

M. Tech. in Transportation Engineering

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: Equip the students with strong foundation in civil and environmental (Transportation) 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 (transportation) 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 (transportation) 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 (transportation) 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.	CE5111	Urban Transportation Planning	3	0	0	3
3.	CE5112	Pavement Analysis and Design	3	0	0	3
4.	CE5113	Traffic Engineering and Management	3	0	3	4.5
5.	CE51XX/ CE61XX	DE-I (Transportation Elective)	3	0	0	3
6.	CE51XX/ CE61XX	DE-II (Transportation Elective/ Department Elective)	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	2	5	23.5

IDE (Inter Disciplinary electives) in the curriculum aims to create multitasking professionals/ scientists with learning opportunities for students across disciplines/aperture 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.	CE5212	Highway Materials	3	0	3	4.5
2.	CE5213	Railway Engineering	3	0	0	3
3.	CE5214	Computer Applications in Transportation Engineering	2	1	0	3
4.	CE52XX/ CE62XX	DE-III (Transportation Elective)	3	0	0	3
5.	CE52XX/ CE62XX	DE-IV (Transportation Elective/ Department Elective)	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
	TOTAL		20	2	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

Department Elective - I (Transportation Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6125	Bituminous materials	3	0	0	3
2.	CE6126	Intelligent Transportation Systems	3	0	0	3
3.	CE6127	Pavement Management Systems	3	0	0	3

Department Elective - II (Transportation Elective/ Department Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engineering	3	0	0	3
2.	CE6106	Soil Dynamics	3	0	0	3
3.	CE6107	Rock Slope Engineering	3	0	0	3
4.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
5.	CE6111	Rock Mechanics	3	0	0	3
6.	CE6113	Pavement Geotechniques	3	0	0	3
7.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
8.	CE6116	Bridge Engineering and Design	3	0	0	3
9.	CE6122	Advanced Concrete Technology	3	0	0	3
10.	CE6128	Highway Geometric Design and Safety	3	0	0	3
11.	CE6129	Airport Engineering	3	0	0	3
12.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3

Department Elective - III (Transportation Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6227	Traffic Flow Theory	3	0	0	3
2.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3
3.	CE6229	Advanced Flexible Pavement Analysis and Design	3	0	0	3

Department Elective - IV (Transportation Elective/ Department Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5217	Geoinformatics for Engineers	3	0	0	3
2.	CE6206	Geotechnical Earthquake Engineering	3	0	0	3
3.	CE6208	Mine Wastes Generation and Management	3	0	0	3
4.	CE6209	Coupled Process in Fractured Geological Media	3	0	0	3
5.	CE6210	Ground Improvement Techniques	3	0	0	3
6.	CE6211	Utilization of industrial byproducts for geotechnical applications	3	0	0	3
7.	CE6213	Design of Underground Excavations	3	0	0	3

8.	CE6214	Special Topics in Geotechnical Engineering	3	0	0	3
9.	CE6215	Forensic Geotechnical Engineering	3	0	0	3
10.	CE6218	Finite Element Method	3	0	0	3
11.	CE6219	Structural Health Monitoring	3	0	0	3
12.	CE6223	Uncertainty, Risk and Reliability Analyses in Civil Engineering	3	0	0	3
13.	CE6230	Advanced Concrete Pavement Analysis and Design	3	0	0	3
14.	CE6231	Advanced Pavement Material Characterization	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.	CE5111	Urban Transportation Planning	3	0	0	3
3.	CE5112	Pavement Analysis and Design	3	0	0	3
4.	CE5113	Traffic Engineering and Management	3	0	3	4.5
5.	CE51PQ/ CE61PQ	DE-I (Transportation Elective)	3	0	0	3
6.	CE51PQ/ CE61PQ	DE-II (Transportation Elective/ Department Elective)	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	2	5	23.5

