

B. Tech. (Civil Engineering) – M. Tech. (Geotechnical Engineering)

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: Equip the students with strong foundation in civil and environmental engineering for both research and industrial scenarios.	Program Learning Outcome 1a: Student develops ability to design and conduct experiments. Program Learning Outcome 1b: Student is able to organize and analyze the experiment data to draw conclusions.
Program Goal 2: Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure.	Program Learning Outcome 2: Students are able to (i) develop material and process specifications, (ii) analyze and design projects, (iii) perform estimate and costing and (iv) manage technical activities.
Program Goal 3: Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure.	Program Learning Outcome 3a: Student develops understanding of professional and ethical responsibility. Program Learning Outcome 3b: Student is able to consider economic, environmental, and societal contexts while developing engineering solutions.
Program Goal 4: Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice.	Program Learning Outcome 4a: Students is prepared for leading roles/profiles in government sector, construction industry, consultancy services, NGOs, corporate houses and international organizations. Program Learning Outcome 4b: Student develops ability to identify, formulate, and solve engineering problems
Program Goal 5: Nurture interdisciplinary education for finding innovative solutions.	Program Learning Outcome 5: Student is able to solve complex engineering problems by applying principles of engineering and science.

Semester – VII

Sl. No.	Course Code	Course	L	T	P	C
1.	XX41PQ	B. Tech. Elective - I	3	0	0	3
2.	XX41PQ	B. Tech. Elective - II	3	0	0	3
3.	XX41PQ	IDE - III	3	0	0	3
4.	HS41PQ	HSS Elective – II	3	0	0	3
5.	XX4198	Summer Internship*	0	0	12	3
6.	XX4199	Project – I	0	0	12	6
7.	CE5105	Advanced Soil Mechanics	3	0	0	3
TOTAL			12	0	24	24

***Note :**

For specific cases of internship after VIth Semester, the performance evaluation would be made on joining the VIIth Semester and graded accordingly in the VIIth Semester:

Note :

a) (i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening vacation between Semester VI and VII that may be done in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

a) (ii) Further, on return from internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

b) (i) In the VIIth semester, students can opt for a semester long internship on recommendation of the DAPC and approval of the Competent Authority.

b) (ii) On approval of semester long internship, at the maximum two courses (properly mapped/aligned syllabus) at par with institute electives may be opted from NPTEL and / or SWAYAM and the other two more should be done at the institute through course overloading in any other semester (either before or after the internship) and/or during following summer semester.

b) (iii) The candidates opting two courses from NPTEL and / or SWAYAM would be required to appear in the examination at the Institute as scheduled in the Academic Calendar.

Semester – VIII

Sl. No.	Course Code	Course	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	CE5204	Advanced Foundation Engineering	3	0	0	3
3.	CE5205	Computational Geomechanics	3	0	2	4
4.	CE52PQ/ CE62PQ	M Tech Elective - I	3	0	0	3
5.	CE4299	Project - II	0	0	12	6
TOTAL			12	0	14	20

Semester – IX

Sl. No.	Course Code	Course	L	T	P	C
1.	CE51PQ/ CE61PQ	M Tech Elective - II	3	0	0	3
2.	CE51PQ/ CE61PQ	M Tech Elective - III	3	0	0	3
3.	CE51PQ/ CE61PQ	M Tech Elective - IV	3	0	0	3
4.	CE5199	Project - III	0	0	16	8
TOTAL			9	0	16	17

Semester – X

Sl. No.	Course Code	Course	L	T	P	C
1.	CE5299	Project – IV**	0	0	36	18
TOTAL			0	0	36	18

****Note: M. Tech. Project outside the Institute**

In the IXth Semester, students can opt for a semester long M. Tech. project subject to confirmation from an Institution of repute for research project, on the assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC based on progress report and presentation would be mandatory for a final decision by the competent authority.

Total Credits = 208 (including B. Tech. Sem I to Sem VI credits)

ELECTIVE GROUPS

SEMESTER VII

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4101	Introduction to Bridge Engineering	3	0	0	3
2.	CE4102	Prestressed and Precast Concrete Structures	3	0	0	3
3.	CE4103	Fundamentals of Solid Mechanics	3	0	0	3
4.	CE4104	Matrix Method for Structural Analysis	3	0	0	3

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4105	Stochastic Hydrology	3	0	0	3
2.	CE4106	Irrigation Engineering and Hydraulic Structures	3	0	0	3
3.	CE4107	Elementary Soil Behaviour	3	0	0	3
4.	CE4108	Fundamentals of Geoenvironmental Engineering	3	0	0	3
5.	CE4109	Biogeotechnical Engineering	3	0	0	3
6.	CE4110	Pavement Geotechnology	3	0	0	3

M. Tech. Elective I (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6206	Geotechnical Earthquake Engineering	3	0	0	3
2.	CE6207	Soil-Structure Interaction Analysis	3	0	0	3
3.	CE6208	Mine Wastes Generation and Management	3	0	0	3
4.	CE6209	Coupled Process in Fractured Geological Media	3	0	0	3
5.	CE6210	Ground Improvement Techniques	3	0	0	3
6.	CE6211	Utilization of industrial byproducts for geotechnical applications	3	0	0	3
7.	CE6212	Rock Engineering for River Valley Projects	3	0	0	3
8.	CE6213	Design of Underground Excavations	3	0	0	3
9.	CE6214	Special Topics in Geotechnical Engineering	3	0	0	3
10.	CE6215	Forensic Geotechnical Engineering	3	0	0	3

M. Tech. Elective II (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6106	Soil Dynamics	3	0	0	3
2.	CE6107	Rock Slope Engineering	3	0	0	3
3.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
4.	CE6109	Geoenvironmental Engineering	3	0	0	3
5.	CE6110	Biogeotechnics	3	0	0	3

M. Tech. Elective III (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6111	Rock Mechanics	3	0	0	3
2.	CE6112	Environmental Rock Engineering	3	0	0	3
3.	CE6113	Pavement Geotechnics	3	0	0	3
4	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3

M. Tech. Elective IV (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engineering	3	0	0	3
2.	CE6103	Environmental Toxicology and Risk Assessment	3	0	0	3
3.	CE6115	Advanced Structural Mechanics	3	0	0	3
4.	CE6116	Bridge Engineering and Design	3	0	0	3
5.	CE6125	Bituminous materials	3	0	0	3
6.	CE6128	Highway Geometric Design and Safety	3	0	0	3
7.	CE6129	Airport Engineering	3	0	0	3

Semester – VII

Sl. No.	Course Code	Course	L	T	P	C
1.	XX41PQ	B. Tech. Elective - I	3	0	0	3
2.	XX41PQ	B. Tech. Elective - II	3	0	0	3
3.	XX41PQ	IDE - III	3	0	0	3
4.	HS41PQ	HSS Elective – II	3	0	0	3
5.	XX4198	Summer Internship*	0	0	12	3
6.	XX4199	Project – I	0	0	12	6
7.	CE5105	Advanced Soil Mechanics	3	0	0	3
TOTAL			12	0	24	24

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4101	Introduction to Bridge Engineering	3	0	0	3
2.	CE4102	Prestressed and Precast Concrete Structures	3	0	0	3
3.	CE4103	Fundamentals of Solid Mechanics	3	0	0	3
4.	CE4104	Matrix Method for Structural Analysis	3	0	0	3

Course	CE4101 Introduction to Bridge Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Introduction to Bridge Engineering
Learning Mode	Lectures
Learning Objectives	Lectures: Complies with PLO-1, 2, 3 and 4 1. Apply the fundamental principles of bridge engineering, including load distribution, dead and live load analyses etc. to evaluate the performance of different types of bridges. 2. Design of various bridge components following various Indian as well as international standards and safety regulations. 3. To become proficient in using advanced computational tools and software for the modelling, simulation considering dynamic loading like wind and earthquake.
Course Description	This course offers a comprehensive exploration of bridge engineering and design, covering fundamental principles, methodologies, and practical applications. This course covers key aspects including structural analysis, material selection, construction techniques, and environmental considerations.
Course Outline	Introduction: Classification of Bridges, General Features of Design, IRC Loading (viz. 70R, Class AA tracked and wheeled vehicle), Design Codes, Working Stress Method, Limit State Method of Design as per IS456 and IRC 112; Analysis & Design: Consideration of various loading (dead load, vehicular load etc.), Slab bridge, Box Culvert, T-beam bridge, Box Girder bridge.
Learning Outcome	At the end of the course, student would be able to Lectures: 1. Understand behaviour of structural steel members. 2. Estimation of various design loads including wind loads. 3. Identify and interpret the appropriate relevant design codes. 4. Familiar with design and fabrication of steel members.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Swami Saran, Analysis and Design of Substructures: Limit State Design, 28 February 2018.
2. K. K. Rakshit, Design and Construction and Highway Bridges.
3. Raju N. K, Design of Bridges, 5Ed (Pb 2019) – 1 January 2019.
4. Daniel J. Inman, Charles R. Farrar, Vicente Lopes Junior, Valder Steffen Junior, Damage Prognosis: For Aerospace, Civil and Mechanical Systems, John Wiley & Sons, 2005.
5. Latest version of relevant IRC (viz. IRC6, IRC112 etc.) and IS (viz. IS456, IS800 etc.) codes.

Course	CE4102 Prestressed and Precast Concrete Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Prestressed and Precast Concrete Structures
Learning Mode	Lectures
Learning Objectives	Lectures: Complies with PLO-1, 2, 3 and 4 1. Familiarize with the concept of pre-stressed concrete and design of pre-stressed concrete structures. 2. Analyse prestressed concrete structural members and estimate the losses of prestress.
Course Description	The course deals with the design of pre-stressed concrete structures for various types of loading and will provides an understanding of behaviour of pre-stressed concrete members under various action of forces.
Course Outline	Analysis and design of beams - Rectangular, Flanged and I section, for limit state of flexure. Analysis and design of end blocks in post tensional members -primary and secondary distribution zones, Bursting and spalling tensions. Shear strength of prestressed concrete beams and design of shear reinforcement. Bond in prestressed concrete. Analysis and design of prestressed concrete structures such as concrete pipes and sleepers. Precast Structural Building components such as slab panels, beams, columns. Prefabricated building using precast load bearing and non-load bearing wall panels. Prefab systems, structural schemes, and their classification including design considerations. Joints - requirements of structural joints and their design considerations.
Learning Outcome	At the end of the course, student would be able to Lectures: 1. Become familiar with basic of pre-stressed concrete structure. 2. Understand the behaviour of pre-stressed concrete structural members structures under flexure, shear, axial forces, combined flexure and axial forces, and in-plane shear forces. 3. Learn the methods of pre-stressed concrete construction and detailing practices.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. IS 1343: Code of Practice for Prestressed Concrete by Bureau of Indian Standards.
2. Guyon Y.: Prestressed Concrete, Vol. I & II, John Wiley and Sons, New York.
3. Krishna Raju, N.: Prestressed Concrete, Tata McGraw Hill Publications Company, New Delhi.
4. Lin T. Y.: Prestressed Concrete, Tata McGraw Hill, New Delhi.
5. Dayaratnam P. and Sarah P.: Prestressed Concrete Structures.
6. Elliott K. S.: Precast Concrete Structures, CRC Press; 2nd edition, 2019.

Course	CE4103 Fundamentals of Solid Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Fundamentals of Solid Mechanics
Learning Mode	Lectures
Learning Objectives	Lectures: Complies with PLO-1, 2, 3 and 4 1. Understand the concept of deformation, linear and nonlinear measures of strain and stress. 2. Introduce failure theory of different materials. 3. Predict the behaviour elastic solids under different loading.
Course Description	The course deals with analysis of deformable bodies. This course provides the students an exposure for linear and non-linear analysis of solids, analysis of stress and strain, fundamental physical principles, constitutive relation of materials, and two-dimensional electrostatics problems.
Course Outline	Introduction: Suffix notation system, tensor algebra; Strain analysis: deformation and velocity gradients, Lagrangian and Eulerian description of strain, principal strains and strain invariants, compatibility conditions; Stress analysis: forces and moments, theory of stress, energetically conjugate stress and strain measures, plane stress and plane strain, principal stresses and stress invariants, compatibility equations, equilibrium equations; Fundamental physical principles: conservation of mass, linear momentum, angular momentum, and energy; Constitutive theory: St. Venant's principal, linear elasticity and generalized Hook's law, stress, strain and energy based failure theory, yield criteria; Introduction to elasticity: two-dimensional problems, torsion, buckling.
Learning Outcome	At the end of the course, student would be able to Lectures: 1. Understand the concept of deformation mechanisms in solid and different measures of strain and stress. 2. Gain knowledge on material model of liner elastic solid body. 3. Analysis of problem in elastic deformable body.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbook/ Reference book:

1. S. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw Hill Book Company, International Ed, 1970.
2. L. S. Srinath. Advanced Mechanics of Solids, McGraw Hill Education, 2010.
3. Allan F. Bower. Applied Mechanics of Soilds, CRC Press, 2010.
4. Irving H. Shames and Francs A. Cozzarelli. Elastic and Inelastic Stress Analysis, Taylor & Francis Group; Revised edition, 1997.
5. Romesh C. Batra. Element of Continuum Mechanics, AIAA, 2012.

