

M. Tech. in Civil Engineering (Credit Rationalized)

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.

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	CE5181	Advanced Engineering Mathematics	3	0	0	3
3.	CE5182	Civil Engineering Design – I	1	2	0	3
4.	CE5183	Civil Engineering Lab-I	0	0	3	1.5
5.	CE51XX/ CE61XX	Elective-I	3	0	0	3
6.	CE51XX/ CE61XX	Elective-II	3	0	0	3
7.	CE51XX/ CE61XX	Elective-III	3	0	0	3
8.	XX61PQ	IDE	3	0	0	3
	TOTAL		17	4	5	23.5

IDE (Inter Disciplinary electives) in the curriculum aims to create multitasking professionals/scientists with learning opportunities for students across disciplines/apptitude of their choice by opting level (5 or 6) electives, as appropriate, listed in the approved curriculum.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CE5281	Civil Engineering Design – II	1	2	0	3
2.	CE5282	Finite Element Methods	3	0	0	3
3.	CE5283	Civil Engineering Lab-II	0	0	3	1.5
4.	CE52XX/ CE62XX	Elective-IV	3	0	0	3
5.	CE52XX/ CE62XX	Elective-V	3	0	0	3
6.	CE52XX/ CE62XX	Elective-VI	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		19	3	3	23.5

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	CE6198	Summer Internship/Mini Project*	0	0	12	3
2.	CE6199	Project I **	0	0	30	15
	TOTAL		0	0	42	18

***Note: Summer Internship (Credit based)**

(i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening summer vacation between Semester II and III. It may be pursued 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.

(ii) Further, on return from 60 days 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.

**** Note: M. Tech. Project outside the Institute:** A project-based internship may be permitted in industries/academia (outside IITP) in 3rd or 4th semester in accordance with academic regulations. In the IIIrd 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.

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	CE6299	Project II	0	0	42	21
	TOTAL		0	0	42	21

Total Credit from Semester I to IV : 86

ELECTIVE GROUPS

Departmental Elective – DE-I, DE-II and DE-III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5103	Solid and Hazardous Waste Management	3	0	0	3
2.	CE5117	Water Resources Management	3	0	0	3
3.	CE6101	Atmospheric Physics and Chemistry	3	0	0	3
4.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engg.	3	0	0	3
5.	CE6103	Environmental Toxicology and Risk Assessment	3	0	0	3
6.	CE6104	Environmental Hydraulics	3	0	0	3

7.	CE6105	Atmospheric Science and Climate Change	3	0	0	3
8.	CE6106	Soil Dynamics	3	0	0	3
9.	CE6107	Rock Slope Engineering	3	0	0	3
10.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
11.	CE6109	Geoenvironmental Engineering	3	0	0	3
12.	CE6110	Biogeotechnics	3	0	0	3
13.	CE6111	Rock Mechanics	3	0	0	3
14.	CE6112	Environmental Rock Engineering	3	0	0	3
15.	CE6113	Pavement Geotechnics	3	0	0	3
16.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
17.	CE6115	Advanced Structural Mechanics	3	0	0	3
18.	CE6116	Bridge Engineering and Design	3	0	0	3
19.	CE6117	Masonry Structures	3	0	0	3
20.	CE6118	Wind Analysis and Design of Structures	3	0	0	3
21.	CE6119	Special Topics in Structural Analysis	3	0	0	3
22.	CE6120	Analysis Plates and Shells Structure	3	0	0	3
23.	CE6121	Prestressed Concrete Structure: Theory & Design	3	0	0	3
24.	CE6122	Advanced Concrete Technology	3	0	0	3
25.	CE6123	Structural Fire Engineering	3	0	0	3
26.	CE6124	Advanced Structural Dynamics	3	0	0	3
27.	CE6125	Bituminous materials	3	0	0	3
28.	CE6126	Intelligent Transportation Systems	3	0	0	3
29.	CE6127	Pavement Management Systems	3	0	0	3
30.	CE6128	Highway Geometric Design and Safety	3	0	0	3
31.	CE6129	Airport Engineering	3	0	0	3
32.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3
33.	CE6131	Sustainability of Water Resources System	3	0	0	3

Departmental Elective – DE-IV, DE-V and DE-VI						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5217	Geoinformatics for Engineers	3	0	0	3
2.	CE5218	Groundwater Hydrology	3	0	0	3
3.	CE5219	Open Channel Hydraulics	3	0	0	3
4.	CE6201	E-waste Management for Circular Economy	3	0	0	3
5.	CE6202	Industrial Pollution Control and Prevention	3	0	0	3
6.	CE6203	Water Supply and Sewerage Network Design	3	0	0	3
7.	CE6204	Design of Water and Wastewater Treatment Facilities	3	0	0	3
8.	CE6205	Advanced Water and Wastewater Engineering	3	0	0	3
9.	CE6206	Geotechnical Earthquake Engineering	3	0	0	3
10.	CE6207	Soil-Structure Interaction Analysis	3	0	0	3

11.	CE6208	Mine Wastes Generation and Management	3	0	0	3
12.	CE6209	Coupled Process in Fractured Geological Media	3	0	0	3
13.	CE6210	Ground Improvement Techniques	3	0	0	3
14.	CE6211	Utilization of industrial byproducts for geotechnical applications	3	0	0	3
15.	CE6212	Rock Engineering for River Valley Projects	3	0	0	3
16.	CE6213	Design of Underground Excavations	3	0	0	3
17.	CE6214	Special Topics in Geotechnical Engineering	3	0	0	3
18.	CE6215	Forensic Geotechnical Engineering	3	0	0	3
19.	CE6216	Special Topics in Rock Engineering for Infrastructural Development	3	0	0	3
20.	CE6227	Traffic Flow Theory	3	0	0	3
21.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3
22.	CE6229	Advanced Flexible Pavement Analysis and Design	3	0	0	3
23.	CE6230	Advanced Concrete Pavement Analysis and Design	3	0	0	3
24.	CE6231	Advanced Pavement Material Characterization	3	0	0	3
25.	CE6232	Porous Media Flow: Advanced topics	3	0	0	3

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to students other than CE)

Sl. No.	Subject Code	Subject Name	L	T	P	C
1.	CE6132	Data Science for Engineers	3	0	0	3

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	CE5181	Advanced Engineering Mathematics	3	0	0	3
3.	CE5182	Civil Engineering Design – I	1	2	0	3
4.	CE5183	Civil Engineering Lab-I	0	0	3	1.5
5.	CE51XX/ CE61XX	Elective-I	3	0	0	3
6.	CE51XX/ CE61XX	Elective-II	3	0	0	3
7.	CE51XX/ CE61XX	Elective-III	3	0	0	3
8.	XX61PQ	IDE	3	0	0	3
	TOTAL		17	4	5	23.5

Course	CE5181 Advanced Engineering Mathematics
Course Credit	3-0-0-3

(L-T-P-C)	
Course Title	Advanced Engineering Mathematics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. To brush up the undergraduate level understanding in light with some advanced approaches. 2. To develop proficiency in numerical techniques and algorithms pertaining to various civil engineering problems. 3. To form a stepping stone towards advance understanding of Probabilistic Methods in Engineering.
Course Description	This course deals with the numerical method for non-linear equation solution, numerical integration, solution of liner system of equations, curve fittings, solution of differential equations. Second part of the course basic concept of probability theory and statistics, estimation of distribution property, stochastic data generation, risk and reliability methods for civil engineering.
Course Outline	Module – I: Numerical Methods Introduction to Numerical Methods: Objectives of numerical methods, sources of error in numerical solutions: truncation error, round off error, order of accuracy - Taylor series expansion Roots of Equations: Graphical Methods, Bisection Method, Simple Fixed-Point Iteration, Newton-Raphson Method, Secant Method, modified Secant Method Direct Solution of Linear systems: Naive Gauss elimination, LU Decomposition, matrix Inverse, error analysis and system condition, Gauss-Seidel, Gauss-Jordon, Jacobi iteration, Factorization, Cholesky decomposition. Diagonal dominance, condition number, ill-conditioned matrices Curve Fitting: Linear Regression, Polynomial Regression, interpolation, spline fitting Numerical Calculus: Trapezoidal and Simpson's rule for integration Solving Differential Equation: Euler's method, Runge-Kutta method, Boundary-Value and Eigenvalue Problem and their application, solving partial differential equation Introduction to Finite Element Method: Strong form of the differential equation. Weak form. Galerkin method: the finite element approximation, Application in one and two-dimension. Module – II: Probabilistic Methods in Engineering Introduction: Concept of risk, and uncertainty in 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 engineering problems. Methods of risk Analysis: Composite risk analysis; Direct integration method; Method using safety margin, reliability index and safety factor. Applications of risk and reliability analysis in engineering systems.
Learning Outcome	At the end of the course, student would be able to 1. Understand the different numerical methods for solving non-linear equations and numerical integration method. 2. Should be able to solve differential equations numerically. 3. Understand basic concept probability theory and statistics. 4. Should be able to fit statistical distribution and parameter estimation. 5. Should be able to perform MC simulation and perform risk and reliability analysis.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Text/ Reference books:

1. S. Chapra and R. Canale, Numerical Methods for Engineers, 6th Ed., McGraw Hill, 2010.
2. S. Guha and R. Srivastava, Numerical Methods: For Engineering and Science, 1st Ed., Oxford University Press, 2010.
3. Scheaffer, R. L., Mulekar, M. S. and McClave, J. T., Probability and statistics for Engineers, 5th Edition, Brooks / Cole, Cengage Learning, 2011.
4. Ang, A. H-S., and Tang, W. H., Probability Concepts in Engineering, Vol. 1, John Wiley and Sons, 2006.
5. Halder, A and Mahadevan, S., Probability, Reliability and Statistical Methods in Engineering Design, John Wiley and Sons, 2000.
6. Benjamin, J., and Cornell. A., Probability, Statistics, and Decision for Civil Engineers. McGraw Hill, 1963.

Course	CE5182 Civil Engineering Design – I
Course Credit (L-T-P-C)	1-2-0-3
Course Title	Civil Engineering Design – I
Learning Mode	Lectures and Tutorial
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are 1. Understand the fundamental principles of reinforced concrete design. 2. Understand the fundamental principles of water and waste water treatment plant design.
Course Description	The course deals with the design of (i) various structures for various types of loading, (ii) water and waste water treatment plant.
Course Outline	Design and detailing of different elements of reinforced concrete multi storied buildings manually as well as using latest design and detailing softwares. Design of reinforced concrete retaining walls and Water Tanks. Design of various unit operations of water treatment plant; Design of sewer and sewerage system; Design of various unit operations of sewage treatment plant.
Learning Outcome	At the end of the course, student would be able to 1. Design reinforced concrete structures. 2. Design water and waste water treatment plant design.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Text books:

1. S. U. Pillai and D. Menon, Reinforced Concrete Design, Tata McGraw-Hill, 3rd edition, 2009.
2. P. C. Varghese, Advanced Reinforced Concrete Design, PHI Learning, 2nd edition, 2011.
3. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
4. Manual on Water Supply and Treatment, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 1999.
5. S. J. Arceivala and S. R. Asolekar, Wastewater Treatment for Pollution Control and Reuse, 3rd Edition, McGraw-Hill Education (India) Pvt. Ltd., New Delhi, 2006.

Reference books:

1. J. Macgregor and J. K. Wight, Reinforced Concrete: Mechanics and Design, Prentice Hall, 5th edition, 2008.
2. J. C. Crittenden, R. R. Trussell, D. W. Hand, K. J. Howe, G. Tchobanoglous, MWH's Water Treatment: Principles and Design, 3rd Edition, John Wiley & Sons, 2012.

3. S. R. Qasim, Wastewater Treatment Plants: Planning, Design, and Operation, Second Edition, CRC Press, 1998.

Course	CE5183 Civil Engineering Lab-I
Course Credit (L-T-P-C)	0-0-3-1.5
Course Title	Civil Engineering Lab-I
Learning Mode	Laboratory
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are 1. To understand laboratory testing procedure. 2. To understand parameters required to be measured in laboratory for civil engineering materials.
Course Description	This course deals with laboratory testing of materials used in structure and transportation infrastructure construction.
Course Outline	Concrete mix design, casting and testing of cubes and cylinders, Experiments to illustrate buckling of structural members; load-deformation behaviour of beams, columns, joints, and frames under various loads, mode shapes, natural frequency, damping factors from free and forced vibrations, shake table tests. California bearing ratio; Evaluation of Bitumen for various properties, Bitumen ductility test; Viscosity of bitumen; LA abrasion testing.
Learning Outcome	At the end of the course, student would be able to 1. Evaluate pavement material based on its specification requirements. 2. Develop laboratory testing plan
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Text books:

1. H.E., Troxell, G.E. and Hauck, G.F., The testing of engineering materials, 1982.
2. S. K. Khanna and C. E. G. Justo, Highway Engineering, Nem Chand Bros., 2002.