SEMESTER – I: CORE

Course	CE5111
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Urban Transportation Planning
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 scope; Definition and basic principles; Transportation problems; Types of models; Planning methodologies; Conventional transportation planning process; Travel demand modelling and forecasting; Trip generation - regression, category analysis; Trip distribution - growth factor, Fratar and Furness methods, calibration of Gravity model, intervening opportunities model, competing opportunities model, LP model; Modal split models - aggregate and disaggregate models, discriminant, logit and probit analysis; Traffic Assignment - route building, capacity restraint, multipath, incremental and equilibrium assignment; Graph theory applications in transport network analysis; Urban goods movement; Land use - transport models: historical development, case studies, ISGLUTI Study, recent developments. Laboratory Component: Solving case study problems in travel demand modelling with the help of transportation planning and econometric packages. Developing computer programs for the calibration of travel demand, land-use and land use-transport models.
Learning Outcome	At the end of the course, student would be able to: 1. Ability to access road safety and prepare road safety audit report. 2. Ability to design road geometry.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

References:

1. Hutchinson, B.G., Principles of Urban Transport Systems Planning, McGraw Hill, New York, 1974.
2. Ortuzar, J. and Willumsen, L.G., Modelling Transport, Wiley, Chinchestor, 1994.

3. Oppenheim, N., Urban Travel Demand Modeling: From Individual Choices to General Equilibrium, Wiley, New York, 1995.
4. Thomas, R., Traffic Assignment Techniques, Avebury Technical, Aldershot, 1991.
5. Taniguchi, E., Thompson, R.G., Yamada, T. and Van Duin, R., City Logistics - Network Modelling and Intelligent Transport Systems, Elsevier, Pergamon, Oxford, 2001.
6. Bruton, M.J., Introduction to Transportation Planning,
7. Hutchinson, London, 1985. Dickey, J.W., Metropolitan Transportation Planning, Tata McGraw Hill, New Delhi, 1975.

Course	CE5112
Course Credit	3-0-0-3
Course Title	Pavement Analysis and Design
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 To impart knowledge to students related to analysis and design of flexible and rigid pavements for highways.
Course Description	In this course analysis and design of different type of pavements will be covered. The course will help students understand stresses in pavements. The practices used in road construction industry in design and drawing pavement cross-sections.
Course Outline	Introduction: Components of pavement structure, importance of subgrade soil, properties on pavement performance. Functions of subgrade, subbase, base course and wearing course. Stresses in Flexible Pavements: Stresses in homogeneous masses and layered systems, deflections, shear failures, equivalent wheel and axle loads. Design Elements of Flexible Pavements: Loading characteristics-static, impact and repeated loads, effects of dual wheels and tandem axles, area of contact and tyre pressure, modulus or CBR value of different layers, equivalent single wheel load, equivalent stress and equivalent deflection criterion; equivalent wheel load factors, climatic and environmental factors. Design Methods for Flexible Pavements: California bearing ratio (CBR) method, AASHTO 1993 method, Design of flexible pavements IRC 37. Rigid Pavements: Wheel load stresses, Soil subgrade, Westergaard's analysis, Bradbury's approach, Arlington test, Pickett's corner load theory and influence charts. Temperature Stresses: Westergaard's and Thomlinson's analysis of warping stresses, Combination of stresses due to different causes, Effect of temperature variation on Rigid Pavements. Reinforced Concrete Slabs: Concrete slabs-general details. Design of Tie Bars and Dowel Bars. Design of Rigid pavements using IRC 58-2015 and AASHTO guidelines. Software: IITPave and ABAQUS
Learning Outcome	At the end of the course, student would be able to: 1. Perform flexible and rigid pavement analysis and design for highways.

	2. Understand various factors influencing pavement design.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Khanna, S.K. and Justo, C.E.G., "Highway Engineering", Nem Chand Jain & Bros.
2. Papagianna, A. T. and Masad, E. A. "Pavement Design and Materials." John Wiley & Sons, Inc., 2008.
3. Huang, Y. H. "Pavement analysis and design." Pearson, 2004.

