

M. Tech. in Structural Engineering

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

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	CE5108	Advanced Structural Analysis	3	0	2	4
3.	CE5109	Structural Dynamics	3	0	2	4
4.	CE5110	Theory of Plates and Shells	3	0	0	3
5.	CE51XX/ CE61XX	DE- I: Structure Elective	3	0	0	3
6.	CE51XX/ CE61XX	DE- II: Structure / Department Elective	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
TOTAL						24

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

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CE5209	Advanced Concrete Design	3	0	2	4
2.	CE5210	Earthquake Resistant Design of Structures	3	0	2	4
3.	CE5211	Stability of Structures	3	0	0	3
4.	CE52XX/ CE62XX	DE-3: Structure Elective	3	0	0	3
5.	CE52XX/ CE62XX	DE-4: Structure / Department Elective	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
TOTAL						24

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						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

**** 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:

(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.

(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						21

Total Credits: 87

ELECTIVE GROUPS

Department Elective - I (Structure Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6115	Advanced Structural Mechanics	3	0	0	3
2.	CE6116	Bridge Engineering and Design	3	0	0	3
3.	CE6117	Masonry Structures	3	0	0	3
4.	CE6118	Wind Analysis and Design of Structures	3	0	0	3
5.	CE6119	Special Topics in Structural Analysis	3	0	0	3
6.	CE6120	Analysis Plates and Shells Structure	3	0	0	3
Department Elective-II (Structure / Department Elective)						

Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6106	Soil Dynamics	3	0	0	3
2.	CE6107	Rock Slope Engineering	3	0	0	3
3.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
4.	CE6111	Rock Mechanics	3	0	0	3
5.	CE6113	Pavement Geotechnics	3	0	0	3
6.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
7.	CE6121	Prestressed Concrete Structure: Theory & Design	3	0	0	3
8.	CE6122	Advanced Concrete Technology	3	0	0	3
9.	CE6123	Structural Fire Engineering	3	0	0	3
10.	CE6124	Advanced Structural Dynamics	3	0	0	3
11.	CE6128	Highway Geometric Design and Safety	3	0	0	3
12.	CE6129	Airport Engineering	3	0	0	3
13.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3

Department Elective - III (Structure Elective)

Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6217	Advanced Steel Design	3	0	0	3
2.	CE6218	Finite Element Method	3	0	0	3
3.	CE6219	Structural Health Monitoring	3	0	0	3
4.	CE6220	Condition Assessment and Retrofitting of Structures	3	0	0	3
5.	CE6221	Advanced Topics in Reinforced Concrete Design	3	0	0	3
6.	CE6222	Seismic Analysis and Design of Structures	3	0	0	3

Department Elective-IV (Structure / 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.	CE6207	Soil-Structure Interaction Analysis	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.	CE6213	Design of Underground Excavations	3	0	0	3
7.	CE6215	Forensic Geotechnical Engineering	3	0	0	3
8.	CE6223	Uncertainty, Risk and Reliability Analyses in Civil Engineering	3	0	0	3
9.	CE6224	Nonlinear Structural Mechanics	3	0	0	3
10.	CE6225	Theory of Random Vibration	3	0	0	3
11.	CE6226	Analysis of Structural Stability	3	0	0	3
12.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3
13.	CE6230	Advanced Concrete Pavement Analysis and Design	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.	CE5108	Advanced Structural Analysis	3	0	2	4
3.	CE5109	Structural Dynamics	3	0	2	4
4.	CE5110	Theory of Plates and Shells	3	0	0	3
5.	CE51PQ/ CE61PQ	DE- I: Structure Elective	3	0	0	3
6.	CE51PQ/ CE61PQ	DE- II: Structure / Department Elective	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
TOTAL						24

Course	CE5108 Advanced Structural Analysis
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Advanced Structural Analysis
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLOs 1, 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the analysis and design different type of structural elements under static loading. 2. Predict nonlinear behaviour of different structures and structural components under static loading. Practical: 1. Predict the response beam and column structural elements under static load and correlate with theoretical results. 2. Determine behaviour of different structures such as truss, frame, bridge under static and moving loads. 3. Learn the use structural analysis software for analysis and design.
Course Description	The course deals with analysis of structures using matrix methods. This course provides the students an exposure for linear and non-linear analysis of structures. Practical of the course will focuses on the understanding of behaviour and response of different civil engineering structures (beam, column, truss, frame, bridge) under static and moving loads.
Course Outline	Lecture: Basics of structural analysis: static & dynamic loading, linear & nonlinear structural behaviour, geometric & material nonlinearity, hysteretic behaviour; Classical linear analysis of frames and trusses: displacement method, slope deflection equations & matrix displacement method, effect of foundation settlement and temperature; Geometric nonlinear analysis of frames and trusses: displacement method, nonlinear slope-deflection equations & nonlinear behaviour, linearized iterative matrix displacement method, geometric stiffness matrix, tangent stiffness matrix, P- Δ effect, buckling of frames, tension structures; Material nonlinear analysis of frames: basics of plasticity, distributed plasticity & lumped plasticity, incremental nonlinear analysis. Practical: Bending moments and deflection analysis of determinate and indeterminate beams, Deflection analysis of determinate and indeterminate beams, Unsymmetrical bending and shear centre, Analysis of pin jointed frameworks, Bending moments in a portal frame, Column buckling, Flexural test on steel beam, Analysis of 2-D and 3-D truss, Analysis on suspension cable bridge, Influence line diagram of bridge under moving loads, Introduction of structural analysis software SAP2000.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Analyse structures for designing them. 2. Should be able to understand various types of elements used for structural analysis. 3. Perform nonlinear analysis of structures.

	Practical: 1. Understand behaviour of different structural components such as beam and column under static load. 2. Estimate response of different civil engineering structures such as truss, frame, bridge under static loads. 3. Determination of influence line diagram for bridge structure. 4. Use of structural analysis software.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. W. McGuire, R. H. Gallagher and R. D. Ziemian, Matrix Structural Analysis, Wiley, 2000.
2. D. Menon, Advanced Structural Analysis. Alpha Science Intl Ltd, 2009.
3. S. Muthukrishnan, Nonlinear Analysis of Structures, CRC Press, 1st Edition, 2017.
4. W. Lacarbonara, Nonlinear Structural Mechanics: Theory, Dynamical Phenomena and Modeling, Springer-Verlag New York Inc., 1st Edition, 2016.
5. A. H. Nayfeh and P. F. Pai, Linear and Nonlinear Structural Mechanics, Wiley-VCH, 1st Edition, 2004.

Course	CE5109 Structural Dynamics
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Structural Dynamics
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLOs 1, 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the analysis and design different type of SDOF and MDOF structures under dynamic loading. 2. Effect of different system properties on the dynamic response of SDOF and MDOF structures.