Departmental Elective – DE-I, DE-II and DE-III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5103	Solid and Hazardous Waste Management	3	0	0	3

2.	CE5117	Water Resources Management	3	0	0	3
3.	CE6101	Atmospheric Physics and Chemistry	3	0	0	3
4.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engg.	3	0	0	3
5.	CE6103	Environmental Toxicology and Risk Assessment	3	0	0	3
6.	CE6104	Environmental Hydraulics	3	0	0	3
7.	CE6105	Atmospheric Science and Climate Change	3	0	0	3
8.	CE6106	Soil Dynamics	3	0	0	3
9.	CE6107	Rock Slope Engineering	3	0	0	3
10.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
11.	CE6109	Geoenvironmental Engineering	3	0	0	3
12.	CE6110	Biogeotechnics	3	0	0	3
13.	CE6111	Rock Mechanics	3	0	0	3
14.	CE6112	Environmental Rock Engineering	3	0	0	3
15.	CE6113	Pavement Geotechnics	3	0	0	3
16.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
17.	CE6115	Advanced Structural Mechanics	3	0	0	3
18.	CE6116	Bridge Engineering and Design	3	0	0	3
19.	CE6117	Masonry Structures	3	0	0	3
20.	CE6118	Wind Analysis and Design of Structures	3	0	0	3
21.	CE6119	Special Topics in Structural Analysis	3	0	0	3
22.	CE6120	Analysis Plates and Shells Structure	3	0	0	3
23.	CE6121	Prestressed Concrete Structure: Theory & Design	3	0	0	3
24.	CE6122	Advanced Concrete Technology	3	0	0	3
25.	CE6123	Structural Fire Engineering	3	0	0	3
26.	CE6124	Advanced Structural Dynamics	3	0	0	3
27.	CE6125	Bituminous materials	3	0	0	3

28.	CE6126	Intelligent Transportation Systems	3	0	0	3
29.	CE6127	Pavement Management Systems	3	0	0	3
30.	CE6128	Highway Geometric Design and Safety	3	0	0	3
31.	CE6129	Airport Engineering	3	0	0	3
32.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3
33.	CE6131	Sustainability of Water Resources System	3	0	0	3

Course Number	CE5103: Solid and Hazardous Waste Management
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Solid and Hazardous Waste Management
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 3 and 4 1. To familiarize the students about the problem of solid waste generation and hazardous composition, and impact on the environment and human health on the backdrop of national legislations 2. To train students to understand, plan, design, and implement various steps and processes involved for solid and hazardous waste management 3. To inculcate scientific and technical knowledge, to prepare students to address present issues and challenges along with the emerging techniques for solid and hazardous waste management for a circular economy
Course Description	The course intends to provide basic as well as advanced concepts and engineering practices involved in solid and hazardous waste management. The course will provide a broader understanding of municipal solid waste generation and influencing factors, composition, hazardous waste characteristics, segregation and collection, processing and disposal techniques for solid and hazardous waste management with theoretical and practical aspects. Further, the course intends to provide and discuss real-life case studies on solid and hazardous waste recycling for urban mining and circular economy.
Course Content	Municipal Solid Waste Management – Fundamentals: Sources; composition; generation rates; collection of waste; separation, transfer and transport of waste; treatment and disposal options; Hazardous Waste Management Fundamentals: Characterization of waste; compatibility and flammability of chemicals; fate and transport of chemicals; health effects; Specific waste streams: construction and demolition (C&D) waste, electronic waste (e-waste), etc.; National Legislations: Municipal solid waste (management and handling) rules; hazardous waste (management and handling) rules; biomedical waste handling rules; e-waste management rules; batteries (management and handling) rules; Physicochemical Treatment of Solid and Hazardous Waste: Physico-chemical treatment processes for MSW (combustion, stabilization and solidification of hazardous wastes); physicochemical processes for hazardous wastes (soil vapour extraction, air stripping, chemical oxidation); Biological Treatment of Solid and Hazardous Waste: Composting;

	bioreactors; anaerobic decomposition of solid waste; principles of biodegradation of toxic waste; inhibition; co-metabolism; oxidative and reductive processes; slurry phase bioreactor; in-situ remediation; Landfill Design: Disposal of solid waste including sanitary landfill; Landfill design for solid and hazardous wastes; leachate collection and removal; landfill covers; incineration; Emerging Concepts and Practices: Urban mining and circular economy with real-life case studies; Planning, site and design aspects of solid waste engineering.
Learning Outcome	At the end of the course, students would be able to: 1. Understand about the problem of municipal solid waste generation and composition with the influencing factors, hazardous waste characteristics, national legislations, and adverse effects on the environment and human health. 2. Comprehend, understand, devise and adopt various steps and processes involved in the solid and hazardous waste management in integrated manner. 3. Plan and implement various processing and disposal techniques for solid and hazardous waste management for a circular economy 4. Learn and understand about present issues and challenges along with the emerging techniques for solid and hazardous waste management
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text Books:

1. CPHEEO, Manual on Municipal Solid Waste Management, Central Public Health & Environmental Engineering Organisation (CPHEEO), Ministry of Housing and Urban Affairs, Govt. of India, 2016.
2. LaGrega, M.D., Buckingham, P.L. and Evans, J.C., Hazardous Waste Management, 2nd edition, Medtech, 2015.
3. Tchobanoglous, G., Theisen, H. and Vigil, S.A., Integrated Solid Waste Management: Engineering Principles and Management Issues, Indian edition, McGraw Hill, 2014.
4. Vesilind, P.A., Worrel, W.A. and Ludwig, C., Solid Waste Engineering: A Global Perspective, SI edition, CL Engineering, 2016.

Reference Books:

1. Bagchi, A., Design of Landfills and Integrated Solid Waste Management, 3rd edition, Wiley, 2004.
2. Wentz, C.A., Hazardous Waste Management, 2nd edition, McGraw-Hill, 1995.

Course	CE5117: Water Resources Management
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Water Resources Management
Learning Mode	Lectures
Learning Objectives	Complies with PLO 2, 3, 4 and 5 Students will be introduced to the role of disciplines of ecology and socio-economics, and legal and regulatory settings in the context of integrated water resources management.
Course Description	The course examines the development, use, management, and conservation of water resources in India and worldwide about the multiple, multi-scale interconnections between Integrated water resource management, and environmental and socioeconomic issues. In particular, it considers multidisciplinary approaches to water management problems and its sustainability.
Course Outline	Economics of water resources systems: principles of engineering economics; Microeconomics and efficient resource allocation, conditions of project optimality; Planning for multipurpose water resource projects; Introduction to mathematical optimization techniques; Multi-objective optimization; Application of optimization techniques; Water resources planning under uncertainty; Stochastic planning models; Application of simulation models. Regulation policies and governance of water; Water quality monitoring and measurement; Water and climate.
Learning Outcome	After attending this course, the following outcomes are expected: 1. Students will understand the theory and practice of water management at international, national and local scales 2. Understand hydrological, socioeconomic and environmental aspects of water management and apply critical thinking to water management 3. They will gain a broad understanding of the complexities of dealing with water resources problems
Assessment Method	Assignments, Projects and case studies, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Q. Grafton and K. Hussey, Water Resources Planning and Management, Cambridge University
2. J.A.A. Jones, Global Hydrology: Processes, Resources, and Environmental Management, Prentice Hall, New York, 399 pp., 1998 (ISBN: 9780582098619).
3. S.A. Thompson, Water Use, Management, and Planning in the United States, Academic Press, San Diego, 371 pp., 1999 (ISBN: 9780126893403)

Course Number	CE6101- Atmospheric Physics and Chemistry
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Atmospheric Physics and Chemistry
Learning Mode	Lectures

Learning Objectives	Complies with PLOs 3,4 and 5: 1. Equip the students with a strong foundation and strengthen their knowledge in atmospheric physics and chemistry. 2. The student will be able to apply advanced theory and analysis for problem-solving in atmospheric sciences. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills.
Course Description	This coursework will provide insights in the field of atmospheric sciences. The objective of this course is to provide students' knowledge about radiative and climatic effects of gases and particles; formation and chemistry of clouds; meteorology of air pollution; atmospheric chemistry and atmospheric chemical/transport models.
Prerequisite course	Air pollution and control, Environmental Studies, or any other equivalent course.
Course Outline	Atmospheric Physics: Atmosphere as a Physical system, Composition of Atmosphere, Atmospheric Dynamics, Stability and Transport, General Circulation, Moisture in the Atmosphere, Cloud Formation; Solar and terrestrial radiation; Effect of pollutants on Earth's radiation budget; Radiation scattering by aerosols and clouds; Greenhouse Effect, Global Warming, Introduction to Atmospheric Models: Simple Radiative model, Models for global warming and cooling. Atmospheric Chemistry: Thermodynamics of Chemical Reactions, Chemical Kinetics, Bimolecular Reactions Photo-dissociation, Stratospheric Ozone, Chapman Chemistry, Catalytic Cycles, Transport of Chemicals; the Antarctic Ozone Hole; Multi-phase Processes, Tropospheric Chemistry, Aerosol formation; Aerosol Dynamics: Discrete and continuous aerosol size distributions; Thermodynamics of atmospheric aerosols; Homogeneous and heterogeneous nucleation; Sedimentation and dry deposition; Chemical equilibria; Aerosol-cloud interactions; Aerosol and Global Climate: Trends in anthropogenic emissions and troposphere composition.
Learning Outcome	The course structure will impart: 1. High-quality knowledge to students on chemical and physical processes involved in the emissions, transport, transformation and fate of atmospheric pollutants. 2. Insights into sources and sinks of gases and particles of importance for environment and climate. 3. Importance of electromagnetic radiation laws will be examined in relation to earth's radiative balance and photo-chemistry. 4. Understanding of interplay of atmospheric gases and particles, transformation of gases and particles, their transport and fate in the atmosphere will be examined.
Assessment Method	Quizzes, Presentations, Mid-semester and End-semester Examination

Textbooks:

1. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change by John H. Seinfeld and Spyros N. Pandis, 3rd Edition, John Wiley & Sons, Inc., 2016.
2. Introduction to Atmospheric Chemistry, Daniel J. Jacob, Princeton University Press, 1999.

Reference books:

1. Environmental Chemistry, Stanley E. Manahan, 9th Edition, CRC Press, 2009.
2. Atmospheric Science: An Introductory Survey by Wallace, J.M., and P. V. Hobbs, 2nd edition, Elsevier, 2006.
3. Modeling of Atmospheric Chemistry by G. P. Brasseur and Daniel J. Jacob, Cambridge University Press, 2017.
4. Atmospheric Thermodynamics: Elementary Physics and Chemistry by G. R. North and T.L. Erukhimova, Cambridge University Press, 2009.
5. Atmospheric Chemistry by Julian Heicklen, Academic Press, 1976.
6. Atmospheric Chemistry by Ann M. Holloway and Richard P Wayne, RSC Publication, 2010.
7. Meteorology Today by Ahrens, C. Donald, 9th edition, Wadsworth Publishing Co. Inc., 2008.
8. Atmospheric Reaction Chemistry by Hajime Akimoto, Springer, 2016.
9. Chemistry of the Upper and Lower Atmosphere B.J. Finlayson -Pitts and J.N. Pitts, Jr., Academic Press, 2000.
10. IPCC, 2007 Fourth Assessment Report, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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, 1995.
5. Csuros, M. and Csuros, C., 2016. Environmental sampling and analysis for metals. CRC Press.
6. Popek, E.P., 2017. Sampling and analysis of environmental chemical pollutants: a complete guide. Elsevier.
7. 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.
8. 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, toxicokinetics, 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	CE6104: Environmental Hydraulics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Environmental Hydraulics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 4 The objective of this course is 1. Analyze fluid flow in pipes and open channels. 2. Design both separate and combined drainage systems. 3. Understand the ground water hydraulics and the movement of pollutants in groundwater. 4. Understand the hydraulics of water and wastewater treatment plants.
Course Description	This course covers fluid dynamics in pipes and open channels, including turbulent and viscous flow, pipe network analysis, and groundwater hydraulics. Students will learn to design drainage systems, estimate aquifer parameters, and understand the hydraulics of water and wastewater treatment plants.

Course Outline	Fundamentals of Friction and Flow in Pipes, Turbulent and Viscous Flow, Analysis Methods for Pipe Networks including Hardy-Cross, Basic Open Channel Hydraulics, Energy and Momentum Equations, Critical Flow, Channel Control and Transitions, Uniform and Gradually Varied Flow, Computation of Flow Profiles, Unsteady Flow and Hydraulic Jumps, Design of Drainage Systems, Groundwater Hydraulics, Aquifer Parameter Estimation, Confined and Unconfined Aquifers, Steady and Unsteady Flow into Wells, Dupuit Approximations, Well Systems, Well Losses, Recharge, Well Development, Pollutant Transport in Groundwater, Hydraulics of Water and Wastewater Treatment Plants.
Learning Outcome	At the end of the course, students would be able to: 1. Understand the mechanics of flowing water 2. Design and evaluate drainage systems 3. Apply principles of open channel hydraulics to understand critical flow, uniform and gradually varied flow, and hydraulic jumps. 4. Understand the hydraulics of water and wastewater treatment plants
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books and Reference:

1. V.P. Singh, Willi H. Hager, Environmental Hydraulics, Springer, 1996.
2. L. Hamill, Understanding Hydraulics, Palgrave Macmillan; 2nd Rev. Ed., 2001
3. K Subramanya, Flow in Open Channels (5th Edition), McGraw-Hill, 2019.
4. F. M. White and Henry Xue, Fluid Mechanics, McGraw Hill, 2022.
5. Som, Biswas and Chakrabarty, Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw-Hill Education, 2017.
6. V.T. Chow, Open-channel hydraulics, McGraw Hill Publications (1973).
7. Bhagu R Chahar, Groundwater Hydrology, McGraw-Hill Education, 2015
8. Todd D.K., Ground Water Hydrology, John Wiley and Sons, 2000
9. Garg, S.K., Environmental Engineering (Vol. I) Water Supply Engineering, Khanna Publishers, 37th edition, 2024
10. Garg, S.K., Environmental Engineering (Vol. II) Sewage Waste Disposal and Air Pollution Engineering, Khanna Publishers, 40th edition, 2024
11. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.