Reference books:

1. Relevant IRC codes.
2. National Cooperative Highway Research Program (NCHRP) Reports.

Course Number	CE5113
Course Credit (L-T-P-C)	3-0-3-4.5
Course Title	Traffic Engineering and Management
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLO number – 1, 2, and 4 1. To understand various traffic flow parameters 2. To understand how to conduct traffic studies 3. To understand how to design signalized intersections Practical: Complies with PLO number 1 and 4. 1. To understand how to collect, analyze and interpret the traffic data
Course Description	To introduce fundamental knowledge of traffic engineering so that students can understand and be able to deal with traffic issues including safety, planning, design, operation and control. Students will learn and be able to use software such as Highway Capacity Software and Synchro in traffic engineering projects.
Course Content	Introductory concepts of traffic engineering, road user and vehicle characteristics, and Road way geometric characteristics. Traffic Studies – speed, delay, volume, parking, Origin-Destination, capacity, accident, etc. Statistical Applications in Traffic Engineering, Capacity and Level of Service, Traffic control devices: Road Signs, Markings and Islands, Traffic characteristics at unsignalized intersections; Design of signalized intersections; capacity, delay and Level of service at signalized intersection; actuated signal control. Practical on: Spot Speed Study; Measurement of Travel Time and Delay for Congested Corridor; Moving Observer Method Study; Turning Movements and Peak Hour Factor; Plate Method of OD Survey; Acceleration Deceleration Characteristics of Vehicles; Intersection Volume Study; Saturation Flow Measurement; Intersection Delay Measurement; Pedestrian Behaviour Study;
Learning Outcome	At the end of the course, the student will be able to gather the information on 1. Use statistical concepts and applications in traffic engineering. 2. Identify traffic stream characteristics. 3. Understand elements of highway safety and approaches to accident Studies. 4. Design a pre-timed signalized intersection, and determine the signal splits

	5. Identify level of services for arterials. 6. Utilize modern software tools (HCS) for network representation and traffic simulation. 7. Utilize modern software tools to estimate traffic measures such as delay and LOS for signalized and unsignalized intersections. 8. Understand, conduct and interpret data for traffic simulation experiments. 9. Understand the contemporary issues related to the use of advanced technology in traffic modeling and control. 10. Design transportation related project in a team of two or three students and submits a final report. 11. Understand Warrants and ability to use them to evaluate intersections.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester Examination

References

1. Roess, R.P., E.S. Prassas, and W.R. McShane. Traffic Engineering, Fifth Edition, Pearson-Prentice Hall.
2. Khanna, S.K., C.E.G. Justo, and A. Veraragavan. (2018). Highway Engineering, Tenth Edition, Nem Chand & Bros.
3. Kadiyali, L. R. (2008). Traffic Engineering and Transportation Planning, Khanna Publishers, India.
4. Garber, N.J., and L.A. Hoel. (2015). Traffic and Highway Engineering, Fifth Edition Cenage Publications.
5. Chakraborty, P., and A. Das. (2019). Principles of Transportation Engineering, Second Edition. PHI Learning Private Limited.
6. Highway Capacity Manual, (2016), TRB, National Research Council, Washington, D. C.
7. Relevant IRC codes.

Department Elective - I (Transportation Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6125	Bituminous materials	3	0	0	3
2.	CE6126	Intelligent Transportation Systems	3	0	0	3
3.	CE6127	Pavement Management Systems	3	0	0	3

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.

Course Number	CE6126
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Intelligent Transportation Systems
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 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
Course Description	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.
Course Content	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
Learning Outcome	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.