	3. Predict the behaviour of different type of SDOF and MDOF structures and structural components under random excitation such as wind, earthquake, blast, and sea wave loading. Practical: 1. Predict responses and estimate properties of SDOF and MDOF structures under dynamic loading and correlate with theory. 2. Determine the behaviour of different type structures such as shear building, frame structure, bridge under dynamic loads. 3. Learn the use structural analysis software for dynamic analysis of structure and structural components.
Course Description	The course deals with analysis of single and multiple degrees of freedom structures for dynamic loading. This course provides the students an exposure for different dynamic loading such as wind, earthquake, blast, sea wave etc, and analysis of structures under such loading. Practical part of the course will provide in-depth understanding of dynamics of SDOF and MDOF, seismic response of building structures, and use of different type of sensor and equipment for dynamic response measurements, data processing and analysis.
Course Outline	Lecture: Single Degree of Freedom System (SDOF): equation of motion, free undamped and damped response, undamped and damped response to harmonic loading, vibration isolation, evaluation of damping parameter, response to arbitrary periodic, step, pulse excitations and ground motion, numerical evaluation of dynamic response. Multi Degree of Freedom System (MDOF): equations of motion; stiffness matrix; mass matrix; proportional and rayleigh damping matrix; undamped free and forced response using modal superposition. Continuous System: equation of motion; undamped free and forced response concepts of response spectrum, computational and numerical methods. Practical: Free and force vibration of the SDOF system, estimation of natural frequency and damping ratio of SDOF system, Free and force vibration of MDOF system, Modal frequency and mode shape estimation of MDOF shear building, Vibration study of bridge, Shake table testing, Use of advance software for dynamic response analysis of structure.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Analyse and design structures under dynamic loading. 2. Influence of different dynamic properties of system on responses. 3. Understand basic of structural response under random excitation such as wind, earthquake, blast and sea wave. Practical: 1. Understand dynamic properties of SDOF and MDOF system and estimation of dynamic response of SDOF and MDOF structures. 2. Understand principal and use of different sensors. 3. Data analysis and processing for dynamic system.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. A.K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, Prentice Hall, 4th Edition, 2015.
2. R.W. Clough and J. Penzien, Dynamics of Structures, McGraw-Hill, 1975, 2nd edition, 1992.
3. S.S. Rao, Mechanical Vibrations, Prentice Hall, 6th Edition, 2021.
4. J. L. Humar, Dynamics of Structures, Balkema, 2002.
5. S.G. Kelly, Mechanical Vibrations: Theory and Applications, Cognella, Inc., 2nd Edition, 2022.
6. L. Meirovitch, Elements of Vibration Analysis, McGraw-Hill, 1986
7. W.T. Thomson and M.D. Dahleh, Theory of Vibration and Applications, Pearson Education; 5th edition, 2008.
8. S. Timoshenko, Vibration Problems in Engineering, Benediction Classics, 2011.

Course	CE5110 Theory of Plates and Shells
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Theory of Plates and Shells
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Formulate and solve complex problems related to the behaviour of plates and shells using advanced mathematical and computational methods. 2. Perform advanced analysis of structural performance comprising of various plate and shell elements. 3. Use advanced mathematical as well as computational tool for modelling, simulation, and analysis.
Course Description	The course deals with the studying force deformation behaviour of plates and shells members under different loading scenario and boundary condition.
Course Outline	Simple bending of Plates-Assumptions in thin plate theory-Different relationships- Different Boundary Conditions for plates- Plates subjected to lateral loads – Navier’s method for simply supported plates – Levy’s method for general plates – Example problems with different

	types of loading. Circular plates subjected to Axi-symmetrical loads—concentrated load, uniformly distributed load and varying load – Annular circular plate with end moments. Rayleigh-Ritz method – Application to different problems – Finite difference method – Finite element methodology for plates-Orthotropic Plates - Bending of anisotropic plates with emphasis on orthotropic plates – Material Orthotropy– Structural Orthotropy - Plates on elastic foundation. Shells- Classification of shells - Membrane and bending theory for singly curved and doubly curved shells - Various approximations - Analysis of folded plates.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understanding deformation and stress behaviour of plate and shell members under out of plane loading. 2. Perform analytical and numerical solution of plate and shell under different loading and boundary condition.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

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

Department Elective - I (DE-I: Structure Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6115	Advanced Structural Mechanics	3	0	0	3
2.	CE6116	Bridge Engineering and Design	3	0	0	3
3.	CE6117	Masonry Structures	3	0	0	3
4.	CE6118	Wind Analysis and Design of Structures	3	0	0	3
5.	CE6119	Special Topics in Structural Analysis	3	0	0	3
6.	CE6120	Analysis Plates and Shells Structure	3	0	0	3

Course	CE6115 Advanced Structural Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Structural Mechanics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the concept of deformation, linear and nonlinear measures of strain and stress. 2. Introduce failure theory of different materials. 3. Predict the behaviour elastic solids under different loading.
Course Description	The course deals with analysis of deformable bodies. This course provides the students an exposure for linear and non-linear analysis of solids, analysis of stress and strain, fundamental physical principles, constitutive relation of materials, and two-dimensional electrostatics problems.
Course Outline	Introduction: Suffix notation system, tensor algebra; Strain analysis: deformation and velocity gradients, Lagrangian and Eulerian description of strain (Green-Lagrange, Euler-Almansi, Engineering and Logarithmic strain measure), large strain and rotation, finite strain and small deformation theory, principal strains and strain invariants, compatibility conditions; Stress analysis: forces and moments, theory of stress (Cauchy, Kirchhoff, Piola-Kirchhoff I and II, Biot stress measures), energetically conjugate stress and strain measures, plane stress and plane strain, principal stresses and stress invariants, compatibility equations, equilibrium equations; Fundamental physical principles: conservation of mass, linear momentum, angular momentum, and energy, second law of thermodynamics; Constitutive theory: St. Venant's principal, linear elasticity and generalized Hook's law; Stokesian and Newtonian fluids, Navier-Stokes equations, Bernoulli equation, viscoelasticity, stress, strain and energy based failure theory, yield criteria (Mohr-Coulomb, Hoek-Brown, Tresca, Von Mises, and Drucker-Prager); Elasticity: Airy stress function, two-dimensional electrostatics problems, torsion, buckling.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand the concept of deformation mechanisms in solid and different measures of strain and stress. 2. Gain knowledge on material model of liner elastic solid body. 3. Analysis of problem in elastic deformable body.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbook/ Reference book:

1. S. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw Hill Book Company, International Ed, 1970.
2. L. S. Srinath. Advanced Mechanics of Solids, McGraw Hill Education, 2010.
3. Allan F. Bower. Applied Mechanics of Soilds, CRC Press, 2010.

4. Irving H. Shames and Francis A. Cozzarelli. Elastic and Inelastic Stress Analysis, Taylor & Francis Group; Revised edition, 1997.
5. Romesh C. Batra. Element of Continuum Mechanics, AIAA, 2012.

Course	CE6116 Bridge Engineering and Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Bridge Engineering and Design
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Apply the fundamental principles of bridge engineering, including load distribution, dead and live load analyses etc. to evaluate the performance of different types of bridges. 2. Design of various bridge components following various Indian as well as international standards and safety regulations. 3. To become proficient in using advanced computational tools and software for the modelling, simulation considering dynamic loading like wind and earthquake.
Course Description	This course offers a comprehensive exploration of bridge engineering and design, covering fundamental principles, methodologies, and practical applications. This course covers key aspects including structural analysis, material selection, construction techniques, and environmental considerations.
Course Outline	Introduction: Classification of Bridges, General Features of Design, IRC Loading (viz. 70R, Class AA tracked and wheeled vehicle), Design Codes, Working Stress Method, Limit State Method of Design as per IS456:2000 and IRC 112:2020; Analysis & Design: Consideration of various loading (dead load, vehicular load etc.), Slab bridge, Box Culvert, T-beam bridge, Box Girder bridge and Prestressed concrete bridge. Subsoil properties, their uses for substructure design.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Explore structural analysis, materials selection, construction techniques, and sustainability considerations in the context of designing safe, efficient, and resilient bridges. 2. Develop expertise to conceptualize, plan, and execute bridge projects that meet technical standards and address societal needs. 3. Gain knowledge and skills necessary to tackle real-world challenges in bridge engineering, contributing to the development of critical infrastructure systems.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Swami Saran, Analysis and Design of Substructures: Limit State Design, 28 February 2018.
2. K. K. Rakshit, Design and Construction and Highway Bridges.
3. Raju N. K, Design of Bridges, 5Ed (Pb 2019) – 1 January 2019.