Course Number	CE6105- Atmospheric Science and Climate Change
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Atmospheric Science and Climate Change
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 3,4 and 5: 1. Equip the students to strengthen their knowledge in climate change. 2. The student will be able to apply advanced theory for climate change mitigation and adaptation. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills.
Course Description	This coursework will provide insights in the field of climate studies and sciences. The objective of this course is to provide students' knowledge about radiative and climatic effects of pollutants; climate modelling; mitigation, governance, and adaptation; carbon capture, utilization and storage.
Course Outline	Introduction to Earth's climate and atmospheric sciences, Global Climate: Trends in anthropogenic emissions and troposphere composition. Climate monitoring and variability; advanced computing in climate change; impacts of climate change on human health and environment, United Nations Sustainable Development Goals on climate change; Introduction to climate models: Simple Radiative model, Models for global warming and cooling. Climate governance; Climate change mitigation and adaptation; Design innovations; Carbon capture, utilization and storage.
Learning Outcome	The course structure will impart: 1. High-quality knowledge to students on climate studies. 2. Insights into climate adaptation modelling and its application in various fields. 3. Understanding of interplay of climate change and mitigation actions will be examined.
Assessment Method	Quizzes, Presentations, Mid-semester and End-semester Examination

Textbooks:

1. Handbook of Climate Change Mitigation and Adaptation, M. Lackner, B. Sajjadi, W. Chen, Springer, 2022.
2. Climate System Modeling, K. E. Trenberth, Cambridge University Press, 2010.
3. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change by John H. Seinfeld and Spyros N. Pandis, 3rd Edition, John Wiley & Sons, Inc., 2016.

Reference books:

1. Global Warming and Climate Crisis, B. E. Johansen, Springer, 2023.
2. Introduction to Three-Dimensional Climate Modeling, W. M. Washington and C. Parkinson, University Science Books, 2005.
3. Atmospheric Science: An Introductory Survey by Wallace, J.M., and P. V. Hobbs, 2nd edition, Elsevier, 2006.
4. Modeling of Atmospheric Chemistry by G. P. Brasseur and Daniel J. Jacob, Cambridge University Press, 2017.

5. Meteorology Today by Ahrens, C. Donald, 9th edition, Wadsworth Publishing Co. Inc., 2008.
6. IPCC, 2007 Fourth Assessment Report, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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

Outcome	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.

Textbooks:

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

Reference books:

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

	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

	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.

	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 1. Understanding methods of waste management and disposal 2. Learning methods of contaminated site characterization 3. Learning methods of remedial measures of a contaminated site 4. 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:

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

	CE6110: Biogeotechnics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Biogeotechnics
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. Learn about the testing and instrumentation facilities for biological process and geotechnical behaviour. 4. 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: 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:

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

Reference books:

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

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.

	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 Number	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 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 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:

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.

	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.

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Textbooks:

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

Reference books:

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

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:

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 Solids, CRC Press, 2010.
4. Irving H. Shames and Francis A. Cozzarelli. Elastic and Inelastic Stress Analysis, Taylor & Francis Group; Revised edition, 1997.
5. 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	Objective for learning this course are

Objectives	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:

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.

Course	CE6117 Masonry Structures
Course Credit (L-T-P-C)	3-0-0-3

Course Title	Masonry Structures
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Understand the mechanical behaviour of masonry assemblages. 2. Understand the behaviour of unreinforced, confined and reinforced masonry structures under for vertical and lateral loads, including earthquake loads. 3. Procedures for structural assessment and strengthening of existing masonry structures.
Course Description	The course deals with the design of masonry structures for various types of loading. This course provides an understanding of behaviour of unreinforced and reinforced masonry structures under various action of forces.
Course Outline	Properties of constituents: units - burnt clay, concrete blocks, mortar, grout, reinforcement; Masonry bonds and properties, masonry properties - compression strength; Stresses in masonry walls: vertical loads, vertical loads and moments – eccentricity & kern distance, lateral loads - in-plane, out-of-plane; Behaviour of masonry walls and piers: axial and flexure, axial- shear and flexure; Behaviour of Masonry Buildings: unreinforced masonry buildings–importance of bands and corner and vertical reinforcement, reinforced masonry buildings - cyclic loading & ductility of masonry walls; Behaviour of masonry infills in RC frames; Structural design of masonry in buildings: methods of design – WSD, USD, seismic design–seismic loads, code provisions; Seismic evaluation and strengthening of masonry buildings: methods–in-situ, non-destructive testing.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. To categorize, classify and understand the masonry building component and understand the behavior of masonry structure. 2. To make use of fundamental principles and methodologies of analysis and design of masonry structures. 3. Become familiar with basic masonry materials, including clay brick, concrete block, mortar, grout, and reinforcing accessories. 4. Understand the behavior of unreinforced and reinforced masonry structures under flexure, shear, axial forces, combined flexure and axial forces, and in-plane shear forces. 5. Learn methods of masonry construction and detailing practices.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Dayaratnam, P. (1987). Brick and Reinforced Brick Structures, Oxford & IBH Publishing Co. Pvt. Ltd.
2. Drysdale, R. G. Hamid, A. H. and Baker, L. R. (1994). Masonry Structures: Behaviour& Design, Prentice Hall
3. Hendry, A. W. (1998), Structural Masonry, Mc Millan, UK, 2nd edn.
4. Hendry, A. W., Sinha, B. P. and Davies, S. R. (1997). Design of Masonry Structures, E&FN Spon, UK.
5. Sahlin, S. (1971). Structural Masonry, Prentice Hall, Englewood Cliffs, NJ.

6. Schneider, R. S. and Dickey, W. L. (1994). Reinforced Masonry Design, Prentice Hall, 3rd edn.
7. Paulay, T. and Priestley, M. J. N. (1992). Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley.

Course	CE6118 Wind Analysis and Design of Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Wind Analysis and Design of Structures
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. To impart knowledge about the basic principles of the wind engineering pertinent to the structural design. 2. Introduce different approaches available to analyze the effect of wind loading on various wind sensitive structures. 3. Use of codes and analytical methods for wind resistance design of structures. 4. Introduction of wind tunnel testing of structures.
Course Description	This course provides a detailed understanding of wind engineering in terms of atmospheric boundary layer, aerodynamics of bluff bodies as applied to design of structures. Methods of computation of design wind speed, wind pressure and loads as per the code will be explained here. Basic concepts of wind tunnel testing will be covered to emphasize the

	importance of experimental methods. At the end analysis and design of structures under wind loads will be covered.
Course Outline	Introduction: wind mechanics and wind effects on structures, wind damages, damage index, wind impact on structures; Wind engineering: wind climate and structure, characteristics of windstorms, Atmospheric pressure distribution, wind turbulence, gradient wind, and atmospheric boundary layer (ABL), mean wind speed profiles, wind spectra, short and long-term statistics of wind, Aerodynamics of bluff bodies: vortex shedding, along and across wind response, aerodynamic instability due to aeroelastic excitation, aerodynamic damping, structural interaction with aerodynamic forces, Wind effects on structure: nature of wind loads and factors affecting wind loads, estimation of design wind speed, pressure coefficients, and design wind pressure, peak and gust factors, analysis and design of tall structures such as buildings, chimneys, towers and bridges, codes of practices for analysis and design of the wind sensitive structures; Experimental procedures: wind tunnel and salient features, ABL simulation, measurement of flow parameters, forces, displacements and strains, use of statistical methods for data analysis, estimation of the along and across wind forces.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand wind mechanics and synthesize the wind induced responses under extreme wind loading. 2. Estimation of design wind speed and structural interaction with aerodynamic forces and prediction of aerodynamic instability. 3. Determine the wind loads as per the codes and standards and assess the wind damages and wind impact on structures. 4. Design of wind tunnel test and interpretation of experimental results for structural design.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. E. Simiu and R. H. Scanlan, Winds Effects on Structures: Fundamentals and Applications to Design, Wiley-Interscience, 3rd edition, 1996.
2. E. Simiu and T. Miyata, Design of Buildings and Bridges for Wind, Wiley, 1st edition, 2006.
3. J. D. Holmes and S. Bekele, Wind Loading of Structures, CRC Press, 4th edition, 2021.
4. B. S. Taranath, Wind and Earthquake Resistant Buildings, CRC Press, 1st edition, 2004.
5. Indian Standard, IS:875, Code of practice for design loads for buildings and structures, Part 3, Wind Loads, Bureau of Indian Standards, New Delhi.

Course	CE6119 Special Topics in Structural Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Special Topics in 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 to advanced structural analysis: static & dynamic loading, linear & nonlinear structural behaviour, geometric & material nonlinearity, hysteretic behaviour; Classical linear analysis of frames and trusses: displacement method, slope deflection equations & matrix displacement method, effect of foundation settlement and temperature; Geometric nonlinear analysis of frames and trusses: displacement method, nonlinear slope-deflection equations & nonlinear behaviour, linearized iterative matrix displacement method, geometric stiffness matrix, tangent stiffness matrix, P- Δ effect, buckling of frames, tension structures; Material nonlinear analysis of frames: basics of plasticity, distributed plasticity & lumped plasticity, incremental nonlinear analysis. Introduction to nonlinear static analysis of structures with geometric nonlinear and elasto-plastic behaviour as well as analysis based on simplified plastic methods; Nonlinear structural analysis: mathematical preliminaries for 1st and 2nd order elastic and inelastic structural analysis, incremental methods, unbalanced forces calculation and iterative methods, material and geometric nonlinear beam-column element, force and displacement control beam-column element, advanced structural analysis using software.

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. 3. Perform nonlinear analysis of structures.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. W. McGuire, R. H. Gallagher and R. D. Ziemian, Matrix Structural Analysis, Second Edition, Wiley, 2015.
2. D. Menon, Advanced Structural Analysis. Narosa, 2015.
3. S. Muthukrishnan, Nonlinear Analysis of Structures, CRC Press, 1st Edition, 2017.
4. W. Lacarbonara, Nonlinear Structural Mechanics: Theory, Dynamical Phenomena and Modeling, Springer-Verlag New York Inc., 1st Edition, 2016.
5. A. H. Nayfeh and P. F. Pai, Linear and Nonlinear Structural Mechanics, Wiley-VCH, 1st Edition, 2004.

Course	CE6120 Analysis Plates and Shells Structure
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analysis Plates and Shells Structure
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Formulate and solve complex problems related to the behaviour of plates and shells using advanced mathematical and computational methods. 2. Perform advanced analysis of structural performance comprising of various plate and shell elements. 3. Use advanced mathematical as well as computational tool for modelling, simulation, and analysis.
Course Description	The course deals with the studying force deformation behaviour of plates and shells members under different loading scenario and boundary condition.
Course Outline	Simple bending of Plates-Assumptions in thin plate theory-Different relationships- Different Boundary Conditions for plates- Plates subjected to lateral loads – Navier’s method for simply supported plates – Levy’s method for general plates – Example problems with different types of loading. Circular plates subjected to Axi-symmetrical loads–concentrated load, uniformly distributed load and varying load – Annular circular plate with end moments. Rayleigh-Ritz method – Application to different problems – Finite difference method – Finite element methodology for plates-Orthotropic Plates - Bending of anisotropic plates with emphasis on orthotropic plates – Material Orthotropy – Structural Orthotropy - Plates on elastic foundation. Shells- Classification of shells - Membrane and bending theory for singly curved and doubly curved shells - Various approximations - Analysis of folded plates; Advanced topics in plate and shells: nonlinear behaviour of plate and shells, elastic and inelastic stability analysis of plates and shells, application of FEM software in analysis of plates and shells, case studies from real-world infrastructures comprising of plate and shell elements, some cutting cutting-edge research innovations in line with global knowledge standard on plates and shells.
Learning Outcome	At the end of the course, student would be able to

	Lecture: 1. Understanding deformation and stress behaviour of plate and shell members under out of plane loading. 2. Perform analytical and numerical solution of plate and shell under different loading and boundary condition.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Szilard, R., Theories and applications of plate analysis: classical, numerical, and engineering methods, Hoboken, NJ: John Wiley, 2003.
2. Timoshenko, S., and Krieger, S.W., Theory of Plates and Shells, McGraw-Hill, 1959.
3. Ugural, A.C., Stresses in Plates and Shells, 1999.
4. Gould, P.L., Analysis of Shells and Plates, 1998.
5. Ventsel, E. and Krauthammer, T., Thin Plates and Shells: Theory, Analysis, and Applications, Marcel Dekker, 2001.