Course	CE4104 Matrix Methods of Structural Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Matrix Methods of Structural Analysis
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Understand the analysis and design different type of structural elements under static loading. 2. Predict nonlinear behaviour of different structures and structural components under static loading.
Course Description	The course deals with advanced analysis methods of structures. This course provides the students an exposure for linear and non-linear analysis of structures.
Course Outline	Introduction Structures, loads and response; determinate and indeterminate structures; stiffness and flexibility; Analysis of Indeterminate structures; Force and displacement methods; Mathematical preliminaries; Matrix algebra; stiffness and flexibility matrices; Analysis of Trusses; Analysis of Beams; Analysis of plane frames; Implementation issues; Beyond matrix method: Introduction to nonlinear analysis.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Analyse structures for designing them. 2. Should be able to understand various types of elements used for structural analysis.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. R C Hibbeler, Structural Analysis, Ninth Edition, Pearson, 2017.
2. W. McGuire, R. H. Gallagher and R. D. Ziemian, Matrix Structural Analysis, Second Edition, Wiley, 2015.
3. D. Menon, Advanced Structural Analysis. Narosa, 2015.
4. Amin Ghali, Adam M Neville and Tom G Brown, ""Structural Analysis:A Unified Classical and Matrix Approach"", Sixth Edition, 2007, Chapman & Hall.

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4105	Stochastic Hydrology	3	0	0	3
2.	CE4106	Irrigation Engineering and Hydraulic Structures	3	0	0	3
3.	CE4107	Elementary Soil Behaviour	3	0	0	3
4.	CE4108	Fundamentals of Geoenvironmental Engineering	3	0	0	3
5.	CE4109	Biogeotechnical Engineering	3	0	0	3
6.	CE4110	Pavement Geotechnology	3	0	0	3

Course	CE4105 Stochastic Hydrology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Stochastic Hydrology
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, 4 and 5 This course is designed to present an understanding of statistical tools applied to hydrologic problems. The objective of this course is to introduce the concepts of probability theory and stochastic processes with applications in hydrologic analysis and design.
Course Description	The course covers the modelling of hydrologic time series with specific techniques for data generation and hydrologic forecasting. Case study applications will be discussed.
Course Outline	Statistical methods in hydrology, probability distribution of hydrologic variables, hypothesis testing and goodness of fit, flood frequency analysis, single and multiple regression analysis, classification of time series, characteristics of hydrologic time series, statistical principles and techniques for hydrologic time series modelling, time series modelling of annual and periodic hydrologic time series (including AR, ARMA, ARIMA, and DARMA models), multivariate modelling of hydrologic time series, practical considerations in time series modelling applications.
Learning Outcome	By taking this course, students will be able to: 1. Analyse hydrological and climatological data using advanced statistical methods and characterize water resources and hydrometeorological data. 2. Analyse hydrologic time series, and perform frequency analysis to estimate the magnitude of an event, frequency of occurrence and associated uncertainty.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Haan, C.T., Statistical Methods in Hydrology, First East-West Press Edition, New Delhi, 1995.
2. Bras, R.L. and Rodriguez-Iturbe, Random Functions and Hydrology, Dover Publications, New York, USA, 1993.
3. Clarke, R.T., Statistical Models in Hydrology, John Wiley, Chinchester, 1994.
4. Kite, G.W., Frequency and Risk Analyses in Hydrology, Water Resources Publications, Fort Collins, CO, 1977.
5. Yevjevich V., Probability and statistics in Hydrology, Water Resources Publications, Colorado, 1972.
6. Ang, A.H.S. and Tang, W.H., Probabilistic concepts in Engineering Planning Design, Vol. 1, Wiley, New York, 1975.

Course	CE4106 Irrigation Engineering and Hydraulic Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Irrigation Engineering and Hydraulic Structures
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, 4 and 5 1. Students will understand the soil-water-crop management and the role of irrigation system. 2. The students will be exposed to the various irrigation and flood control structure and their design principles.
Course Description	This course offers an introduction to irrigation practices and the development, conservation, regulation and use of water resources through the design of hydraulic structures.
Course Outline	Introduction to irrigation: Necessity and scope, irrigation practices, soil-crop-water requirement. Water resource Development: reservoir planning. Dams: Types of dams, their function and design. Design of Spillways. Diversion work. Distribution System: Flow irrigation canal, theory and design of canals, canal outlet, canal regulation work, cross drainage work, canal head work. Introduction to river engineering.
Learning Outcome	At the end of the course, students would be able to understand: 1. The soil-water-crop relation and the need for irrigation. 2. The principles of design of hydraulic structures.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Modi P.N. Irrigation Water Resources And Water Power Engineering, Rajsons Publications, New Delhi 2013
2. Punamia, B. C., & Lal, B..Irrigation and water power engineering. 17th Edition, Laxmi Publications
3. Santosh Kumar Garg, Irrigation Engineering and Hydraulic Structure, Khanna publishers, 2023
4. R. N. Reddy , Irrigation Engineering, Daya Publishing House, 2010
5. P. Novak, A.I.B. Moffat, C. Nalluri, R. Narayanan, Hydraulic Structures, CRC Press, 2017
6. Relevant IS codes

	CE4107 Elementary Soil Behaviour
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Elementary Soil Behaviour
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, 4, and 5. The objectives of this course are to 1. Understand the significance of different clay mineral in behaviour of soils and its determination. 2. Comprehend the arrangement of soil particles and its relevance in behaviour of soils. 3. Analyse the mechanism behind the physio-chemical interactions within soils. 4. Develop an understanding of the factors determining and controlling the engineering properties and behaviour of soils.
Course Description	This course is offered as an elective course in department. This course basically comprises with several topics which should be covered to deal with basics of soil behaviour subjected to variation in climatic changes. Board topics are different clay mineral in behaviour of soils and its determination, arrangement of soil particles and its relevance in behaviour of soils, mechanism behind the physio-chemical interactions within soils, and factors determining and controlling the engineering properties and behaviour of soils under different conditions.
Course Outline	Identification and Classification of Clay Minerals; Origin and description of clay minerals; Determination of soil composition and fabric; Physio-Chemical Behaviour of Soil; Soil-chemical interactions; Microbially Induced Calcite Precipitation (MICP); Effective, Inter-granular and Total stress; Water–Air interactions in soils; Volume Change, Shear Strength and Deformation Behaviour.
Learning Outcome	At the end of the course, student would be able to: 1. Recognize the significance of different clay mineral in behaviour of soils and its determination. 2. Understand the arrangement of soil particles and its relevance in behaviour of soils. 3. Analyse the mechanism behind the physio-chemical interactions within soils. 4. Apply knowledge for determining and controlling the engineering properties and behaviour of soils under different conditions, with an emphasis on Why they are What they are for research/professional perspectives as well as for societal needs.
Assessment Method	Assignments , Quizzes , Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Mitchell, J. K. and Soga, K. Fundamentals of soil behaviour, Wiley, New York, 2005.
2. Yong, R. N. and Warkentin, B. P. Soil properties and behaviour, Elsevier, 2012.
3. Lambe, T.W. and Whitman, R.V. Soil mechanics, John Wiley and Sons, New York, 1979.

Reference books:

1. Grim, R. E. Applied clay mineralogy, McGraw Hill, New York, 1966.
2. Fredlund, D. G., Rahardjo, H. and Fredlund, M. D. Unsaturated soil mechanics in engineering practice, Wiley, 2012.
3. Malcom, D. Bolton A guide to soil mechanics, University Press (India) Pvt. Ltd., 2003.
4. All relevant codes and research papers.

	CE4108 Fundamentals of Geoenvironmental Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Fundamentals of Geoenvironmental Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. Understanding methods of waste management and disposal 2. Learning methods of contaminated site characterisation 3. Learning methods of remedial measures of a contaminated site
Course Description	The course covers the source of various types of waste and its proper disposal, remediation of contamination sites. Municipal solid waste and industrial waste disposal techniques. Role of compacted unsaturated clay as liner material in landfill.
Course Outline	Production and classification of wastes, contaminated site characterization, Selection of waste disposal sites, selection criteria. Design of various landfill components such as liners, covers, leachate collection and removal, gas generation and management, ground water monitoring, stability analysis. Ash disposal facilities, dry disposal, wet disposal, design of ash containment system, stability of ash dykes, mine tailings. Planning, source control, soil washing, bioremediation, stabilization of contaminated soils and risk assessment approaches
Learning Outcome	At the end of the course, student would be able to: 1. Able to manage and dispose particular type of waste 2. Should be able to characterize contaminated site 3. Should be able to take appropriate remedial measures for a contaminated site
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. H D Sharma and K R Reddy, "Geoenvironmental Engineering: Site Remediation, waste containment, and emerging waste management technologies", John Wiley and Sons, 2004.
2. R N. Yong, "Geoenvironmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation", Thomson Telford, 2000.
3. D. G. Fredlund and H. Rahardjo, "Soil Mechanics for Unsaturated soils", Wiley Publication, 1993.

Reference books:

1. R Kerry Rowe, R M Quigley, Richard W I Brachman and John R Booker, "Barrier Systems for Waste Disposal Facilities", 2nd edn, CRC press, 2019.
2. L N Reddy and H.I. Inyang, "Geoenvironmental Engineering: Principles and Applications", Marcel Dekker, 2000
3. James K Mitechell, K Soga, "Fundamentals of soil behaviour", Wiley Publication, 2005.
4. Charles W.W.Ng, B Menzies, "Advanced unsaturated soil mechanics and engineering", CRC Press, 2014.
5. All relevant IS and International Codes.

	CE4109 Biogeotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Biogeotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, and 5. The objectives of this course are to 1. Understand the significance of geomicrobiology in geotechnical engineering. 2. Comprehend various biological process in ground/soil improvement. 3. Apply the knowledge for upscaling to develop sustainable geomaterials.
Course Description	This course combines the principles of environmental biotechnology and geotechnical engineering. Geotechnical engineers design, build, and maintain structures in the subsurface. This course will be able to provide combine and apply basic theory and concepts from soil mechanics and biology in engineering applications. This course also brings an understanding about various geomicrobiological process for soil improvement.
Course Outline	Introduction to Biogeotechnics, Biological process of the subsurface materials, Stoichiometry and kinetics of bio-chemical reactions, Microbially Induced Calcite Precipitation (MICP), Root-Inspired Foundations, Enzymatically Induced Calcite Precipitation (EICP), Self-healing materials, Termite mounds-, Snake- and Ant-Inspired Excavations, Microbial Ecology, Biofilms, and Zeolite Sorption, Production of bio-cements. Instrumentation and testing for evaluating biological process and geotechnical material behaviour, Upscaled model tests and field trails.
Learning Outcome	At the end of the course, student would be able to: 1. Understand the importance of geomicrobiology in geotechnical engineering. 2. Comprehend various bio-chemical reactions and their application in biological process for ground/soil improvement. 3. Investigate biological process and geotechnical behaviour. 4. Apply the knowledge for upscaling to develop sustainable geomaterials.
Assessment Method	Assignments , Quizzes , Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

4. Ehrlich, H., Newman, D. Geomicrobiology (5th ed.). Boca Raton: CRC Press (2021).
5. Hemond, Harold F., and Elizabeth J. Fechner. Chemical fate and transport in the environment. academic press, 2022.
6. Rittmann, Bruce E., and Perry L. McCarty. "Environmental biotechnology: principles and applications." (No Title) (2001).

