engineering.
3. International Society for Rock Mechanics (ISRM) suggested methods and technical resources.
4. BIS Standards related to Rock Engineering and Tunnelling.
5. IIT lecture series on Underground Construction and Rock Engineering.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*

- *Partial Delivery of course by Industry expert/ industrial visits*
- *ICT-Enabled Teaching*
- *Role Play*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Analyze the engineering properties of rock masses and prepare a design report for slopes, foundations or underground excavations based on laboratory and field investigations.	*24*
2	Prepare a case study on tunnel construction, rock support systems or underground excavation failures with recommendations for safe and economical design.	*24*
3	Perform numerical or analytical stress analysis of underground openings and evaluate rock support requirements using appropriate software or analytical methods.	*24*
4	Develop a tunnel excavation and support plan considering geological conditions, groundwater control and construction methodology for a selected infrastructure project.	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete a MOOC (NPTEL/SWAYAM) on Rock Mechanics, Tunnelling Engineering or Underground Construction.	*24*
2	Review recent research papers on rock engineering, tunnel support systems and underground excavation technologies.	*24*
3	Study ISRM suggested methods and relevant BIS Standards related to rock mechanics and tunnelling, and prepare a technical report.	*24*

Sample rubrics for TW activities:

3

Criteria	*4 - Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*
Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*
Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

4

GEOTECHNICAL EARTHQUAKE ENGINEERING			
Course Code	**1MCGT205B**	**Scheme**	**2026**
Type of Course	Professional Elective Course (PEC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the principles of engineering seismology, seismic hazards, and dynamic soil behaviour relevant to geotechnical earthquake engineering.
2. **CO2:** Analyze dynamic soil properties, stress paths, and ground response using laboratory and field investigation techniques.
3. **CO3:** Evaluate liquefaction potential and recommend suitable soil improvement techniques for seismic hazard mitigation.
4. **CO4:** Design machine foundations subjected to dynamic loading by considering soil–structure interaction and codal provisions.
5. **CO5:** Apply seismic design principles and geotechnical engineering practices to improve the safety and performance of infrastructure in earthquake-prone regions.
6. **CO6:** Critically evaluate earthquake-induced geotechnical failures and propose sustainable mitigation and remediation strategies.

Module-1

Introduction to Geotechnical Earthquake Engineering:

- Fundamentals of geotechnical earthquake engineering, seismic hazards, and their impact on geotechnical and structural systems.
- Types of seismic hazards including ground shaking, liquefaction, landslides, retaining structure failures, lifeline hazards, tsunami, and seiche hazards.
- Historical earthquakes, seismic hazard mitigation measures, and earthquake-resistant geotechnical practices.
- Dynamic soil properties, Mohr circle representation, principal stresses, and stress path concepts.
- Measurement of dynamic soil properties using laboratory and field tests, and interpretation of observed ground response.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Liquefaction:

- Fundamentals of liquefaction, flow liquefaction, cyclic mobility, and mechanisms of soil failure during earthquakes.
- Evaluation of liquefaction hazards and susceptibility based on historical, geological, compositional, and state criteria.
- Initiation of liquefaction, generation of excess pore water pressure, and influencing factors.
- Effects of liquefaction on foundations, embankments, retaining structures, and other geotechnical systems.
- Assessment methods and engineering measures for mitigating liquefaction-induced damage.

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Soil Improvement for Remediation of Seismic Hazards

- Ground improvement techniques for seismic hazard mitigation using densification and reinforcement methods. Vibro-compaction, vibro-flotation, dynamic compaction, blasting, and compaction grouting techniques.
- Reinforcement methods including stone columns, compaction piles, drilled inclusions, and deep mixing techniques.
- Grouting methods, drainage systems, and soil stabilization techniques for improving seismic performance.
- Verification of ground improvement using laboratory, in-situ, and geophysical testing methods.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

General Principles of Machine Foundation Design

- Types of machines, machine foundations, design requirements, permissible amplitudes, and allowable soil pressures.
- Modes of vibration of reciprocating machine foundations and behaviour under dynamic loading.
- Dynamic analysis using linear elastic weightless spring method and elastic half-space method.
- Effects of footing shape, embedded block response, and soil–foundation interaction on foundation performance.
- Design procedures, codal provisions, and practical considerations for reciprocating machine foundations.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Foundations for Impact and Rotary Machines

- Dynamic analysis and design principles of foundations for impact machines, including hammer foundations.
- Design considerations and vibration characteristics of rotary machine and turbo-generator foundations. Evaluation of dynamic loads using resonance, amplitude, and combined analysis methods.
- Practical design procedures, codal provisions, and performance requirements for machine foundations.
- Engineering applications, case studies, and modern practices in machine foundation design under dynamic loading.

Linked COs: CO5 & 6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Anil K. Chopra, *Dynamics of Structures*, latest edition.
2. Steven L. Kramer, *Geotechnical Earthquake Engineering*, latest edition.
3. Swami Saran, *Soil Dynamics and Machine Foundations*, latest edition.
4. Vinod Hosur, *Earthquake Resistant Design of Building Structures*, latest edition.
5. Pankaj Agarwal and Manish Shrikhande, *Earthquake Resistant Design of Structures*, latest edition.

Reference Books

1. Duggal, *Earthquake Resistant Design of Structures*, latest edition.
2. IS 1893 (Part 1): *Criteria for Earthquake Resistant Design of Structures*, latest edition.
3. IS 13920: *Ductile Detailing of Reinforced Concrete Structures*, latest edition.
4. IS 4326 and IS 13828 related to earthquake-resistant construction, latest editions.
5. Recent journal articles on geotechnical earthquake engineering, liquefaction and seismic hazard mitigation.

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Geotechnical Earthquake Engineering and Soil Dynamics.
2. SWAYAM online courses on Earthquake Engineering and Geotechnical Engineering.
3. IIT lecture series on Engineering Seismology and Machine Foundations.
4. BIS Standards related to earthquake-resistant design.
5. Technical resources on seismic hazard assessment and soil improvement techniques.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

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- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Perform liquefaction hazard assessment and recommend appropriate soil improvement techniques for a selected site.	24
2	Prepare a case study on earthquake-induced geotechnical failures such as liquefaction, landslides or retaining wall failures with mitigation measures.	24
3	Analyze and design machine foundations subjected to dynamic loading using analytical methods or software tools.	24
4	Conduct seismic hazard evaluation and prepare a geotechnical earthquake risk mitigation plan for infrastructure projects.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete a MOOC (NPTEL/SWAYAM) on Geotechnical	24

	Earthquake Engineering, Soil Dynamics or Engineering Seismology.	
2	Review recent research papers on liquefaction, seismic hazard analysis and earthquake-resistant geotechnical design.	24
3	Study IS 1893, IS 13920 and other relevant earthquake engineering standards and prepare a technical report.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

ANALYSIS AND DESIGN OF MACHINE FOUNDATIONS			
Course Code	**1MCGT205C**	**Scheme**	**2026**
Type of Course	Professional Elective Course (PEC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the fundamentals of vibration theory, dynamic soil properties and their significance in machine foundation engineering.
2. **CO2:** Analyze different types of machine foundation systems subjected to dynamic loads using vibration principles and soil–foundation interaction concepts.
3. **CO3:** Evaluate the dynamic response of foundations considering soil–structure interaction, damping and vibration characteristics.
4. **CO4:** Design foundations for reciprocating, impact and rotary machines using analytical methods and codal provisions.
5. **CO5:** Apply vibration isolation techniques, remedial measures and practical design considerations for machine foundations.
6. **CO6:** Critically evaluate machine foundation performance and recommend safe, economical and sustainable foundation solutions for industrial applications.

Module-1

Fundamentals of Vibrations and Dynamic Soil Properties:

- Fundamentals of vibrations including free and forced vibrations, undamped and damped systems, degree of freedom, resonance, and vibration isolation.
- Theory of vibration response of single-degree-of-freedom systems and dynamic characteristics of engineering structures.
- Dynamic soil properties including elastic constants, shear modulus, damping ratio, Poisson's ratio, and coefficient of elastic uniform compression.
- Laboratory and field methods for determining dynamic soil properties and interpretation of test results.
- Vibration measuring instruments, engineering applications of soil dynamics, and significance of dynamic soil behaviour in machine foundation design.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Principles of Machine Foundation Design:

- Types of machines, classification of machine foundations, and general requirements for dynamic foundation design.
- Design criteria including permissible amplitudes, allowable soil pressure, codal provisions, and vibration limits.
- Theory of vibrations applied to machine foundations using spring–mass–dashpot systems and dynamic equilibrium concepts.
- Natural frequency, transmissibility, damping effects, resonance, and vibration control in machine foundations.
- Engineering principles, design methodology, and practical considerations for safe and economical machine foundation systems**.**

Linked COs: CO2 **Number of Hours: 8 hrs**

1

Module-3

Foundations for Reciprocating Machines:

- Characteristics of dynamic forces generated by reciprocating machines and their effects on foundation performance.
- Modes of vibration of block foundations and behaviour under dynamic loading conditions.
- Analysis of machine foundations using the linear elastic weightless spring method and elastic half-space theory.
- Effect of foundation embedment, soil stiffness, and soil–foundation interaction on dynamic response.
- Design procedures, codal recommendations, and practical considerations for reciprocating machine foundations.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Foundations for Impact and Rotary Machines

- Dynamic analysis and design principles of hammer foundations subjected to impact loading.
- Behaviour and design of foundations for rotary machines, including turbo-generator foundations.
- Evaluation of design loads, vibration characteristics, and dynamic response of rotary machine foundations.
- Analytical methods including resonance method, amplitude method, and combined method for machine foundation design.
- Codal provisions, engineering design criteria, and practical applications of impact and rotary machine foundations.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Soil–Foundation Interaction and Special Topics:

- Soil–structure interaction concepts and dynamic response of embedded foundations under machineinduced vibrations.
- Analysis and design of pile-supported machine foundations considering dynamic loading and soil behaviour.
- Vibration isolation techniques, damping systems, and remedial measures for vibration control.
- Field measurements, instrumentation, monitoring techniques, and performance evaluation of machine foundations.
- Case studies on industrial machine foundations, failure analysis, rehabilitation methods, and modern engineering practices.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Swami Saran, *Soil Dynamics and Machine Foundations*, Galgotia Publications Pvt. Ltd., 3rd Edition, 2016.
2. Shamsher Prakash, V. K. (Vijay Kumar) Puri, *Foundations for Machines: Analysis and Design*, John Wiley & Sons, 1st Edition, 1988.books.
3. D. D. Barkan, *Dynamics of Bases and Foundations*, McGraw-Hill Book Company, 1st English Edition, 1962.
4. Steven L. Kramer, Jonathan P. Stewart, *Geotechnical Earthquake Engineering*, CRC Press (Taylor & Francis Group), 2nd Edition, 2024.taylorfrancis+3
5. J. E. Bowles, *Foundation Analysis and Design*, McGraw-Hill Education, 5th Edition, 1997 (often reprinted as 2001 International Student Edition, ISBN 0071188444).