Course	CE6121 Pre-Stressed Concrete Structure: Theory & Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pre-Stressed Concrete Structure: Theory & Design
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 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, ultimate flexural strength, recommendations of I.S. codes. 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 - mode of failure in beams, recommendations of I.S. code, ultimate shear strength of concrete, Design of shear reinforcement, Bond in prestressed concrete. Analysis and design of continuous (up to two spans) and fixed beams. Elastic analysis, secondary moments, concordant cable, linear transformations. Analysis and design of prestressed concrete structures such as concrete pipes and Sleepers. Analysis and design of portal frames, single storey and limited to two bays (fixed and hinged). Design of pre-stressed concrete bridges (simply supported) for I.R.C. loadings or equivalent uniformly distributed loads.
Learning Outcome	At the end of the course, student would be able to Lecture: 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. • Dayaratnam P., Prestressed Concrete Structures.

Course	CE6122 Advanced Concrete Technology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Concrete Technology
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Understand the role of various materials used for concrete mix and the behaviour of high strength concrete. 2. Provide scientific and technical knowledge for the of process of making

	high strength concrete. 3. Provide strong foundation and understanding the behaviour structural concrete and problems associated with concrete.
Course Description	The course deals with concrete technology. This course provides the students an exposure advanced topic on concrete technology which are not covered in undergraduate design courses.
Course Outline	Cement production and composition Cement chemistry Aggregates for concrete Chemical admixtures Chemical and Mineral admixtures Mineral admixtures High performance concrete mixture proportioning Topics in fresh concrete Topics in hardened concrete Creep and shrinkage Durability of concrete Durability of concrete.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Designing high strength concrete. 2. Should be able to understand various types of problems and their solutions in structural concrete.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Mehta, P. K., and Monteiro, P. J. M., 'Concrete: Microstructure, Properties, and Materials,' Fourth Edition (Indian Edition), McGraw Hill, 2014.
2. Neville, A. M., 'Properties of Concrete,' Pitman Publishing, Inc., MA, 1981.
3. Hewlett, P. C., Ed., 'Lea's Chemistry of Cement and Concrete,' Fourth Edition, Arnold Publishers, NY, 1998.
4. Bentur, A., Diamond, S., and Berke, N.S., 'Steel Corrosion in Concrete,' E&FN Spon, UK, 1997.
5. Taylor, H. W. F., 'Cement Chemistry,' Academic Press, Inc., San Diego, CA, 1990.
6. Lea, F. M., 'The Chemistry of Cement and Concrete,' Chemical Publishing Company, Inc., New York, 1971.
7. Mindess, S., and Young, J. F., 'Concrete,' Prentice Hall, Inc., NJ, 1981.
8. J. Newman and B. S. Choo, Eds., 'Advanced Concrete Technology', Four Volume Set, Elsevier, 2003

Course	CE6123 Structural Fire Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Structural Fire Engineering
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Introduce various codes and concept related to fire engineering. 2. Introduce basic concept of structural mechanics. 3. Equip the students with a strong foundation and understanding the behaviour various structures exposed to fire. 4. Provide scientific and technical knowledge for the design of various structures exposed to fire.

Course Description	This course will discuss the analysis and design of structures exposed to fire. It will cover the fundamentals of fire behavior, heat transfer, the effects of fire loading on materials and structural systems, and the principles and design methods for fire resistance design.
Course Outline	Fire Safety in Buildings: Fire Safety Objectives, Fire Safety Concepts, Controlling Fire Spread; Fire and Heat: Fuels, Description of Fires; Fire Resistance tests & Methods of Assessing Fire Resistance; Design of Structures Exposed to Fire: Review of Mechanics, Loads, Load Combinations, Structural Design at Normal Temperatures, Structural Design for Fire Conditions; Steel Structures: Behavior of Steel Structures in Fire, Material Properties at Elevated Temperatures, Calculation Methods for Evaluating Fire Resistance; Design of Steel Members Exposed to Fire; Concrete Structures: Behavior of Concrete Structures in Fire, Material Properties at Elevated Temperatures, Protection Strategies, Calculation Methods for Evaluating Fire Resistance, Design of Concrete Members Exposed to Fire.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand the fundamental behaviours of individual structural elements and structural systems in fires. 2. Temperatures in structural assemblies using hand calculation methods and finite element software. 3. Loads and safety factors for structural fire design. 4. Fire performance of steel and concrete structures using hand and advanced calculation method.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Hurley, Morgan J. et al; SFPE Handbook of Fire Protection Engineering; Springer New York: Imprint: Springer, 2016. Lennon, Tom; Structural fire engineering; ICE Publishing, 2011.
2. Purkiss, J. A; Fire safety engineering design of structures; Butterworth-Heinemann, 1996.
3. Wang, Y. C; Steel and composite structures: behaviour and design for fire safety; Spon Press, 2002.
4. Buchan, A H and Abu, A K; Structural Design for Fire Safety; 2nd; John Wiley and Sons, 2016.

Course	CE6124 Advanced Structural Dynamics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Structural Dynamics
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Understand the analysis and design different type of SDOF and MDOF structures under dynamic loading. 2. Effect of different system properties on the dynamic response of SDOF and MDOF structures. 3. Predict the behaviour of different type of SDOF and MDOF structures and structural components under random excitation such as wind, earthquake, blast, and sea wave loading.
Course Description	The course deals with analysis of single and multiple degrees of freedom structures for dynamic loading. This course provides the students an exposure for different dynamic loading such as wind, earthquake, blast, sea wave etc, and analysis of structures under such loading. Practical part of the course will provide in-depth understanding of dynamics of SDOF and MDOF, seismic response of building structures, and use of different type of sensor and equipment for dynamic response measurements, data processing and analysis.
Course Outline	Lecture: Single Degree of Freedom System (SDOF): equation of motion, Hamilton's formulations of SDOF system, free undamped and damped response, undamped and damped response to harmonic loading, vibration isolation, evaluation of

	damping parameter, response to arbitrary periodic, step, pulse excitations and ground motion, numerical evaluation of dynamic response. Multi Degree of Freedom System (MDOF): equations of motion (influence coefficient method); stiffness matrix, lumped and consistent mass matrix; proportional and rayleigh damping matrix, undamped free and forced response using modal superposition, Lagrange's and Hamilton's formulations of MDOF system. Continuous System: equation of motion of cables, bars, shafts, beams, undamped free and forced response concepts of response spectrum, computational and numerical methods, Introduction of random vibration: stochastic processes, power spectral density and correlation functions, stochastic analysis of linear dynamical systems to Gaussian inputs, SDOF, MDOF. Special topics in structural dynamics: structural dynamic of nonlinear system, semi-discrete equations of motion, explicit time integration, implicit time integration, dissipative integration algorithms, stability and accuracy.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Analyse and design structures under dynamic loading. 2. Influence of different dynamic properties of system on responses. 3. Understand basic of structural response under random excitation such as wind, earthquake, blast and sea wave.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. A.K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, Prentice Hall, 4th Edition, 2015.
2. R.W. Clough and J. Penzien, Dynamics of Structures, McGraw-Hill, 1975, 2nd edition, 1992.
3. S.S. Rao, Mechanical Vibrations, Prentice Hall, 6th Edition, 2021.
4. J. L. Humar, Dynamics of Structures, Balkema, 2002.
5. S.G. Kelly, Mechanical Vibrations: Theory and Applications, Cognella, Inc., 2nd Edition, 2022.
6. L. Meirovitch, Elements of Vibration Analysis, McGraw-Hill, 1986
7. W.T. Thomson and M.D. Dahleh, Theory of Vibration and Applications, Pearson Education; 5th edition, 2008.
8. S. Timoshenko, Vibration Problems in Engineering, Benediction Classics, 2011.
9. N. C. Nigam, Introduction to Random Vibrations, MIT Press, Cambridge, 1983.
10. D.E. Newland, An Introduction to Random Vibrations, Spectral and Wavelet Analysis, Dover Publications Inc., 3rd edition, 2005.

Course	CE6125
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.

CourseNumber	CE6126
CourseCredit (L-T-P-C)	3-0-0-3
CourseTitle	Intelligent Transportation Systems
LearningMode	Lectures
Learning Objectives	To understand various functional areas of ITS and its relevance in smart cities To understand various data collection strategies of ITS To understand various ITS plans around the world To understand ITS user needs and services To understand evaluation of the ITS applications To apply latest technologies in solving congestion related problems
CourseDescription	Intelligent Transportation Systems (ITS) represent a major transition in transportation on many dimensions. This course considers ITS as a lens through which one can view many transportation issues. ITS is an international program intended to improve the effectiveness and efficiency of surface transportation systems through advanced technologies in information systems, communications, and sensors.
CourseContent	Introduction to Intelligent Transportation systems (ITS): Definition, objectives, benefits of ITS. ITS programs in the world – Overview of ITS implementations in developed countries and developing countries. ITS Data Collection Techniques: Intrusive and Non-intrusive, Data Analysis Techniques for ITS: Machine learning techniques, filtering techniques, time series analysis, prediction techniques, optimization. ITS Functional Areas. ITS User Needs and Services: Travel and traffic management; Public transportation management; Electronic payment; Commercial vehicle operations; Information management. ITS Architecture and Standards ITS Architecture: ITS standards, rationale, development process; ITS Policy Issues – institutional, legal etc. User Response and Evaluation: User response to ITS implementations around the world; Evaluation of the ITS implementations
LearningOutcome	At the end of the course, the student will be able to gather the information on 1. What ITS is? 2. Differences between intrusive and non-intrusive technologies 3. Various performance evaluation strategies of ITS applications, 4. Relevance of ITS in the context of developing countries especially with the national mission of smart cities, 5. Understand the differences between various functional areas of ITS etc.
Assessment Method	Assignments, Term Projects, Technical paper presentations, quizzes, mid-semester examination and end-semester examination

References:

1. Joseph S. Sussman: Perspectives on Intelligent Transportation Systems (ITS), Springer; 2005th edition (April 7, 2005)
2. Robert Gordon, Intelligent Transportation Systems: Functional Design for Effective Traffic Management, Springer 2016.
3. Roger W. Vickerman, International Encyclopaedia of Transportation, Elsevier, 2021.
4. Chowdhury, M. A. and Sadek, A. W., Fundamentals of Intelligent Transportation Systems Planning, Artech House. 2003.

5. McQueen, B. and McQueen, J., Intelligent Transportation System Architectures, Artech House. 2003
6. Williams, B., "Intelligent Transportation Systems Standards", Artech House. 2008
7. Ghosh, S. and Lee, T., Intelligent Transportation System - New Principles & Architectures, CRC Press.

Course	CE6127
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pavement Management System
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 1. Understand the major activities involved in managing highway pavements required for managing pavements and exercised, on a daily basis, by a highway organization. 2. Training on data collection and analysis involved in pavement management system.
Course Description	The course outline the technical activities necessary to set up a pavement management system for an existing pavement network. The data to be collected and the analysis process in the pavement management system.
Course Outline	<u>Introduction to Pavement Management System</u> Commitment for a Pavement Management System, Strategies, policies, specifications and feedback system. <u>Network level and Project level pavement management.</u> Quality control and specifications <u>Pavement Monitoring and Evaluation</u> Pavement surveys. Functional and structural evaluation of the existing highway network. Pavement distresses and durability aspects of pavement design. Pavement condition ratings. <u>Rehabilitation and Maintenance Techniques</u> Restoration, recycling, resurfacing, and routine and major maintenance activities <u>Economic analysis</u> Life cycle cost analysis, Life cycle environmental analysis
Learning Outcome	At the end of the course, student would be able to: 1. Develop an effective project management system for transportation agencies. 2. Design different pavement surveys. 3. Manage pavement data so it can be used effectively.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester

	examination.
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Textbooks:

1. Relevant IRC and ASTM standards for pavement condition surveys and condition rating
2. Miller, John S., and William Y. Bellinger. Distress identification manual for the long-term pavement performance program. No. FHWA-RD-03-031. United States. Federal Highway Administration. Office of Infrastructure Research and Development, 2003.
3. Huang, Y. H. "Pavement analysis and design." Pearson, 2004.
4. Papagianna, A. T. and Masad, E. A. "Pavement Design and Materials." John Wiley & Sons, Inc., 2008.
5. Construction and Rehabilitation of Concrete Pavement. American Concrete Paving Association, Arlington Heights, IL.

Course	CE6128
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
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.