Reference books:

5. Coduto, Donald P., Man-chu Ronald Yeung, and William A. Kitch. "Geotechnical engineering: principles and practices." (No Title) (2011).
6. Zheng, Chunmiao, and Gordon D. Bennett. Applied contaminant transport modeling. Vol. 2. New York: Wiley-Interscience, 2002.
7. All relevant codes and research papers

Course Number	CE4110: Pavement Geotechnology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pavement Geotechnology
Learning Mode	Lectures
Learning Objectives	Complies with program learning outcome 1a; 3a 1. Equip the students with a strong foundation and strengthen their knowledge in pavement geotechnics. 2. The student will be able to apply advanced theory and analysis for problem-solving in pavement geotechnics. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills. 4. The student will be able to apply fundamentals in identifying, formulating, and solving complex engineering problems in pavement geotechnics.
Course Description	This coursework will provide practical insights for students in the field of Pavement Geotechnics. The students will be taught the recent developments and design principles to face current and future highway problems in relevance with pavement geotechnics.
Course Content	Geotechnical properties of geomaterials such as soil, rock, soil-rock mixture, and alternative geomaterials. Introduction to stabilized geomaterials. Introduction to various types of pavement, subgrades, materials, subbase, base, and asphalt concrete materials relevant to pavement Geotechnics, Elastic theories and stress distribution in pavements, Geosynthetic stabilized pavements, geotechnical parametric studies for AASHTO, MEPDG, and IRC designs.
Learning Outcome	Students would be able to learn the core principles of pavement designs and advanced sustainable pavement techniques. Exploration of alternative materials, design approaches, and innovation in pavement geotechnics will be disseminated through this course.

Textbooks:

1. Huang, Y. H. (2004). Pavement analysis and design, Second edition, Upper Saddle River, NJ: Pearson Prentice Hall.
2. Yoder, E. J., & Witczak, M. W. (1991). Principles of pavement design. John Wiley & Sons.
3. Mallick, R. B., & El-Korchi, T. (2008). Pavement engineering: principles and practice. CRC Press.
4. Frost, M. W., Jefferson, I., Faragher, E., Roff, T. E. J., & Fleming, P. R. (Eds.). (2003). Transportation Geotechnics: Proceedings of the Symposium Held at The Nottingham Trent University School of Property and Construction on 11 September 2003. Thomas Telford Publishing.
5. Ellis, E., Yu, H. S., McDowell, G., Dawson, A. R., & Thom, N. (Eds.). (2008). Advances in Transportation Geotechnics: Proceedings of the International Conference Held in Nottingham, UK, 25-27 August 2008. CRC Press.
6. Miura, S., Ishikawa, T., Yoshida, N., Hisari, Y., & Abe, N. (Eds.). (2012). Advances in Transportation Geotechnics 2. CRC Press.

Reference books:

1. Ferguson, B. K., & Ferguson, B. K. (2005). Porous pavements. Boca Raton, FL: Taylor & Francis.
2. Rogers, M., & Enright, B. (2016). Highway engineering. John Wiley & Sons.
3. Nikolaides, A. (2014). Highway engineering: Pavements, materials and control of quality. CRC Press.
4. Babu, G. L. S., Kandhal, P. S., Kottayi, N. M., Mallick, R. B., & Veeraragavan, A. (2019). Pavement Drainage: Theory and Practice. CRC Press.
5. Babu, G.L.S., (2006). An Introduction to Soil Reinforcement and Geosynthetics, Universities Press (India) Pvt. Ltd.
6. All relevant codes and standards

Course Number	CE5105 Core 01: Advanced Soil Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Soil Mechanics
Learning Mode	Lectures
Learning Objectives	Complies with PLO- 1, 2 & 3 1. To provide the knowledge of the advanced concepts in soil mechanics 2. to expose the student to various advanced laboratory and field tests for soils, and their interpretation 3. To train students to plan and design Geotechnical structures 4. To provide scientific and technical knowledge, to prepare students to address the field problems in Geotechnical Engineering
Course Description	This course intends to bridge the basic concepts with the advanced topics related to soil mechanics. Topics ranging from soil structures, classification, to stress/strain behaviour, shear strength, slope stability and basic elasticity and plasticity concepts are covered. Not all the concepts explained in this course are advanced, but attempts to add clarity to the knowledge gained at undergraduate level.
Course Outline	Introduction: Geotechnical Engineering. Nature of Soil, Soil Structure. Shear Strength of Soils. A Simple Model to interpret Shear Strength, Drained and Un-drained Strength, Laboratory and Field Tests, Factors Affecting Shear Strength, Useful Correlations. Slope Instability, Finite Slope, Stability analyses, Application of software. Theory of Elasticity: Stress-Strain Relationship for various loading conditions, Elastic Stress Analysis, Introduction to Computer Program SIGMAW. Theory of Plasticity and Models for Soils: Elements of Plasticity, Yield Criteria (Mohr-Coulomb, Drucker-Prager), Post-yield Behavior, Flow Rule, Incremental Stress-Strain Relationship, Elastic-Perfectly Plastic Model, Hardening Plasticity Based Model.
Learning Outcome	At the end of the course, student would be able to: 1. Determine the geotechnical design parameters using laboratory test methods for different loading and drainage conditions 2. Analyse and determine the state of stress in the soil using elasticity and plasticity concepts 3. Assess the stability of the slopes and design the countermeasures for unstable slopes 4. Use and operate the software like SLOPE/W and SIGMAW for solving practical problems
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Das, B.M., Advanced Soil Mechanics (5th edition), CRC Press, Taylor and Francis Group, 2020
2. Atkinson, J.H. An Introduction to the Mechanics of Soil and Foundations. McGraw Hill, 1993

Reference books:

1. Budhu, M., Soil Mechanics and Foundation (3rd edition), John Wiley & Sons Inc, 2011
2. Lambe, T.W. and Whitman, R.V. Soil mechanics, John Wiley and Sons, New York, 1979.
3. A.P.S. Selvadurai, Plasticity & Geomechanics, Cambridge University Press, 2002.

All relevant IS and International Codes.

Semester – VIII

Sl. No.	Course Code	Course	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	CE5204	Advanced Foundation Engineering	3	0	0	3
3.	CE5205	Computational Geomechanics	3	0	2	4
4.	CE52PQ/ CE62PQ	M Tech Elective - I	3	0	0	3
5.	CE4299	Project - II	0	0	12	6
TOTAL			12	0	14	20

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan. Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods. Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation. Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.).

	Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

Course	CE5204 Core-4: Advanced Foundation Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Foundation Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of foundation engineering. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure. 4. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice. 5. Nurture interdisciplinary education for finding innovative solutions.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to foundation engineering. Topics ranging from isolated footing, mat foundation, pile foundation and machine foundation are covered. The course started with the basic knowledge gained by the attendee during undergraduate level regarding the foundation design. Most of the institute does not cover mat foundation in the first course on foundation engineering. Therefore, advanced level analysis and design concepts of various foundation designs will be taught in the next part of this course. Introduction to seismic design of foundation along with codal provisions will be also taught in this course.
Course Outline	Static bearing capacity of footings, bearing capacity of footings resting on layered soils and footing on or near slopes, tilt, rotation and horizontal displacement of foundations subjected to eccentric-inclined loads, foundations on rocks. Analysis of raft foundations, circular and annular rafts, structural design of shallow raft foundations. Seismic design of shallow foundations. Pile foundations load capacity and settlements, various methods of analysis of laterally loaded pile foundations, uplift capacity. Piles subjected to dynamic loads, seismic design of pile foundations, structural design of pile foundations. Machine foundations for reciprocating machines, impact type, rotary machines such as turbines, turbo-generator. IS code provisions on foundations, codal provisions on structural and earthquake resistant design of foundations.
Learning Outcome	At the end of the course, student would be able to: 1. Design isolated footing using various methods available along with the method suggested in the IS code. 2. Design mat/raft foundation using IS code and ACI code 3. Design pile foundation in various type of soil deposit 4. Design machine foundation considering the dynamic load transferred to the foundation.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. V. N.S. Murthy, Advanced foundation Engineering, CBS Publishers & Distributers, 2011.
2. B. M. Das, Principles of Foundation Engineering, Cengage Learning, Eighth Edition, 2011.

Reference books:

1. J.E. Bowles, Foundation Analysis and Design, McGraw-Hill, 2001.
2. H. G. Poulos, and E. H. Davis, Pile Foundation Analysis and Design, Krieger Pub Co., 1990.
3. All relevant IS and International Codes.

Course	CE5205 Core-5: Computational Geomechanics
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Computational Geomechanics
Learning Mode	Laboratory + Practical
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To introduce about application of mechanics in geotechnical engineering problems 2. To train students to analyze different Geotechnical structures under different loading conditions 3. To train the students to solve complex practical problems
Course Description	The course intends to train the students to use the different geotechnical software tools to analyse the different geotechnical structures.
Course Outline	Theory: Numerical modeling, constitutive modeling of soils and rock, continuum and discrete element modeling; Concept of stress and strain, principle stresses and strains. Octahedral stresses and strains, finite element discretization of a continuum; Geomechanics problems of plane strain and axisymmetric problem; Principle of effective stress, permeability and flow; Fundamentals of Tensors; Mohr-Coulomb failure criteria, soil laboratory tests; Critical state and stress paths; Failure criteria for soils, associated and non-associated flow rule; Simulation of soil-structure interaction problems, application in consolidation, bearing capacity and slope stability problems using numerical approaches. Practical: Analyses of different geotechnical structures such as shallow foundations, deep foundations, slopes, embankments, retaining structures, dams, tunnels, buried pipes, excavation support systems etc. under static and dynamic loading conditions using various softwares such as PLAXIS 2D and 3D, FLAC, Geostudio and Rock Science etc.
Learning Outcome	At the end of the course, student would be able to: 1. Understand the basics and concept of geomechanics in geotechnical applications 2. Independently able to operate different software tools 3. Able to select appropriate material, models and input parameters 4. Validation and interpretation of the results 5. Design and analysis the various geotechnical structures
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Wood, D.M., Geotechnical Modelling, CRC Press, 2004
2. Bolton, M.D. A Guide to Soil Mechanics, Cambridge University Press, 1991. Salgado, R., The Engineering of Foundations, McGraw Hill, 2008

Reference books:

1. Potts and Zdravkonics, Finite element analysis in geotechnical engineering: Part-I Theory & part-II Applications, Thomas Telford Publishers, 1999.
2. Budhu, M., Soil Mechanics and Foundation (3rd edition), John Wiley & Sons Inc, 2011.
3. All relevant IS and International Codes.

M. Tech. Elective I (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6206	Geotechnical Earthquake Engineering	3	0	0	3
2.	CE6207	Soil-Structure Interaction Analysis	3	0	0	3
3.	CE6208	Mine Wastes Generation and Management	3	0	0	3
4.	CE6209	Coupled Process in Fractured Geological Media	3	0	0	3
5.	CE6210	Ground Improvement Techniques	3	0	0	3
6.	CE6211	Utilization of industrial byproducts for geotechnical applications	3	0	0	3
7.	CE6212	Rock Engineering for River Valley Projects	3	0	0	3
8.	CE6213	Design of Underground Excavations	3	0	0	3
9.	CE6214	Special Topics in Geotechnical Engineering	3	0	0	3
10.	CE6215	Forensic Geotechnical Engineering	3	0	0	3

Course	CE6206: Geotechnical Earthquake Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geotechnical Earthquake Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of geotechnical earthquake engineering. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure. 4. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to geotechnical engineering. Topics ranging from continental drift, seismic hazard analysis, wave propagation, liquefaction assessment, seismic slope stability and design of retaining structure are covered. The course started with the basic knowledge gained by the attendee during undergraduate level regarding the wave propagation. Therefore, the basics about earthquake engineering will be studied by the students. Introduction to seismic design of retaining structure and slope stability analysis will be also taught in this course.
Course Outline	Introduction, Significant historical earthquakes, Continental drift and plate tectonics, Internal structure of earth, Sources of seismic activity, Size of the earthquake, Strong ground motion and its measurement, Ground motion parameters, Estimation of ground motion parameters, Identification and evaluation of earthquake sources, Seismic hazard analysis, Deterministic seismic hazard analysis, Probabilistic seismic hazard analysis, Wave propagation, Waves in unbounded media, Waves in semi-infinite body, Waves in layered body, Dynamic soil properties and Measurement of dynamic soil properties, Ground response analysis, Local site effects and design of ground motions, Liquefaction, Initiation and effects of liquefaction, Evaluation of liquefaction hazards, Liquefaction susceptibility, Seismic slope stability analysis, and Seismic design of retaining walls.
Learning Outcome	At the end of the course, student would be able to: 1. Design earthquake resistant structure using various methods available along with the method suggested in the IS code. 2. Liquefaction potential assessment using IS code and other methods in practice. 3. Perform seismic hazard analysis for any site. 4. Seismic design of retaining walls considering the dynamic load transferred to the foundation.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Kramar S.L, Geotechnical Earthquake Engineering, Prentice Hall International series, Pearson Education Pvt. Ltd.
2. J.E. Bowles, Foundation Analysis and Design, McGraw-Hill, 2001.