Reference Books:

1. *IS 2974 (all relevant parts), Code of Practice for Design and Construction of Machine Foundations (Parts 1–5: foundations for reciprocating, impact and rotary type machines), Bureau of Indian Standards, latest active revisions and draft updates (e.g., IS 2974: Part 4:1979, reviewed 2025; new draft revisions and proposed IS 2974: Part 1:2026).*
2. *Braja M. Das, G. V. Ramana, Principles of Soil Dynamics, Cengage Learning, 2nd Edition, 2011 (revised from earlier 1993 PWS-Kent edition).*
6. *Anil K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, Pearson, 6th Edition (including SI Edition), 2023.*
7. *C. Venkatramaiah, Geotechnical Engineering, New Age International (P) Ltd., 6th Edition (latest revised reprint; widely cited base edition 2006, with later updated prints carrying revised content).*

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Soil Dynamics and Machine Foundations.
2. SWAYAM online courses related to Soil Dynamics and Foundation Engineering.
3. IIT lecture series on Machine Foundations and Dynamic Analysis.
4. BIS Standards related to machine foundation design.
5. PLAXIS and ANSYS tutorials for dynamic foundation analysis.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Analyze and design machine foundations for reciprocating, impact or rotary machines using analytical methods and relevant IS codes.	24
2	Prepare a case study on industrial machine foundation failures, vibration problems and suitable remedial measures.	24
3	Perform dynamic analysis of machine foundations using PLAXIS, ANSYS or other suitable software and evaluate soil–foundation interaction.	24
4	Develop a vibration isolation and foundation design proposal for an industrial machine considering dynamic loading and field conditions.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Complete a MOOC (NPTEL/SWAYAM) on Soil Dynamics, Machine Foundations or Structural Dynamics.	24

2	Review recent research papers on machine foundation analysis, vibration control and soil–foundation interaction.	24
3	Study IS 2974 and other relevant standards related to machine foundations and prepare a technical report on codal design provisions.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

GEOSYNTHETICS AND GEOENVIRONMENTAL ENGINEERING			
Course Code	**1MCGT205D**	**Scheme**	**2026**
Type of Course	Professional Elective Course (PEC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the classification, engineering properties, functions and applications of geosynthetic materials in civil engineering.
2. **CO2:** Analyze soil–geosynthetic interaction for reinforcement, separation, filtration, drainage and protection applications.
3. **CO3:** Design geosynthetic-reinforced foundations, embankments, retaining structures, pavements and hydraulic systems.
4. **CO4:** Evaluate geoenvironmental problems related to waste containment, contaminant transport, landfill engineering and environmental protection systems.
5. **CO5:** Apply geosynthetics and geoenvironmental engineering principles to develop sustainable geotechnical and environmental engineering solutions.
6. **CO6:** Critically evaluate geosynthetic and geoenvironmental systems and recommend appropriate design, monitoring and remediation measures for field applications.

Module-1

Fundamentals of Geosynthetics

- *Introduction, historical development, scope, applications, and classification of geosynthetics used in geotechnical engineering.*
- *Types of geosynthetics including geotextiles, geogrids, geomembranes, geonets, geocells, geosynthetic clay liners (GCLs), and geocomposites.*
- *Manufacturing methods, material properties, and physical, hydraulic, mechanical, and durability characteristics of geosynthetics.*
- *Functions of geosynthetics including separation, filtration, drainage, reinforcement, protection, and containment in civil engineering works.*
- *Testing, evaluation, selection criteria, and engineering applications of geosynthetic materials.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Geosynthetics in Reinforcement and Ground Improvement

- *Soil reinforcement mechanisms, soil–geosynthetic interaction, and reinforced soil concepts for geotechnical applications.*
- *Geosynthetic-reinforced foundations and techniques for improving bearing capacity and settlement performance.*
- *Reinforced embankments on soft soils, reinforced soil walls, and stabilization of steep slopes.*
- *Soil nailing, reinforced earth structures, and construction techniques for ground improvement.*
- *Design considerations, construction practices, and performance evaluation of reinforced soil systems.*

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Geosynthetics in Transportation and Hydraulic Engineering

- *Applications of geosynthetics in highways, railways, airfields, and pavement systems.*
- *Separation, filtration, drainage, reinforcement, subgrade stabilization, and base improvement using geosynthetics.*
- *Use of geosynthetics in railway embankments, erosion control, and slope protection works.*
- *Applications in river training, canals, reservoirs, hydraulic structures, and water resource projects.* *Design considerations, construction methods, and field performance of geosynthetic systems.*

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Fundamentals of Geoenvironmental Engineering

- *Introduction to geoenvironmental engineering and characteristics of municipal, industrial, and hazardous wastes.*
- *Soil and groundwater contamination mechanisms, waste–soil interaction, and contaminant transport processes.*
- *Environmental site investigation, characterization techniques, and assessment of contaminated sites.*
- *Risk assessment methods, remediation techniques, and environmental protection measures.*
- *Regulatory requirements, environmental standards, and sustainable waste management practices.*

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Geosynthetics in Environmental Protection Systems

- *Applications of geosynthetics in geoenvironmental engineering and environmental protection systems.*
- *Landfill liners, covers, leachate collection systems, geomembranes, and geosynthetic clay liners for waste containment.*
- *Geosynthetic applications in ash ponds, lagoons, mining projects, drainage layers, and barrier systems.*
- *Design considerations for landfill stability, environmental monitoring, and long-term performance of containment systems.*
- *Sustainable waste management practices, case studies, and modern applications of geosynthetics in environmental engineering.*

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. R. M. Koerner, *Designing with Geosynthetics*, 6th/7th Edition, Xlibris Corporation/Pearson Education.
2. S. K. Shukla, *Fundamentals of Geosynthetic Engineering*, Taylor & Francis/CRC Press.
3. H. D. Sharma and K. R. Reddy, *Geoenvironmental Engineering*, John Wiley & Sons.
4. R. K. Rowe (Ed.), *Geotechnical and Geoenvironmental Engineering Handbook*, Springer.
5. R. M. Koerner (Ed.), *Geosynthetics in Civil Engineering*, Woodhead Publishing

Reference Books

1. H. D. Sharma and S. P. Lewis, *Waste Containment Systems: Waste Stabilization and Landfills*, CRC Press.
2. Relevant ASTM and BIS Standards related to Geosynthetics and Geoenvironmental Engineering.
3. C. Venkatramaiah, *Geotechnical Engineering*, latest edition.
4. Braja M. Das, *Principles of Foundation Engineering*, latest edition.
5. Recent journal articles on geosynthetics, landfill engineering and environmental geotechnology.

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Geosynthetics and Geoenvironmental Engineering.

2. International Geosynthetics Society (IGS) technical resources.
3. Geosynthetic Institute (GSI) publications and design guidelines.
4. IIT lecture series on Environmental Geotechnology and Waste Management.
5. SWAYAM online courses related to Geotechnical and Environmental Engineering.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*
- *Partial Delivery of course by Industry expert/ industrial visits*
- *ICT-Enabled Teaching*
- *Role Play*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Design and analysis of geosynthetic-reinforced foundations, embankments or retaining structures using appropriate analytical methods or software.	*24*
2	Prepare a case study on landfill engineering, waste containment systems or geoenvironmental remediation using geosynthetics.	*24*
3	Evaluate the performance of geosynthetics in transportation or hydraulic engineering applications through design assignments or software analysis.	*24*

4	Develop a geoenvironmental management plan for a landfill, ash pond or contaminated site incorporating geosynthetic barrier systems.	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Complete a MOOC (NPTEL/SWAYAM) on Geosynthetics, Geoenvironmental Engineering or Environmental Geotechnology.	*24*
2	Review recent research papers on reinforced soil structures, landfill engineering or contaminant transport.	*24*
3	Study relevant ASTM and BIS Standards related to geosynthetics and prepare a technical report on design applications.	*24*

Sample rubrics for TW activities:

Criteria	*4 - Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*
Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*
Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

EARTH AND EMBANKMENT DAMS			
Course Code	**1MCGT205E**	**Scheme**	**2026**
Type of Course	Professional Elective Course (PEC)	**Semester**	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	**CIE Marks**	50
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	90 (42:0:0:48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Type of Examination (SEE)	Theory	**Exam Hours**	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the planning, classification, components, and construction materials used in earth and embankment dams.
2. **CO2:** Analyze seepage behaviour, stress distribution, and stability of earth dams under different loading conditions.
3. **CO3:** Design essential components of earth dams, including filters, drains, impervious cores, and seepage control systems.
4. **CO4:** Evaluate slope stability, deformation behaviour, and seismic performance of embankment dams using analytical methods.
5. **CO5:** Assess dam safety, instrumentation, monitoring systems, and potential failure mechanisms for effective risk management.
6. **CO6:** Critically evaluate earth dam performance and recommend suitable rehabilitation, strengthening, and sustainable dam safety measures.

Module-1

Introduction and Types of Dams:

- Classification, types, advantages, limitations, and applications of earth and embankment dams.
- Site selection criteria and planning considerations for earth dam construction.
- Components of earth dams including core, shell, filters, drains, and cutoffs, and their functions.
- Engineering properties, selection criteria, and suitability of soils used for embankment construction. Compaction characteristics, borrow area investigation, and quality control during dam construction

Linked COs: CO1 **Number of Hours: 08 hrs**

Module-2

Seepage Analysis:

- Seepage through earth dams, flow mechanisms, and construction of flow nets for seepage analysis.
- Determination of phreatic line and evaluation of seepage characteristics in embankment dams.
- Seepage control measures including filters, drainage systems, and cutoff arrangements.
- Design principles and performance of filters and internal drainage systems in earth dams.
- Piping mechanisms, causes of failure, and preventive measures for safe dam performance.