Course	CE6130 Analytical Methods in Civil Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analytical Methods in Civil Engineering
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. To brush up the undergraduate level understanding in light with some advanced approaches. 2. To develop p proficiency in numerical techniques and algorithms pertaining to various civil engineering problems. 3. To form a stepping stone towards advance understanding of risk and reliability analyses.
Course Description	First part of this course deals with the numerical method for non-linear equation solution, numerical integration, solution of liner system of equations, curve fittings, solution of differential equations. Second part of the course basic concept of probability theory and statistics, estimation of distribution property, stochastic data generation, risk and reliability methods for civil engineering.
Course Outline	<i>Module – I: Linear Algebra and Differential Equation</i> Linear algebra: Rank of a matrix, solutions of linear systems, linear independence and linear transformations, eigenvalues, eigenvectors, matrices similarity, basis of eigenvectors, diagonalization; Differential equations: homogeneous linear equations of second order, second order homogeneous equations with constant coefficients, case of complex roots, complex exponential function, non-homogeneous equations, solution by undetermined coefficients and variation of parameters. <i>Module – II: Numerical Methods</i> Introduction to Numerical Methods: Objectives of numerical methods, Sources of error in numerical solutions: truncation error, round off error, order of accuracy - Taylor series expansion; Roots of equations: Graphical method, Bisection method, Simple fixed-point iteration, Newton-Raphson method, Secant method, Modified secant method; Direct Solution of Linear systems: Naive Gauss elimination, LU decomposition, Gauss-Seidel, Gauss-Jordon, Jacobi iteration, Cholesky decomposition; Curve fitting: linear regression, polynomial regression, interpolation, spline fitting; Numerical Calculus: trapezoidal and Simpson's rule for integration; Solving differential equation: Euler's method, Runge-Kutta method, boundary value and eigenvalue problem and their application, solving partial differential equation. <i>Module – III: Probability and Statistics</i> Introduction: concept of risk, uncertainty in engineering analysis and design, fundamental of probability models; Analytical models of random phenomena: Bayesian analysis, analysis of variance (ANOVA), tests of hypothesis, confidence interval, properties of good estimates, interval estimation, maximum likelihood estimates, Sample size determination, central limit theorem, expected value, and return period; Miscellaneous Topics: Fitting theoretical and tests of goodness-of-fit (chi-square test, Kolmogorov-Smirnovtest), identification of outliers, regression with discrete dependent variables; Application of Monte Carlo simulation (MCS): determination of function of random variables using MCS

	methods, application of MCS in various problems.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand the different numerical methods for solving non-linear equations and numerical integration method. 2. Should be able to solve differential equations numerically. 3. Understand basic concept probability theory and statistics. 4. Should be able to fit statistical distribution and parameter estimation. 5. Should be able to perform MC simulation and preform risk and reliability analysis.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. E. Kreyszig, Advanced Engineering Mathematics, Wiley, 10th edition, 2011.
2. M. D. Greenberg, Advanced Engineering Mathematics, Pearson, 2nd edition, 1998.
3. S. Chapra and R. Canale, Numerical Methods for Engineers, McGraw Hill, 6th edition, 2010.
4. S. Guha and R. Srivastava, Numerical Methods: For Engineering and Science, Oxford University Press, 1st edition, 2010.
5. R. L. Scheaffer, M. S. Mulekar, and J. T. McClave, Probability and statistics for Engineers, Brooks / Cole, Cengage Learning, 5th Edition, 2011.
6. A. Halder and S. Mahadevan, Probability, Reliability, and Statistical Methods in Engineering Design, Wiley, 2000.
7. H. S. Ang and W. H. Tang, Probability Concepts in Engineering Planning and Design, John Wiley, 1975.
8. J. Benjamin and A. Cornell, Probability, Statistics, and Decision for Civil Engineers, McGraw Hill, 1963.

Course	CE6131: Sustainability of Water Resources System
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Sustainability of Water Resources System
Learning Mode	Lectures
Learning Objectives	Complies with PLO 2, 3, 4 and 5 Students will be introduced to the role of disciplines of ecology and socio-economics, and legal and regulatory settings in the context of integrated water resources management.

Course Description	The course examines the development, use, management, and conservation of water resources and the sustainability of water resources systems.
Course Outline	Advanced topics related to the sustainable management of groundwater systems will be discussed, emphasizing research applications.
Learning Outcome	After attending this course, the following outcomes are expected: 1. Students will understand the theory and practice of sustainable water resources management at international, national and local scales 2. Understand hydrological, socioeconomic and environmental aspects of water management and apply critical thinking to water management 3. They will gain a broad understanding of the complexities of dealing with water resource problems and develop research-based solution techniques.
Assessment Method	Assignments, Projects and case studies, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Q. Grafton and K. Hussey, Water Resources Planning and Management, Cambridge University
2. J.A.A. Jones, Global Hydrology: Processes, Resources, and Environmental Management, Prentice Hall, New York, 399 pp., 1998 (ISBN: 9780582098619).
3. S.A. Thompson, Water Use, Management, and Planning in the United States, Academic Press, San Diego, 371 pp., 1999 (ISBN: 9780126893403)

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CE5281	Civil Engineering Design – II	1	2	0	3
2.	CE5282	Finite Element Methods	3	0	0	3
3.	CE5283	Civil Engineering Lab-II	0	0	3	1.5
4.	CE52XX/ CE62XX	Elective-IV	3	0	0	3
5.	CE52XX/ CE62XX	Elective-V	3	0	0	3
6.	CE52XX/ CE62XX	Elective-VI	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		19	3	3	23.5

Course	CE5281 Civil Engineering Design – II
Course Credit (L-T-P-C)	1-2-0-3
Course Title	Civil Engineering Design – II
Learning Mode	Lectures and Tutorial
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are 1. Understand the fundamental principles of ground water hydrology. 2. Understand the fundamental principles of foundation design.
Course Description	The course deals with the design of (i) Modeling of Groundwater Flow, (ii) various geotechnical foundation problems, (iii) Advance techniques in survey.
Course Outline	Numerical Modeling of Groundwater Flow and Solute Transport for an aquifer site using Advanced industry standard software GMS (Groundwater Modeling Systems). Design of shallow and deep foundations for buildings and bridges. Design of foundation for off-shore structures. Setting out of building plans using advanced survey equipments. The geometric and structural design of flexible pavements including their layout.
Learning Outcome	At the end of the course, student would be able to 1. Model groundwater flow. 2. Design foundation for various structures. 3. Set surveying plan for civil infrastructures.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Text books:

1. Bear, Jacob, Cheng, Alexander H.-D., Modeling Groundwater Flow and Contaminant Transport, Springer
2. Freeze A, Cherry JA, Groundwater, Prentice Hall, 1979.
3. V. N. S. Murthy, Advanced foundation Engineering, CBS Publishers & Distributors, 2011

Reference books:

1. J.E. Bowles, Foundation Analysis and Design, McGraw-Hill, 2001.

Course	CE5282 Finite Element Method
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Finite Element Method
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Provide scientific and technical knowledge for the basis for the development of finite element analysis procedure. 2. Equip the students with a strong foundation and understanding for the finite element analysis process of the problems related to various civil and mechanical engineering.
Course Description	The course deals with understanding finite element analysis of various problems. This course provides the students an exposure for topics on analysis of problems related to various civil and mechanical engineering problems which are not covered in undergraduate design courses.
Course Outline	Basic concepts of engineering analysis; Methods of weighted residuals and variational formulations; Finite element discretization; Shape function; Lagrange and serendipity families; Element properties, iso-parametric elements; Criteria for convergence; Numerical evaluation of finite element matrices (Gauss quadrature integration); Assemblage of elements; Analysis of plane stress/strain, axis-symmetric solids; Three dimensional stress analysis; Flow through porous media; Error analyses: estimate of error, error bounds; Solution technique: finite element programming, use of package programs.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand various numerical methods for analysing engineering problems through FEM. 2. Analysis of various civil and mechanical engineering problems. 3. Ability to analyse complex structural system.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Text/Reference books:

1. T. R. Chandrapatula and A. D. Belegundu, Introduction to finite elements in engineering, Third Edition, Prentice Hall of India, 2001.
2. P. Seshu, Text book of finite element analysis, Prentice Hall of India, 2003.
3. J. N. Reddy, An introduction to the finite element method, McGraw Hill Inc. 1993.
4. R. D. Cook. D. S. Malkus. M. E. Plesha, and R. J. Witt, Concepts and application of finite element analysis, fourth Edition, John Wiley & Sons, 2002.
5. O.C. Zienkiewicz and R. L. Taylor, The Finite element method, Butterworth Heinemann (Vol. I and Vol. II), 2000.
6. C.S. Krishnamoorthy, Finite Element Analysis, Theory and programming, Tata McGraw Hill, 1994.

7. K.J. Bathe, Finite Element Procedures in Engg. Analysis, Prentice Hall of India, 1996.

Course	CE5283 Civil Engineering Lab-II
Course Credit (L-T-P-C)	0-0-3-1.5
Course Title	Civil Engineering Lab-II
Learning Mode	Laboratory
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are 1. To understand laboratory testing procedure. 2. To understand fluid mechanics and fundamental aspects of fluid behaviour. 3. To understand geotechnical tests on soil.
Course Description	This course deals with laboratory testing related to (i) water and wastewater treatment (ii) fundamental aspects of fluid behaviour and (iii) geotechnical testing.
Course Outline	General principles of environmental sample collection and data analysis; Analytical methods of commonly encountered water/wastewater and air quality parameters; Settling column analysis; Optimum coagulant dose; Chlorine dose and residual chlorine; Advance instrumentations for environmental analysis: atomic absorption spectrometer, total organic carbon analyzer, microwave digester, ion chromatography, etc.; Characterization of various environmental samples, viz. drinking water, river water, wastewater, sludge, soil, etc. Open channel flow; Study of different types of flow using Reynold's apparatus, Measurement of flow using a Parshall flume. Cone penetration test; direct shear testing of soils; Plate load test; Triaxial Test, Compaction Properties of soil.
Learning Outcome	At the end of the course, student would be able to 1. Evaluate water based on its specification requirements. 2. Understand the principles of flow measurement 3. Develop laboratory testing plan for soil.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Text/Reference books:

1. D. Fratta, J. Aguetant, and L. R. Smith, Soil Mechanics Laboratory Testing, Boca Raton, CRC Press, USA, 2007.
2. C. N. Sawyer, P. L. McCarty and G. F. Parkin, Chemistry for Environmental Engineers, McGraw-Hill, 1994.
3. APHA, Standard Methods Examination of Water and Wastewater, American Public Health Association, Washington DC, 1995.
4. P. N. Modi and S.M. Seth, Hydraulics and Fluid Mechanics, Standard Book House, 1998.

Departmental Elective – DE-IV, DE-V and DE-VI						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5217	Geoinformatics for Engineers	3	0	0	3
2.	CE5218	Groundwater Hydrology	3	0	0	3
3.	CE5219	Open Channel Hydraulics	3	0	0	3

4.	CE6201	E-waste Management for Circular Economy	3	0	0	3
5.	CE6202	Industrial Pollution Control and Prevention	3	0	0	3
6.	CE6203	Water Supply and Sewerage Network Design	3	0	0	3
7.	CE6204	Design of Water and Wastewater Treatment Facilities	3	0	0	3
8.	CE6205	Advanced Water and Wastewater Engineering	3	0	0	3
9.	CE6206	Geotechnical Earthquake Engineering	3	0	0	3
10.	CE6207	Soil-Structure Interaction Analysis	3	0	0	3
11.	CE6208	Mine Wastes Generation and Management	3	0	0	3
12.	CE6209	Coupled Process in Fractured Geological Media	3	0	0	3
13.	CE6210	Ground Improvement Techniques	3	0	0	3
14.	CE6211	Utilization of industrial byproducts for geotechnical applications	3	0	0	3
15.	CE6212	Rock Engineering for River Valley Projects	3	0	0	3
16.	CE6213	Design of Underground Excavations	3	0	0	3
17.	CE6214	Special Topics in Geotechnical Engineering	3	0	0	3
18.	CE6215	Forensic Geotechnical Engineering	3	0	0	3
19.	CE6216	Special Topics in Rock Engineering for Infrastructural Development	3	0	0	3
20.	CE6227	Traffic Flow Theory	3	0	0	3
21.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3
22.	CE6229	Advanced Flexible Pavement Analysis and Design	3	0	0	3
23.	CE6230	Advanced Concrete Pavement Analysis and Design	3	0	0	3

24.	CE6231	Advanced Pavement Material Characterization	3	0	0	3
25.	CE6232	Porous Media Flow: Advanced topics	3	0	0	3

Departmental Elective – IV, V and VI

Course	CE5217: Geoinformatics for Engineers
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geoinformatics for Engineers
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 & 3- 1. To provide fundamental knowledge in the Basics of GIS. 2. Train students to download, process and prepare the GIS data for Water resources applications. 3. Provide scientific and technical knowledge, to prepare students to prepare maps using GIS for Water resources applications.
Course Description	This course will discuss fundamental concepts in GIS. The course will cover theory and real-world practice in map preparation, flood mapping, rivers and canal mapping and GIS software and databases.
Course Outline	Definition – Basic components of GIS – Map projections and coordinate system – Spatial data structure: raster, vector – Spatial Relationship – Topology – Geodata base models: hierarchical, network, relational, object-oriented models – Integrated GIS database -common sources of error – Data quality: Macro, Micro and Usage level components - Meta data - Spatial data transfer standards. Thematic mapping – Measurement in GIS: length, perimeter, and areas – Query analysis– Reclassification – Buffering - Neighbourhood functions - Map overlay: vector and raster overlay – Interpolation – Network analysis – Digital elevation modelling. Analytical Hierarchy Process, – Object oriented GIS – AM/FM/GIS – Web Based GIS Spatial data sources – GIS approach water resources system – Thematic maps -Rainfall-runoff modelling – Groundwater modelling – Water quality modelling – Flood inundation mapping and Modelling – Drought monitoring – Cropping pattern change analysis –Performance evaluation of irrigation commands. Site selection for artificial recharge - Reservoir sedimentation. Introduction to various remote sensing satellite data (Like Landsat, Sentinel, Radar data, DEM, GRACE etc) and their applications for different water resources engineering applications.
Learning Outcome	At the end of the course, student would be able to: 1. Understand technical aspects and properties of GIS. 2. Download and perform GIS based analysis on different satellite data. 3. Basic flood mapping using Optical and SAR data.
Assessment Method	Assignments (10%), Quizzes (10%), Mid-semester examination (30%) and End-semester examination (50%).