4. Daniel J. Inman, Charles R. Farrar, Vicente Lopes Junior, Valder Steffen Junior, Damage Prognosis: For Aerospace, Civil and Mechanical Systems, John Wiley & Sons, 2005.

Course	CE6117 Masonry Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Masonry Structures
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture:

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

Textbooks/ Reference books:

1. Dayaratnam, P. (1987). Brick and Reinforced Brick Structures, Oxford & IBH Publishing Co. Pvt. Ltd.
2. Drysdale, R. G. Hamid, A. H. and Baker, L. R. (1994). Masonry Structures: Behaviour& Design, Prentice Hall
3. Hendry, A. W. (1998), Structural Masonry, Mc Millan, UK, 2nd edn.
4. Hendry, A. W., Sinha, B. P. and Davies, S. R. (1997). Design of Masonry Structures, E&FN Spon, UK.
5. Sahlin, S. (1971). Structural Masonry, Prentice Hall, Englewood Cliffs, NJ.
6. Schneider, R. S. and Dickey, W. L. (1994). Reinforced Masonry Design, Prentice Hall, 3rd edn.
7. Paulay, T. and Priestley, M. J. N. (1992). Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley.

Course	CE6118 Wind Analysis and Design of Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Wind Analysis and Design of Structures
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. To impart knowledge about the basic principles of the wind engineering pertinent to the structural design. 2. Introduce different approaches available to analyze the effect of wind loading on various wind sensitive structures. 3. Use of codes and analytical methods for wind resistance design of structures. 4. Introduction of wind tunnel testing of structures.
Course Description	This course provides a detailed understanding of wind engineering in terms of atmospheric boundary layer, aerodynamics of bluff bodies as applied to design of structures. Methods of computation of design wind speed, wind pressure and loads as per the code will be explained here. Basic concepts of wind tunnel testing will be covered to emphasize the

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

Textbooks/ Reference books:

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

Course	CE6119 Special Topics in Structural Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Special Topics in Structural Analysis
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the analysis and design different type of structural elements under static loading. 2. Predict nonlinear behaviour of different structures and structural components under static loading.
Course Description	The course deals with advanced analysis methods of structures. This course provides the students an exposure for linear and non-linear analysis of structures.
Course Outline	Introduction to advanced structural analysis: static & dynamic loading, linear & nonlinear structural behaviour, geometric & material nonlinearity, hysteretic behaviour; Classical linear analysis of frames and trusses: displacement method, slope deflection equations & matrix displacement method, effect of foundation settlement and temperature; Geometric nonlinear analysis of frames and trusses: displacement method, nonlinear slope-deflection equations & nonlinear behaviour, linearized iterative matrix displacement method, geometric stiffness matrix, tangent stiffness matrix, P- Δ effect, buckling of frames, tension structures; Material nonlinear analysis of frames: basics of plasticity, distributed plasticity & lumped plasticity, incremental nonlinear analysis. Introduction to nonlinear static analysis of structures with geometric nonlinear and elasto-plastic behaviour as well as analysis based on simplified plastic methods; Nonlinear structural analysis: mathematical preliminaries for 1st and 2nd order elastic and inelastic structural analysis, incremental methods, unbalanced forces calculation and iterative methods, material and geometric nonlinear beam-column element, force and displacement control beam-column element, advanced structural analysis using software.
Learning Outcome	At the end of the course, student would be able to

	Lecture: 1. Analyse structures for designing them. 2. Should be able to understand various types of elements used for structural analysis. 3. Perform nonlinear analysis of structures.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

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

Course	CE6120 Analysis Plates and Shells Structure
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analysis Plates and Shells Structure
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Formulate and solve complex problems related to the behaviour of plates and shells using advanced mathematical and computational methods. 2. Perform advanced analysis of structural performance comprising of various plate and shell elements. 3. Use advanced mathematical as well as computational tool for modelling, simulation, and analysis.
Course Description	The course deals with the studying force deformation behaviour of plates and shells members under different loading scenario and boundary condition.
Course Outline	Simple bending of Plates-Assumptions in thin plate theory-Different relationships- Different Boundary Conditions for plates- Plates subjected to lateral loads – Navier’s method for simply supported plates – Levy’s method for general plates – Example problems with different types of loading. Circular plates subjected to Axi-symmetrical loads– concentrated load, uniformly distributed load and varying load – Annular circular plate with end moments. Rayleigh-Ritz method – Application to different problems – Finite difference method – Finite element methodology for plates-Orthotropic Plates - Bending of anisotropic plates with emphasis on orthotropic plates – Material Orthotropy – Structural Orthotropy - Plates on elastic foundation. Shells-Classification of shells - Membrane and bending theory for singly curved and doubly curved shells - Various approximations - Analysis of folded plates; Advanced topics in plate and shells: nonlinear behaviour of plate and shells, elastic and inelastic stability analysis of plates and shells, application of FEM software in analysis of plates and shells, case studies from real-world infrastructures comprising of plate and shell elements, some cutting cutting-edge research innovations in line with global knowledge standard on plates and shells.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understanding deformation and stress behaviour of plate and shell members under out of plane loading. 2. Perform analytical and numerical solution of plate and shell under different loading and boundary condition.

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

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

Department Elective-II (DE-II: Structure / Department Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6106	Soil Dynamics	3	0	0	3

2.	CE6107	Rock Slope Engineering	3	0	0	3
3.	CE6108	Constitutive Modelling in Geotechnics	3	0	0	3
4.	CE6111	Rock Mechanics	3	0	0	3
5.	CE6113	Pavement Geotechnics	3	0	0	3
6.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
7.	CE6121	Prestressed Concrete Structure: Theory & Design	3	0	0	3
8.	CE6122	Advanced Concrete Technology	3	0	0	3
9.	CE6123	Structural Fire Engineering	3	0	0	3
10.	CE6124	Advanced Structural Dynamics	3	0	0	3
11.	CE6128	Highway Geometric Design and Safety	3	0	0	3
12.	CE6129	Airport Engineering	3	0	0	3
13.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3

Course	CE6106 Soil Dynamics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Soil Dynamics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

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

Course	CE6107 Rock Slope Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Rock Slope Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are Lecture: 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 Lecture:

	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/ Reference books:

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

Course	CE6108 Constitutive Modelling in Geotechnics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Constitutive Modelling in Geotechnics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

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

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

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

Course	CE6113 Pavement Geotechnics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pavement Geotechnics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1a and 3a and the objective for learning this course are Lecture:

	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 Outline	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	At the end of the course, student would be able to Lecture: 1. 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.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