Department Elective - II (Transportation Elective/ Department Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engineering	3	0	0	3
2.	CE6106	Soil Dynamics	3	0	0	3
3.	CE6107	Rock Slope Engineering	3	0	0	3
4.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
5.	CE6111	Rock Mechanics	3	0	0	3
6.	CE6113	Pavement Geotechniques	3	0	0	3
7.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
8.	CE6116	Bridge Engineering and Design	3	0	0	3
9.	CE6122	Advanced Concrete Technology	3	0	0	3
10.	CE6128	Highway Geometric Design and Safety	3	0	0	3
11.	CE6129	Airport Engineering	3	0	0	3
12.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3

Course	CE6102
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.
5. Ott, W.R. Environmental Statistics and Data Analysis, Lewis Publishers, New Jersey, 1995.
7. Csuros, M. and Csuros, C., 2016. Environmental sampling and analysis for metals. CRC Press.
8. Popek, E.P., 2017. Sampling and analysis of environmental chemical pollutants: a complete guide. Elsevier.
9. 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.
10. Rong, Y. ed., 2011. Practical environmental statistics and data analysis. ILM publications.

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

Learning Outcome	At the end of the course, student would be able to: 1. Estimate dynamic soil properties using various methods available along with the method suggested in the IS code. 2. Understand the basics of wave propagation. 3. Liquefaction potential assessment using IS code and other methods in practice. 4. Vibration isolation of structures using various active and passive isolation technique.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

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.

Course	CE6107
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:

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

Reference books:

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

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

Textbooks:

1. Wood, David Muir. Soil behaviour and critical state soil mechanics. Cambridge university press, 1990.

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

Reference books:

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

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

Textbooks:

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

References:

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

Course	CE6113
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pavement Geotechnics
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1a and 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.
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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. Nikolaidis, 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.

Course	CE6114
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:

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

Course	CE6116
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Bridge Engineering and Design
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, and 5 1. Equip the students with a strong foundation in civil and environmental engineering for both research and industrial scenarios. 2. Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure. 3. Nurture interdisciplinary education for finding innovative solutions.
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: 1. Explore structural analysis, materials selection, construction techniques, and sustainability considerations in the context of designing safe, efficient, and resilient bridges. 2. Develop the expertise needed 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	CE6122
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Concrete Technology
Learning Mode	Lectures
Learning Objectives	Lecture: Complies with PLO- number 1, 2, 4 and 5 1. Equip the students with a strong foundation in civil and environmental engineering for both research and industrial scenarios. 2. Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure. 3. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice. 4. Nurture interdisciplinary education for finding innovative solutions.
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 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	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
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analytical Methods in Civil Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 Objective for learning this course are: 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-Smirnov test), 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 perform 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. Haldar 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.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CE5212	Highway Materials	3	0	3	4.5
2.	CE5213	Railway Engineering	3	0	0	3
3.	CE5214	Computer Applications in Transportation Engineering	2	1	0	3
4.	CE52XX/ CE62XX	DE-III (Transportation Elective)	3	0	0	3
5.	CE52XX/ CE62XX	DE-IV (Transportation Elective/ Department Elective)	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
TOTAL			20	2	3	23.5

Course	CE5212
Course Credit (L-T-P-C)	3-0-3-4.5
Course Title	Highway Materials
Learning Mode	Lectures and Practical
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 and cement mixes. 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>Soil</u>: Classification of soil, identification and strength tests – Atterberg limits, compaction tests, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), Modulus of subgrade reaction, Resilient Modulus, Permeability, Free Swelling Index (FSI), Deleterious materials, sand equivalent test, Soil stabilization techniques. <u>Aggregates</u>: Origin and classification, physical, mechanical and durability properties, sampling techniques, aggregate texture, polish stone value, alkali-aggregate reactivity. Nonlinearity in fine and coarse grained material. Fillers and its specifications. <u>Binders</u>: <i>Bitumen</i>: Bitumen sources and manufacturing, bitumen constituents and its properties, rheology, bitumen-emulsion, cutback, modified bitumen, separation, long-term and short-term properties. <i>Cement</i>: Manufacturing, composition, type of cement, physical properties of cement: consistence, setting times, soundness and strength. <u>Stabilized materials</u>: Stabilization methods, Subgrade stabilization, Sub-base stabilization, Base stabilisation, Estimation of resilient modulus.