Reference books:

1. Ikuo Towhata, Geotechnical Earthquake Engineering, Springer series, 2008.
2. All relevant IS and International Codes.

Course	CE6207: Soil-Structure Interaction Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Soil-Structure Interaction
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of soil and structural interaction. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure under dynamic loading.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to geotechnical engineering. Topics ranging from general concept of soil-structure interaction, beams on elastic foundation, modern concept of analysis of piles and pile groups are covered.
Course Outline	General soil-structure interaction problems. Contact pressures and soil-structure interaction for shallow foundations. Concept of sub grade modulus, effects/parameters influencing subgrade modulus. Analysis of foundations of finite rigidity, Beams on elastic foundation concept, introduction to the solution of beam problems. Curved failure surfaces, their utility and analytical/graphical predictions from Mohr-Coulomb envelope and circle of stresses. Earth pressure computations by friction circle method. Earth pressure distribution on walls with limited/restrained deformations, Dubravo's analysis. Earth pressures on sheet piles, braced excavations. Design of supporting system of excavations. Arching in soils. Elastic and plastic analysis of stress distribution on yielding bases. Analysis of conduits. Design charts for practical use. Modern concept of analysis of piles and pile groups. Axially, laterally loaded piles and groups. Interaction analysis. Reese and Matlock's solution. Elastic continuum and elasto-plastic analysis of piles and pile groups. Hrennikoff's analysis. Ultimate lateral resistance of piles by various approaches. Non-linear load-deflection response. Uplift capacity of piles and anchors.
Learning Outcome	At the end of the course, student would be able to: 1. Design earthquake resistant structure using various methods available along with the method suggested in the IS code. 2. Apply beam on elastic foundation concept in analysis and design of various problem related to geotechnical engineering. 3. Ultimate lateral resistance of piles by various approaches.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. J. P. Wolf, "Dynamic Soil-Structure Interaction", Prentice-Hall, 1985.
2. S.L. Kramer, Geotechnical Earthquake Engineering, Prentice Hall, 1996.

Reference books:

1. H. G. Poulos, and E. H. Davis, Pile Foundation Analysis and Design, Krieger Pub Co., 1990.
2. Structure Soil Interaction- State of Art Report, Institution of Structural Engineers, 1978.
3. All relevant IS and International Codes.

Course	CE6208: Mine Wastes Generation and Management
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Mine Wastes Generation and Management
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, 4, and 5 1. Understand and explain the mining operations, regulations and acts. 2. Explain the various types of mine generated wastes, characterizations techniques and application. 3. Describe the mine waste disposal techniques and stability analysis of overburden dumps. 4. Comprehend the mine generated contaminated leachate and ground pollution. 5. Analyse technical strategies, approaches and solutions to engineer's role and responsibility for mine waste management risk analysis, potential application, safety factors for sustainable development.
Course Description	The course covers various mine waste generated during the mining operation and their characteristics, mining regulations and acts, waste disposal, potential application and stability analysis of mine overburden waste, leachate formation and ground contamination. This course deals with geomechanics and rehabilitation techniques of mine generated wastes, valorization of mine wastes, risk analysis and mining safety.
Course Outline	Introduction to mining operations and risk; overview of Indian & international mining regulations and acts; different types of mine waste generated during the mining operation; mine waste disposal & rehabilitation; geochemical compositions, physical & chemical nature of mine wastes; disposal of mine wastes; geomechanics of mine waste disposal & rehabilitation; characterizations and application of mining wastes for infrastructure projects; valorization of mining wastes; leachate formation and ground contamination due to mining wastes; stability analysis of mining wastes overburden dumps, reintegration of mine wastes; mining wastes risk assessment & remedial measures; mining safety.
Learning Outcome	At the end of the course, student would be able to: 1. Describe and explain the mining operations, regulations and acts. 2. Explain the various types of mine generated wastes, characterizations techniques and application. 3. Describe the mine waste disposal techniques and stability analysis of overburden dumps. 4. Understand the mine generated contaminated leachate and ground pollution. 5. Analyze technical strategies, approaches and solutions to engineer's role and responsibility for mine waste management risk analysis, potential application, safety factors for sustainable development.
Assessment Method	Assignments, Quizzes, Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Singh, T N. Surface Mining, Lovely Prakashan, India, 2020.
2. Karra, Ram Chandar, Gayana, B C, Rao, Shubhananda P Mine Waste Utilization, CRC Press, 2022.
3. Hutchison, Ian P.G. and Ellis, Rechar D., Mine Waste Management, CRC Press, India, 1992.

4. Lottermoser, Bernd G., Mine Wastes Characterization, Treatment and Environmental Impacts, Springer, 3rd edition, 2010.

References:

1. Pradhan, S. P., Vishal, V., & Singh, T. N. (Eds.). Landslides: theory, practice and modelling. Springer International Publishing, 2019.
2. Pathak, Pankaj, Rout, Prangya Ranjan, Urban Mining for Waste Management and Resource Recovery, CRC Press, 2021
3. Indian and international acts and regulations for mining operations and waste management
4. Referred journal and publications.

Course	CE6209: Coupled Process in Fractured Geological Media
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Coupled Process in Fractured Geological Media
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2 and 3 1. Understand the coupling mechanisms between various processes (e.g., fluid flow, heat transfer, and mechanical deformation) in fractured geological media. 2. Analyze the impact of fractures on the behavior of fluid flow, heat transfer, and mechanical deformation in geological formations. 3. Apply numerical modeling techniques to simulate coupled processes in fractured media and predict their behavior under different conditions. 4. Develop strategies for managing and controlling coupled processes to optimize resource extraction, geological storage, or environmental remediation in fractured geological environments.
Course Description	The Coupled Processes in Fractured Geological Media course delves into the complex interactions occurring within fractured rock formations. Students explore coupled hydro-mechanical-chemical processes occurring in subsurface environments. Topics include fluid flow, stress distribution, and chemical reactions in fractured media. Emphasis is placed on understanding how these processes affect geotechnical engineering, hydrology, and environmental management. Students learn modeling techniques and practical applications for characterizing and predicting behavior in fractured geological systems.
Course Outline	Introduction to Fractured Geological Media, Rock Mechanics Fundamentals, Hydrological Processes in Fractured Media, Thermal-Hydrological-Mechanical (THM) Coupling, Chemical Processes and Reactive Transport, Geomechanical-Fluid Interaction, Case Studies and Applications.
Learning Outcome	At the end of the course, student would be able to: 1. Students will grasp the complex interactions between fluid flow, heat transfer, and mechanical deformation in fractured geological formations. 2. They will learn to analyze coupled processes influencing subsurface systems such as groundwater flow, geothermal energy, and hydrocarbon reservoirs. 3. Learners will develop skills to model and simulate coupled phenomena to solve real-world problems in fractured media. 4. The course prepares students to address challenges in resource management, environmental remediation, and energy extraction.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Goodman, R. E. Introduction to rock mechanics, John Wiley and Sons, 1989.
2. R. Pusch. Waste Disposal in Rock. Elsevier. 1994
3. Coupled Processes Associated with Nuclear Waste Repositories" by Jacques Delay, Peter A. Witherspoon, François X. Dégerine
4. Randall F. Barron and Brian R. Barron. Design for Thermal Stresses. Wiley, 2011

5. Fractured Rock Hydrogeology" by John M. Sharp Jr.

References:

6. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.
7. Hoek, E., & Brown, E. Underground excavations in rock, CRC Press, 1980.
8. Singh, B., & Goel, R. K. Engineering rock mass classification, Elsevier, 2011.
9. "Coupled Processes in Subsurface Deformation, Flow, and Transport" edited by George Pinder, Catherine A. Peters

Course	CE6210: Ground Improvement Techniques
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Ground Improvement Techniques
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, 4 & 5 1. Understand the importance of ground improvement for civil engineering structures. 2. Examine the problematic soil and select a suitable ground improvement technique. 3. Analyze and Design the various ground improvement techniques. 4. Understand the construction methodology, equipment and quality control aspects. 5. Know the national and international codal guidelines and provisions.
Course Description	Construction in weak and problematic soil is inevitable nowadays. The course addresses various ground improvement techniques along with principles, design issues and construction procedures. The course has been broadly divided into two modules namely ground improvement techniques and the reinforced earth.
Course Outline	Problematic soil and need for ground improvements, Mechanical modifications using mechanical and dynamic compaction, Accelerated consolidation using preloading and vertical drains, Soil stabilisation using additives and deep soil mixing, Grouting, Vibro techniques, Drainage and dewatering methods; Soil nailing; Soil nailing; Underpinning, Introduction to geosynthetics and reinforced earth; Applications and advantages of reinforced soil structure; Principles, concepts and mechanism of reinforced soil; Soil-reinforcement interface friction; Behaviour of Reinforced earth walls; Bearing capacity improvement and design of foundations resting on reinforced soil; embankments on soft soils; Design of reinforced soil slopes, Use of geosynthetics for separations, drainage and filtration; practical applications of of geosynthetics; Geosynthetics in landfill system; Use of jute, coir, natural geotextiles, waste products such as scrap tire, LDPE and HDPE strips, as reinforcing material.
Learning Outcome	At the end of the course, student would be able to: 1. Identify the problematic soil and select a suitable ground improvement technique 2. Design the various ground improvement techniques 3. Understand the construction methodology, equipment and quality control aspects 4. Know the national and international codal guidelines and provisions
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Manfred R. Hausmann, Engineering Principles of Ground Modification, McGraw-Hill Pub, Co., 1990.
2. Koerner, R.M. Designing with Geosynthetics, Prentice Hall, New Jersey, USA, 4th edition, 1999.
3. Jie Han, Principles and Practice of Ground Improvement, Wiley Publishers, 2015.

Reference books:

1. B.M. Das, Principle of Geotechnical Engineering, Cengage Learning, eighth Edition, 2013.
2. V. N. S. Murthy, Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering, CRC Press, Taylor & Francis Group, Third Indian Reprint, 2013.
3. All relevant IS and international codes and relevant research papers/reports

Course	CE6211: Utilization of Industrial Byproducts for Geotechnical Applications
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Utilization of industrial byproducts for geotechnical applications
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, 4, and 5 1. Understand various sources and characteristics of industrial byproducts and their application as geomaterials. 2. Explain bulk application of industrial by products for soil stabilization and ground improvement with or without admixtures. 3. Analyse and elucidate the behaviour of industrial byproducts subjected to contamination, various remediation and immobilization techniques. 4. Apply the knowledge for economical, environmental and sustainable infrastructure development.
Course Description	The course covers various sources of industrial byproducts in India, status and potential applications. Further, this course deals with utilization of industrial byproducts as geomaterial for soil stabilization and ground improvement with or without using admixtures. This course also emphasizes the advanced characterizations techniques of industrial by products and behaviour subjected to contamination, various remediation and immobilization techniques.
Course Outline	Introduction to industrial byproducts and its types; characteristics and role of industrial byproducts and admixtures; purpose-based classification of soils; principles of soil stabilization and ground improvement; methods of stabilization using industrial byproducts with or without chemical admixtures such as lime, cement, bitumen and special chemicals; mechanisms, uses and limitations; advanced characterizations technique and use of fly ash, rice husk ash, biochar, marble waste, and quarry generated wastes, mine slurry, slag, and other waste materials for both shallow and deep soil stabilization and ground improvement; potential application of industrial wastes as geomaterials and its behaviour subjected to contamination agents; remediation and immobilization techniques of industrial byproducts; methods and applications of grouting; Application to embankments, excavations, foundations and sensitive soils.
Learning Outcome	At the end of the course, student would be able to: 1. Describe various sources and characteristics of industrial byproducts and their application as geomaterials. 2. Explain bulk application of industrial by products for soil stabilization and ground improvement with or without admixtures. 3. Understand the behaviour of industrial byproducts subjected to contamination, various remediation and immobilization techniques. 4. Apply the knowledge for economical, environmental and sustainable infrastructure development.
Assessment Method	Assignments , Quizzes , Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Ingles, O.G. and Metcalf, J.B., Soil Stabilization, Principles and Practice, Butterworths, 1972.
2. Bowen, R., Grouting in Engineering Practice, Allied Science Publishers Ltd., 1975.

3. Jie Han, Principles and Practice of Ground Improvement, Wiley Publishers, 2015.

References:

1. Yong, R. N. and Warkentin, B. P. Soil properties and behaviour, Elsevier, 2012.
2. Mitchell, J. K. and Soga, K. Fundamentals of soil behaviour, Wiley, New York, 2005.
3. B.M. Das, Principle of Geotechnical Engineering, Cengage Learning, eighth Edition, 2013.
4. All relevant IS and international codes and relevant research papers/reports.