REFERENCES:

1. Lillesand, T.M. and Kiefer, R.W., Remote Sensing, and Image Interpretation III Edition. John Wiley and Sons, New York. 1993.
2. Burrough P.A. and McDonnell R.A., Principles of Geographical Information Systems. Oxford University Press. New York. 1998.
3. Ian Heywood Sarah, Cornelius, and Steve Carver: An Introduction to Geographical Information Systems. Pearson Education. New Delhi, 2002.
4. Jensen, J.R., Introductory digital image processing: a remote sensing perspective, Fourth Edition, Pearson, 2017
5. Joseph, G & Jagannathan, C., Fundamentals of remote sensing (3rd edition), The Orient Blackswan, 2018.

Course	CE5218: Groundwater Hydrology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Groundwater Hydrology
Learning Mode	Lectures
Learning Objectives	Complies with PLO-1, 2, 3, 4, and 5 1. To provide fundamental knowledge of groundwater hydrology. 2. Train students to plan, design and model groundwater systems. 3. Provide scientific and technical knowledge, to apply the learning in

	sustainable management of groundwater resources.
Course Description	This course will discuss fundamental concepts of groundwater flow, its occurrence, movement, and flow principles. It will also cover issues related to groundwater management, such as pollution and over-exploitation.
Course Outline	Characteristics of groundwater, Global distribution of water, Role of groundwater in water resources system and their management, groundwater column, aquifers, classification of aquifers. Hydrogeological cycle, water level fluctuations, Groundwater balance. Darcy's Law, Hydraulic conductivity, Aquifer transmissivity and storativity, Dupuit assumptions Storage coefficient - Specific yield Heterogeneity and Anisotropy, Direct and indirect methods for estimation of aquifer parameters. Governing equation for flow and contaminant transport through porous medium - Steady and unsteady state flow - Initial and boundary conditions, solution of flow equations. Tracer techniques using environmental isotopes. Surface water groundwater interaction. Steady and unsteady flow to a well in a confined and unconfined aquifer - Partially penetrating wells - Wells in a leaky confined aquifer - Multiple well systems - Wells near aquifer boundaries - Hydraulics of recharge wells. Dynamic equilibrium in natural aquifers, groundwater budgets, management potential of aquifers, safe yield, seepage from surface water, stream-aquifer interaction, artificial recharge. Hydrodynamic dispersion - occurrence of dispersion phenomena, coefficient of dispersion - Aquifer advection-dispersion equation and parameters - initial and boundary conditions - method of solutions, solution of advection-dispersion equation. Climate change and impact on groundwater. Groundwater monitoring and groundwater sampling techniques. Introduction to sustainable groundwater management.
Learning Outcome	After attending this course, the following outcomes are expected: 1. Student should be able to develop an understanding about the occurrence, movement, and fate of groundwater in aquifer systems. 2. Students comprehend the physical principles of groundwater flow and solute transport processes and can represent those processes through mathematical equations in assessing water quantity and quality in ground-water systems. 3. Students should be able to understand the challenges associated with groundwater resources and apply the scientific method and critical thinking in groundwater quantity and quality management.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Bhagu R Chahar, Groundwater Hydrology, McGraw-Hill Education, 2015

2. Todd D.K., Ground Water Hydrology, John Wiley and Sons, 2000
3. Freeze A, Cherry JA, Groundwater, Prentice Hall, 1979.
4. Bear J., Hydraulics of Groundwater, Dover Publications INC, 1979
5. Integrated Groundwater Management, Springer Open
6. Richard W Healey, Estimating Groundwater Recharge, Cambridge University Press

Course	CE5219: Open Channel Hydraulics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Open Channel Hydraulics
Learning Mode	Lectures
Learning Objectives	Complies with PLO 1, 2, 3, 4 and 5 Students will be enabled to understand the fundamental principles governing open channel hydraulics for the design of engineering systems. The course is intended to assist students in developing the skills needed for systematic decomposition and solution of real-world problems.
Course Description	This course covers principles of flow in open channels, conservation laws, critical flow, uniform flow, gradually varied flow, unsteady flow, flow through hydraulic structures, hydraulic jump, and flow routing, analytical and numerical techniques will also be discussed, programming assignments will be carried out in common software and MATLAB.

Course Outline	Difference between Open Channel Flow and Pipe Flow, Types of Channel, Geometric parameters of a channel, Classification of Open Channel Flow, Continuity and Momentum equation. Resistance flow formula, Velocity distribution, Equivalent roughness coefficient, Velocity coefficients, Uniform flow in rigid boundary channel, Uniform flow in mobile boundary channel. Concept of Specific Energy, Critical Depth, Alternate depth, Specific Force, Sequent depth. Governing equation of GVF, Classification of Gradually Varied Flow, Computation of GVF profile, Rapidly Varied Flow, hydraulic Jump, Flow over a Hump, Flow in Channel Transition. Concept of best hydraulic section, Design of rigid boundary canal, design of channel in alluvial formation-Kennedy's theory, Lacy's theory, Method of Tractive force, Free-board in canal. Wave and their classification, Celerity of wave, Surges, Characteristic equation.
Learning Outcome	At the end of the course, student would be able to: 1. Learn the form of mass, momentum and energy equations under non hydrostatic pressure distribution and non-uniform velocity profiles. 2. Analyse gradually varied flows numerically. 3. Learn how to analyse rapidly varied flow numerically. 4. Design rigid-boundary and erodible channels. 5. Gain information about the flow through spillways and culverts. 6. Basic components of sediment transport in open channels.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. K Subramaniya, Flow in Open Channels, McGraw Hill, 1997.
2. V.T. Chow, Open-channel hydraulics, McGraw Hill Publications (1973).
3. Sturm, 2001, Open-Channel Hydraulics, McGraw Hill.
4. H. Chaudhury, Open channel flow, Second Edition. Springer (2008).
5. Rajesh Srivastava, Flow through open channels, Oxford University Press (2008).

Course Number	CE6201: E-waste Management for Circular Economy
Course Credit (L-T-P-C)	3-0-0-3
Course Title	E-waste Management for Circular Economy
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4 and 5 1. To familiarize the students about the problem of e-waste generation and hazardous composition, and impact on the environment and human health 2. To acquaint the students with existing international and national legislations, knowledge and practices regarding e-waste management 3. To train the students to plan, implement and operate recycling plants for environmentally-sound e-waste management for resource recovery for a circular economy with case studies
Course Description	The course intends to provide an overview of e-waste generation and associated influencing factors, composition, international and national legislations and various e-waste recycling techniques for resource recovery for a circular economy. Further, the course intends to provide and discuss case studies on e-waste recycling.
Course Content	E-waste and waste electrical and electronic equipment (WEEE), e-waste generation: global and national, factors affecting e-waste generation, classification of e-waste, average obsolescence rate or end of life period, formulas used for estimation of e-waste generation; Components of e-waste, composition of e-waste including printed circuit boards (PCBs), rechargeable batteries, spent magnet, ceramic based equipment, solar PV, etc.; Hazardous materials in e-waste, e-waste toxicity by standard toxicity tests and toxicity standard; International legislation: the Basel convention, WEEE Directive in the European Union, Restrictions of Hazardous Substances (RoHS) Directive, COP; E-waste management rules and amendments in India, Roles and responsibilities of stakeholders - Manufacturers and producers, refurbishes and the recyclers, Guidelines for e-waste management by CPCB; concept and meaning of expected producer responsibility (EPR) and recycling target; E-waste management in developed and developing countries, Informal sectors and rudimentary processes and crude methods, associated pollution, occupational hazards, economics of the informal sectors and loss of valuable materials, way forward for converting informal to formal sector; Sustainability and sustainable development goals (SDGs) in the context of e-waste, Circular economy and urban mining concepts; formal e-waste management framework, sustainable techniques for segregation and dismantling, closed loop recycling, zero discharge concept, energy efficiency; E-waste minimization and hazard

	reduction: 3Rs, green design with green materials, R to R concept with the Right to Repair Rule and Act, refurbishing concept, modular design; Recycling techniques: Basics of metallurgical techniques and urban mining, pyro-, hydro- and biometallurgical techniques, pulverization, steps and different process for recycling and recovery, beneficiation, Case studies on e-waste recycling.
Learning Outcome	At the end of the course, students would be able to: 1. Understand about the problem of e-waste generation, hazardous composition, national and international legislations, and detrimental effects on the environment and human health 2. Devise and adopt various strategies on e-waste minimization and hazard reduction with green design, right to repair, and refurbishing 3. Plan and implement environmentally-sound e-waste recycling techniques for resource recovery for a circular economy with case studies 4. Learn about the state-of-the-art and emerging e-waste recycling techniques for sustainability.
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text and Reference Books:

1. Hussain, C.M., Environmental Management of Waste Electrical and Electronic Equipment, Elsevier, 2021.
2. Indian E-waste (Management) Rules, 2022.
3. Fowler, B., Electronic Waste: Toxicology and Public Health Issues, Elsevier, 2017.
4. Prasad, M.N.V., Vithanage, M. and Borthakur, A., Handbook of Electronic Waste Management: International Best Practices and Case Studies, Butterworth-Heinemann, 2019.

Course Number	CE6202: Industrial Pollution Control and Prevention
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Industrial Pollution Control and Prevention
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4 and 5

	1. To learn and implement cleaner production activities and industrial (solid, liquid and gaseous) waste/emission management strategies for pollution control and prevention 2. To discuss the most commonly applied treatment technologies and explain their suitability for industrial (solid, liquid and gaseous) waste/emission treatment applications as well as their advantages and disadvantages based on waste characteristics 3. To able to select the most appropriate treatment technology and devise a treatment train/chain (sequence of treatment processes) to treat an industrial waste/emission stream (solid, liquid and gaseous) for a selected industry 4. To recognize waste treatment technologies applied to industrial waste treatment and analyze industrial waste schemes from case studies presented from a range of industries
Course Description	The course intends to provide an overview of various types of industries including manufacturing industry, process flow schematics with materials/water requirements and waste/emission generation with composition. Further, the course intends to cover and discuss pollution prevention and cleaner production approaches along with waste treatment and emission control techniques with industrial case studies.
Course Content	Introduction to Industrial Waste: Types of industries and industrial pollution, Types of industrial wastes - solid, liquid and gaseous wastes, Hazardous waste - definition and concept, Basics of Water Quality Parameters, Basics of Air Pollution, Characteristics of industrial wastes, Effects of industrial wastes on environment and human health, Toxicity and risk assessment; Environmental standards and legislations; Pollution Prevention and Cleaner Production: Waste minimization, Source reduction, Use of alternate raw materials, Process modifications, Recycle, reuse and byproduct recovery, Zero liquid discharge (ZLD), Opportunities and barriers to cleaner production; Emerging topics – Industry 4.0 and 5.0 concept, and Design for the environment (DfE); Waste Treatment and Emission Control Techniques: Physico-chemical and biological treatment of wastewater, Concept of common effluent treatment plant (CETP), Concept of zero discharge, Industrial sludge management, Industrial air pollution, Control of gaseous emissions; Pollution Control in Major Industries – Case Studies: Manufacturing processes and flow sheets, Sources and characteristics of wastes, Waste treatment and disposal methods – Thermal power plants, Iron and steel, Metal plating, Fertilizer, Refinery, Tannery, Food industry, etc.
Learning Outcome	At the end of the course, students would be able to: 1. Comprehend and understand about the manufacturing processes with materials/water requirements and waste/emission generation with composition in various secondary/manufacturing industries with case studies 2. Devise, integrate and implement cleaner production, water management, effluent treatment processes, sludge handling and disposal, and air pollution control towards devising an industrial waste treatment train/chain for a selected industry in a sustainable

	manner 3. Learn about the state-of-the-art and emerging industrial practices/regimes aiming towards pollution control and prevention.
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text Book:

1. de Nevers, N., Air Pollution Control Engineering, Waveland Press, 2010.
2. Eckenfelder Jr., W.W., Industrial Water Pollution Control, 3rd Edition, McGraw-Hill, 2000.
3. Wark, K. and Warner, C. F., Air Pollution- Its Origin and Control, Harper & Row, 1981.
4. Wise, D.L. and Trantolo, D.J. (eds.), Process Engineering for Pollution Control and Waste Minimization, 1st Edition, Marcel Dekker, 1994.