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Stability Analysis of Slopes

- Types of slope failures in earth dams and factors affecting slope stability.
- Stability analysis using Swedish Circle Method, Bishop's Method, and factor of safety evaluation.
- Stability assessment during construction and under steady seepage conditions.
- Stability analysis during sudden drawdown and critical loading conditions.
- Engineering measures for improving slope stability and ensuring safe embankment performance.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Stress, Deformation and Seismic Considerations:

 Stress distribution, settlement, consolidation, and deformation behaviour of embankment dams.

- Crack formation, causes, preventive measures, and performance monitoring of earth dams.
- Earthquake forces acting on embankment dams and principles of dynamic stability analysis. Liquefaction behaviour of embankment materials and seismic design considerations.
- Engineering evaluation of dam performance under static and earthquake loading conditions.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Design and Safety of Dams:

- Design principles of earth dams, zoned embankments, and selection of suitable dam sections.
- Instrumentation systems, monitoring techniques, and performance evaluation of earth dams.
- Dam safety assessment, inspection procedures, and maintenance practices.
- Failure mechanisms of earth dams, rehabilitation methods, and strengthening techniques.
- Case studies of dam failures and modern engineering practices for safe and sustainable dam design.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. J. L. Sherard, R. J. Woodward, S. F. Gizienski, Earth and Earth-Rock Dams: Engineering Problems of Design and Construction, John Wiley & Sons, 1st Edition, 1963.
2. Robin Fell, Patrick MacGregor, David Stapledon, Graeme Bell, Mark Foster, Geotechnical Engineering of Dams, CRC Press (Taylor & Francis Group), 2nd Edition, 2018.
3. K. R. Arora, Soil Mechanics and Foundation Engineering, Standard Publishers Distributors, 7th Edition, Reprint 2025.
4. U.S. Bureau of Reclamation, Design of Small Dams, U.S. Department of the Interior, Bureau of Reclamation, 3rd Edition, 1987 (Water Resources Technical Publication).
5. International Commission on Large Dams (ICOLD), ICOLD Bulletins on Dam Design and Safety (e.g., Bulletins on dam safety, risk assessment, dam monitoring and surveillance), latest series as published by ICOLD, Paris (specific bulletin numbers and years to be selected according to course focus) **Reference Books**

1. Relevant IS Codes related to earth dams and embankments (latest active editions), including:

- IS 7894:1975, Code of practice for stability analysis of earth dams.
- IS 8826:1978, Guidelines for design of large earth and rockfill dams.
- IS 9429:1999, Drainage system for earth and rockfill dams – Code of practice.
- IS 10635:1993, Freeboard requirements in embankment dams – Guidelines.
- IS 12169:1987, Criteria for design of small embankment dams.
- IS 14591:1999, Temperature control of mass concrete for dams – Guideline.
- IS 14690:1999, Quality control during construction of earth and rockfill dams – Recommendations.
- IS 14954:2001, Distress and remedial measures in earth and rockfill dams – Guidelines.
- (You can group these as “Relevant IS Codes: Earth and Rockfill Dams” in the syllabus list.)

2. C. Venkatramaiah, Geotechnical Engineering, New Age International (P) Ltd., 6th Edition (latest revised reprint; base revised edition 2006).
3. Braja M. Das, Nagaratnam Sivakugan, Principles of Foundation Engineering, Cengage Learning, 9th Edition, 2019; note that some catalogues now show updated printing with 10th Edition, 2024, under Cengage Learning, Boston.
4. R. F. Craig, Jonathan Knappett, Craig’s Soil Mechanics, CRC Press (Taylor & Francis Group), 9th Edition, 2020

Web links and Video Lectures (e-Resources)

1. NPTEL courses on Geotechnical Engineering and Dam Engineering.
2. SWAYAM online courses related to Earth Dams and Foundation Engineering.
3. U.S. Bureau of Reclamation technical manuals and dam engineering resources.
4. ICOLD publications on dam safety and rehabilitation.
5. GeoStudio and PLAXIS tutorials for seepage and slope stability analysis.

Teaching-Learning Process (Innovative Delivery Methods):

2 The follow

ing are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course

outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Seepage analysis and stability assessment of an earth or embankment dam using analytical methods or GeoStudio/PLAXIS.	24
2	Prepare a case study on earth dam failures (piping, slope instability, settlement or overtopping) with recommendations for rehabilitation.	24
3	Design assignment on filters, drains, zoned embankments and seepage control systems for a selected dam project.	24
4	Evaluate instrumentation, monitoring techniques and dam safety measures for an existing earth dam.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete a MOOC (NPTEL/SWAYAM) on Dam Engineering, Geotechnical Engineering or Embankment Design.	24
2	Review recent research papers on seepage control, slope stability, dam safety or seismic performance of embankment dams.	24
3	Learn GeoStudio or PLAXIS through online tutorials and prepare a technical report on seepage or stability analysis.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

DEEP EXCAVATION AND RETAINING STRUCTURES			
Course Code	**1MCGT205F**	**Scheme**	**2026**
Type of Course	*Professional Elective Course (PEC)*	**Semester**	*II*
Teaching Hours/Week (L:T:P)	*42 (3:0:0)*	**CIE Marks**	*50*
Total Hours of Pedagogy per Semester CI (L/T): LI(P):TW&SL	*90 (42:0:0:48)*	**SEE Marks**	*50*
Credits	*03*	**Total Marks**	*100*
Type of Examination (SEE)	*Theory*	**Exam Hours**	*03*

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the principles, behavior, and applications of deep excavation systems and retaining structures in geotechnical engineering.
2. **CO2:** Analyze lateral earth pressures, excavation support systems, and stability under static and dynamic loading conditions.
3. **CO3:** Design retaining structures such as sheet pile walls, diaphragm walls, braced excavations, anchored systems, and reinforced earth structures.
4. **CO4:** Evaluate groundwater effects, deformation behavior, and soil–structure interaction associated with deep excavations.
5. **CO5:** Apply numerical and analytical methods to assess the performance of excavation support systems under practical field conditions.
6. **CO6:** Critically evaluate deep excavation projects and recommend safe, economical, and sustainable retaining solutions using modern engineering practices.

Module-1

Introduction to Deep Excavation and Earth Pressure Theories

- *Fundamentals of deep excavations, need, scope, and applications in urban infrastructure, metro systems, tunnels, basements, and underground construction.*
- *Types of retaining structures, their functions, selection criteria, and applications under different site conditions.*
- *Lateral earth pressure theories including Rankine and Coulomb theories for the evaluation of earth pressures on retaining structures.*
- *Active, passive, and at-rest earth pressures, including the influence of surcharge loads and external loading conditions.*
- *Earth pressures under seismic loading, stability analysis of retaining walls, and design considerations for safe excavation systems.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Sheet Pile Walls and Braced Excavations

- *Types, behaviour, and design principles of cantilever and anchored sheet pile walls for deep excavation support.*
- *Braced excavations, cofferdams, and temporary support systems used in urban construction projects. Apparent earth pressure diagrams and their application in the design of excavation support systems.*
- *Design of structural components including struts, wales, tie rods, and anchorage systems for braced excavations.*
- *Excavation sequences, construction procedures, stability assessment, and performance evaluation of braced excavation systems.*

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Advanced Retaining Systems

- *Design principles and applications of diaphragm walls, contiguous pile walls, and secant pile walls in deep excavations.*
- *Anchored retaining systems, tieback anchors, and their behaviour under static and dynamic loading conditions.*
- *Reinforced earth retaining structures, soil nailing techniques, and ground reinforcement methods for excavation support.*
- *Excavation-induced ground movements, settlement behaviour, and their effects on adjacent structures and utilities.*
- *Instrumentation, monitoring techniques, and performance evaluation of deep excavation and retaining systems.*

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Groundwater Control and Excavation Stability

- *Groundwater problems associated with deep excavations, seepage forces, piping, boiling, and related failure mechanisms.*
- *Dewatering techniques including well point systems, deep wells, ejector systems, and groundwater control methods.*
- *Stability analysis of excavations considering uplift pressure, basal heave, seepage effects, and groundwater conditions.*
- *Behaviour and stability of excavations in soft clay, sandy soils, and layered soil deposits under different loading conditions.*
- *Safety measures, risk mitigation strategies, and construction practices for safe and stable excavation works.*

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Numerical Analysis and Engineering Applications

- *Fundamentals of Finite Element Method (FEM) and numerical modelling techniques for deep excavation analysis.*
- *Soil–structure interaction concepts and prediction of excavation-induced deformation in retaining systems.*
- *Top-down and bottom-up construction methods, including their advantages, limitations, and field applications.*
- *Excavation risk assessment, monitoring, failure analysis, and remedial measures for deep excavation projects.*
- *Engineering applications and case studies of deep excavations in metro rail, tunnels, underground stations, and basement construction projects.*

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. Braja M. Das, Nagaratnam Sivakugan, Principles of Foundation Engineering, Cengage Learning, 9th Edition, 2019 (SI Edition; more recent 10th Edition SI printings are now available from Cengage).
2. J. E. Bowles, Foundation Analysis and Design, McGraw-Hill Education, 5th Edition, 1997 (widely used International Student Edition, often reprinted around 2001, ISBN 0-07-118844-4).
3. C. Venkatramaiah, Geotechnical Engineering, New Age International (P) Ltd., 6th Edition, latest revised reprint (base revised edition around 2006, subsequently updated and reissued).
4. Gopal Ranjan, A. S. R. Rao, Basic and Applied Soil Mechanics, New Age International (P) Ltd., 5th Edition, 2024 (colour revised edition).
5. H. Y. Fang (editor), Foundation Engineering Handbook, Springer / Springer Science+Business Media, 2nd Edition (revised and expanded), circa early 1990s; still widely cited as a comprehensive reference on foundation engineering practice.