Course	CE6212: Rock Engineering for River Valley Projects
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Rock Engineering for River Valley Projects
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2 and 3 1. Understand the geological processes shaping river valleys and the behavior of rock masses within them. 2. Analyze and assess geological hazards such as landslides, rockfalls, and erosion affecting river valley infrastructure. 3. Develop skills in rock slope stability analysis, support design, and mitigation measures specific to river valley environments. 4. Apply engineering principles to design sustainable and resilient solutions for infrastructure projects in river valleys, considering geological constraints and environmental impacts.
Course Description	"Rock Engineering for River Valley Projects" covers the geotechnical aspects of river valley infrastructure. Students learn about slope stability, rock mechanics, and foundation design tailored to river environments. The course emphasizes risk assessment, mitigation strategies, and engineering solutions for dams, bridges, and other structures in rocky river valleys. Practical applications and case studies provide insights into real-world challenges and solutions.
Course Outline	Introduction to River Valley Projects, Geological Considerations, Rock Mechanics Fundamentals, Design of River Valley Structures, Case Studies, Instrumentation and Monitoring, Construction Techniques and Management, Future Trends and Sustainability
Learning Outcome	At the end of the course, student would be able to: 1. Understand principles of rock mechanics relevant to river valley projects. 2. Analyze geological conditions to design stable structures for dams, tunnels, and slopes. 3. Apply engineering techniques for rock stabilization and slope reinforcement. 4. Develop skills to mitigate geological hazards and ensure the safety and sustainability of river valley infrastructure.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Goodman, R. E. Introduction to rock mechanics, John Wiley and Sons, 1989.
2. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.
3. Hoek, E, & Brown, E. Underground excavations in rock, CRC Press, 1980.

References:

1. Singh, B., & Goel, R. K. Engineering rock mass classification, Elsevier, 2011.
2. Jaeger, J. C., Cook, N. G., & Zimmerman, R. Fundamentals of rock mechanics, John Wiley & Sons, 2009.
3. Debasis, D., & Kumar, V. A. Fundamentals and applications of rock mechanics, PHI Learning Pvt. Ltd. New Delhi, India, 2016.

Course	CE6213: Design of Underground Excavations
Course Credit (L-T-P-C)	3-0-0-4
Course Title	Design of Underground Excavations
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2 and 3 1. Understand the principles of underground excavation design, including site investigation and geological mapping. 2. Gain proficiency in analyzing rock mass behavior and selecting appropriate support systems. 3. Learn excavation methods, tunnelling techniques, and their applications in various geological conditions. 4. Develop skills to design safe, cost-effective, and sustainable underground structures while considering geological, geotechnical, and structural factors.
Course Description	This course covers principles of underground excavation design including rock mechanics, support systems, and excavation methods. Topics include ground behavior, stability analysis, tunnelling methods, and practical design considerations. Students learn to develop safe and efficient designs for tunnels, mines, and underground structures.
Course Outline	Introduction to Underground Excavations, Rock Mechanics Fundamentals, Site Investigation and Geotechnical Data Collection, Excavation Methods, Support Systems for Underground Excavations, Tunnel Design, Cavern and Underground Structure Design, Instrumentation and Monitoring, Case Studies and Project Examples
Learning Outcome	At the end of the course, student would be able to: 1. Understanding principles of rock mechanics for underground openings. 2. Ability to analyze and design support systems for stability and safety. 3. Proficiency in assessing geological conditions and their impact on excavation design. 4. Skill development in designing underground excavations for various engineering purposes like tunnels, mines, or underground structures.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Goodman, R. E. Introduction to rock mechanics, John Wiley and Sons, 1989.
2. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.
3. Hoek, E, & Brown, E. Underground excavations in rock, CRC Press, 1980.

References:

1. Singh, B., & Goel, R. K. Engineering rock mass classification, Elsevier, 2011.
2. Jaeger, J. C., Cook, N. G., & Zimmerman, R. Fundamentals of rock mechanics, John Wiley & Sons, 2009.
3. Debasis, D., & Kumar, V. A. Fundamentals and applications of rock mechanics, PHI Learning Pvt. Ltd. New Delhi, India, 2016.

Course	CE6214: Special Topics in Geotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Special Topics in Geotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of geotechnical engineering. 2. Equip the students with a strong foundation in various topics in offshore geotechnical engineering. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to geotechnical engineering. Topics ranging from geotechnical earthquake engineering, offshore geotechnical engineering, Tunnels and Earth & Rockfill dams are covered.
Course Outline	Elements of geotechnical earthquake engineering: seismic loading and its effect on earth structures; dynamic response of single, and multi-degree of freedom systems and continuous systems; behaviour of soil under dynamic loading; pore pressure generation and liquefaction effects; seismicity and seismic design parameters; Engineering Seismology and Seismic Microzonation Offshore geotechnical engineering: nature of submarine soils; offshore soil investigations; seabed sediments; wave action on seabed; submarine slope stability; seabed anchor systems Numerical methods in geotechnical engineering: application of finite element method to the solution of stress, deformation, seepage, and consolidation problems; numerical solutions for soil dynamics problems; soil-structure interaction. Tunnels: Drilling and blasting of rocks; Grouting; Instrumentation and measurements in tunnelling, Analysis and Design Earth & Rockfill dams: Analysis and Design, field and laboratory investigations; foundation conditions and treatment; seepage and seepage control; stability analysis; deformation analysis; seismic considerations; instrumentation and monitoring
Learning Outcome	At the end of the course, student would be able to: 1. Design earthquake resistant structure using various methods available along with the method suggested in the IS code. 2. Perform offshore soil investigations and design of offshore structure. 3. Design earth and rockfill dams considering the seepage and seismic loads.

Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.
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Textbooks:

1. J.E. Bowles, Engineering Properties of Soils and Their Measurement, McGraw-Hill, 1992.
2. Kramar S.L, Geotechnical Earthquake Engineering, Prentice Hall International series, Pearson Education Pvt. Ltd.
3. J.E. Bowles, Foundation Analysis and Design, McGraw-Hill, 2001.

Reference books:

1. Ikuo Towhata, Geotechnical Earthquake Engineering, Springer series, 2008.
2. All relevant IS and International Codes.

Course	CE6215: Forensic Geotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Forensic Geotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, & 5. The learning objectives of this course are as follows: 1. To deal with investigations of different failures of engineered projects or facilities or structures related to civil engineering. 2. To analyze failures related to civil engineering, geotechnical, geoenvironmental and geological domains for professional practice, codes of analysis and design and implementation. 3. To apply the knowledge for further design and construction of any structures.
Course Description	This course is designed to understand and examine the various failure of civil and geotechnical engineering project due to different physical, environmental and geological causes. Further, knowledge gathered from this course will help in improving professional practice, developing codal provision and design and implementation.
Course Outline	Introduction, Forensic geotechnical engineering: theory and practice; Types of failure and damages, Preliminary investigations and information, Interaction between neighboring Structures, Planning the investigations, Site investigations and instrumentations, Settlement and failures of sub structures, Foundation design in difficult soil and climatic conditions, Ground water moisture related problems of substructures, Repairs and crack diagnosis, Back analysis in geotechnical engineering, Importance of uncertainty in forensic geotechnical engineering, Ethical and legal issues, Various Case studies of failures of civil engineering structures.
Learning Outcome	At the end of the course, student would be able to: 1. Understand the necessity and importance of forensic investigation in geotechnical engineering for various projects. 2. To deal with investigations of different failures of engineered projects or facilities or structures related to civil engineering. 3. To comprehend the techniques for mitigation of the failure damage. 4. To analyze failures related to civil engineering, geotechnical, geoenvironmental and geological domains for professional practice, codes of analysis and design and implementation.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

4. Rao, V. V. S., and GL Sivakumar Babu, eds. Forensic Geotechnical Engineering. India: Springer India, 2016.
5. Puzrin, Alexander M., Eduardo E. Alonso, and Núria M. Pinyol. Geomechanics of failures. Dordrecht, The Netherlands: Springer, 2010.
6. Iwasaki, Y. Instrumentation and Monitoring for Forensic Geotechnical Engineering. Forensic Geotechnical Engineering (2016): 145-163.

Reference books:

1. Day, Robert W. Forensic geotechnical and foundation engineering. McGraw-Hill, 2011.

2. Alonso, Eduardo E., Núria M. Pinyol, and Alexander M. Puzrin. Geomechanics of failures: advanced topics. Vol. 277. Berlin: Springer, 2010.
3. Lacasse, Suzanne. Forensic geotechnical engineering theory and practice. Forensic Geotechnical Engineering (2016): 17-37.
4. Franck, Harold, and Darren Franck. Forensic engineering fundamentals. Boca Raton, FL: CRC Press, 2013.
5. All relevant IS and international codes and research articles and reports.

Semester – IX

Sl. No.	Course Code	Course	L	T	P	C
1.	CE51PQ/ CE61PQ	M Tech Elective - II	3	0	0	3
2.	CE51PQ/ CE61PQ	M Tech Elective - III	3	0	0	3
3.	CE51PQ/ CE61PQ	M Tech Elective - IV	3	0	0	3
4.	CE5199	Project - III	0	0	16	8
TOTAL			9	0	16	17

M. Tech. Elective II (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6106	Soil Dynamics	3	0	0	3
2.	CE6107	Rock Slope Engineering	3	0	0	3
3.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
4.	CE6109	Geoenvironmental Engineering	3	0	0	3
5.	CE6110	Biogeotechnics	3	0	0	3

Course	CE6106: Soil Dynamics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Soil Dynamics
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of soil dynamics. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure. 4. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to soil dynamics. Topics ranging from wave propagation, estimation of dynamic properties and vibration isolation are covered. The course started with the basic knowledge gained by the attendee during undergraduate level regarding the geotechnical engineering. Estimation of dynamic soil properties along with static properties will be covered in this course. The basic concept behind the vibration isolation will also be taught in this course.
Course Outline	Principles of dynamics and vibrations: Vibration of elementary systems-vibratory motion-single and multi-degree of freedom system-free and forced vibration with and without damping. Waves and wave propagation in soil media: Wave propagation in an elastic homogeneous isotropic medium- Raleigh, shear and compression waves. Dynamic properties of soils: Stresses in soil element, coefficient of elastic, uniform and non-uniform compression, shear effect of vibration dissipative properties of soils, Determination of dynamic soil properties, Field tests, Laboratory tests, Model tests, Stress-strain behavior of cyclically loaded soils, Estimation of shear modulus, Modulus reduction curve, Damping ratio, Linear, equivalent-linear and non-linear models, Ranges and applications of dynamic soil tests, Cyclic plate load test, Liquefaction. Vibration isolation: Vibration isolation technique, mechanical isolation, foundation isolation, isolation by location, isolation by barriers, active passive isolation tests.
Learning Outcome	At the end of the course, student would be able to: 1. Estimate dynamic soil properties using various methods available along with the method suggested in the IS code. 2. Understand the basics of wave propagation. 3. Liquefaction potential assessment using IS code and other methods in practice. 4. Vibration isolation of structures using various active and passive isolation technique.

Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.
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Textbooks:

3. Swami Saran, Soil Dynamics and Machine Foundations, Galgotia Publications Pvt. Ltd, 1999.
4. B. M. Das and G. V. Ramana, Principles of Soil Dynamics, 2nd edition, Cengage Learning, 2011.

Reference books:

4. S. Prakesh & V. K. Puri, Foundation for machines, McGraw-Hill 1993.
5. Kramar S.L, Geotechnical Earthquake Engineering, Prentice Hall International series, Pearson Education (Singapore) Pvt. Ltd.
6. All relevant IS and International codes.