	<u>Recycled Pavement Materials:</u> Crumbed rubber, Construction and Demolition (C&D) waste, Steel Slag, Recycled Asphalt Pavement (RAP). <u>Mix Designs:</u> <i>Design of granular sub-base</i> and their desirable properties; Design of Wet Mix Macadam and its desirable properties. <i>Bituminous Mix Design</i> and its desirable properties using Marshall Method MS-2. Asphalt cold Mix Design as per MS-14, Asphalt Institute and MORTH. <i>Concrete Mix Design</i> – constituents and their requirements, fresh and hardened concrete properties, factors influencing mix design. Dry lean concrete. Paving quality concrete (PQC). <u>Quality Control and Tolerance:</u> Field construction, Quality control plan, Control charts, QA/QC tests. Laboratory tests in this course will include: Aggregate & Soil Tests: Coarse and Fine Aggregate Specific Gravity; California Bearing Ratio. Binder Test: Penetration Test; Softening Point Test; Ductility Test; Viscosity Test. Asphalt Mix Test: Marshall mix design; Quality Control Tests: Binder Extraction Test; In-situ Density Measurement.
Learning Outcome	At the end of the course, student would be able to: 1. Select and design material for road construction. 2. Evaluate pavement material based on its specification requirements. 3. Understand different conventional and recycled materials used in road construction. 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.
3. S. K. Khanna and C. E. G. Justo, Highway Engineering, Nem Chand Bros., 2002.

Reference books:

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

Course	CE5213
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Railway Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- 2 1. Understand factors that control railway alignment. 2. Understand structural and geometric design of tracks. 3. Understand track maintenance operation.
Course Description	This course deals with the basics of ballasted track design. Course aims to teach factors that govern the structural and geometric design of tracks.
Course Outline	History of Indian railways and importance of railways; Factors controlling railway alignment; Components of railway track, functions and requirements; Geometric design of tracks; Analysis and design of track layers: Axle load, train speed considerations; Factors affecting the performance of ballast and subballast; Track drainage; Train resistance and tractive power requirements.
Learning Outcome	At the end of the course, student would be able to: 1. Factors governing railway alignment 2. Design railway tracks 3. Design track maintenance operation.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination

Textbooks/ References:

1. Coenraad Esveld., “Modern Rail Track Design”, MRT productions.
2. BuddhimaIndraratna, Wadud Salim, CholatRujikiatkamjorn, “Advanced Rail Geotechnology - Ballasted Track”, CRC Press, 2011.
3. S.C. and Arora.S.P, “A Text Book of Railway Engineering”, Dhanpat Rail Publications, 2013.
4. J S Mundrey, “Railway Track Engineering”, Mc. Graw Hill Education, 2015.

Course Number	CE5214
Course Credit (L-T-P-C)	2-1-0-3
Course Title	Computer Applications in Transportation Engineering
Learning Mode	Lectures and Tutorials
Learning Objectives	Complies with PLO number – 1, 2, 3 and 4 To gain basic knowledge on traffic and highway engineering related simulation software and how to build COM interfaces for solving practical problems.
Course Description	This course focuses on the fundamentals behind some of the most popular computer software packages used in the transportation planning, design, operations, and management of transportation systems. Topics include signal optimization and evaluation at various levels of spatiotemporal scales, forecasting of traffic flows and passenger volumes for both long-term and short-term planning, simulation of traffic and transit systems, design and evaluation of Intelligent Transportation Systems.
Course Content	Introduction to a <i>programming language</i> MATLAB, R, Python; Introduction to a <i>microscopic traffic simulation software</i> VISSIM; Introduction to Synchro, HCS, and AIMSUN. Introduction to a <i>highway design software</i> MXROADS Introduction to a <i>pavement analysis and design software</i> IITPave, KenPave, AASHTOWare, KGPBACK, Abaqus. Airport Pavement Analysis – BAKFAA, FAARFIELD, etc.
Learning Outcome	At the end of the course, the student will be able to 1. Understand how to use microscopic simulation software VISSIM, AIMSUN, optimization software Synchro and analysis software HCS 2. Learn basics of programming languages such as R, python and MATLAB 3. Understand how to frame COM interfaces with various simulation softwares to solve real-world problems.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination

References:

1. Highway Capacity Manual
2. Indo-Highway Capacity Manual
3. Relevant Software/Programming manuals

Department Elective - III (Transportation Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6227	Traffic Flow Theory	3	0	0	3
2.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3
3.	CE6229	Advanced Flexible Pavement Analysis and Design	3	0	0	3

Course Number	CE6227
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Traffic Flow Theory
Learning Mode	Lectures
Learning Objectives	Complies with PLO number – 1, 2, and 4 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.
Course Content	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.
Learning Outcome	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
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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	Complies with PLO number – 1, 2, and 4 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 smoothening, 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, Back calculation 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.

Department Elective - IV (Transportation Elective/ Department Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5217	Geoinformatics for Engineers	3	0	0	3
2.	CE6206	Geotechnical Earthquake Engineering	3	0	0	3
3.	CE6208	Mine Wastes Generation and Management	3	0	0	3
4.	CE6209	Coupled Process in Fractured Geological Media	3	0	0	3
5.	CE6210	Ground Improvement Techniques	3	0	0	3
6.	CE6211	Utilization of industrial byproducts for geotechnical applications	3	0	0	3
7.	CE6213	Design of Underground Excavations	3	0	0	3
8.	CE6214	Special Topics in Geotechnical Engineering	3	0	0	3
9.	CE6215	Forensic Geotechnical Engineering	3	0	0	3
10.	CE6218	Finite Element Method	3	0	0	3
11.	CE6219	Structural Health Monitoring	3	0	0	3
12.	CE6223	Uncertainty, Risk and Reliability Analyses in Civil Engineering	3	0	0	3
13.	CE6230	Advanced Concrete Pavement Analysis and Design	3	0	0	3
14.	CE6231	Advanced Pavement Material Characterization	3	0	0	3

Course	CE5217
CourseCredit (L-T-P-C)	3-0-0-3
CourseTitle	Geoinformatics for Engineers
LearningMode	Lectures
LearningObjectives	Complies with PLO number – 1, 2, and 4 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.
CourseDescription	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.
CourseOutline	Definition–Basic components of GIS– Map projections and coordinate system –Spatial data structure: raster, vector – Spatial Relationship –Topology– Geodatabase models: hierarchical, network, relational, object-oriented models – Integrated GIS database -common sources of error – Data quality: Macro, Micro and Usage level components - Metadata-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.
LearningOutcome	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%).
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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	CE6206
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geotechnical Earthquake Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of geotechnical earthquake engineering. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure. 4. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to geotechnical engineering. Topics ranging from continental drift, seismic hazard analysis, wave propagation, liquefaction assessment, seismic slope stability and design of retaining structure are covered. The course started with the basic knowledge gained by the attendee during undergraduate level regarding the wave propagation. Therefore, the basics about earthquake engineering will be studied by the students. Introduction to seismic design of retaining structure and slope stability analysis will be also taught in this course.
Course Outline	Introduction, Significant historical earthquakes, Continental drift and plate tectonics, Internal structure of earth, Sources of seismic activity, Size of the earthquake, Strong ground motion and its measurement, Ground motion parameters, Estimation of ground motion parameters, Identification and evaluation of earthquake sources, Seismic hazard analysis, Deterministic seismic hazard analysis, Probabilistic seismic hazard analysis, Wave propagation, Waves in unbounded media, Waves in semi-infinite body, Waves in layered body, Dynamic soil properties and Measurement of dynamic soil properties, Ground response analysis, Local site effects and design of ground motions, Liquefaction, Initiation and effects of liquefaction, Evaluation of liquefaction hazards, Liquefaction susceptibility, Seismic slope stability analysis, and Seismic design of retaining walls.