Reference Books

1. M. J. Tomlinson, Foundation Design and Construction, Pearson Education, 7th Edition, 2001.
2. R. F. Craig, Jonathan Knappett, Craig's Soil Mechanics, CRC Press (Taylor & Francis Group), 9th Edition, 2019–2020.
3. Ralph B. Peck, Walter E. Hanson, Thomas H. Thornburn, Foundation Engineering, John Wiley & Sons, 2nd Edition, 1974 (later Wiley reissues; classic text on foundation and earth-retaining structure design).
4. Relevant BIS/IS Codes on earth retaining structures, excavation and foundation engineering (latest active editions), for listing as "Relevant IS Codes":
5. IS 1904:1986, Code of practice for design and construction of foundations in soils – General requirements.
6. IS 12051:1986, Code of practice for design and construction of retaining walls.
7. IS 14593:1998, Design and construction of reinforced soil walls and embankments – Code of practice.
8. IS 3764:1992, Code of safety for excavation work.

Web links and Video Lectures (e-Resources)

1. NPTEL lectures on Deep Excavation and Retaining Structures.
2. SWAYAM courses related to Geotechnical and Foundation Engineering.
3. PLAXIS, GeoStudio and ANSYS tutorials for excavation analysis.
4. IIT lecture videos on retaining structures and excavation support systems.
5. BIS Standards and technical manuals related to retaining structures and foundation engineering.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*
- *Partial Delivery of course by Industry expert/ industrial visits*
- *ICT-Enabled Teaching*
- *Role Play*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Analyze and design a retaining structure (sheet pile wall, diaphragm wall or anchored wall) for a selected excavation project.	*24*
2	Prepare a case study on deep excavation failures, instrumentation and monitoring techniques with recommendations for safe construction.	*24*
3	Perform numerical modelling of deep excavation systems using PLAXIS/GeoStudio and interpret deformation and stability results.	*24*
4	Develop a groundwater control and excavation support plan for a metro, basement or tunnel construction project.	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Complete a MOOC (NPTEL/SWAYAM) on Deep Excavation, Retaining Structures or Foundation Engineering.	*24*

2	Review recent research papers on excavation support systems, soil–structure interaction or retaining wall performance.	*24*
3	Learn PLAXIS or GeoStudio through online tutorials and prepare a technical report on excavation analysis.	*24*

Sample rubrics for TW activities:

Criteria	*4 - Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*
Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*
Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

NUMERICAL MODELLING IN GEOTECHNICAL ENGINEERING			
Course Code	1MCGT206A	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (SEE):	Theory	Exam Hours	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

- **CO1:** Explain the fundamentals of numerical modelling techniques and their applications in geotechnical engineering.
- **CO2:** Develop numerical models for stress–strain analysis, seepage, consolidation, and stability problems using finite element and finite difference methods.
- **CO3:** Apply constitutive soil models and appropriate boundary conditions in geotechnical numerical simulations.
- **CO4:** Analyze geotechnical structures such as foundations, retaining structures, tunnels, and embankments using numerical modelling software.
- **CO5:** Evaluate numerical modelling results through verification, validation, sensitivity analysis, and comparison with analytical or field data.
- **CO6:** Solve practical geotechnical engineering problems using commercial numerical modelling software while interpreting engineering implications and limitations.

Module-1

Introduction to Numerical Modelling in Geotechnical Engineering

- Need for numerical methods in geotechnical engineering.
- Review of continuum mechanics and governing equations.
- Overview of numerical techniques.
- Finite Difference Method (FDM), Finite Element Method (FEM), Boundary Element Method (BEM), and Discrete Element Method (DEM).
- Advantages, limitations, and engineering applications of numerical modelling.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Finite Element Modelling of Geotechnical Problems

- Fundamentals of finite element method and mesh generation.
- Element types, boundary conditions, and loading.
- Stress–strain relationships and constitutive soil models.
- Numerical solution procedures and convergence criteria.
- Modelling of seepage, consolidation, and deformation problems.

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Numerical Analysis of Geotechnical Structures

- Numerical modelling of shallow and deep foundations.
- Analysis of retaining walls and excavation support systems.
- Numerical modelling of slopes and embankments. Tunnel and underground excavation analysis.
- Soil–structure interaction in geotechnical systems.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Advanced Numerical Modelling:

- Coupled hydro-mechanical analysis.
- Dynamic analysis under earthquake loading.
- Unsaturated soil modelling.

- Three-dimensional numerical modelling techniques.
- Model verification, validation, and sensitivity analysis.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Software Applications and Engineering Case Studies

- Numerical modelling using PLAXIS, FLAC, ABAQUS, and MIDAS GTS NX.
- Calibration of numerical models using laboratory and field data.
- Numerical analysis of foundations, tunnels, and earth structures.
- Case studies on geotechnical engineering applications.
- Emerging trends in numerical modelling and AI-based geotechnical analysis.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Text Books

1. D. M. Potts, L. Zdravković, *Finite Element Analysis in Geotechnical Engineering, Volume 1: Constitutive Modelling* and *Volume 2: Application*, Thomas Telford / ICE Publishing, latest available editions.
2. C. S. Desai, J. T. Christian, *Numerical Methods in Geotechnical Engineering*, McGraw-Hill / Taylor & Francis (depending on edition), latest available edition.
3. I. M. Smith, D. V. Griffiths, L. Margetts, *Programming the Finite Element Method*, Wiley-Blackwell, 5th Edition (or latest available edition).

Reference Books

1. O. C. Zienkiewicz, R. L. Taylor, J. Z. Zhu, *The Finite Element Method: Its Basis and Fundamentals*, Butterworth-Heinemann / Elsevier, latest multi-volume edition.
2. K. J. Bathe, *Finite Element Procedures*, Prentice Hall / Klaus-Jürgen Bathe (self-published reprints), latest available edition.
3. D. V. Griffiths, P. A. Lane, *Slope Stability Analysis by Finite Elements*, CRC Press / Taylor & Francis, latest available edition.
4. Itasca Consulting Group, *FLAC – Fast Lagrangian Analysis of Continua: Theory and Background Manual*, Itasca Consulting Group, latest version corresponding to current FLAC
5. R. B. J. Brinkgreve and co-authors, *PLAXIS Material Models Manual*, Plaxis / Bentley Systems, latest version corresponding to current PLAXIS 2D/3D.

Web links and Video Lectures (e-Resources) 1. NPTEL – Geoenvironmental Engineering.

2. NPTEL – Groundwater Hydrology.
3. NPTEL – Environmental Engineering.
4. SWAYAM Courses on Sustainable Infrastructure.
5. Central Ground Water Board (CGWB) Technical Reports.
6. Ministry of Environment, Forest and Climate Change (MoEFCC) Guidelines.
7. Bureau of Indian Standards (BIS): IS 2720 Series, IS 1498, IS 6403, IS 1892.
8. United Nations Sustainable Development Goals (SDGs) Learning Resources

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits ICT-Enabled Teaching

 Role Play

Assessment Structure (both CIE and SEE)
The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.
Continuous Internal Evaluation:
Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]
A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only
As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Develop a finite element model of a shallow foundation, retaining wall, or slope using PLAXIS/FLAC and compare the numerical results with analytical solutions.	24
2	Conduct a parametric study on the influence of soil properties, mesh density, and constitutive models on the behaviour of a selected geotechnical structure and prepare a technical report.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete an NPTEL/SWAYAM course on Finite Element Method, Numerical Methods, or Geotechnical Modelling and prepare a summary report.	24

2	Review recent journal papers on numerical modelling applications in geotechnical engineering and prepare a seminar presentation highlighting modelling approaches, validation techniques, and engineering outcomes.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

Artificial Intelligence and Machine Learning for Geo- Engineering Applications			
Course Code	**1MCGT206B**	*Scheme*	*2026*
Type of Course	**Professional Elective Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (SEE):	*Theory*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** *Explain the fundamentals of Artificial Intelligence (AI), Machine Learning (ML), and data analytics relevant to geo-engineering applications.*
2. **CO2:** *Apply data preprocessing, feature engineering, and supervised learning techniques to solve geotechnical and geo-environmental engineering problems.*
3. **CO3:** *Analyze geotechnical datasets using machine learning algorithms for prediction, classification, and pattern recognition.*
4. **CO4:** *Evaluate the performance of AI and ML models for foundation engineering, slope stability, ground improvement, and geological hazard assessment.*
5. **CO5:** *Assess advanced AI techniques, including deep learning and optimization methods, for solving complex geo-engineering problems.*
6. **CO6:** *Apply AI and ML tools for intelligent decision-making, predictive modelling, and sustainable geotechnical engineering practice.*

Module-1

Introduction to Artificial Intelligence and Machine Learning

- *Introduction to Artificial Intelligence, Machine Learning, and Data Science.*
- *Applications of AI and ML in geotechnical, geological, and geo-environmental engineering.*
- *Types of machine learning: supervised, unsupervised, semi-supervised, and reinforcement learning.*
- *Engineering datasets: collection, preprocessing, normalization, and visualization.*
- *Overview of AI software and programming tools (Python, MATLAB, Scikit-learn).*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Supervised Learning Techniques for Geo-Engineering

- *Regression techniques: Linear Regression, Polynomial Regression.*
- *Classification techniques: Logistic Regression, Decision Trees, Random Forest.*
- *Support Vector Machines (SVM).*
- *Artificial Neural Networks (ANN).*
- *Model evaluation using accuracy, precision, recall, RMSE, MAE, and cross-validation.*

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Unsupervised Learning and Predictive Modelling

- *Clustering techniques: K-Means and Hierarchical Clustering.*
- *Principal Component Analysis (PCA) for dimensionality reduction.*
- *Feature selection and feature importance.*
- *Predictive modelling of soil properties, bearing capacity, settlement, and permeability.*
- *Comparison of conventional empirical methods and AI-based prediction models.*

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

AI Applications in Geo-Engineering

- *AI applications in foundation design and settlement prediction.*
- *Machine learning for slope stability assessment and landslide susceptibility mapping.*
- *AI-based prediction of liquefaction potential.*
- *Intelligent monitoring of tunnels, retaining structures, and earth dams.*
- *Geographic Information Systems (GIS) and Remote Sensing integrated with AI.*

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Advanced AI Techniques and Engineering Applications

- *Deep Learning concepts and Convolutional Neural Networks (CNN).*
- *Optimization techniques: Genetic Algorithms (GA) and Particle Swarm Optimization (PSO).*
- *Explainable AI (XAI) and ethical considerations in engineering.*
- *Digital Twins and AI-enabled geotechnical monitoring systems.*
- *Case studies on AI applications in geotechnical, transportation, mining, and geo-environmental engineering.*