Reference Books:

1. Cooper, C.D. and Alley, F.C., Air Pollution Control: A Design Approach, Waveland Press, 2002.
2. Ghassemi, A. (ed.), Handbook of Pollution Control & Waste Minimization, 2nd Edition, Marcel Dekker, 2002.
3. Metcalf & Eddy, Wastewater Engineering - Treatment and Reuse (Revised by Tchobanoglous, G., Burton, F.L. and Stensel, H.D.), Tata McGrawHill, 2004.

Course Number	CE6203- Water Supply and Sewerage Network Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Water Supply and Sewerage Network Design
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2 and 4: 1. To study and analyze the design criteria of water supply and sewer system 2. To study and analyze the wells and reservoir and service storage for the water supply system 3. To layout and design the water distribution system 4. To layout and design the sewerage system 5. To layout and design the pump station.
Course Description	This course aims to equip students with the skills to design comprehensive water supply systems and sanitary sewer systems, including all necessary pumping station design. Students are expected to demonstrate their knowledge and understanding by applying them to case studies involving a water distribution network and a sewer network

Course Outline	Overview of water supply system components; estimation of water demand; considerations for design period, population growth, and flow rates in water supply systems; factors influencing water consumption and demand variability; design and optimization of water distribution networks, including analysis methods; types of reservoirs, design parameters, and approaches to reservoir design; fundamentals of designing water pumping stations. Principles of wastewater collection system design, including separate, combined, and semi-combined sewers; estimation of dry weather flows; sewer pipe hydraulics, focusing on pipe sizing and design; design of manhole chambers and stormwater overflows; design and operation of pumping stations. Maintenance strategies for water supply and wastewater systems
Learning Outcome	At the end of the course, students would be able to: 1. Understand the components and design principles for water distribution networks, focusing on demand, flow rates, reservoir design and pumping stations. 2. Learn to design wastewater collection systems, including pipe sizing, dry weather flow estimation, and manhole placement. 3. Gain knowledge of operation and maintenance strategies for water supply and wastewater systems.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books:

1. Peavy, H. S., Rowe, D. R. and Tchobanoglous, G., Environmental Engineering, McGraw-Hill International Ed., 1985.
2. McGhee, T. J., Water Supply and Sewerage, McGraw Hill International, 1991.
3. Goel, S, Water and Wastewater Engineering, Cambridge University Press, First edition (12 December 2019)

Reference Books:

1. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
2. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.
3. AWWA/ ASCE, Water Treatment Plant Design, 3rd Edition- McGraw Hill, 1998.
4. Quasim, S. R., Motley E. M. and Zhu, G., Water Works Engineering- Planning, Design and Operation, Prentice Hall, 2000.

Course	CE6204: Design of Water and Wastewater Treatment Facilities
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Design of Water and Wastewater Treatment Facilities
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 4 1. Understand the principles of water and wastewater treatment for different project scales. 2. Learn the design methodologies for on-site water treatment plants and wastewater treatment plants. 3. Develop skills in selecting appropriate treatment technologies and equipment. 4. Gain hands-on experience through a comprehensive design project that covers all aspects of on-site water and wastewater systems.
Course Description	This course provides an in-depth exploration of the design principles and engineering practices involved in on-site water and wastewater treatment plants for small to large-scale projects. Through a combination of theoretical instruction, case studies, and design projects, students will gain a comprehensive understanding of the entire process of water and wastewater treatment.
Course Outline	Design of water and wastewater treatment facilities: Selection of site, Design of various units; Hydraulics of treatment plant: flow measurement and hydraulic control points, hydraulic analysis of unit

	operations, hydraulic profile through the treatment plant.
Learning Outcome	At the end of the course, students would be able to: 1. Design water treatment plant including treatment units like sedimentation, filtration, and disinfection, meeting water quality standards. 2. Design wastewater treatment plants, including primary and secondary treatment processes. 3. Analyze hydraulic profiles and flow dynamics in water and wastewater treatment plants.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books:

1. Nazaroff, W.W. and Alvarez-Cohen, L., Environmental Engineering Science, Wiley, 2000.
2. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G., Environmental Engineering, McGraw-Hill International Ed., 1985.
3. Goel, S, Water and Wastewater Engineering, Cambridge University Press, First edition (12 December 2019)
4. J. M. Montgomery, Water Treatment Principles and Design, John Wiley & Sons, 1985
5. T. J. McGhee, Water Supply and Sewerage, McGraw-Hill, Inc, 1991.
6. Qasim, S. R., Wastewater Treatment Plant, Planning Design and Operation, CBS Publishing Japan Ltd, New York, 1985
7. S. J Arceivala and S. R. Asolekar, Wastewater Treatment for Pollution Control and Reuse, Tata McGraw Hill, 2006.
8. Metcalf & Eddy, Wastewater Engineering- Treatment and Reuse (Revised by G. Tchobanoglous, F. L. Burton and H. D. Stensel), Tata McGraw Hill, 4th Edn., 2004.

Reference Books:

1. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
2. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.

Course Number	CE6205: Advanced Water and Wastewater Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Water and Wastewater Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 3 and 4 1. To acquaint students with advanced knowledge and practices in water and wastewater treatment engineering. 2. Train students to plan, design and operate water treatment plant and wastewater treatment plant in real-life scenario. 3. Provide advanced scientific and technical knowledge to prepare students to address issues and challenges in water and wastewater treatment engineering sector.
Course Description	The course intends to provide a deeper understanding of advanced concepts of principles and processes for water supply and treatment, and wastewater treatment with a major emphasis to advanced treatment techniques for water reuse. The course also intends to cover design aspects of water and wastewater treatment for the improvement of water quality in real-life scenario.
Course Content	Water requirements – Water demand, forecasting and management, Surface water and Ground water sources, Water quality and drinking water standards, Determination of reservoir capacity, Transportation and distribution of water, Distribution system design and analysis, Optimization of pipe network systems, Distribution reservoirs and service storage, Pumping and design considerations for pumps, Water treatment systems, Physico-chemical processes, Sedimentation, Coagulation, Flocculation, Granular media filtration, Disinfection, Water softening, Adsorption and ion exchange processes. Wastewater- Sources, nature and characteristics, Estimation of wastewater flow rate and fluctuations, Estimation of storm water. Combined and separate sewerage systems - Design, Sewer materials, Sewer appurtenances, Construction and maintenance of sewers and

	pumping of sewage, Analysis of wastewater - determination of solids, COD, BOD, nutrients and their significance, BOD progression and its formulations. Wastewater treatment systems with advance processes- Primary, secondary and tertiary treatments, screens, grit chambers, sedimentation tanks, chemical precipitation, Biological treatment - objectives, methods and design of activated sludge and trickling filter units, moving bed biofilm reactor, membrane bioreactor, sequencing batch reactor, wastewater reuse and emerging contaminants removal techniques; Sewage sludge - its treatment, disposal and reuse, Effluent standards and disposal.
Learning Outcome	At the end of the course, students would be able to: 1. Comprehend advanced knowledge of principles and processes involved in water and wastewater treatment with a major focus to water reuse 2. Comprehend, understand and apply various advanced practices and techniques for water and wastewater treatment with a goal towards water reuse in real-life scenario 3. Comprehend, understand and apply best available technique for a particular contaminant or a set of contaminants including emerging contaminants for improvement in water quality 4. Analyze and understand the current issues and challenges in the water and wastewater treatment sector
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text Books:

1. H. S. Peavy, D. R. Rowe and George Tchobanoglous, Environmental Engineering, McGraw-Hill International Ed., 1985.
2. M. L. Davis and D. A. Cornwell, Introduction to Environmental Engineering, McGraw-Hill, Inc., 2014.
3. C. N. Sawyer, P. L. McCarty and G. F. Parkin, Chemistry for Environmental Engineers, McGraw- Hill, 1994.
4. Rumana Riffat, Fundamentals of Wastewater Treatment and Engineering, CRC Press, 2012.

Reference Books:

1. Metcalf & Eddy, Wastewater Engineering- Treatment and Reuse (Revised by G. Tchobanoglous, F. L. Burton and H. D. Stensel), Tata McGraw Hill, 4th Edn., 2004.
2. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
3. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.

	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.

	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.
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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.

	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.
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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, Rechard 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.

	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

	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 geo-synthetics 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.

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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

	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.

	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.

	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.

	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.

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.

	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.

CourseNumber	CE6227
CourseCredit (L-T-P-C)	3-0-0-3
CourseTitle	Traffic Flow Theory
LearningMode	Lectures
Learning Objectives	To gain insight into theory and modeling of traffic flow operations, to learn to apply theory and mathematical models to solve practical problems.
CourseDescription	This course discusses fundamental traffic flow characteristics and traffic flow variables. Their definitions are presented, and visualization/analysis techniques are discussed and empirical facts are presented. The empirical relation between the flow variables are discussed. Shockwave analysis and a review of macroscopic traffic flow models are presented. Traffic flow stability issues are discussed as well as numerical solution approaches. The lectures also show how macroscopic models are derived from microscopic principles. This course provides an overview of human factors relevant for the behavior of drivers. The car-following model and other approaches to describe the lateral driving task will be discussed. The lectures also pertain to general gap acceptance modeling and lane changing.
CourseContent	Traffic Characteristics: Macroscopic variables, Microscopic variables, Relationships between micro and macroscopic variables, Check for various statistical distributions, chi-square test; Microscopic Traffic Flow Models: Car following theories, Assumptions and results from Pipes, Forbes, and GM family of car-following models; Static/Equilibrium Traffic Stream Models: Models by Greenshields', Greenberg's, Underwoods, Drew's, GM Models to various equilibrium relations; Dynamic Traffic Flow Models: First-order fluid-dynamic models - Lighthill Whitham and Richards (LWR) model – Solutions using characteristic curves, Introduction to higher order models; Transients in Traffic Flow: Shock wave analysis, Principles and definitions, Types of shockwaves arising in various traffic settings, Applications and uses of shock wave analysis; Queuing Theory and Applications: Gap acceptance models, Definitions and Principles of queuing theory, Applications and properties of queues for traffic management.
LearningOutcome	At the end of the course, the student will be able to gather the information on 1. Identify differences between microscopic and macroscopic variables 2. Learn how macroscopic models are derived from microscopic principles 3. Understand car-following models 4. Understand the concepts of shockwave theory in traffic flow. 5. Understand the analogy of fluid flow models with traffic flow. 6. Application of queuing theory in traffic flow.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination

References:

1. Adolf D. May. Traffic Flow Fundamentals. Prentice-Hall International (1990)
2. Daganzo, C.F. Fundamentals of transportation and traffic operations. Vol. 30. Oxford: Pergamon, 1997.
3. Elefteriadou, L. An introduction to traffic flow theory. Vol. 84. New York, NY, USA: Springer, 2014.
4. Daiheng Ni, Traffic Flow Theory, PHI 5. Partha Chakraborty, Animesh Das: Principles of Transportation Engineering, 2nd Edition by PHI.
5. Leutzbach, W. Introduction to the theory of traffic flow. Vol. 47. Berlin: Springer-Verlag, 1988.
6. Henry Lieu. Revised Monograph on Traffic Flow Theory, Federal Highway Administration Research and Technology, 2017.