Course	CE6107: Rock Slope Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Rock Slope Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. Learning Objectives of Rock Slope Engineering: Understand the geological and geotechnical principles governing the stability of rock slopes, including the factors influencing rock mass behavior, such as geological structure, rock type, weathering, and groundwater conditions. 2. Gain proficiency in conducting site investigations and geological mapping to characterize rock slope conditions, identify potential failure mechanisms, and assess the stability of rock slopes using qualitative and quantitative methods. 3. Learn to apply engineering principles and analytical techniques to analyze the stability of rock slopes, including limit equilibrium methods, numerical modeling, and probabilistic approaches, to evaluate factors such as slope geometry, rock strength parameters, and external loading conditions. 4. Acquire knowledge of rock slope stabilization and mitigation techniques, including rock reinforcement, slope scaling, rock bolting, rockfall protection measures, and slope monitoring systems, and understand their applicability based on site-specific conditions and project requirements. 5. Develop the ability to design effective risk management strategies for rock slope engineering projects, including risk assessment, hazard identification, and implementation of risk control measures to ensure the safety of infrastructure, minimize environmental impacts, and optimize project performance.
Course Description	Rock Slope Engineering course offers a comprehensive examination of the principles, methodologies, and practices essential for the assessment, design, and management of rock slopes in various geotechnical and engineering applications. Through a combination of theoretical concepts, practical case studies, and hands-on exercises, students will gain an understanding of the geological factors influencing slope stability, methods for slope assessment and characterization, and techniques for slope stabilization and risk mitigation. Emphasizing a multidisciplinary approach, the course covers topics including rock mechanics, geotechnical investigation, slope stability analysis, monitoring and instrumentation, and the application of engineering principles to mitigate hazards associated with rock slopes. By the conclusion of the course, students will possess the knowledge and skills necessary to effectively evaluate, design, and manage rock slopes to ensure the safety and sustainability of infrastructure projects in challenging terrain.
Course Outline	Principles of rock slope design, Basic mechanics of slope failure, Structural geology and data interpretation, Site investigation and geological data collection, Rock strength properties and their measurement, Plane failure, Wedge failure, circular failure, Toppling failure, Numerical analysis, Stabilization of rock slopes, Movement monitoring
Learning Outcome	At the end of the course, student would be able to:

	1. Geotechnical Understanding: Develop a comprehensive grasp of the geological factors influencing rock slope stability, including rock mass properties, weathering processes, and the impact of discontinuities. 2. Risk Assessment and Management: Acquire skills in conducting thorough risk assessments for rock slopes, identifying potential failure modes, and implementing effective risk management strategies to mitigate hazards. 3. Design and Implementation of Stabilization Measures: Learn to design and implement appropriate stabilization measures for rock slopes, including rock bolts, shotcrete, and rockfall protection systems, based on site-specific conditions and project requirements. 4. Application of Analytical Techniques: Gain proficiency in utilizing analytical techniques such as limit equilibrium methods and numerical modeling to assess slope stability and make informed decisions regarding slope design and stabilization measures.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

- Duncan C. Wyllie, Chris Mah, Rock Slope Engineering: Fourth Edition, 2004,
- Evert Hoek, Jonathan D. Bray, Rock Slope Engineering, Third Edition, 1974
- Ramamurthy T, Engineering in Rocks for Slopes, Foundations and Tunnels, 2014

Reference books:

- Engineering rock mechanics: Part 1, by John A. Hudson and John P. Harrison
- Engineering rock mechanics: Part 2, by John A. Hudson and John P. Harrison
- Fundamentals of rock mechanics by J. C. Jaeger, N. G. W. Cook, and R. W. Zimmerman

Course	CE6108: Constitutive Modelling in Geotechnics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Constitutive Modelling in Geotechnics
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 5. To understand and analyse the numerical and constitutive modelling and its application in geomaterials to solve the complex geotechnical engineering problems.
Course Description	This course has been designed to provide a fundamental of continuum-mechanics approaches to constitutive and numerical modeling of geomaterials in geotechnical problems. Further, the course aims to provide some knowledge about applications of the constitutive and numerical models within the different existing numerical codes. The various applications, special topics and case studies will be covered in this course to analyse and understand the real geotechnical problems and finding the future solutions.
Course Outline	Introduction and Tensor Analysis, Stresses and strains, Equations of Continuum Mechanics and Thermodynamics, Elasticity, Plasticity and yielding, Introduction to upper and lower bounds, selected boundary value problems, Elastic-plastic model for soils: elastic and plastic volumetric strains, plastic hardening, plastic shear strains, plastic potentials, flow rule. Cam clay model: critical state line, shear strength, stress-dilatancy, index properties, prediction of conventional soil tests. Applications and special topics.
Learning Outcome	At the end of the course, student would be able to: 1. Understand the basic of continuum mechanics. 2. Learn the various elastic-plastic model for soils and its applications 3. Comprehend about the cam clay model and its importance in geotechnical engineering. 4. Expose with various case studies and special topics to analyze the real geotechnical problem.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Wood, David Muir. Soil behaviour and critical state soil mechanics. Cambridge university press, 1990.
2. Atkinson, J. H., and P. L. Bransby. The mechanics of soils, an introduction to critical state soil mechanics. No. Monograph. 1977.
3. Chan, W.K. and Saleeb, A.F., Constitutive equations for engineering materials, Volume 1: Elasticity and modelling, Elsevier, 1994.
4. Chan, W.K. and Saleeb, A.F., Constitutive equations for engineering materials, Volume 2: Plasticity and modelling, Elsevier, 1994.

Reference books:

1. Harr, Milton Edward. Foundations of Theoretical Soil Mechanics. McGraw-Hill, 1966.
2. Desai, C.S. and Siriwardane, H.J., Constitutive laws for engineering materials with emphasis on geologic materials, Prentice Hall, 1984.

Course	CE6109 Geoenvironmental Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geoenvironmental Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 4. Understanding methods of waste management and disposal 5. Learning methods of contaminated site characterization 6. Learning methods of remedial measures of a contaminated site 7. Understanding application of unsaturated soil in Geoenvironmental Engineering
Course Description	The course covers the source of various types of waste and its proper disposal, remediation of contamination sites. Municipal solid waste and industrial waste disposal techniques. Role of compacted unsaturated clay as liner material in landfill.
Course Outline	Production and classification of wastes, contaminated site characterization, Selection of waste disposal sites, selection criteria. Design of various landfill components such as liners, covers, leachate collection and removal, gas generation and management, ground water monitoring, stability analysis. Ash disposal facilities, dry disposal, wet disposal, design of ash containment system, stability of ash dykes, mine tailings. Planning, source control, soil washing, bioremediation, stabilization of contaminated soils and risk assessment approaches. Basics of unsaturated soil, soil suction, suction measurement techniques, SWCC, application of unsaturated soil in Geoenvironmental engineering.
Learning Outcome	At the end of the course, student would be able to: 1. Able to manage and dispose particular type of waste 2. Should be able to characterise contaminated site 3. Should be able to take appropriate remedial measures for a contaminated site 4. Should be able to use unsaturated clay as liner material in Geoenvironmental application.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

4. H D Sharma and K R Reddy, "Geoenvironmental Engineering: Site Remediation, waste containment, and emerging waste management technologies", John Willey and Sons, 2004.
5. R N. Yong, "Geoenvironmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation", Thomson Telford, 2000.
6. D. G. Fredlund and H. Rahardjo, "Soil Mechanics for Unsaturated soils", Wiley Publication, 1993.

Reference books:

2. R Kerry Rowe, R M Quigley, Richard W I Brachman and John R Booker, "Barrier Systems for Waste Disposal Facilities", 2nd edn, CRC press, 2019.
6. L N Reddy and H.I. Inyang, "Geoenvironmental Engineering: Principles and Applications", Marcel Dekker, 2000
7. James K Mitechell, K Soga, "Fundamentals of soil behaviour", Wiley Publication, 2005.
8. Charles W.W.Ng, B Menzies, "Advanced unsaturated soil mechanics and engineering", CRC Press, 2014

Course	CE6110: Biogeotechnics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	XX61PQ: Biogeotechnics
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, and 5. The objectives of this course are to - Understand the significance of geomicrobiology in geotechnical engineering. - Comprehend various biological process in ground/soil improvement. - Learn about the testing and instrumentation facilities for biological process and geotechnical behaviour. - Apply the knowledge for upscaling to develop sustainable geomaterials.
Course Description	This course combines the principles of environmental biotechnology and geotechnical engineering. Geotechnical engineers design, build, and maintain structures in the subsurface. This course will be able to provide combine and apply basic theory and concepts from soil mechanics and biology in engineering applications. This course also brings an understanding about various geomicrobiological process for soil improvement.
Course Outline	Introduction to Biogeotechnics, Biological process of the subsurface materials, Stoichiometry and kinetics of bio-chemical reactions, Microbially Induced Calcite Precipitation (MICP), Root-Inspired Foundations, Enzymatically Induced Calcite Precipitation (EICP), Self-healing materials, Termite mounds-, Snake- and Ant-Inspired Excavations, Microbial Ecology, Biofilms, and Zeolite Sorption, Production of bio-cements. Instrumentation and testing for evaluating biological process and geotechnical material behaviour, Upscaled model tests and field trails. Special topics and case studies.
Learning Outcome	At the end of the course, student would be able to: - Understand the importance of geomicrobiology in geotechnical engineering. - Comprehend various bio-chemical reactions and their application in biological process for ground/soil improvement. - Investigate biological process and geotechnical behaviour. - Apply the knowledge for upscaling to develop sustainable geomaterials.
Assessment Method	Assignments, Quizzes, Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

- Ehrlich, H., Newman, D. Geomicrobiology (5th ed.). Boca Raton: CRC Press (2021).
- Hemond, Harold F., and Elizabeth J. Fechner. Chemical fate and transport in the environment. academic press, 2022.
- Rittmann, Bruce E., and Perry L. McCarty. "Environmental biotechnology: principles and applications." (No Title) (2001).

Reference books:

- Coduto, Donald P., Man-chu Ronald Yeung, and William A. Kitch. Geotechnical engineering: principles and practices. Pearson India (2011).
- Zheng, Chunmiao, and Gordon D. Bennett. Applied contaminant transport modeling. Vol. 2. New York: Wiley-Interscience, 2002.
- All relevant codes and research papers.

M. Tech. Elective III (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6111	Rock Mechanics	3	0	0	3
2.	CE6112	Environmental Rock Engineering	3	0	0	3
3.	CE6113	Pavement Geotechnics	3	0	0	3
4	CE6114	Probalistic Methods in Geotechnical Engineering	3	0	0	3

Course	CE6111: Rock Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Rock Mechanics
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2 and 3 1. Understand the fundamentals of geology. 2. Comprehend and analyse the properties of the intact and jointed rock mass. 3. Recognize and analyse different Rock Mass Classification systems and the stress-strain behaviour, strength and deformability of rock mass. 4. Solve complex engineering problems by applying principles of engineering and mechanics.
Course Description	This course is offered as a core course in department to understand the basics of rock mechanics and behaviors of rocks for various construction purposes such as foundations, underground excavation, landslide etc.
Course Outline	Introduction to Rock Mechanics: Basic knowledge of geology; Problems associated with rock mechanics; General terminologies- Interior of earth, rock forming minerals, identification, intact rock, discontinuities and rock mass; Rock as engineering material. Properties, Mechanics and Classification of Intact Rock; Mechanical properties; Factors affecting strength of rocks; Intact rock classification; Rock cycle; Basic principles- stress and strain; Rock failure criteria. Properties and Mechanics of Rock Discontinuities; Plotting of geological data and its application; Shear behaviour of rock; Shear strength criteria; Flow through discontinuities. Rock mass classification systems; Strength criteria; Time dependent behaviour in rocks; Field investigation; Dynamic and thermal properties of rock.
Learning Outcome	At the end of the course, student would be able to: 1. Understand the basics of rock mechanics 2. Learn and analyze the physical, mechanical, and hydraulic characteristics of the intact and jointed rock mass. 3. Acquaint with different Rock Mass Classification systems. 4. Recognize and analyse the stress-strain behaviour, strength and deformability of rock mass. 5. Solve complex engineering problems by applying principles of engineering and mechanics.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Goodman, R. E. Introduction to rock mechanics, John Wiley and Sons, 1989.
2. Hudson, J. A., & Harrison, J. P. Engineering rock mechanics: an introduction to the principles, (Vol.: I-IV), Elsevier, 2000.
3. Harrison, J. P., & Hudson, J. A. Engineering rock mechanics: part 2: illustrative worked examples, Elsevier, 2000.
4. Ramamurthy, T., Engineering in rocks for slopes, foundations and tunnels, Prentice Hall India, 2010.

References:

1. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.

2. Hoek, E, & Brown, E. Underground excavations in rock, CRC Press, 1980. Singh, B., & Goel, R. K. Engineering rock mass classification, Elsevier, 2011.
3. Mogi, K. Experimental rock mechanics, CRC Press, 2006. Bieniawski, Z. T. Rock mechanics in mining & tunnelling, A.A. Balkema, Rotterdam, 1984.
4. Jaeger, J. C., Cook, N. G., & Zimmerman, R. Fundamentals of rock mechanics, John Wiley & Sons, 2009.
5. Debasis, D., & Kumar, V. A. Fundamentals and applications of rock mechanics, PHI Learning Pvt. Ltd. New Delhi, India, 2016.