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

Course	CE6114 Probabilistic Methods in Geotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Probabilistic Methods in Geotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are Lecture: 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 Lecture: 1. Analyzed structure using various probabilistic methods available along with the method suggested in the Euro code. 2. Perform reliability analysis for various geotechnical problems. 3. Assess composite risk using various techniques to estimate failure of geotechnical structures.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Ang, A. H-S., and Tang, W. H., Probability Concepts in Engineering, Vol. 1, John Wiley and Sons, 2006.
2. Scheaffer, R. L., Mulekar, M. S. and McClave, J. T., Probability and statistics for Engineers, 5th Edition, Brooks / Cole, Cengage Learning, 2011.
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	CE6121 Pre-Stressed Concrete Structure: Theory & Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pre-Stressed Concrete Structure: Theory & Design
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Familiarize with the concept of pre-stressed concrete and design of pre-stressed concrete structures. 2. Analyse prestressed concrete structural members and estimate the losses of prestress.
Course Description	The course deals with the design of pre-stressed concrete structures for various types of loading and will provides an understanding of behaviour of pre-stressed concrete members under various action of forces.
Course Outline	Analysis and design of beams - Rectangular, Flanged and I section, for Limit State of flexure, ultimate flexural strength, recommendations of I.S. codes. Analysis and design of end blocks in post tensional members -primary and secondary distribution zones, Bursting and spalling tensions. Shear strength of prestressed concrete beams - mode of failure in beams, recommendations of I.S. code, ultimate shear strength of concrete, Design of shear reinforcement, Bond in prestressed concrete. Analysis and design of continuous (up to two spans) and fixed beams. Elastic analysis, secondary moments, concordant cable, linear transformations. Analysis and design of prestressed concrete structures such as concrete pipes and Sleepers. Analysis and design of portal frames, single storey and limited to two bays (fixed and hinged). Design of pre-stressed concrete bridges (simply supported) for I.R.C. loadings or equivalent uniformly distributed loads.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Become familiar with basic of pre-stressed concrete structure. 2. Understand the behaviour of pre-stressed concrete structural members structures under flexure, shear, axial forces, combined flexure and axial forces, and in-plane shear forces. 3. Learn the methods of pre-stressed concrete construction and detailing practices.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. IS 1343: Code of Practice for Prestressed Concrete by Bureau of Indian Standards.
2. Guyon Y.: Prestressed Concrete, Vol. I & II, John Wiley and Sons, New York.
3. Krishna Raju, N.: Prestressed Concrete, Tata McGraw Hill Publications Company, New Delhi.
4. Lin T. Y.: Prestressed Concrete, Tata McGraw Hill, New Delhi. • Dayaratnam P., Prestressed Concrete Structures.

Course	CE6122 Advanced Concrete Technology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Concrete Technology
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture:

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

Textbooks/ Reference books:

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

Course	CE6123 Structural Fire Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Structural Fire Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Introduce various codes and concept related to fire engineering. 2. Introduce basic concept of structural mechanics.

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

Textbooks/ Reference books:

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

Course	CE6124 Advanced Structural Dynamics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Structural Dynamics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the analysis and design different type of SDOF and MDOF structures under dynamic loading. 2. Effect of different system properties on the dynamic response of SDOF and MDOF structures. 3. Predict the behaviour of different type of SDOF and MDOF structures and structural components under random excitation such as wind, earthquake, blast, and sea wave loading.
Course Description	The course deals with analysis of single and multiple degrees of freedom structures for dynamic loading. This course provides the students an exposure for different dynamic loading such as wind, earthquake, blast, sea wave etc, and analysis of structures under such loading. Practical part of the course will provide in-depth understanding of dynamics of SDOF and MDOF, seismic response of

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

Textbooks/ Reference books:

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

Course	CE6128 Highway Geometric Design and Safety
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Highway Geometric Design and Safety
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, and 4 and the objective for learning this course are Lecture: 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 Lecture: 1. Ability to access road safety. 2. 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	CE6129 Airport Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Airport Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, and 4 and the objective for learning this course are Lecture: 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 Outline	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 Lecture: 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/ Reference books:

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.
6. Federal Aviation Administration Specifications.
7. International Civil Aviation Organisation Specifications.

Course	CE6130 Analytical Methods in Civil Engineering
Course Credit	3-0-0-3

(L-T-P-C)	
Course Title	Analytical Methods in Civil Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. To brush up the undergraduate level understanding in light with some advanced approaches. 2. To develop p proficiency in numerical techniques and algorithms pertaining to various civil engineering problems. 3. To form a stepping stone towards advance understanding of risk and reliability analyses.
Course Description	First part of this course deals with the numerical method for non-linear equation solution, numerical integration, solution of liner system of equations, curve fittings, solution of differential equations. Second part of the course basic concept of probability theory and statistics, estimation of distribution property, stochastic data generation, risk and reliability methods for civil engineering.
Course Outline	<i>Module – I: Linear Algebra and Differential Equation</i> Linear algebra: Rank of a matrix, solutions of linear systems, linear independence and linear transformations, eigenvalues, eigenvectors, matrices similarity, basis of eigenvectors, diagonalization; Differential equations: homogeneous linear equations of second order, second order homogeneous equations with constant coefficients, case of complex roots, complex exponential function, non-homogeneous equations, solution by undetermined coefficients and variation of parameters. <i>Module – II: Numerical Methods</i> Introduction to Numerical Methods: Objectives of numerical methods, Sources of error in numerical solutions: truncation error, round off error, order of accuracy - Taylor series expansion; Roots of equations: Graphical method, Bisection method, Simple fixed-point iteration, Newton-Raphson method, Secant method, Modified secant method; Direct Solution of Linear systems: Naive Gauss elimination, LU decomposition, Gauss-Seidel, Gauss-Jordon, Jacobi iteration, Cholesky decomposition; Curve fitting: linear regression, polynomial regression, interpolation, spline fitting; Numerical Calculus: trapezoidal and Simpson's rule for integration; Solving differential equation: Euler's method, Runge-Kutta method, boundary value and eigenvalue problem and their application, solving partial differential equation. <i>Module – III: Probability and Statistics</i> Introduction: concept of risk, uncertainty in engineering analysis and design, fundamental of probability models; Analytical models of random phenomena: Bayesian analysis, analysis of variance (ANOVA), tests of hypothesis, confidence interval, properties of good estimates, interval estimation, maximum likelihood estimates, Sample size determination, central limit theorem, expected value, and return period; Miscellaneous Topics: Fitting theoretical and tests of goodness-of-fit (chi-square test, Kolmogorov-Smirnovtest), identification of outliers, regression with discrete dependent variables; Application of Monte Carlo simulation (MCS): determination of function of random variables using MCS methods, application of MCS in various problems.
Learning Outcome	At the end of the course, student would be able to

	Lecture: 1. Understand the different numerical methods for solving non-linear equations and numerical integration method. 2. Should be able to solve differential equations numerically. 3. Understand basic concept probability theory and statistics. 4. Should be able to fit statistical distribution and parameter estimation. 5. Should be able to perform MC simulation and 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.	CE5209	Advanced Concrete Design	3	0	2	4
2.	CE5210	Earthquake Resistant Design of Structures	3	0	2	4
3.	CE5211	Stability of Structures	3	0	0	3
4.	CE52XX/ CE62XX	DE-3: Structure Elective	3	0	0	3
5.	CE52XX/ CE62XX	DE-4: Structure / Department Elective	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
TOTAL						24

Course	CE5209 Advanced Concrete Design
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Advanced Concrete Design
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLOs 1, 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understanding of selected advanced topics in the field of reinforced concrete design. 2. Understand the fundamental principles of reinforced concrete design. 3. Identify disturbed-regions (D-regions) where application of the strut-and-tie method is appropriate. Practical: 1. Methods of testing of materials used in the concrete structures. 2. Understand the instrumentation and use of various sensors and devices to measure physical response. 3. Experiments and hands-on to appreciate the concepts of structural design.