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. *Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 1st Edition, 2016.*
2. *Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow, O'Reilly Media, 3rd Edition, 2023.*
3. *Andriy Burkov, The Hundred-Page Machine Learning Book, Andriy Burkov (self-published through Leanpub / Amazon), 1st Edition, 2019 (with subsequent corrected printings).*

Reference Books

1. *Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 1st Edition, 2006 (Information Science and Statistics series).*
2. *Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer Series in Statistics, 2nd Edition, 2009 (latest widely used edition).*
3. *Jürgen Schmidhuber, Deep Learning in Neural Networks: An Overview, Neural Networks, Vol. 61, pp. 85–117, 2015 (survey article; arXiv:1404.7828).*
4. *Pijush Samui, S. Sekhar, V. E. Balas (eds.), Handbook of Neural Computation, Elsevier / Academic Press, 1st Edition, 2017 (includes applications in civil and geotechnical engineering).*
5. *M. A. Shahin, M. B. Jaksa, H. R. Maier, Artificial Neural Network Applications in Geotechnical Engineering, key review paper in Australian Geomechanics, Vol. 36(1), pp. 49–62, 2001 (often cited under the broader theme "Artificial Intelligence Applications in Geotechnical Engineering").*

Web links and Video Lectures (e-Resources)

1. *NPTEL – Artificial Intelligence.*
2. *NPTEL – Machine Learning.*
3. *NPTEL – Python for Data Science.*
4. *SWAYAM Courses on Artificial Intelligence and Machine Learning.*

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped Classroom*
- *Problem-Based Learning (PBL)*
- *Case-Based Teaching*
- *Simulation and Virtual Labs*
- *Partial Delivery of course by Industry expert/ industrial visits*

2

- *ICT-Enabled Teaching*
- *Role Play*

Assessment Structure (both CIE and SEE)
The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.
Continuous Internal Evaluation:
Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]
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Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**Machine Learning Model Development:** *Develop a regression or classification model using geotechnical datasets to predict soil properties, bearing capacity, settlement, or slope stability, and compare the performance of different algorithms.*	*24*
2	**AI-Based Geotechnical Data Analytics Assignment:** *Collect and preprocess geotechnical field or laboratory data, perform feature selection, train machine learning models, and evaluate prediction accuracy using appropriate performance metrics.*	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	*Complete an NPTEL/SWAYAM module on Artificial Intelligence, Machine Learning, or Python for Data Science and prepare a technical report.*	*24*

2	*Develop a concept map illustrating AI, machine learning algorithms, deep learning, optimization techniques, GIS integration, and their applications in geo-engineering.*	*24*

3 **Sample rubrics for TW activities:**

Criteria	*4 - Excellent*	*3 - Good*	*2 - Satisfactory*	*1 - Needs Improvement*
Problem understanding	*Clear problem framing with strong justification.*	*Mostly clear with minor gaps.*	*Basic attempt with limited clarity.*	*Poorly defined problem.*
Data and method	*Appropriate data and sound methodology.*	*Mostly appropriate with minor issues.*	*Limited data or partial method.*	*Inadequate or incorrect method.*
Analysis	*Robust interpretation and valid results.*	*Generally sound with minor errors.*	*Partial analysis with gaps.*	*Weak or incorrect analysis.*
Recommendations	*Strong, feasible, and contextspecific.*	*Relevant with minor limitations.*	*Generic recommendations.*	*Incomplete or unrealistic.*

Presentation	*Well organized and professional.*	*Good organization with minor issues.*	*Acceptable but uneven.*	*Poorly presented.*

SOIL STRUCTURE INTERACTION			
Course Code	**1MCGT206C**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PEC):	Theory	Exam Hours	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** Explain the fundamentals, objectives, significance, and principles of Soil–Structure Interaction (SSI), including the behavior of fixed-base and flexible-base structures.
2. **CO2:** Analyze the fundamental mechanisms of Soil–Structure Interaction, including substructure analysis, kinematic interaction, inertial interaction, and the effects of foundation embedment.
3. **CO3:** Apply discrete and continuum soil models to represent soil–structure interaction and evaluate their suitability for engineering applications.
4. **CO4:** Analyze the dynamic behavior and stiffness characteristics of surface, embedded, shallow, and deep foundations subjected to dynamic loading.
5. **CO5:** Evaluate the effects of material and geometric nonlinearities, including soil–pile–structure interaction, on the seismic and dynamic response of engineering structures.
6. **CO6:** Apply Soil–Structure Interaction principles and dynamic analysis techniques to solve practical foundation engineering problems and assess the performance of structures under static and earthquake loading.

Module-1

Introduction to Soil–Structure Interaction:

- Objectives, practical significance, and importance of Soil–Structure Interaction (SSI).
- Concept of fixed base structures and assumptions in conventional structural analysis.
- Behavior of structures resting on soft ground and influence of soil flexibility.
- Introduction to soil–foundation–structure interaction under static and dynamic loading.
- Modelling of unbounded (semi-infinite) soil media and associated challenges.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Fundamentals of Soil–Structure Interaction:

- Rational methods of substructure analysis and principles of SSI.
- Equation of motion for rigid base and flexible base systems.
- Kinematic interaction and its effects on structural response.
- Inertial interaction between soil and structure during dynamic loading.
- Effect of foundation embedment on the dynamic behavior of structures

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Modelling of Soil–Structure Interaction:

- Discrete soil models: Winkler, Pasternak, Filonenko-Borodich, Hetenyi, Kerr, and Rhines models.
- Continuum soil models: Vlazov, Reissner, Biot, Gorbunov, and Posadov models.
- Comparison between discrete and continuum modelling approaches.
- Selection of appropriate soil models for engineering applications. Modelling of boundaries and simulation of infinite soil domains.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Dynamic Analysis of Structure and Foundation:

- Dynamic stiffness characteristics of surface foundations.
- Dynamic behavior of embedded foundations.
- Analysis of shallow (strip) foundations subjected to dynamic loads.
- Dynamic response of deep (pile) foundations.
- Foundation impedance functions and their significance in SSI analysis

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Nonlinear Analysis and Engineering Applications:

- Material nonlinearity of soil and constitutive behavior.
- Geometrical nonlinearity in soil–foundation–structure systems.
- Soil–pile–structure interaction under dynamic loading.
- Engineering applications of dynamic Soil–Structure Interaction in buildings, bridges, and industrial structures.
- Case studies and practical considerations in dynamic SSI analysis.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. P. S. Selvadurai, Elastic Analysis of Soil–Foundation Interaction, Elsevier Scientific Publishing Company / Elsevier–North Holland, 1st Edition, 1979 (Developments in Geotechnical Engineering, Vol. 17; later reprinted by Elsevier Science & Technology).
2. J. E. Bowles, Foundation Analysis and Design, McGraw-Hill Education, 5th Edition, 1997 (widely used International Student Edition, often reprinted around 2001, ISBN 0-07-118844-4).
3. Indrajit Chowdhury, S. P. Dasgupta, Dynamics of Structure and Foundation – A Unified Approach, CRC Press / Taylor & Francis Group, two-volume set (Vol. 1: Fundamentals; Vol. 2: Applications), latest available edition. **Reference Books**

1. M. J. Tomlinson, Foundation Design and Construction, Pearson Education, 7th Edition, 2001 (earlier 5th–6th editions widely cited; comprehensive manual for practicing engineers).
2. N. P. Kurian, Design of Foundation Systems – Principles and Practices, Narosa Publishing House, 3rd Edition, 2005 (originally published 1992; widely used Indian text on integrated soil–structure design).
3. J. W. Bull (ed.), Soil–Structure Interaction: Numerical Analysis and Modelling, CRC Press / Taylor & Francis, 1st Edition, 1994 (reissued as eBook and paperback in later years).
4. C. S. Desai, J. T. Christian (eds.), Numerical Methods in Geotechnical Engineering, McGraw-Hill Book Company, 1st Edition, 1977 (783 pages; classic edited volume on FEM and numerical modelling in geomechanics).

Web links and Video Lectures (e-Resources) *1.* IPCC reports and summaries for policymakers.

2. NPTEL lectures on Soil-Structure Interaction and Foundation Engineering
3. NPTEL – Soil Mechanics and Foundation Engineering Video Lectures.
4. NPTEL – Structural Dynamics and Earthquake Engineering Courses.
5. SWAYAM Online Courses on Geotechnical Engineering and Soil–Structure Interaction.
6. National Information Centre of Earthquake Engineering (NICEE), IIT Kanpur – Lecture Notes and Learning Resources.
7. Bureau of Indian Standards (BIS) – IS 1893:2016, IS 2911, IS 6403, and IS 1904 Codes.
8. OpenSees Official Documentation and Tutorials for SSI Modelling.

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)
The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.
Continuous Internal Evaluation:
Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]
A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.
In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only
As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl.	Term Work (TW) Activity	Number of Hours / No.	Semester 1	Soil–Structure Interaction
Modelling Exercise:	24			
	Model a simple soil–foundation–structure system using discrete or continuum approaches and compare the response with a fixed-base structure.			
2	**Foundation Dynamic Analysis Assignment:**	24		
	Analyze the dynamic response of surface, embedded, shallow, or pile foundations under static and dynamic loading conditions, and evaluate foundation stiffness characteristics.			
3	**Soil–Structure Interaction Case Study:**	24		
	Prepare a case study on the performance of buildings, bridges, or industrial structures considering soil–structure interaction effects during earthquake loading.			
				3

4 **Nonlinear SSI Mini-Project:** 24
Investigate the influence of material and geometric nonlinearities, soil–pile–structure interaction, or foundation embedment on the seismic performance of a selected structure using analytical or numerical methods.