Course Number	CE6228
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analytical Techniques for Infrastructure Systems Analysis
Learning Mode	Lectures
Learning Objectives	To provide knowledge of quantitative techniques with application potential for Infrastructure systems.
Course Description	This course provides a comprehensive introduction to the analytical methods and tools used in the analysis of infrastructure (transportation) systems. The course focuses on the application of these techniques to real-world transportation systems and includes a mix of theoretical and practical content. Students will learn about various analytical techniques including but not limited to traffic flow theory, network analysis, demand forecasting, and system optimization. The course will cover both traditional methods such as regression analysis and newer techniques such as machine learning and data analytics. The course will also delve into the use of software tools for transportation analysis and modeling. Students will get hands-on experience with these tools through assignments and projects.
Course Content	Modelling and Simulation: Model Classification, Mathematical; Physical and Analog models, steps involved in simulation, Monte Carlo simulation, validation and verification of simulation models Multivariate Data Analysis: Vectors and Matrices, Simple estimate of centroid, standard deviation, dispersion, variance and co-variance, correlation matrices, principal component analysis Curve Fitting: Method of least squares, curvilinear regression, Multiple regression, checking adequacy of model, correlation, multiple linear regression; Queuing Theory: General structure, operating characteristics, deterministic queuing model, probabilistic queuing models, and simulation of queuing system; Forecasting Models: Moving averages, exponential smoothing, trend projections, causal models, time series analysis of vehicle growth & accidents Neural Networks: Basic concepts; neural network architecture, back propagation networks.
Learning Outcome	The student will be able to 1. Understand and Apply Modelling and Simulation Techniques 2. Perform Curve Fitting 3. Understand and Apply Queuing Theory 4. Perform Multivariate Data Analysis 5. Develop and Use Forecasting Models and Neural networks for the transportation related problems
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination

References

1. Vohra, N.D., "Quantitative Techniques in Management", Tata McGraw Hill, 2001.

2. Johnson, R. A. and Wichern, D.W., “Applied Multivariate Statistical Analysis”, Prentice Hall., 2003.
3. Johnson, R., “Probability and Statistics for Engineers”, Prentice Hall. 2009
4. Hair, J. and Anderson, R., “Multivariate Data Analysis”, Prentice Hall. 2010

Course	CE6229
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Flexible Pavement Analysis and Design
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2 and 4 1. To provide knowledge of recent developments in asphalt material characterization for pavement analysis. 2. Train students to design pavement and overlays. 3. Learn computation of stress distribution and distress mechanisms in pavement. 4. Learn life-cycle analysis of flexible pavements
Course Description	This course will discuss fundamental concepts in design and analysis of flexible pavement. Course will cover Empirical and Mechanistic-Empirical pavement design approaches. Students will learn how to conduct life-cycle cost and environmental analysis for flexible pavements. Students will also learn use of non-destructive tests in pavement condition evaluation and overlay design.
Course Outline	<u>Development of Various Design Methods for Flexible Pavement:</u> Empirical pavement design approach, AASHTO 1993 method, Mechanistic empirical pavement design approach, Asphalt Institute method, IRC Method, MEPDG Method. <u>Theoretical and Numerical Models for Analysis of Flexible Pavement:</u> Axle load configurations, Stresses and strains in pavements, Boussinesq solution, Equivalent Thickness Method, Multi-layer elastic solutions, Multi-layer viscoelastic solutions, 2-D and 3-D Finite element models. <u>Selection of Pavement Design Input Parameters and Pavement Performance Models:</u> Traffic loading, Environmental factors in pavement design, Reliability, Pavement material models for asphalt mix and unbound materials, Pavement performance models, Effects of heavy vehicles on pavement response and performance. <u>Sustainability Analysis:</u> Introduction to sustainability in pavement design, Life-cycle cost analysis, Environmental analysis, Nondestructive testing, Backcalculation of pavement in situ properties, Design of overlays. <u>Software:</u> KENPAVE

Learning Outcome	At the end of the course, student would be able to: 1. Design flexible pavements using Indian Codes and learn best practices. 2. Ability to compute stress-strain distribution in pavement. 3. Identify different type of distresses in pavement and determine condition of pavement using nondestructive testing. 4. Identify factors influencing pavement design. 5. Perform pavement life cycle cost and environmental analysis.
Assessment Method	Assignments , Quizzes , Mid-semester examination and End-semester examination .

Textbooks:

1. Huang, Y. H. "Pavement analysis and design." Pearson, 2004.
2. Papagianna, A. T. and Masad, E. A. "Pavement Design and Materials." John Wiley & Sons, Inc., 2008.
3. Chakroborty, P. and Das, A. "Principles of Transportation Engineering." PHI Learning, 2017.

Reference books:

1. Ullidtz, P. "Pavement Analysis." Elsevier, 1987.
2. Mechanistic-Empirical Pavement Design Guide – A Manual of Practice, AASHTO 2008.

Course	CE6230
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Concrete Pavement Analysis and Design
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2 and 4 1. Differentiate between the various Portland Cement Concrete pavement systems. 2. To provide knowledge of recent developments in concrete material characterization for rigid pavement analysis. 3. Train students to design concrete pavement and overlays. 4. Learn computation of stress distribution and distress mechanisms in rigid pavement. 5. Explain the underlying mechanisms associate with load and material related distresses.
Course Description	This course will discuss fundamental concepts in design and analysis of rigid pavement. Theoretical models for analysis of rigid pavement systems. Evaluation and application of current design practices related to rigid pavements. Course will cover Empirical and Mechanistic-Empirical pavement design approaches. Students will also learn different mechanisms associated with distress in rigid pavements.
Course Outline	<u>INTRODUCTION TO PCC PAVEMENTS:</u> Typical pavement cross-section and plan, Types of PCC pavements, Jointed systems, CRCP, Overlays, 2-lift systems, Precast systems, Prestressed-Post tension systems, Evolution of pavement design, Empirical and Mechanistic-Empirical designs. <u>OVERVIEW OF AASHTO 86/93:</u> Significant inputs needed for the design, Serviceability concept, Impact of inputs on the slab thickness-sensitivity, Limitations of the design process, Need for a systems approach to design-M-E PDG. <u>PCC PAVEMENT DISTRESSES:</u> Functional and structural distress, Load related distress, Material related distress, Underlying mechanism(s) of distresses, Relationship between distress mechanism(s) and design. <u>PCC PAVEMENT RESPONSE:</u> Load related response, Thermal response. <u>Material Characterization:</u> Fresh mixture properties, Mechanical properties, Thermal properties, Fracture properties, Durability

	properties. <u>Traffic Characterization:</u> ESALs, Load Spectra. <u>PCC Design Methods (New and Overlays):</u> PCA design method, AASHTO'98, M-E PDG. <u>CONSTRUCTION OF PCC PAVEMENTS:</u> Conventional pavement construction, Two-lift construction, Modular pavement construction, Concrete Overlays. <u>SPECIAL TOPICS IN PCC PAVEMENTS:</u> Porous concrete, Pannel concrete, Roller Concrete.
Learning Outcome	At the end of the course, student would be able to: 1. Design rigid pavements using Indian Codes and learn best practices. 2. Ability to compute stress-strain distribution in rigid pavement. 3. Identify different type of distresses in rigid pavement. 4. Identify factors influencing rigid pavement design.
Assessment Method	Assignments , Quizzes , Mid-semester examination and End-semester examination .

Textbooks:

1. Huang, Y. H. "Pavement analysis and design." Pearson, 2004.
2. Papagianna, A. T. and Masad, E. A. "Pavement Design and Materials." John Wiley & Sons, Inc., 2008.
3. Chakroborty, P. and Das, A. "Principles of Transportation Engineering." PHI Learning, 2017.

Reference books:

1. Ullidtz, P. "Pavement Analysis." Elsevier, 1987.
2. Mechanistic-Empirical Pavement Design Guide – A Manual of Practice, AASHTO 2008.

Course	CE6231
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Pavement Material Characterization
Learning Mode	Lectures

Learning Objectives	Complies with PLO number – 1, 2, and 4 1. To understand characteristic properties of material used in road construction. 2. To understand performance evaluation techniques of road construction materials. 3. To understand design of asphalt mix. 4. To understand different type of waste and recycled materials used in road construction. 5. To understand quality control plan in road construction.
Course Description	This course deals with materials used in road construction. Source, properties and performance evaluation methods of pavement materials are important in selecting them road construction project. The course will help students understand the practices used in road construction industry in selection, design and quality control of pavement materials.
Course Outline	<u>Characterization of Pavement Materials:</u> (1) Asphalt mix: Definitions, Production types and Classification of asphalt mix. (2) Aggregates: Definitions, Sources, Production types, Engineering and Consensus properties. (3) Asphalt binder: Definitions, Sources, Production types, Chemistry and Physical properties, Performance tests and Specifications, Specifications for modified binders. (4) Soil: Definitions, Classification and Engineering properties. (5) Emulsion: Definitions, Classification and Engineering properties; Image based material evaluation, non-destructive testing of material properties. <u>Advance topics in Asphalt Binder and Mixes:</u> Performance grading of asphalt binder, Binder modification, Superpave mix design, Design using recycled materials. <u>Asphalt Mix Modeling:</u> Introduction to viscoelasticity, Rheological properties – viscoelastic models, Viscoplastic models, nonlinear viscoelasticity, Interconversion of viscoelastic properties. <u>Failure Modeling:</u> Fatigue Models, Rutting models, Moisture damage mechanism. <u>Unbound materials:</u> Nonlinearity in fine and coarse grained material; Stabilized granular layer, Design of stabilized materials. <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. Understand different conventional and recycled materials used in road construction?

	2. Select and design material for road construction. 3. Evaluate pavement material based on performance related properties. 4. Develop quality control plan for pavement materials in road construction projects.
Assessment Method	Assignments , Quizzes , Mid-semester examination and End-semester examination .

Textbooks:

1. Huang, Y. H. "Pavement analysis and design." Pearson, 2004.
2. Papagianna, A. T. and Masad, E. A. "Pavement Design and Materials." John Wiley & Sons, Inc., 2008.

Reference books:

1. Kim., Y. R. "Modeling of Asphalt Concrete." McGraw-Hill, 2009, 1st Edition.
2. National Cooperative Highway Research Program (NCHRP) Reports.
3. MORTH. "Ministry of Road Transportation & Highways Specifications for Road and Bridge Works." 2013.

Course	CE6232: Porous Media Flow: Advanced topics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Porous Media Flow: Advanced topics
Learning Mode	Lectures
Learning Objectives	Complies with PLO-1, 2, 3, 4, and 5 4. To provide fundamental knowledge of groundwater hydrology. 5. Train students to plan, design and model groundwater systems. 6. Provide scientific and technical knowledge, to apply the learning in sustainable management of groundwater resources.
Course Description	This course will discuss advanced concepts of porous media flow, its occurrence, movement, and flow principles. It will also cover issues

	related to groundwater management, such as pollution and over-exploitation.
Course Outline	Advanced topics in groundwater flow and solute transport will be discussed in this subject, emphasising research applications.
Learning Outcome	After attending this course, the following outcomes are expected: 4. Student should be able to develop an understanding about the occurrence, movement, and fate of groundwater in aquifer systems. 5. Students comprehend the physical principles of groundwater flow and solute transport processes and can represent those processes through mathematical equations in assessing water quantity and quality in ground-water systems. 6. Students should be able to understand the challenges associated with groundwater resources and apply the scientific method and critical thinking in groundwater quantity and quality management.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Bhagu R Chahar, Groundwater Hydrology, McGraw-Hill Education, 2015
2. Todd D.K., Ground Water Hydrology, John Wiley and Sons, 2000
3. Freeze A, Cherry JA, Groundwater, Prentice Hall, 1979.
4. Bear J., Hydraulics of Groundwater, Dover Publications INC, 1979
5. Integrated Groundwater Management, Springer Open
6. Richard W Healey, Estimating Groundwater Recharge, Cambridge University Press

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.

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to students other than CE)

Sl. No.	Subject Code	Subject Name	L	T	P	C
1.	CE6132	Data Science for Engineers	3	0	0	3

Course	CE6132: Data Science for Engineers
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Data Science for Engineers
Desirable Prerequisites	Knowledge of Remote Sensing and GIS/Advanced Geomatics, digital image processing, machine learning and AI
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 & 3- 1. To provide fundamental knowledge in the basics of Data Science. 2. Train students to understand the various applications of Machine Learning and modelling for research applications. 3. Provide scientific and technical knowledge to the students on Errors and Adjustments.
Course Description	This course will discuss fundamental concepts in data science for Civil Engineers. The course will cover theory and real-world practice in data, errors and adjustments to help deal with various research-related problems.
Course Outline	Overview of probability and statistics; statistical learning: definition, principles and different types of statistical learning, assessing model accuracy, bias-variance tradeoff; regression models: simple linear and multiple linear and non-linear; resampling methods: assessing model prediction quality, cross-validation, bootstrap; model selection and regularisation: dimensionality reduction, ridge and lasso; unsupervised learning: clustering approaches, K-means and hierarchical clustering; supervised learning: classification problem, classification using logistic regression, naive Bayes, classification with Support Vector Machines, neural networks. Background of Errors, Expectations and Error Propagation, Random Errors, Model Development and Problem-solving, Observations and Equations, Conditions and Combined Equations, Errors in Surveying.
Learning Outcome	At the end of the course, students would be able to: 1. Understand technical aspects and properties of Data Science. 2. Perform error adjustments in Civil Engineering problems. 3. Skilled to develop more accurate, robust and error-free predictive and classification models.
Assessment Method	Assignments (10%), Quizzes (10%), Mid-semester examination (30%) and End-semester examination (50%).

REFERENCES:

1. Gillani, D. Charles, Adjustment Computations: Spatial Data Analysis, 6th Edition, John Wiley and Sons, 2017.
2. James, G., Witten, D., Hastie, T., & Tibshirani, R., Introduction to Statistical Learning, Springer, 2nd Edition, 2013.
3. Lillesand, T.M. and Kiefer, R.W., Remote Sensing, and Image Interpretation III Edition. John Wiley and Sons, New York. 1993.
4. Mehrotra, A.K., Geo-statistics for Beginners, Zorba, 2020.
5. Ian Heywood Sarah, Cornelius, and Steve Carver: An Introduction to Geographical Information Systems. Pearson Education. New Delhi, 2002.
6. Leick, A., GPS satellite surveying, John Wiley and Sons, 4th Edition, 2015.
7. Ogundare, O.J., Precision Surveying: The Principles and Geomatics Practice, John Wiley and Sons, 2015.