Course Description	The course deals with the design of various structures for various types of loading. This course provides the students an exposure for advanced topics on designing of RC structures which are not covered in undergraduate design courses. Practical of the course will cover destructive and non-destructive testing of RC structural elements and mix-design of concrete.
Course Outline	Lecture: Yield line theory for slabs: Basic principles, methods of yield line analysis. Deep beams: analysis and design as per Indian Standard and strut and tie method. Columns: derivation of axial compression and bending interaction curves, design of slender columns, design for biaxial bending. Analysis and design for torsion: behaviour of reinforced concrete members subjected to torsion, Design methods of torsion, difference between equilibrium and compatibility torsion, concept of equivalent shear and bending; design examples, design for combined loading (Torsion + Bending + Shear). Moment redistribution in continuous beams; bond and development length, curtailment of reinforcing steel. Design philosophies and procedures for liquid retaining structures. Design of RC shear walls. Practical: Non-destructive test (UPV & rebound hammer); semi-destructive (core cutting), Mix design; Testing of reinforcement bar (mild & HYSD) in tension; Testing of RC beams and column under different loading conditions.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand various types of loading on structures. 2. Analysis of structures for various types of loading. 3. Design of concrete structures for various types of loading. 4. Ability to design complex structural system. Practical: 1. Be familiar with the materials used for building structures. 2. Learn different testing methods of materials used in the concrete structures. 3. Understand the working principle of various sensors and devices to measure physical response of structures. 4. Develop the various concepts of structural design through experiments and hands-on.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. S.U. Pillai and D. Menon, Reinforced Concrete Design, Tata McGraw Hill, 4th Edition, 2021.
2. P. C. Varghese, Advanced Reinforced Concrete Design, PHI, 2009.
3. N. Krishnaraju, Advanced Reinforced Concrete Design, CBS Publisher, 2013.
4. M.L. Gambhir, "Fundamentals of Reinforced Concrete Design", Prentice Hall of India Private Limited, 2006.
5. J. G. MacGregor and J. K. Wight, Reinforced Concrete: Mechanics and Design, Prentice Education India, 6th edition, 2016.
6. T. Paulay and M.J.N. Priestley, Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley and Sons Inc., 1992.

Course	CE5210 Earthquake Resistant Design of Structures
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Earthquake Resistant Design of Structures
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLOs 1, 2, 4, and 5 and the objective for learning this course are Lecture: 1. Develop a comprehensive technical understanding of the phenomena called earthquake in general. 2. Learn to perform seismic analysis and design of structures using latest IS codes in light with recent developments in the field of earthquake engineering. 3. Make familiar with structural dynamics, response spectrum analysis, time-history analysis, and nonlinear dynamic analysis for earthquake-resistant design. Practical: 1. Predict responses and estimate properties of building frame structure under earthquake loading and correlate with theory. 2. Determine the behaviour of different retrofitting systems such as isolator, damper and bracing for seismic vibration control building frame structure. 3. Learn the use of structural analysis and FEM software for linear and non-linear dynamic analysis of structure and structural components under seismic excitation.
Course Description	The course aims at developing detailed understanding with the design of various structures against seismic loading. This course provides the students an exposure for earthquake resistant designing of structures which are not usually covered in undergraduate design courses. Structural Dynamics or any equivalent course is the prerequisite for this course. Practical part of the course will provide in-depth understanding of dynamics of SDOF and MDOF, seismic response of building structures, and use of different type of sensor and equipment for dynamic response measurements, data processing and analysis.
Course Outline	Lecture: Causes of earthquakes and seismic waves, magnitude, intensity and energy release, characteristics of earthquakes; Liquefaction; Seismic risk; EQ response of structures, single-degree-of freedom dynamics, concept of response spectra and introduction to multi-degree-of-freedom systems; Design response spectrum, idealization of structures, response spectrum analysis, equivalent lateral force concepts; Philosophy of earthquake resistant design, ductility, redundancy & over-strength, damping, supplemented damping; Code provisions; Seismic behaviour of concrete, steel and masonry structures, material properties; Behaviour and analysis of members under cyclic loads; Seismic detailing provisions; Review of damage in past earthquakes. Practical:

	Free and force vibration tests for dynamic properties estimation of building frame, Shake table testing for dynamic response analysis of building frame under earthquake, Shake table testing of building under earthquake to study the effect of isolator, damper and bracing on response control, Application of advance software for the nonlinear dynamic analysis under earthquake loading, Analysis and design of seismic retrofitting system.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand earthquake loading on structures and apply the knowledge of structural dynamics. 2. Teach seismic design practices in real-life applications and introduce various codes of practice. Practical: 1. Understand dynamic properties and dynamic behaviour of building frame structure under seismic loading. 2. Analysis and design of earthquake resistance structure and seismic retrofitting system such as isolator, damper, and bracing for response control. 3. Use of advanced software for nonlinear dynamic analysis of structures and data processing.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. R. Villaverde, Fundamental Concepts of Earthquake Engineering, CRC Press, 1st edition, 2009.
2. A. K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, Prentice Hall, 4th edition, 2015.
3. T. K. Datta, Seismic Analysis of Structures, Wiley, 1st edition, 2011.
4. S. K. Duggal, Earthquake Resistant Design of Structures, Oxford Univ. Press, 2013.
5. M. Shrikhande and P. Agarwal, Earthquake Resistant Design of Structures, Prentice hall India, 2006.
6. S. L. Kramer, Geotechnical Earthquake Engineering, Prentice Hall, 1996.
7. R. W. Clough and J. Penzien, Dynamics of Structures, McGraw-Hill, 1975, 2nd edition, 1992.
8. N. M. Newmark and E. Rosenblueth, Fundamentals of Earthquake Engineering, Prentice Hall, 1971.
9. D. Key, Earthquake Design Practice for Buildings, Thomas Telford, London, 1988.
10. T. Paulay, Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley & Sons Inc, 1st edition, 1992.

Course	CE5211 Stability of Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Stability of Structures
Learning Mode	Lectures

Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the concept of stability and buckling for different structural elements such as beam, column, frame, and plates. 2. Elastic and inelastic buckling analysis of different structures and its components under static and dynamic scenario. 3. Gain knowledge on analysis and design of structure considering the issues with stability.
Course Description	The course deals with stability of structure under static and dynamic loading. This course provides the students an exposure for bucking analysis and behaviour of different structural elements.
Course Outline	Criteria for design of structures: stability, strength, and stiffness; Classical concept of stability; Stability of discrete systems: linear and nonlinear behaviour; Stability of continuous systems: stability of columns: axial flexural buckling, lateral bracing of columns, combined axial flexural torsion buckling; Stability of frames: member buckling versus global buckling, slenderness ratio of frame members; Stability of beams: lateral torsion buckling; Stability of plates: axial flexural buckling, shear flexural buckling, buckling under combined loads; Introduction to inelastic buckling and dynamic stability.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Stability analysis of different structural members. 2. Elastic and inelastic buckling analysis structures. 3. Perform nonlinear analysis and design of structures accounting the aspect of stability and buckling.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Z. P. Bazant, Stability of structures: elastic, inelastic, fracture and damage theories, World Scientific Publishing Company, 2010.
2. S. P. Timoshenko and J. M. Gere, Theory of elastic stability, Dover Publications, 2nd Edition, 2009.
3. A. Kumar, Stability of structures, Allied Publishers Ltd, New Delhi, 1998.
4. M. L. Gambhir, Stability analysis and design of structures, Springer, New York, 2004.
5. I. Elishakoff, J. H. Starnes, and Y. Li, Non-classical problems in the theory of elastic stability, Cambridge University Press, 2001.