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl.	Self-Learning (SL) Activity	Number of Hours / No.	Semester
1	Read selected IPCC summary sections and prepare a reflective note.	24	
2	Develop a concept map on risk, vulnerability, and resilience.	24	
3	Complete a MOOC module on climate change or disaster risk reduction.	24	

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

DISASTER RISK REDUCTION IN GEO-INFRASTRUCTURES			
Course Code	**1MCGT206D**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (SEE):	Theory	Exam Hours	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** Explain the concepts of disaster risk, hazard, vulnerability, resilience, and disaster risk reduction (DRR) in geo-infrastructure systems.
2. **CO2:** Analyze geotechnical hazards such as landslides, earthquakes, floods, liquefaction, erosion, and subsidence affecting geo-infrastructure.
3. **CO3:** Evaluate the vulnerability and resilience of foundations, embankments, retaining structures, slopes, tunnels, and transportation infrastructure under multi-hazard conditions.
4. **CO4:** Apply geotechnical investigation, monitoring, numerical modelling, and GIS-based techniques for disaster risk assessment and mitigation planning.
5. **CO5:** Design disaster-resilient geo-infrastructure using modern engineering practices, risk management strategies, and relevant national and international guidelines.
6. **CO6:** Integrate sustainability principles, climate adaptation, digital technologies, Industry 5.0 concepts, and professional engineering practices into disaster risk reduction for geo-infrastructure.

Module-1

Introduction to Disaster Risk Reduction in Geo-Infrastructures

- Introduction to disasters, disaster management, hazard, vulnerability, resilience, and Disaster Risk Reduction (DRR).
- Natural and anthropogenic geotechnical hazards affecting geo-infrastructure.
- Disaster risk assessment framework, exposure, capacity, and resilience concepts.
- Sendai Framework, Sustainable Development Goals (SDGs), and climate-resilient infrastructure.
- Role of geotechnical engineers in disaster mitigation and resilient infrastructure development.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Geotechnical Hazards and Risk Assessment

- Earthquake-induced ground failures, soil liquefaction, and lateral spreading.
- Landslides, slope failures, land subsidence, and sinkholes.
- Flood-induced erosion, scour, coastal hazards, and shoreline instability.
- Hazard zonation, vulnerability assessment, and risk mapping.
- Applications of GIS, Remote Sensing, and geospatial techniques in disaster risk assessment.

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Vulnerability Assessment of Geo-Infrastructure

- Vulnerability assessment of shallow and deep foundations, retaining walls, embankments, and earth dams. Assessment of transportation infrastructure, tunnels, and underground structures under disaster conditions.
- Lifeline infrastructure resilience and post-disaster performance evaluation.
- Geotechnical monitoring using inclinometers, piezometers, settlement markers, UAVs, LiDAR, and remote sensing.
- Performance evaluation, resilience assessment, and infrastructure rehabilitation planning.

Linked COs: CO3 **Number of Hours: 9 hrs**

1

Module-4
Disaster Mitigation and Resilient Geotechnical Design • Slope stabilization techniques and ground improvement methods for hazard mitigation. • Seismic design of foundations, retaining structures, and flood protection systems. • Riverbank stabilization, erosion control, and bio-engineering techniques. • Early warning systems and disaster preparedness for geo-infrastructure. • Risk-informed geotechnical design and resilient engineering practices. **Linked COs: CO4** **Number of Hours: 8 hrs**
Module-5
Advanced Technologies and Engineering Applications • Numerical modelling for disaster simulation and soil-structure interaction analysis. • Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), and Digital Twins in disaster management. • Climate change adaptation and sustainable geotechnical engineering aligned with SDGs and Industry 5.0. • Post-disaster damage assessment and rehabilitation of geo-infrastructure. • Case studies on disaster-resilient infrastructure, including earthquakes, landslides, floods, and urban geotechnical failures. **Linked COs: CO5, CO6** **Number of Hours: 8 hrs**

Suggested Learning Resources

Text Books

1. W. H. K. Lee, H. Kanamori, P. C. Jennings, C. Kisslinger (eds.), *International Handbook of Earthquake and Engineering Seismology*, Academic Press (Elsevier), Part A (2002) and Part B (2003).
2. Steven L. Kramer, Jonathan P. Stewart, *Geotechnical Earthquake Engineering*, originally Prentice Hall; latest fully updated edition in the Springer Series in Geomechanics and Geoengineering (2nd Edition), 2024.
3. J. Michael Duncan, Stephen G. Wright, Thomas L. Brandon, *Soil Strength and Slope Stability*, John Wiley & Sons, 2nd Edition, 2014.
4. Ikuo Towhata, *Geotechnical Earthquake Engineering*, Springer, Springer Series in Geomechanics and Geoengineering, 1st Edition, 2008 (latest reprints with corrections.
5. Robert D. Holtz, William D. Kovacs, Thomas C. Sheahan, *An Introduction to Geotechnical Engineering*, Prentice Hall / Pearson, 2nd Edition, 2010

Reference Books / Codes / Guidelines

1. FEMA publications on disaster risk reduction, including *Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards* and other FEMA mitigation and risk-reduction guidance documents.
2. NDMA (India) Guidelines on landslides, earthquakes and floods, including: *Guidelines on Management of Landslides and Snow Avalanches* (2009), *Guidelines on Management of Earthquakes* (2007), *Guidelines on Management of Floods* (2008), and *Landslide Risk Management Strategy* (2019)
3. IS 1893 (Part 1):2016, *Criteria for Earthquake Resistant Design of Structures – Part 1: General Provisions and Buildings*, Bureau of Indian Standards (latest active seismic design code in practice).
4. IS 6403:1981 (reaffirmed), *Code of practice for determination of bearing capacity of shallow foundations*, Bureau of Indian Standards.
5. IS 14458 (Parts 1–8), *Retaining Wall for Hill Area – Guidelines* (selection, design and construction of various wall types including gabion and RCC walls), Bureau of Indian Standards, latest parts and revisions up to 2025.services.bis.gov+2
6. IS 14804, *Guidelines for ground improvement* (Indian Standard on ground improvement; latest status and text to be taken from BIS CED-43/CED-56 listings when finalizing the syllabus).
7. UNESCO disaster risk reduction manuals and resources on risk management and heritage/infrastructure protection, as compiled in UNESCO's DRR resource portals.

2

Teaching-Learning Process (Innovative Delivery Methods):

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- Simulation and Virtual Labs
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- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Hazard and vulnerability assessment of a selected geo-infrastructure using GIS/Remote Sensing and preparation of technical report.	24
2	Disaster risk assessment and mitigation plan for a slope, retaining wall, embankment or transportation corridor considering climate resilience and sustainability.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete an NPTEL/SWAYAM course on Disaster Management, Geotechnical Earthquake Engineering or Climate Resilience and submit a learning report.	24
2	Review an international journal paper on disaster-resilient geo-infrastructure emphasizing sustainability, Industry 5.0, AI, Digital Twins and engineering innovations.	24

3 **Sample rubrics for TW activities:**

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

4

PROBABILITY AND RELIABILITY IN GEOTECHNICAL ENGINEERING			
Course Code	**1MCGT206E**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (SEE):	Theory	Exam Hours	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** Explain the fundamentals of probability, statistics, uncertainty, and reliability concepts relevant to geotechnical engineering.
2. **CO2:** Apply probability distributions, statistical methods, and reliability indices to evaluate uncertainty in soil properties and geotechnical parameters.
3. **CO3:** Analyze reliability of geotechnical systems using Level I and Level II reliability methods and probabilistic approaches.
4. **CO4:** Evaluate reliability-based design of shallow foundations, slopes, retaining structures, and earth dams under uncertain loading and soil conditions.
5. **CO5:** Analyze risk, failure probability, and system reliability of geotechnical structures considering spatial variability and model uncertainty.
6. **CO6:** Apply reliability-based approaches and probabilistic methods for decision-making, design optimization, and performance assessment of geotechnical engineering systems.

Module-1

Introduction to Probability and Reliability in Geotechnical Engineering

Need for probability and reliability concepts in geotechnical engineering.

- Sources of uncertainty in geotechnical investigations and design.
- Types of uncertainties: inherent variability, statistical uncertainty, model uncertainty, and human errors.
- Basic probability concepts, random variables, probability distributions, and statistical parameters.
- Applications of probability and reliability in geotechnical engineering practice.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Statistical Methods and Reliability Fundamentals

- Descriptive statistics for geotechnical data.
- Probability distributions used in geotechnical engineering (Normal, Lognormal, Exponential, Gamma, Weibull).
- Correlation, covariance, regression, and hypothesis testing.
- Reliability concepts: limit state function, probability of failure, reliability index.
- First Order Second Moment (FOSM) method and reliability assessment.

Linked COs: CO2 **Number of Hours: 8 hrs**

Module-3

Reliability Analysis Methods

- Reliability-Based Design Philosophy
- Uncertainties in loads and resistances, limit-state function, failure probability and reliability index (concept only).
- Level I Reliability Methods
- Safety-factor based design (ASD, LRFD), characteristic values, partial safety factors, limitations in quantifying actual safety.
- Level II Methods – FORM
- Idea of transforming to standard normal space, design point (MPP), reliability index β, qualitative link to Pf.

1

- **Monte Carlo Simulation & Numerical Methods**
- Basic steps: sampling random variables, evaluating limit state, estimating P_f; pros and cons compared to FORM.
- **Sensitivity & Deterministic vs Probabilistic Design**
- Concept of variable influence on reliability, qualitative comparison of factor-of-safety design versus reliability-based design in terms of safety and economy.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Reliability of Geotechnical Systems:

- *Geotechnical uncertainty: soil variability, limited site data, model and construction uncertainties.*
- *Limit states: bearing failure, settlement, slope failure, sliding/overturning, seepage/piping.* ❖ **Shallow and Pile Foundations**
- *Reliability of shallow foundations: bearing capacity and settlement as limit states; key random variables (soil strength, loads, dimensions).*
- *Reliability of pile foundations: axial and lateral capacity; variability in soil layers, pile properties, and load effects.*

❖ **Slopes, Embankments, Retaining Walls, Earth Dams**

- *Reliability of slopes and embankments: factor of safety vs probability of failure; influence of shear strength and pore pressure uncertainty.*
- *Reliability of retaining walls and earth dams: sliding, overturning, bearing, deformation, seepage and piping considered as failure modes.*

❖ **System Reliability in Geotechnical Engineering**

- *Series and parallel systems: multiple elements and failure modes in foundations, slopes, and dams.*
- *Qualitative understanding of how component reliability combines at system level.*

Linked COs: CO4 **Number of Hours: 9 hrs**

Module-5

Risk Assessment and Engineering Applications

- Risk analysis and risk management in geotechnical engineering.
- Spatial variability of soil properties.
- Bayesian updating and decision-making under uncertainty.
- Reliability-based design optimization (RBDO).
- Case studies on reliability assessment of foundations, slopes, tunnels, and earth-retaining structures.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Textbooks

1. A. H-S. Ang, W. H. Tang, *Probability Concepts in Engineering Planning and Design* (Vol. 1: Basic Principles; Vol. 2: Decision, Risk and Reliability), John Wiley & Sons, classic 1975 two-volume set; more recent combined 2nd Edition under the title *Probability Concepts in Engineering* (2011).
2. Gregory B. Baecher, John T. Christian, *Reliability and Statistics in Geotechnical Engineering*, John Wiley & Sons, 1st Edition, 2003
3. M. E. Harr, *Probabilistic Estimates for Multivariate Analyses in Geotechnical Engineering* (often cited together with Harr's earlier texts on reliability and probability in civil engineering; published by McGraw-Hill

Reference Books

1. J. T. Christian, *Geotechnical Engineering Reliability* (monograph and selected papers / chapters; the theme is often represented through Christian's contributions in reliability texts and TC304 reference lists—can be

cited generically as "Christian, J.T. – Geotechnical Engineering Reliability" in the syllabus).