Course	CE6112: Environmental Rock Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Environmental Rock Engineering
Learning Mode	Lectures and practical
Learning Objectives	Complies with PLO- number 1, 2 and 3 1. Understand Rock Mechanics and Environmental Interactions: Gain foundational knowledge of rock mechanics principles and their environmental implications. 2. Assess and Mitigate Environmental Impacts: Develop skills to assess, design, and implement strategies to mitigate environmental impacts of rock engineering projects. 3. Apply Sustainable and Regulatory Practices: Integrate sustainable engineering practices and ensure compliance with environmental regulations in project planning and execution. 4. Enhance Interdisciplinary and Professional Skills: Cultivate interdisciplinary collaboration, critical thinking, and effective communication to address complex environmental challenges in rock engineering.
Course Description	This course explores the interaction between rock mechanics and environmental considerations. Topics include slope stability, underground excavation, waste disposal, and geohazard mitigation strategies. Students learn principles for sustainable rock engineering practices in various environmental contexts.
Course Outline	Introduction to Rock Mechanics and Environmental Considerations, Geological Hazards and Risk Assessment, Rock Mass Properties and Characterization, Stress-strain behaviour of rocks and rock masses: Elastic, elastoplastic, and brittle, Crack phenomena and mechanisms of rock fracture, Temperature, pressure and water related, problems, Effect of temperature on rock behaviour. Fluid flow through intact and fissured rocks, Time dependent behaviour of rocks: Creep, Viscoelasticity and Viscoplasticity, Continuum and discontinuum theories: Equivalent material, Block and Distinct element Application: Waste disposal, Radioactive and hazardous wastes, repositories, location and design, VLH, VDH and KBS3 concepts. Waste container, barriers, rock structure, embedment, buffers and seals. Performance assessment, quality control and monitoring. Case histories. Hazardous Earth processes, high ground stresses, rock bursts, subsidence. Earthquakes, tectonic stresses, creep, ground motions, damage, prediction. Volcanic activity and hazard. Tsunamis. Case studies. Thermal analysis, Thermo-mechanical analysis, thermo-hydro-mechanical analysis. Rock dynamics. Physical modelling.
Learning Outcome	At the end of the course, student would be able to: 1. Environmental Rock Engineering focuses on understanding the interaction between rock mechanics and the environment. 2. Learners comprehend the effects of natural processes and human activities on rock formations. 3. They develop skills to assess, mitigate, and manage environmental risks related to rock engineering projects. 4. The course equips students to design sustainable solutions for geological hazards and environmental protection.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

6. Goodman, R. E. Introduction to rock mechanics, John Wiley and Sons, 1989.

7. R. Pusch. Waste Disposal in Rock. Elsevier. 1994
8. Harrison, J. P., & Hudson, J. A. Engineering rock mechanics: part 2: illustrative worked examples, Elsevier, 2000.
5. Randall F. Barron and Brian R. Barron. Design for Thermal Stresses. Wiley, 2011
6. Ramamurthy, T., Engineering in rocks for slopes, foundations and tunnels, Prentice Hall India, 2010.

References:

9. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.
10. Hoek, E., & Brown, E. Underground excavations in rock, CRC Press, 1980. Singh, B., & Goel, R. K. Engineering rock mass classification, Elsevier, 2011.
11. Mogi, K. Experimental rock mechanics, CRC Press, 2006. Bieniawski, Z. T. Rock mechanics in mining & tunnelling, A.A. Balkema, Rotterdam, 1984.
12. Jaeger, J. C., Cook, N. G., & Zimmerman, R. Fundamentals of rock mechanics, John Wiley & Sons, 2009.
13. Debasis, D., & Kumar, V. A. Fundamentals and applications of rock mechanics, PHI Learning Pvt. Ltd. New Delhi, India, 2016.

Course	CE6113 Pavement Geotechnics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pavement Geotechnics
Learning Mode	Lectures
Learning Objectives	Complies with program learning outcome 1a; 3a 5. Equip the students with a strong foundation and strengthen their knowledge in pavement geotechnics. 6. The student will be able to apply advanced theory and analysis for problem-solving in pavement geotechnics. 7. The student will prepare for further research and graduate study by critical thinking and improving research skills. 8. The student will be able to apply fundamentals in identifying, formulating, and solving complex engineering problems in pavement geotechnics.
Course Description	This coursework will provide practical insights for students in the field of Pavement Geotechnics. The development of sustainable approaches for green technology-based highways for global road networks is given the highest priority. This coursework will disseminate knowledge to the students in pavement geotechnics. The students will be taught the recent sustainable developments and design principles to face current and future highway problems in relevance with pavement geotechnics.
Course Content	Geotechnical properties of geomaterials such as soil, rock, soil-rock mixture, and alternative geomaterials. Stabilized geomaterials, Various types of pavements, subgrade characterization and geotechnics, challenges faced in constructing subgrades. Subbase, base, and asphalt concrete materials relevant to pavement geotechnics. Elastic theories and stress distribution in pavements. Estimation of resilient modulus of pavements. Geotechnical design parameters for pavements.. Geosynthetic stabilization of constructed layers and interlayers. Asphalt concrete courses and their stabilization technique, Stress distribution of pavement system in stabilized and unstabilized ground conditions. Geosynthetic stabilized pavements, low-carbon cement stabilized pavements, geotechnical parametric studies for AASHTO, MEPDG, and IRC designs. Porous pavement geotechnics, Analysis of pavement distress studies using KENPAVE and IIT Pave. Low-carbon materials and sustainable geosynthetic materials used for pavements. Important concepts on permeable pavements and inverted pavements. Semi and full-depth reclamation techniques of pavements. The waste material used for pavement. Field and case studies.
Learning Outcome	The course structure will impart high-quality knowledge on students to face current and future problems faced by the world's largest road networks. Students would be able to learn the core principles of pavement designs and advanced sustainable pavement techniques. Exploration of alternative materials, design approaches, and innovation in pavement geotechnics will be disseminated through this course.

Textbooks:

7. Huang, Y. H. (2004). Pavement analysis and design, Second edition, Upper Saddle River, NJ: Pearson Prentice Hall.
8. Yoder, E. J., & Witczak, M. W. (1991). Principles of pavement design. John Wiley & Sons.

9. Mallick, R. B., & El-Korchi, T. (2008). *Pavement engineering: principles and practice*. CRC Press.
10. Frost, M. W., Jefferson, I., Faragher, E., Roff, T. E. J., & Fleming, P. R. (Eds.). (2003). **Transportation Geotechnics**: Proceedings of the Symposium Held at The Nottingham Trent University School of Property and Construction on 11 September 2003. Thomas Telford Publishing.
11. Ellis, E., Yu, H. S., McDowell, G., Dawson, A. R., & Thom, N. (Eds.). (2008). **Advances in Transportation Geotechnics**: Proceedings of the International Conference Held in Nottingham, UK, 25-27 August 2008. CRC Press.
12. Miura, S., Ishikawa, T., Yoshida, N., Hisari, Y., & Abe, N. (Eds.). (2012). **Advances in Transportation Geotechnics 2**. CRC Press.

Reference books:

7. Ferguson, B. K., & Ferguson, B. K. (2005). **Porous pavements**. Boca Raton, FL: Taylor & Francis.
8. Rogers, M., & Enright, B. (2016). **Highway engineering**. John Wiley & Sons.
9. Nikolaides, A. (2014). **Highway engineering: Pavements, materials and control of quality**. CRC Press.
10. Babu, G. L. S., Kandhal, P. S., Kottayi, N. M., Mallick, R. B., & Veeragavan, A. (2019). *Pavement Drainage: Theory and Practice*. CRC Press.
11. Babu, G.L.S., (2006). *An Introduction to Soil Reinforcement and Geosynthetics*, Universities Press (India) Pvt. Ltd.

Course	CE6114: Probabilistic Methods in Geotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Probabilistic Methods in Geotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of probabilistic methods in geotechnical engineering. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to the application of probabilistic methods in geotechnical engineering. Topics ranging from risk, uncertainty, Monte Carlo simulation, and FORM are covered. The course started with the basic knowledge gained by the attendee up to undergraduate level regarding the probabilistic methods. Thereafter, the basics and advanced concept related to risk and reliability analysis will be studied by the students.
Course Outline	Introduction: Concept of risk; and uncertainty in geotechnical engineering analysis and design; Fundamental of probability models. Analytical models of random phenomena: Bayesian Analysis; Analysis of variance (ANOVA); Application of central limit theorem; confidence interval; expected value; and return period. Application of Monte Carlo simulation (MCS): Determination of function of random variables using MCS methods; Application of MCS in various geotechnical engineering problems. Determination of Probability Distribution Model: Probability paper; testing of goodness-of-fit of distribution models. Methods of risk Analysis: Composite risk analysis; Direct integration method; Method using safety margin; reliability index and safety factor; FORM; SORM; Applications of risk and reliability analysis in engineering systems.
Learning Outcome	At the end of the course, student would be able to: 1. Analyzed structure using various probabilistic methods available along with the method suggested in the Euro code. 2. Perform reliability analysis for various geotechnical problems. 3. Assess composite risk using various techniques to estimate failure of geotechnical structures.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

5. Ang, A. H-S., and Tang, W. H., Probability Concepts in Engineering, Vol. 1, John Wiley and Sons, 2006.
6. Scheaffer, R. L., Mulekar, M. S. and McClave, J. T., Probability and statistics for Engineers, 5th Edition, Brooks / Cole, Cengage Learning, 2011.

Reference books:

7. Halder, A and Mahadevan, S., Probability, Reliability and Statistical Methods in Engineering Design, John Wiley and Sons, 2000.
8. All relevant IS and International Codes.

M. Tech. Elective IV (5/6 level)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engineering	3	0	0	3
2.	CE6103	Environmental Toxicology and Risk Assessment	3	0	0	3
3.	CE6115	Advanced Structural Mechanics	3	0	0	3
4.	CE6116	Bridge Engineering and Design	3	0	0	3
5.	CE6125	Bituminous materials	3	0	0	3
6.	CE6128	Highway Geometric Design and Safety	3	0	0	3
7.	CE6129	Airport Engineering	3	0	0	3

Course	CE6102: Sampling, Analytical Methods and Statistics for Environmental Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Sampling, Analytical Methods and Statistics for Environmental Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 4 The objective of this course is 1. Develop an understanding of various sampling techniques used in environmental engineering. 2. Learn the principles and applications of common analytical methods for environmental samples. 3. Gain proficiency in statistical analysis and interpretation of environmental data.
Course Description	This course provides an in-depth exploration of sampling techniques, analytical methods, and statistical analyses used in environmental engineering. Students will learn how to design sampling strategies, select appropriate analytical methods, and apply statistical tools to interpret environmental data.
Course Outline	Sampling: Principles of sample collection, Importance of sampling for environmental analysis, Types of samples (grab samples, composite samples, etc.), Factors to consider in sampling design (location, frequency, timing) Analytical methods: Gravimetric methods, titrimetric methods, electrochemical methods, Spectrometric method of analysis, Chromatographic method of analysis, Advanced analytical techniques (FTIR, XRD, SEM, TEM, TGA, etc.) Quality Assurance and Quality Control (QA/QC): Standard Operating Procedures (SOPs), Documentation and record keeping, Calibration and standardization, Control Samples-blanks, duplicates, spiked samples: accuracy, precision, Limit of Detection (LOD), Limit of Quantification (LOQ) Statistical Analysis: Basics of statistical analysis (mean, median, standard deviation, etc.), Advanced statistical tools: regression, hypothesis testing, ANOVA, Error analysis, Reproducibility/repeatability.
Learning Outcome	At the end of the course, students would be able to: 1. Learn the basics of sample collection, including types, locations, and sampling frequency. 2. Develop expertise in using various analytical techniques, such as gravimetric, titrimetric, electrochemical, spectrometric, and chromatographic methods. 3. Establish and maintain quality assurance and quality control (QA/QC) processes to ensure accuracy, reliability, and consistency in sampling and analysis. 4. Acquire the ability to apply statistical methods to analyze, interpret, and validate environmental data, ensuring accuracy and reliability.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books and Reference:

1. Zhang, C., 2007. Fundamentals of environmental sampling and analysis. John Wiley & Sons.
2. Csuros, M., 2018. Environmental sampling and analysis: lab manual. Routledge.
3. Berthouex, P.M. and Brown, L.C., Statistics for Environmental Engineers, Lewis Publishers, CRC Press, Boca Raton, 1994.
4. Ott, W.R. Environmental Statistics and Data Analysis, Lewis Publishers, New Jersey,
5. 1995.
6. Csuros, M. and Csuros, C., 2016. Environmental sampling and analysis for metals. CRC Press.
7. Popek, E.P., 2017. Sampling and analysis of environmental chemical pollutants: a complete guide. Elsevier.
8. Rice, E.W., Bridgewater, L. and American Public Health Association eds., 2012. Standard methods for the examination of water and wastewater (Vol. 10). Washington, DC: American public health association.
9. Rong, Y. ed., 2011. Practical environmental statistics and data analysis. ILM publications.