Department Elective - III (Structure Elective)						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6217	Advanced Steel Design	3	0	0	3
2.	CE6218	Finite Element Method	3	0	0	3
3.	CE6219	Structural Health Monitoring	3	0	0	3
4.	CE6220	Condition Assessment and Retrofitting of Structures	3	0	0	3

5.	CE6221	Advanced Topics in Reinforced Concrete Design	3	0	0	3
6.	CE6222	Seismic Analysis and Design of Structures	3	0	0	3

Course	CE6217 Advanced Steel Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Steel Design
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Provide scientific and technical knowledge for the basis for the development codal provisions for the design of steel structures. 2. Equip the students with a strong foundation and understanding for the design of steel structures. 3. Prepare students to attain exposure to the practical problems faced in steel design industry.

Course Description	The course deals with concrete technology. This course provides the students an exposure advanced topic on steel design which are not covered in undergraduate design courses.
Course Outline	Concepts of Stability, Introduction to Buckling Behaviour of Columns; Stability of Beam-Columns and Frames; Lateral Instability of Beams; Local Buckling and Post Buckling Behaviour of Plates; Behaviour and Design of Cold Formed Thin Walled Structures Subjected to Flexure and Compression; Plastic Analysis and Design of Steel Structures; Advanced Topics in Bolted and Welded Connections; Behaviour of Steel Concrete Composite Construction and Introduction to Brittle Fracture and Fatigue; Blast loads - impact loads- ice-infested loads on structures- fire loads- fire-resistant design
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Able to analyse to structure under gravity and lateral loads. 2. Designing steel structures with advanced knowledge.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Srinivasan Chandrasekaran and A.K.Jain. 2016. Ocean structures: Construction, Materials, and Operations, CRC Press, Florida, ISBN: 978-149-87-9742-9.
2. S.P. Timoshenko and J.M. Gere, "Theory of Elastic Stability" McGraw-Hill. 1963.
3. A.S. Arya and J.L. Ajmani, "Design of Steel Structures" Nem Chand & Bros. 2000.
4. N. Subramanian, "Design of Steel Structures", Oxford University Press. 2008.
5. M.L. Gambhir, "Stability Analysis and Design of Structures", Springer. 2005.

Course	CE6218 Finite Element Method
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Finite Element Method
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Provide scientific and technical knowledge for the basis for the development of finite element analysis procedure. 2. Equip the students with a strong foundation and understanding for the finite element analysis process of the problems related to various civil and mechanical engineering.
Course Description	The course deals with understanding finite element analysis of various problems. This course provides the students an exposure for topics on analysis of problems related to various civil and mechanical engineering problems which are not covered in undergraduate design courses.
Course Outline	Basic concepts of engineering analysis; Methods of weighted residuals and variational formulations; Finite element discretization; Shape function; Lagrange and serendipity families; Element properties, iso-parametric elements; Criteria

	for convergence; Numerical evaluation of finite element matrices (Gauss quadrature integration); Assemblage of elements; Analysis of plane stress/strain, 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 Lecture: 1. Understand various numerical methods for analysing engineering problems through FEM. 2. Analysis of various civil and mechanical engineering problems. 3. Ability to analyse complex structural system.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

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 Structural Health Monitoring
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Structural Health Monitoring
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are 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	CE6220 Condition Assessment and Retrofitting of Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Condition Assessment and Retrofitting of Structures
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the background of condition assessment, repair, and strengthening of structures. 2. Understand the strategies of surface repair and retrofitting techniques. 3. Attain knowledge of rehabilitation of existing building.
Course Description	The course deals with the evaluation and strengthening of existing structures. This course provides an understanding of existing non-destructive and destructive methods for condition assessment of structures. The students shall learn about various techniques for the strengthening of structures.
Course Outline	Distress identification and repair management: causes of distress in structures, deterioration model of concrete and moisture effects. Preliminary inspection: planning stage, visual inspection and detailed inspection; Evaluation of concrete buildings: destructive testing systems, non-destructive testing techniques, semi-destructive testing techniques, corrosion potential assessment, half-cell potentiometer test, resistivity measurement, identification and estimation of damage. Evaluation of strength of existing structures and analysis necessary to identify critical sections; Surface repair and retrofitting techniques: strategy and design, selection of repair materials, surface preparation, bonding repair materials to existing concrete, placement methods; Strengthening techniques: beam shear capacity strengthening, shear transfer strengthening between members, column strengthening, flexural strengthening, and crack stabilization. Guidelines for seismic rehabilitation of existing buildings, seismic vulnerability and strategies for seismic retrofit.
Learning Outcome	At the end of the course, student would be able to: 1. Introduce the application of different techniques for evaluation and retrofitting of buildings. 2. Present fundamental principles and methodologies for the design of various retrofitting techniques. 3. Estimate causes for distress and deterioration of structures. 4. NDT techniques for condition assessment of structures for identifying damages in structures. 5. Evaluate properties of distressed structural members. 6. Select retrofitting strategy suitable for distress and formulate guide lines for repair management of deteriorated structures
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. ASCE/SEI 41-23 Seismic Evaluation and Retrofit of Existing Buildings. 2023.
2. Varghese P.C., “Maintenance, Repair & Rehabilitation and Minor Works of Buildings” 1st Edition, PHI Learning Private Ltd., New Delhi., 2014.
3. Santhakumar A.R., “Concrete Technology” Oxford University Press, 2007, New Delhi
4. CPWD Handbook on Repair and Rehabilitation of RCC buildings, Govt. of India Press, New Delhi.
5. Emmons, P.H., “Concrete Repair and Maintenance”, Galgotia Publication. 2001.
6. Bungey, S., Lillard, G. and Grantham, M.G., “Testing of Concrete in Structures”, Taylor and Francis. 2001.
7. Malhotra, V.M. and Carino, N.J., “Handbook on Non-destructive Testing of Concrete”, CRC Press. 2004.
8. Bohni, H., “Corrosion in Concrete Structures”, CRC Press. 2005.
9. ATC- 40: Seismic Evaluation and Retrofit of Concrete Buildings, Vol. 1 & 2. 1997.
10. M.J.N. Priestley, Seible, F. and Calvi, G.M., “Seismic Design and Retrofit of Bridges”, John Wiley. 1996.