2. Gordon A. Fenton, D. V. Griffiths, *Risk Assessment in Geotechnical Engineering*, John Wiley & Sons, 1st Edition, 2008.
3. Kok-Kwang Phoon (Ed.), *Reliability-Based Design in Geotechnical Engineering: Computations and Applications*, CRC Press, 1st Edition, 2008.
4. J. Michael Duncan, Stephen G. Wright, Thomas L. Brandon, *Soil Strength and Slope Stability*, John Wiley & Sons, 2nd Edition, 2014.

Web links and Video Lectures (e-Resources)

1. NPTEL – Probability and Statistics (core mathematics course for engineering; available via NPTEL/SWAYAM with full video lectures and notes).
2. NPTEL – Reliability Engineering (Computer Science & Engineering course covering probability distributions, statistical inference and reliability methods, useful as support for reliability-based geotechnical design).
3. NPTEL – Geotechnical Engineering and related civil engineering web/video courses (Soil Mechanics, Geotechnical Engineering I & II, Earthquake Geotechnical Engineering, Soil Dynamics, Slope Stability), offered through NPTEL.
4. SWAYAM courses on Reliability Engineering and Probability and Statistics (NPTEL-hosted MOOCs on the SWAYAM platform providing credit-linked reliability and probability content).
5. IIT Kanpur NPTEL / online lectures on Foundation Design / Foundation Engineering (e.g., NPTEL course "NOC: Foundation Design" by Prof. Nihar Ranjan Patra, IIT Kanpur).

Teaching-Learning Process (Innovative Delivery Methods):

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3

TW/SL activities as per the course outcomes.		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	**Statistical Analysis of Geotechnical Data:** Collect field or laboratory soil data and determine probability distributions, mean, variance, and confidence intervals.	24
2	**Reliability Analysis Assignment:** Evaluate reliability index and probability of failure for shallow foundations, slopes, or retaining walls using FOSM or FORM methods.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Complete an NPTEL/SWAYAM module on Probability, Statistics, or Reliability Engineering and prepare a report.	24
2	Develop a concept map illustrating uncertainty, reliability, risk, probability of failure, and reliability-based design in geotechnical engineering.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.

Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

SUSTAINABLE GEOTECHNICS AND GROUNDWATER PROTECTION			
Course Code	**1MCGT206F**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (SEE):	Theory	Exam Hours	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. **CO1:** Explain the principles of sustainable geotechnics, groundwater systems, and environmental considerations in geotechnical engineering.
2. **CO2:** Analyze the impact of geotechnical engineering activities on groundwater quality and quantity using hydrogeological and environmental assessment methods.
3. **CO3:** Apply sustainable ground improvement techniques, waste utilization methods, and eco-friendly construction materials in geotechnical engineering.
4. **CO4:** Evaluate groundwater protection measures, contaminant transport mechanisms, and remediation techniques for sustainable infrastructure development.
5. **CO5:** Assess the environmental performance of geotechnical systems using sustainability indicators, lifecycle assessment, and risk evaluation methods.
6. **CO6:** Apply sustainable geotechnical practices and groundwater management strategies to solve practical engineering problems while complying with environmental regulations

Module-1

Introduction to Sustainable Geotechnics

- Concepts and principles of sustainable geotechnical engineering.
- Sustainable development goals (SDGs) and their relevance to geotechnical engineering.
- Environmental impacts of geotechnical construction activities.
- Soil, groundwater, and ecosystem interactions.
- Role of geotechnical engineers in sustainable infrastructure development.

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Groundwater Systems and Protection

- Fundamentals of groundwater hydrology and aquifer systems.
- Groundwater flow and recharge mechanisms.
- Sources and types of groundwater contamination.
- Contaminant transport in soils and groundwater.
- Groundwater monitoring, quality assessment, and protection strategies.

Linked COs: CO2 **Number of Hours: 8 hrs**

Module-3

Sustainable Ground Improvement and Geoenvironmental

Engineering □ Sustainable ground improvement techniques.

- Bio-mediated and bio-cementation methods.
- Use of recycled materials and industrial by-products in geotechnical applications.
- Geosynthetics for sustainable infrastructure.
- Design of liners and barriers for waste containment systems.

Linked COs: CO3 **Number of Hours: 9 hrs**

Sustainable Ground Improvement and Geoenvironmental Engineering

- Sustainable ground improvement techniques.
- Bio-mediated and bio-cementation methods.
- Use of recycled materials and industrial by-products in geotechnical applications.
- Geosynthetics for sustainable infrastructure.
- Design of liners and barriers for waste containment systems.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Groundwater Remediation and Environmental Protection

- Soil and groundwater remediation techniques.
- Pump-and-treat systems.
- In-situ and ex-situ remediation methods.
- Permeable reactive barriers.
- Landfill engineering, leachate control, and groundwater protection measures.

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Sustainability Assessment and Engineering Applications

- Life Cycle Assessment (LCA) in geotechnical engineering.
- Carbon footprint and embodied energy of geotechnical works.
- Environmental Impact Assessment (EIA) for geotechnical projects.
- Sustainable design of foundations, embankments, and earth structures.
- Case studies on sustainable geotechnical engineering and groundwater protection.

Linked COs: CO5, CO6 **Number of Hours: 8 hrs**

Suggested Learning Resources

Text Books:

1. Charles W. Fetter, *Applied Hydrogeology*, Pearson Education, 4th Edition (2014), with newer 5th Edition (co-authored with David Kreamer)
2. R. Kerry Rowe (ed.), *Geotechnical and Geoenvironmental Engineering Handbook*, Springer, 1st Edition, 2001.
3. C. W. Fetter, *Contaminant Hydrogeology*, Waveland Press / Macmillan, 2nd–3rd Editions (e.g., 2nd Edition 1999; 3rd Edition 2008), latest available edition.

Reference Books

1. David E. Daniel (ed.), *Geotechnical Practice for Waste Disposal*, Springer Science & Business Media, 1st Edition, 1993.
2. Hari D. Sharma, Sangeeta P. Lewis, *Waste Containment Systems, Waste Stabilization and Landfills: Design and Evaluation*, John Wiley & Sons, 1st Edition, 1994.
3. Lakshmi N. Reddi, Hilary I. Inyang, *Geoenvironmental Engineering: Principles and Applications*, CRC Press, 1st Edition, 2000.
4. Robert M. Koerner, *Designing with Geosynthetics*, Prentice Hall / Xlibris, 5th Edition, 2005 (later printings and online versions as the principal geosynthetics design reference)
5. Donald P. Coduto, Man-chu Ronald Yeung, William A. Kitch, *Geotechnical Engineering: Principles and Practices*, Pearson Education, 2nd Edition, 2011 (original 1st Edition 1999; multiple later printings).

Web links and Video Lectures (e-Resources)

1. NPTEL – Geoenvironmental Engineering / Geo-environmental Engineering (web and video course on geotechnical aspects of waste containment, landfills, slurry ponds and contaminated sites).
2. NPTEL – Ground Water Hydrology and Groundwater Hydrology and Management (courses covering occurrence and movement of groundwater, well hydraulics, contamination, artificial recharge and modelling).
3. NPTEL – Environmental Engineering (civil/chemical engineering courses on water and wastewater treatment, solid waste management, air pollution and environmental impact).
4. SWAYAM Courses on Sustainable Infrastructure (NPTEL/UGC/AICTE hosted MOOCs focusing on sustainable infrastructure, environment and climate-resilient development; to be cited generically as "SWAYAM sustainable infrastructure courses via SWAYAM Central").
5. Central Ground Water Board (CGWB) – Technical Reports and Publications (e.g., Dynamic Ground Water Resources of River Basins of India, annual Ground Water Year Books, Ground Water Quality Reports, aquifer mapping atlases; accessible via CGWB publications portal).
6. Ministry of Environment, Forest and Climate Change (MoEFCC) – Guidelines and Notifications (e.g., EIA Notification 2006 and subsequent amendments for environmental clearance, sectoral guidelines relevant to infrastructure and waste management).
7. Bureau of Indian Standards (BIS) – geotechnical and soil testing codes:

- IS 2720 series, Methods of Test for Soils (Part 1–41 covering classification, compaction, permeability, shear strength, consolidation, etc.).
- IS 1498, Classification and Identification of Soils for General Engineering Purposes.
- IS 6403:1981, Code of practice for determination of bearing capacity of shallow foundations.
- IS 1892:1978, Code of practice for subsurface investigation for foundations.