Course	CE6103: Environmental Toxicology and Risk Assessment
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Environmental Toxicology and Risk Assessment
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 4 and 5 1. To foster awareness of toxicological aspect of surroundings and environment. 2. To prepare students for estimating the risk associated with various chemicals present in environment. 3. It will prepare students for further research study by critical thinking and improving research skills.
Course Description	The primary goal of this course is to comprehend the toxicity of various chemicals, understand dose-response relationship and prepare to develop models for risk assessments.
Course Outline	Importance of environmental toxicology, dose-response relationship, hazard and risk; Routes of exposure, toxico-kinetics, oral route, dermal route, inhalation route, distribution, elimination, absorption and bioavailability; Mechanism of action, endocrine disruption, cytotoxic, enzyme inhibition, reproductive toxicology, teratology, biotransformation and secondary effect; Data sources for exposure risk characterization; Toxicology/epidemiology–Biomarkers; Ecology Trophic levels, BCF (bio concentration factor), BCF modeling, indicator species; Integrated exposure assessment – (case studies); Physiological-based Pharmacokinetic (PBPK) Models EU; Application of statistical and Monte Carlo simulations and other techniques for probabilistic exposure assessment; Risk Characterization, communication and decision making
Learning Outcome	At the end of the course, students would be able to: 1. Able to recognize the toxic compounds and understand their impact on health. 2. Apply fundamental theories and techniques from the chemical and ecological sciences to find out the health risk. 3. Analyse the exposure to different environment. 4. Understanding about risk estimation, characterization, and modelling.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books:

1. Wright, D.A. and Welbourn, P. Environmental toxicology, Cambridge University Press, 2002.
2. Lee, E. S., Hernandez, M. and Forthofe, R. N. Biostatistics: a guide to design, analysis and Discovery, 2nd edition, Academic Press Inc., 2007.
3. Landis, W., Sofield, R., Yu, M. Introduction to Environmental Toxicology, Molecular Substructures to Ecological Landscapes, Fifth Edition, 2018.

Reference book:

1. Cross, C.L. and Daniel, W.W. Biostatistics: a foundation for analysis in the health sciences, 11th edition, Wiley, 2018.
2. Shaw, I. and Chadwick, J. Principles of Environmental Toxicology, CRC Press, 1998.

Course	CE6115 Advanced Structural Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Structural Mechanics
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Understand the concept of deformation, linear and nonlinear measures of strain and stress. 2. Introduce failure theory of different materials. 3. Predict the behaviour elastic solids under different loading.
Course Description	The course deals with analysis of deformable bodies. This course provides the students an exposure for linear and non-linear analysis of solids, analysis of stress and strain, fundamental physical principles, constitutive relation of materials, and two-dimensional electrostatics problems.
Course Outline	Introduction: Suffix notation system, tensor algebra; Strain analysis: deformation and velocity gradients, Lagrangian and Eulerian description of strain (Green-Lagrange, Euler-Almansi, Engineering and Logarithmic strain measure), large strain and rotation, finite strain and small deformation theory, principal strains and strain invariants, compatibility conditions; Stress analysis: forces and moments, theory of stress (Cauchy, Kirchoff, Piola-Kirchhoff I and II, Biot stress measures), energetically conjugate stress and strain measures, plane stress and plane strain, principal stresses and stress invariants, compatibility equations, equilibrium equations; Fundamental physical principles: conservation of mass, linear momentum, angular momentum, and energy, second law of thermodynamics; Constitutive theory: St. Venant's principal, linear elasticity and generalized Hook's law; Stokesian and Newtonian fluids, Navier-Stokes equations, Bernoulli equation, viscoelasticity, stress, strain and energy based failure theory, yield criteria (Mohr-Coulomb, Hoek-Brown, Tresca, Von Mises, and Drucker-Prager); Elasticity: Airy stress function, two-dimensional electrostatics problems, torsion, buckling.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand the concept of deformation mechanisms in solid and different measures of strain and stress. 2. Gain knowledge on material model of liner elastic solid body. 3. Analysis of problem in elastic deformable body.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbook/ Reference book:

6. S. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw Hill Book Company, International Ed, 1970.
7. L. S. Srinath. Advanced Mechanics of Solids, McGraw Hill Education, 2010.
8. Allan F. Bower. Applied Mechanics of Solids, CRC Press, 2010.
9. Irving H. Shames and Francis A. Cozzarelli. Elastic and Inelastic Stress Analysis, Taylor & Francis Group; Revised edition, 1997.
10. Romesh C. Batra. Element of Continuum Mechanics, AIAA, 2012.

Course	CE6116 Bridge Engineering and Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Bridge Engineering and Design
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Apply the fundamental principles of bridge engineering, including load distribution, dead and live load analyses etc. to evaluate the performance of different types of bridges. 2. Design of various bridge components following various Indian as well as international standards and safety regulations. 3. To become proficient in using advanced computational tools and software for the modelling, simulation considering dynamic loading like wind and earthquake.
Course Description	This course offers a comprehensive exploration of bridge engineering and design, covering fundamental principles, methodologies, and practical applications. This course covers key aspects including structural analysis, material selection, construction techniques, and environmental considerations.
Course Outline	Introduction: Classification of Bridges, General Features of Design, IRC Loading (viz. 70R, Class AA tracked and wheeled vehicle), Design Codes, Working Stress Method, Limit State Method of Design as per IS456:2000 and IRC 112:2020; Analysis & Design: Consideration of various loading (dead load, vehicular load etc.), Slab bridge, Box Culvert, T-beam bridge, Box Girder bridge and Prestressed concrete bridge. Subsoil properties, their uses for substructure design.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Explore structural analysis, materials selection, construction techniques, and sustainability considerations in the context of designing safe, efficient, and resilient bridges. 2. Develop expertise to conceptualize, plan, and execute bridge projects that meet technical standards and address societal needs. 3. Gain knowledge and skills necessary to tackle real-world challenges in bridge engineering, contributing to the development of critical infrastructure systems.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

6. Swami Saran, Analysis and Design of Substructures: Limit State Design, 28 February 2018.
7. K. K. Rakshit, Design and Construction and Highway Bridges.
8. Raju N. K, Design of Bridges, 5Ed (Pb 2019) – 1 January 2019.
9. Daniel J. Inman, Charles R. Farrar, Vicente Lopes Junior, Valder Steffen Junior, Damage Prognosis: For Aerospace, Civil and Mechanical Systems, John Wiley & Sons, 2005.

Course	CE6125 Bituminous Materials
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Bituminous Materials
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 1. Understand fundamental properties and behavior of asphalt binders. 2. Describe the fundamental properties and behavior of asphalt concrete. 3. Perform Superpave volumetric mixture design 4. Analyze and understand strengths and weaknesses of various performance test methods 5. Understand quality control of bituminous materials in road construction.
Course Description	In this course bituminous materials used in road construction will be covered in detail. Source, properties and performance evaluation methods of bituminous materials are important in selecting them in road construction project. The course will help students understand rheological properties of bituminous materials. The practices used in road construction industry in selection, design and quality control of bituminous materials will be covered.
Course Outline	<u>Introduction to Bituminous Materials</u> Asphalt binder: Definitions, Classification of asphalt paving materials, Sources, Production types, Chemistry and Physical properties, Performance tests and Specifications, Specifications for modified binders. Emulsion: Definitions, Classification and Engineering properties. <u>Introduction to Viscoelasticity</u> Rheological properties – visco-elastic models. Dynamic Shear modulus, Dynamic modulus, Relaxation modulus, Creep compliance, Indirect Tensile Properties. <u>Asphalt binder tests and specifications</u> Rheological properties, high temperature viscosity, low temperature stiffness, fatigue evaluation. Recent tests: RV, DSR, BBR, MSCR, Stress sweep fatigue test. <u>Asphalt mix</u> Rheological properties, Weight-Volume Relationships, Superpave mix design. Image based analyses. <u>Asphalt Mix Design using Recycled Pavement Materials:</u> Crumbed rubber, Construction and Demolition (C&D) waste, Recycled Asphalt Pavement (RAP). <u>Asphalt Mix Performance Modeling:</u> Beam fatigue, Viscoelastic continuum damage, Rutting. <u>Quality Control and Tolerance:</u> Field construction, Quality control plan, Control charts, QA/QC tests. <u>Software:</u> ABAQUS
Learning Outcome	At the end of the course, student would be able to:

	1. Perform Superpave volumetric mixture design 2. Understand characteristic properties of bituminous materials. 3. Use recycled materials in bituminous mixes for road construction. 4. Develop quality control plan for bituminous materials in road construction projects.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Kim., Y. R. "Modeling of Asphalt Concrete." McGraw-Hill, 2009, 1st Edition.
2. Huang, Y. H. "Pavement analysis and design." Pearson, 2004.
3. Papagianna, A. T. and Masad, E. A. "Pavement Design and Materials." John Wiley & Sons, Inc., 2008.
4. Superpave Mix Design, MS-2, 7th Edition, Asphalt Institute, 2013.

Reference books:

1. MORTH. "Ministry of Road Transportation & Highways Specifications for Road and Bridge Works." 2013.
2. National Cooperative Highway Research Program (NCHRP) Reports.

Course	CE6128: Highway Geometric Design and Safety
Course Credit	3-0-0-3
Course Title	Highway Geometric Design and Safety
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 1. Understand the concept of highway geometry and design controls; 2. Understand the factors influencing road safety; 3. Learn practices and technologies to mitigate road accidents;.
Course Description	The course mainly focuses on factors influencing road geometry and its relation with road safety. The student will learn design factors that need to be considered in highway geometric design based on different expected road users. Need to understand characteristics of drivers, pedestrians, vehicles and road will be illustrated. Students will learn impact of electric and autonomous vehicles on geometric road design.
Course Outline	Introduction and roadway function. Optimization of highway geometric design for autonomous vehicle. Design controls: vehicles and drivers, speed, volume and access; Practical considerations in fixing the alignments, Route layout, Design of roadway cross-section, Longitudinal drains, Estimate earthwork volumes. Sight distances for road segments and intersections, Fixing of gradients, Design of vertical and horizontal curves. Design speed; Sight distance, horizontal and vertical alignment, Intersection design considerations, Environmental considerations, and context sensitive solutions. Impact of Electric Vehicles on Roads. Highway safety; Safety assessment; Driver behavior and crash causality; Elements of highway safety management systems; Safety counter measures; Safety management process; Crash reporting and collision diagrams; Basics of crash statistics; Before-after methods in crash analysis; Highway geometry and safety; Road safety audits; Crash investigation and analysis.
Learning Outcome	At the end of the course, student would be able to: • Ability to access road safety. • Ability to design road geometry.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. J. H. Banks, Introduction to Transportation Engineering, McGraw-Hill, 2002.
2. S. K. Khanna and C. E. G. Justo, Highway Engineering, Nem Chand Bros., 2002.
3. American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets, 5th Edition, 2004.

Course Number	CE6129: Airport Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Airport Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 1. To provide fundamental knowledge in airport engineering. 2. Train students to plan, design and operate airport facilities in industry. 3. To understand design and maintenance of airport runways, taxiways.
Course Description	This course will discuss fundamental concepts in airport engineering. Course will cover planning, design, construction and operation of airport.
Course Content	Basic principles of airport facilities design to include aircraft operational characteristics, noise, site selection, land use compatibility. Airport planning, operational area, ground service areas, airport capacity, runway design, taxiway design, airport pavement analysis and design. Airport pavement material characterization. Airport pavement structural evaluation and maintenance. ICAO design guidelines, FAA mechanistic-empirical design. Runway and Taxiway signs and markings.
Learning Outcome	At the end of the course, student would be able to: 1. Understand basic airport facilities. 2. Design runway and other airport pavements. 3. Design airport operations.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination

Textbooks:

1. Horonjeff R., McKelvey F.X., Sproule W., Young S. "Planning and Design of Airports", 5th Ed. New York: McGraw-Hill.
2. Saxena, S.C., "Airport Engineering – Planning and Design", CBS Publishers.
3. S.C. Rangwala. "Airport Engineering," 13th edition, Charotar Publishing house, 2013.
4. Y. H. Huang, Pavement Analysis and Design (2nd Edition), Pearson Education, India
5. A.T. Papagiannakis and E.A. Masad, Pavement Design and Materials, John Wiley & Sons, Inc.

Reference:

1. Federal Aviation Administration Specifications.
2. International Civil Aviation Organisation Specifications.