Course	CE6221 Advanced Topics in Reinforced Concrete Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Topics in Reinforced Concrete Design
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture:

	1. Understanding of selected advanced topics in the field of reinforced concrete design. 2. Understand the fundamental principles of reinforced concrete design. 3. Identify disturbed-regions (D-regions) where application of the strut-and-tie method is appropriate.
Course Description	The course deals with the design of various structures for various types of loading. This course provides the students an exposure for advanced topics on designing of RC structures which are not covered in undergraduate design courses. Practical of the course will cover destructive and non-destructive testing of RC structural elements and mix-design of concrete.
Course Outline	Lecture: Yield line theory for slabs: Basic principles, methods of yield line analysis. Deep beams: analysis and design as per Indian Standard and strut and tie method. Columns: derivation of axial compression and bending interaction curves, design of slender columns, design for biaxial bending. Analysis and design for torsion: behaviour of reinforced concrete members subjected to torsion, Design methods of torsion, difference between equilibrium and compatibility torsion, concept of equivalent shear and bending; design examples, design for combined loading (Torsion + Bending + Shear). Moment redistribution in continuous beams; bond and development length, curtailment of reinforcing steel. Design philosophies and procedures for liquid retaining structures. Design of RC shear walls, Advanced topics in the field of RC design: strut and tie method for D-regions, design methods of torsion, concept of equivalent shear and bending, design for combined loading.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand various types of loading on structures. 2. Analysis of structures for various types of loading. 3. Design of concrete structures for various types of loading. 4. Ability to design complex structural system.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. S.U. Pillai and D. Menon, Reinforced Concrete Design, Tata McGraw Hill, 4th Edition, 2021.
2. P. C. Varghese, Advanced Reinforced Concrete Design, PHI, 2009.
3. N. Krishnaraju, Advanced Reinforced Concrete Design, CBS Publisher, 2013.
4. M.L. Gambhir, "Fundamentals of Reinforced Concrete Design", Prentice Hall of India Private Limited, 2006.
5. J. G. MacGregor and J. K. Wight, Reinforced Concrete: Mechanics and Design, Prentice Education India, 6th edition, 2016.
6. T. Paulay and M.J.N. Priestley, Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley and Sons Inc., 1992.

Course	CE6222 Seismic Analysis and Design of Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Seismic Analysis and Design of Structures
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Develop a comprehensive technical understanding of the phenomena called earthquake in general. 2. Learn to perform seismic analysis and design of structures using latest IS codes in light with recent developments in the field of earthquake engineering. 3. Make familiar with structural dynamics, response spectrum analysis, time-history analysis, and nonlinear dynamic analysis for earthquake-resistant design.
Course Description	The course aims at developing detailed understanding with the design of various structures against seismic loading. This course provides the students an exposure for earthquake resistant designing of structures which are not usually covered in undergraduate design courses. Structural Dynamics or any equivalent course is the prerequisite for this course. Practical part of the course will provide in-depth understanding of dynamics of SDOF and MDOF, seismic response of

	building structures, and use of different type of sensor and equipment for dynamic response measurements, data processing and analysis.
Course Outline	Lecture: Causes of earthquakes and seismic waves, magnitude, intensity and energy release, characteristics of earthquakes; Liquefaction; Seismic risk; EQ response of structures, single-degree-of freedom dynamics, concept of response spectra and introduction to multi-degree-of-freedom systems; Design response spectrum, idealization of structures, response spectrum analysis, equivalent lateral force concepts; Philosophy of earthquake resistant design, ductility, redundancy & over-strength, damping, supplemented damping; Code provisions; Seismic behaviour of concrete, steel and masonry structures, material properties; Behaviour and analysis of members under cyclic loads; Seismic detailing provisions; Review of damage in past earthquakes. Advance topic in structural earthquake engineering, performance-based design of structure, seismic vulnerability analysis, seismic response analysis inelastic SDOF and MDOF system, seismic analysis and design unsymmetrical structure and connected system, seismic design of retrofitting devices such as isolator, bracing, and damper, introduction to shake table testing for seismic analysis of structure, state-of-the-art on global seismic design practices, use of advance software for seismic analysis and earthquake resistance design of structure.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand earthquake loading on structures and apply the knowledge of structural dynamics. 2. Teach seismic design practices in real-life applications and introduce various codes of practice.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. R. Villaverde, Fundamental Concepts of Earthquake Engineering, CRC Press, 1st edition, 2009.
2. A. K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, Prentice Hall, 4th edition, 2015.
3. T. K. Datta, Seismic Analysis of Structures, Wiley, 1st edition, 2011.
4. S. K. Duggal, Earthquake Resistant Design of Structures, Oxford Univ. Press, 2013.
5. M. Shrikhande and P. Agarwal, Earthquake Resistant Design of Structures, Prentice hall India, 2006.
6. S. L. Kramer, Geotechnical Earthquake Engineering, Prentice Hall, 1996.
7. R. W. Clough and J. Penzien, Dynamics of Structures, McGraw-Hill, 1975, 2nd edition, 1992.
8. N. M. Newmark and E. Rosenblueth, Fundamentals of Earthquake Engineering, Prentice Hall, 1971.
9. D. Key, Earthquake Design Practice for Buildings, Thomas Telford, London, 1988.
10. T. Paulay, Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley & Sons Inc, 1st edition, 1992.

Department Elective-IV (Structure / 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.	CE6207	Soil-Structure Interaction Analysis	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.	CE6213	Design of Underground Excavations	3	0	0	3
7.	CE6215	Forensic Geotechnical Engineering	3	0	0	3
8.	CE6223	Uncertainty, Risk and Reliability Analyses in Civil Engineering	3	0	0	3
9.	CE6224	Nonlinear Structural Mechanics	3	0	0	3
10.	CE6225	Theory of Random Vibration	3	0	0	3
11.	CE6226	Analysis of Structural Stability	3	0	0	3
12.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3
13.	CE6230	Advanced Concrete Pavement Analysis and Design	3	0	0	3

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

Textbooks/ Reference books:

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 Geotechnical Earthquake Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geotechnical Earthquake Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

6. Kramar S.L, Geotechnical Earthquake Engineering, Prentice Hall International series, Pearson Education Pvt. Ltd.
7. J.E. Bowles, Foundation Analysis and Design, McGraw-Hill, 2001.
8. Ikuo Towhata, Geotechnical Earthquake Engineering, Springer series, 2008.
9. All relevant IS and International Codes.

Course	CE6207 Soil-Structure Interaction Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Soil-Structure Interaction Analysis
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, and 4 and the objective for learning this course are Lecture: 1. To provide the knowledge of the advanced concept of soil and structural interaction.

	- Equip the students with a strong foundation in civil engineering for both research and industrial scenarios. - Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure under dynamic loading.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to geotechnical engineering. Topics ranging from general concept of soil-structure interaction, beams on elastic foundation, modern concept of analysis of piles and pile groups are covered.
Course Outline	General soil-structure interaction problems. Contact pressures and soil-structure interaction for shallow foundations. Concept of sub grade modulus, effects/parameters influencing subgrade modulus. Analysis of foundations of finite rigidity, Beams on elastic foundation concept, introduction to the solution of beam problems. Curved failure surfaces, their utility and analytical/graphical predictions from Mohr-Coulomb envelope and circle of stresses. Earth pressure computations by friction circle method. Earth pressure distribution on walls with limited/restrained deformations, Dubravo's analysis. Earth pressures on sheet piles, braced excavations. Design of supporting system of excavations. Arching in soils. Elastic and plastic analysis of stress distribution on yielding bases. Analysis of conduits. Design charts for practical use. Modern concept of analysis of piles and pile groups. Axially, laterally loaded piles and groups. Interaction analysis. Reese and Matlock's solution. Elastic continuum and elasto-plastic analysis of piles and pile groups. Hrennikoff's analysis. Ultimate lateral resistance of piles by various approaches. Non-linear load-deflection response. Uplift capacity of piles and anchors.
Learning Outcome	At the end of the course, student would be able to Lecture: - Design earthquake resistant structure using various methods available along with the method suggested in the IS code. - Apply beam on elastic foundation concept in analysis and design of various problem related to geotechnical engineering. - Ultimate lateral resistance of piles by various approaches.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

- J. P. Wolf, "Dynamic Soil-Structure Interaction", Prentice-Hall, 1985.
- S.L. Kramer, Geotechnical Earthquake Engineering, Prentice Hall, 1996.
- H. G. Poulos, and E. H. Davis, Pile Foundation Analysis and Design, Krieger Pub Co., 1990.
- Structure Soil Interaction- State of Art Report, Institution of Structural Engineers, 1978.
- All relevant IS and International Codes.