Learning Outcome	At the end of the course, student would be able to: 1. Design earthquake resistant structure using various methods available along with the method suggested in the IS code. 2. Liquefaction potential assessment using IS code and other methods in practice. 3. Perform seismic hazard analysis for any site. 4. Seismic design of retaining walls considering the dynamic load transferred to the foundation.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

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

Reference books:

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

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

	5. Analyze technical strategies, approaches and solutions to engineer's role and responsibility for mine waste management risk analysis, potential application, safety factors for sustainable development.
Assessment Method	Assignments, Quizzes, Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Singh, T N. Surface Mining, Lovely Prakashan, India, 2020.
2. Karra, Ram Chandar, Gayana, B C, Rao, Shubhananda P Mine Waste Utilization, CRC Press, 2022.
3. Hutchison, Ian P.G. and Ellis, Rechar D., Mine Waste Management, CRC Press, India, 1992.
4. Lottermoser, Bernd G., Mine Wastes Characterization, Treatment and Environmental Impacts, Springer, 3rd edition, 2010.

References:

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

Course	CE6209
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:

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

Course	CE6210
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. Equip the students with strong foundation in civil and environmental engineering for both research and industrial scenarios. 2. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure. 3. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice. 4. Nurture interdisciplinary education for finding innovative solutions.
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 (sand drains and wick drains), Soil stabilisation using additives and deep soil mixing, Grouting, Vibro techniques, Dewatering methods; 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 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: 5. Identify the problematic soil and select a suitable ground improvement technique 6. Design the various ground improvement techniques 7. Understand the construction methodology, equipment and quality control aspects 8. 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.

Reference books:

1. Jie Han, Principles and Practice of Ground Improvement, Wiley Publishers, 2015.
2. B.M. Das, Principle of Geotechnical Engineering, Cengage Learning, eighth Edition, 2013.
3. V. N. S. Murthy, Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering, CRC Press, Taylor & Francis Group, Third Indian Reprint, 2013.

Course	CE6211
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. Equip the students with strong foundation in civil and environmental engineering for both research and industrial scenarios. 2. Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure. 3. Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure. 4. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice. 5. Nurture interdisciplinary education for finding innovative solutions.
Course Description	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:

	9. Describe various sources and characteristics of industrial byproducts and their application as geomaterials. 10. Explain bulk application of industrial by products for soil stabilization and ground improvement with or without admixtures. 11. Understand the behaviour of industrial byproducts subjected to contamination, various remediation and immobilization techniques. 12. 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.

Course	CE6213
Course Credit (L-T-P-C)	3-0-0-3
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:

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

6. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.
7. Hoek, E., & Brown, E. Underground excavations in rock, CRC Press, 1980.

References:

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

Course	CE6214
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 2. To provide the knowledge of the advanced concept of geotechnical engineering. 3. Equip the students with a strong foundation in various topics in offshore geotechnical engineering. 4. 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.

Course	CE6215
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:

1. Rao, V. V. S., and GL Sivakumar Babu, eds. Forensic Geotechnical Engineering. India: Springer India, 2016.
2. Puzrin, Alexander M., Eduardo E. Alonso, and Núria M. Pinyol. Geomechanics of failures. Dordrecht, The Netherlands: Springer, 2010.
3. 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.

Course	CE6218
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Finite Element Method
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 4 and 5 • Equip the students with a strong foundation in civil and environmental engineering for both research and industrial scenarios. • Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure. • Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice. • Nurture interdisciplinary education for finding innovative solutions.
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, axi-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: 1. Understand various numerical methods for analysing engineering problems. 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.

Textbooks/ 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.
8. C.S. Desai and T. Kundu, , Introduction to finite element method, CRC Press, 2001.