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)
The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.
Continuous Internal Evaluation:
Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]
A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA. In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only
As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**Groundwater Quality Assessment:** Collect and analyze groundwater quality data from a selected area and evaluate potential contamination sources and protection measures.	24
2	**Sustainable Ground Improvement Study:** Compare conventional and sustainable ground improvement techniques for a selected geotechnical project considering environmental and economic aspects.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Complete an NPTEL/SWAYAM module on Geoenvironmental Engineering, Groundwater Hydrology, or Sustainable Infrastructure and prepare a technical report.	24

2	Develop a concept map illustrating sustainable geotechnics, groundwater flow, contamination pathways, remediation techniques, and environmental regulations.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

EXPERIMENTAL GEOTECHNICAL DESIGN LABORATORY			
Course Code	**1MCGTL207**	Scheme	2026
Type of course	Professional Core Course Lab	Semester	II
Teaching Hours/Week (L:T:P)	2(0: 0: 2)	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL:TW	30(0: 0:28:2)	SEE Marks	50
Credits	1	Total Marks	100
Type of Examination (SEE)	**Practical**	Exam Hours	3

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Apply geotechnical design principles to determine safe bearing capacity and design suitable foundations, retaining structures, embankments and ground improvement systems.
2. CO2: Interpret laboratory test data to evaluate stress–strain behaviour, permeability, settlement and expansive soil response.
3. CO3: Analyse the influence of soil type, groundwater condition and loading on foundation performance, seepage, stability and deformation.
4. CO4: Select and justify appropriate geotechnical solutions such as drainage, stabilization, reinforcement and ground improvement for weak or problematic soils.
5. CO5: Prepare complete geotechnical design sheets and laboratory reports with calculations, sketches, observations and engineering conclusions.
6. CO6: Communicate experimental findings and design recommendations effectively through presentations, viva voce and technical discussions.

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6-8 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **80 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **20 marks.**

For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A : FIXED EXPERIMENTS

Students shall complete following experiments in the laboratory.

1. Stress–strain behaviour using triaxial or laboratory data

- Students will conduct or analyse triaxial test data to study the stress–strain response of soils under different drainage conditions. They will determine parameters such as shear strength, cohesion, angle of internal friction and interpret the behavioural pattern of the soil sample. COs: CO2, CO3, CO5

2. Permeability and seepage characteristics

- Students will determine the permeability of soil samples and study seepage characteristics under different conditions. They will evaluate the influence of soil type, void ratio and hydraulic gradient on the movement of water through soil. COs: CO2, CO3, CO4

3. Settlement analysis using consolidation results

- Students will perform consolidation test analysis to estimate settlement characteristics of soil under loading. They will determine compressibility parameters, coefficient of consolidation and predict time-dependent settlement for field conditions. COs: CO2, CO3, CO5

4. Soil shear strength improvement using stabilization/reinforcement

Students will investigate methods of improving soil shear strength using stabilization or reinforcement techniques. They will compare the behaviour of untreated and treated soils and assess the effectiveness of the selected improvement method. COs: CO3, CO4, CO5

5. Swelling and shrinkage behaviour of expansive soils

Students will study the swelling and shrinkage characteristics of expansive soils under different moisture conditions. They will identify the potential problems caused by volume change and recommend suitable remedial measures. COs: CO2, CO3, CO4

6. Laboratory-based geotechnical report and application recommendation

Students will prepare a detailed laboratory report based on the experimental data collected during the course. They will interpret the results, discuss engineering significance, and recommend suitable

PART – B

OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct experiments based on problem statements provided by the course coordinator. These activities promote creativity, analytical thinking, and problemsolving skills.

Students shall complete **2–4 open-ended experiments** from the following:

1. **Safe bearing capacity and isolated footing design**
   Students will use soil parameters and project data to develop and justify a footing design for given loading conditions.
2. **Combined footing design**
   Students will propose and design a combined footing for unequal column loads and spacing constraints.
3. **Raft foundation design**
   Students will analyse a multi-column foundation problem and prepare a raft foundation design with settlement considerations. 4. **Pile foundation design**
   Students will compute pile capacity, number of piles and group efficiency for a given site condition.
5. **Cantilever retaining wall design**
   Students will design a retaining wall and perform stability checks for a given backfill and surcharge condition.
6. **Earth embankment design**
   Students will design an embankment considering stability, seepage and settlement requirements.
7. **Seepage control and drainage design**
   Students will design drainage and seepage control measures for an earth structure or subsoil condition.
8. **Ground improvement for weak soil**
   Students will select and design a ground improvement technique suitable for weak soil conditions.

Textbooks

1. B. C. Punmia, A. K. Jain and A. K. Jain, *Soil Mechanics and Foundations*, Laxmi Publications, 16th Edition.
2. J. E. Bowles, *Engineering Properties of Soils and Their Measurements*, McGraw-Hill Book Co., latest available edition.
3. T. W. Lambe, *Soil Testing for Engineers*, Wiley Eastern Ltd., latest available edition.

Reference Books

1. K. H. Head, *Manual of Soil Laboratory Testing*, Vol. I, II and III, Princeton Press, latest available edition.
2. Braja M. Das, *Principles of Foundation Engineering*, Cengage Learning, latest available edition.
3. J. E. Bowles, *Foundation Analysis and Design*, McGraw-Hill Education, latest available edition.
4. N. P. Kurian, *Design of Foundation Systems: Principles and Practices*, Narosa Publishing House, latest available edition
5. R. K. Rowe (ed.), *Geotechnical and Geoenvironmental Engineering Handbook*, Springer, 1st Edition, 2001.link.

Manuals and Codes

1. Bureau of Indian Standards, *IS 2720 Series – Methods of Test for Soils*, latest applicable parts.
2. Bureau of Indian Standards, *IS 1498 – Classification and Identification of Soils for General Engineering Purposes*.
3. Bureau of Indian Standards, *IS 6403 – Determination of Bearing Capacity of Shallow Foundations*.
4. Bureau of Indian Standards, *IS 1904 – Design and Construction of Foundations in Soils*.
5. Bureau of Indian Standards, *IS 2911 – Design and Construction of Pile Foundations*.
6. Bureau of Indian Standards, *IS 8009 – Settlement of Foundations*.

Recommended software

1. **PLAXIS 2D / 3D – Bentley / Seequent, latest academic or commercial release.**
   Used for finite element analysis of soil deformation, stability, excavation, slope, seepage, soil– structure interaction and groundwater flow.
2. **GeoStudio 2D – Seequent, latest release.**
   Useful for slope stability, seepage analysis, groundwater flow and coupled geotechnical modelling.
3. **FLAC / FLAC3D – Itasca Consulting Group, latest release.**
   Suitable for advanced geotechnical analysis of soil, rock, groundwater and support systems.
4. **GTS NX – Geotechnical engineering finite element software, latest release.**
   Useful for soil and rock deformation, stability, groundwater flow and dynamic analysis.
5. **OpenSees – Open System for Earthquake Engineering Simulation, latest release.**
   Useful for nonlinear analysis, earthquake response and soil–structure interaction studies.
6. **Geo5 – Fine Software, latest release.**
   Useful for routine geotechnical design such as bearing capacity, settlement, slope stability, retaining structures and lab data processing.
7. Foundation design software / pile design tools – for example AllPile, APile, Dartis Foundation **or** similar educational tools for foundation capacity and pile group analysis.
8. Spreadsheet-based design tools – Microsoft Excel with user-defined calculation sheets for footing, retaining wall, pile and slope design.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation (CIE):

For the Professional Core Course Laboratory, the maximum marks prescribed are 100. Out of these, 50 marks are allotted for Continuous Internal Evaluation (CIE) and 100 marks for the Semester End Examination (SEE). The SEE marks obtained out of 100 shall be proportionately scaled down to 50 marks. The final result shall be declared based on the aggregate of the CIE marks (50) and the scaled-down SEE marks (50), totalling 100 marks."

Out of 50 marks, 40 marks shall be assigned for assessment of regular laboratory PART -A classwork, and 10 marks for Part – B. (Table 1)

Out of 40 marks, 25 marks shall be based on the regular classwork and allotment of marks shall be as per rubrics listed in Table 1.

The remaining 15 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table 1.

The open-ended question set for CIE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for 10 marks. The allotment of marks shall be as per rubrics listed in Table 2.

Table – 1 Distribution of marks corresponding to laboratory component

Component	Description	Marks
Allotment of marks for regular classwork		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	10 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	15 marks
	Subtotal	**25**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	10marks
	Subtotal	**15**
	Total	**40**

Table 2 Distribution of marks corresponding to PART -B of the laboratory component

Evaluation Rubrics for continuous internal evaluation CIE). Maximum marks:10

Criteria and Guiding factors	Students' Level and Rubrics Excellent: E, Good: G, Fair: F Needs Improvements: NI			
	E	**G**	**F**	**NI**

(1) Problem Understanding **Criteria:** Is the problem understood correctly and framed appropriately? (i)Clarity in interpreting the given problem. (ii)Identification of relevant concepts and constraints. (iii) Ability to rephrase or model the problem logically.	2.0	1.5	1.0	0.5
(2) Conceptual Knowledge **Criteria**: Are the chosen methods or concepts valid for this type of problem? (i)Application of appropriate theories, principles, or laws. (ii)Integration of multiple concepts where necessary. (iii)Accuracy in stating relevant equations or models.	2.0	1.5	1.0	0.5
(3) Approach and Strategy **Criteria**: Is the approach well thought out and methodical? (i)Logical structure and progression. (ii)Use of diagrams, sketches, or flowcharts if applicable. (iii)Identification of assumptions and boundary conditions.	2.0	1.5	1.0	0.5
(4) Execution and Accuracy **Criteria**: Are the calculations correct? Is the final solution reasonable? (i) Correct application of formulas/methods. (ii)Accuracy of calculations or simulations (if any). (iii)Unit consistency and result verification.	2.0	1.5	1.0	0.5
(5) Innovation or Depth **Criteria**: Has the student shown original thinking or alternative methods? (i)Novel or efficient solutions. (ii)Consideration of alternate approaches. (iii)Interdisciplinary integration or practical extensions.	1	0.75	0.5	0.25
(6) Presentation and Clarity **Criteria**: Is the answer easy to follow and professionally written? (i)Organization and neatness. (ii)Clarity of explanation, labelling, and steps. (iii) Use of proper technical terminology.	1	0.75	0.5	0.25
Total	10	7.5	5.0	2.5

Note:
(i)The marks shown for Excellent, Good, Fair, Needs Improvement are indicative. The evaluator may also assign intermediate scores depending on the quality of work.
(ii)If the total score results in a fraction, it should be rounded off to the next higher integer.
(iii)The listed criteria are guidelines; evaluators may also consider other authentic dimensions (e.g., depth of insight, critical thinking, and practical awareness, recognition of limitations, or justified compromises. (iv)To award the full10 marks in the excellent category, the student must demonstrate reasonably good performance across all six criteria; otherwise, proportionally lower marks may be given.

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