Course	CE6219
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Structural Health Monitoring
Learning Mode	Lectures

Learning Objectives	Complies with PLO number – 1, 2, and 4 Lecture: 1. To develop basic understanding on health monitoring of various civil engineering structures. 2. Become proficient in dealing with commonly used approaches/ algorithms through a fundamental understanding of the basics. 3. Familiar with techniques pertaining to health assessment of various structures like building, bridge, heritage structures etc. 4. Become acquainted with some advanced techniques line with the state-of-the-art in SHM domain
Course Description	This course explores structural health monitoring methods and technologies for assessing the condition and performance of various structures. Case studies on civil infrastructures will be examined to illustrate SHM principles in practice. Additionally, the course covers emerging trends including advancements in sensor technology and data analytics for predictive maintenance.
Course Outline	Introduction to Structural Health Monitoring (SHM): Definition & requirement for SHM, SHM of a bridge, monitoring historical buildings; Non-Destructive Testing (NDT): Classification of NDT procedures, visual inspection, half-cell electrical potential methods, Schmidt Rebound Hammer Test, resistivity measurement, electro-magnetic methods, radiographic Testing, ultrasonic testing, Infra-Red thermography, ground penetrating radar, radio isotope gauges etc., case studies of a few NDT procedures on bridges; Condition Survey & NDE of Concrete Structures: Definition and objective of Condition survey, stages of condition survey (Preliminary, Planning, Inspection and Testing stages), possible defects in concrete structures, quality control of concrete structures; Vibration-based monitoring: Frequency-domain and time-domain analysis, Experimental modal analysis, application of damage detection methods on civil infrastructures.
Learning Outcome	At the end of the course, student would be able to: 1. Perform sensor deployment, data acquisition, and analysis techniques used to detect and quantify structural damage. 2. Develop proficiency in deploying sensor technologies and data acquisition systems to monitor the health of various structures. 3. To analyse collected data, detect structural damage, and make informed decisions regarding maintenance and safety measures. 4. Use the methods in real-life applications.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Daniel J. Inman, Charles R. Farrar, Vicente Lopes Junior, Valder Steffen Junior, Damage Prognosis: For Aerospace, Civil and Mechanical Systems, John Wiley & Sons, 2005.
2. Chee-Kiong Soh, Yaowen Yang, Suresh Bhalla (Eds.), Smart Materials in Structural Health Monitoring, Control and Biomechanics, Springer, 2012.

Course	CE6223
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Uncertainty, Risk and Reliability Analyses in Civil Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 4 and 5 1. Equip the students with a strong foundation in civil and environmental engineering for both research and industrial scenarios. 2. Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure. 3. Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice. 4. Nurture interdisciplinary education for finding innovative solutions.
Course Description	The course deals with the risk and reliability analysis and design of different civil engineering infrastructural system. Also, this course discusses about the basic probability theory and random field generation.
Course Outline	Introduction and overview: Review of basic probability, Functions of random variables. Joint probability distribution, conditional distributions, Joint Normal distribution, Random number generation – Monte Carlo simulations, Formulation of structural reliability problems: limit states, First order reliability methods, importance sampling and other variance reduction techniques, Reliability – historical development, applications, different measures of reliability; Component reliability - time to failure, Reliability-based maintenance, System reliability - representation of failure, series and parallel systems, redundancy, fault trees, Probability-based acceptance criteria: consequence of failure, concepts of risk, utility, Probability-based design. Calibration of target reliability: reliability-based design codes.
Learning Outcome	At the end of the course, student would be able to: 1. Understanding basic concept of probability theory and its application. 2. Risk and reliability analysis of civil engineering infrastructure. 3. Design of civil infrastructure based on risk and reliability.

Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.
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Textbooks/ Reference books:

1. A. Haldar and S. Mahadevan, Probability, Reliability, and Statistical Methods in Engineering Design, Wiley, 2000.
2. H. S. Ang and W. H. Tang, Probability Concepts in Engineering Planning and Design, John Wiley, 1975.
3. R. Ranganathan, Reliability Analysis and Design of Structures, Tata McGraw Hill, New Delhi, 1990.

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 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%).

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Department of Civil and Environmental Engineering

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.