Course	CE6209 Coupled Process in Fractured Geological Media
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Coupled Process in Fractured Geological Media
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, and 3 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

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

Course	CE6210 Ground Improvement Techniques
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Ground Improvement Techniques
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 3, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the importance of ground improvement for civil engineering structures. 2. Examine the problematic soil and select a suitable ground improvement technique.

	3. Analyze and Design the various ground improvement techniques. 4. Understand the construction methodology, equipment and quality control aspects. 5. Know the national and international codal guidelines and provisions.
Course Description	Construction in weak and problematic soil is inevitable nowadays. The course addresses various ground improvement techniques along with principles, design issues and construction procedures. The course has been broadly divided into two modules namely ground improvement techniques and the reinforced earth.
Course Outline	Problematic soil and need for ground improvements, Mechanical modifications using mechanical and dynamic compaction, Accelerated consolidation using preloading and vertical drains, Soil stabilisation using additives and deep soil mixing, Grouting, Vibro techniques, Drainage and dewatering methods; Soil nailing; Soil nailing; Underpinning, Introduction to geo-synthetics and reinforced earth; Applications and advantages of reinforced soil structure; Principles, concepts and mechanism of reinforced soil; Soil-reinforcement interface friction; Behaviour of Reinforced earth walls; Bearing capacity improvement and design of foundations resting on reinforced soil; embankments on soft soils; Design of reinforced soil slopes, Use of geosynthetics for separations, drainage and filtration; practical applications of 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 Lecture: 1. Identify the problematic soil and select a suitable ground improvement technique. 2. Design the various ground improvement techniques. 3. Understand the construction methodology, equipment and quality control aspects. 4. Know the national and international codal guidelines and provisions.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Manfired R. Hausmann, Engineering Principles of Ground Modification, McGraw-Hill Pub, Co., 1990.
2. Koerner, R.M. Designing with Geosynthetics, Prentice Hall, New Jersey, USA, 4th edition, 1999.
3. Jie Han, Principles and Practice of Ground Improvement, Wiley Publishers, 2015.
4. B.M. Das, Principle of Geotechnical Engineering, Cengage Learning, eighth Edition, 2013.
5. V. N. S. Murthy, Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering, CRC Press, Taylor & Francis Group, Third Indian Reprint, 2013.
6. All relevant IS and international codes and relevant research papers/reports

Course	CE6213 Design of Underground Excavations
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Design of Underground Excavations
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, and 3 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

1. Goodman, R. E. Introduction to rock mechanics, John Wiley and Sons, 1989.
2. Hoek, E., & Bray, J. D. Rock slope engineering, CRC Press, 1981.
3. Hoek, E., & Brown, E. Underground excavations in rock, CRC Press, 1980.
4. Singh, B., & Goel, R. K. Engineering rock mass classification, Elsevier, 2011.
5. Jaeger, J. C., Cook, N. G., & Zimmerman, R. Fundamentals of rock mechanics, John Wiley & Sons, 2009.
6. Debasis, D., & Kumar, V. A. Fundamentals and applications of rock mechanics, PHI Learning Pvt. Ltd. New Delhi, India, 2016.

Course	CE6215 Forensic Geotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Forensic Geotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 3, and 5 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

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.
4. Day, Robert W. Forensic geotechnical and foundation engineering. McGraw-Hill, 2011.
5. Alonso, Eduardo E., Núria M. Pinyol, and Alexander M. Puzrin. Geomechanics of failures: advanced topics. Vol. 277. Berlin: Springer, 2010.
6. Lacasse, Suzanne. Forensic geotechnical engineering theory and practice. Forensic Geotechnical Engineering (2016): 17-37.
7. Franck, Harold, and Darren Franck. Forensic engineering fundamentals. Boca Raton, FL: CRC Press, 2013.
8. All relevant IS and international codes and research articles and reports.

Course	CE6223 Uncertainty, Risk and Reliability Analyses in Civil Engineering
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 PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Make familiar the concept of probability theory and statistics. 2. Gain knowledge on stochastic simulation methods. 3. Develop knowledge on risk and reliability analysis of structure.
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, Bayesian Analysis, Analysis of variance (ANOVA), Application of central limit theorem; confidence interval, expected value, and return period, probability paper; testing of goodness-of-fit of distribution models, Random number generation – Monte Carlo simulations, Formulation of structural reliability problems: limit states, composite risk analysis, direct integration method, safety margin method, reliability index and safety factor; FORM and SORM 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, fragility analysis. Calibration of target reliability: reliability-based design codes.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understanding concept of probability theory and 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.

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	CE6224 Nonlinear Structural Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Nonlinear Structural Mechanics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the concept of nonlinear deformation, inelastic measures of strain and stress. 2. Introduce basic concept of plasticity, creep, and viscoelasticity in different structural engineering materials. 3. Prediction of behaviour of nonlinear and inelastic deformable solids and structures under different loading, using codes and software packages.
Course Description	The course deals with nonlinear behaviour of deformable bodies and structures. Provides different nonlinear stress and strain measures that is necessary for analyses of structures with geometrical and material nonlinearity. Also, the course provides principles of numerical solution of nonlinear problems, post critical analysis of structures, linear and nonlinear buckling, and application of the presented theory for the solution of particular nonlinear problems by a FEM program.
Course Outline	Introduction: physical and geometrical nonlinearities in structure, non-linear problems classification and comparison, overview of different strain and stress measures; Plasticity: overview of plasticity theory, uniaxial and multi-axial plasticity, yield criterion and flow rule, work hardening rule, and loading/unloading criterion under cycle loading, uniaxial material models of elastic-plastic material with kinematic and isotropic hardening, Ramberg-Osgood steel material model, Giuffre-Menegotto-Pinto model, Kent-Scott-Park model, and Bouc-Wen model, principles of computational plasticity, finite element treatment of plasticity solution strategy and accuracy; Creep and Viscoelasticity: basic theory of creep, uniaxial and multiaxial creep theory and application in thermo-mechanical problems, viscoelastic materials, time and strain hardening, explicit and implicit time integrations, explicit finite element codes; Nonlinear structural analysis: mathematical preliminaries for 1st and 2nd order elastic and inelastic structural analysis (tangent stiffness matrix, material and geometrical stiffness), incremental methods (Newton-Raphson method, modified Newton-Raphson method, Euler method, Runge-Kutta methods), unbalanced forces calculation and iterative methods (load control, deformation control, work control, and arc length control method), nonlinear beam-column element material and geometric, force and displacement control, plastic stability and buckling, global and local criteria of plastic stability, use of finite element software for small strain plasticity application.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand various types of nonlinearities in structural.

	2. Gain knowledge on different nonlinear material model and solution methods nonlinear problems. 3. Developed skill to analyze of nonlinear solids and structures using different codes and software.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Allan F. Bower. Applied Mechanics of Solids, CRC Press, 2010.
2. Irving H. Shames and Francis A. Cozzarelli. Elastic and Inelastic Stress Analysis, Taylor & Francis Group; Revised edition, 1997.
3. J. Lubliner, Plasticity theory, Dover Publications Inc., Illustrated Edition, 2008.
4. J. C. Simo and T. J. R. Hughes, Computational Inelasticity, Springer-Verlag New York Inc., 2nd Edition, 2000.
5. J. Chakrabarty, Theory of Plasticity, Butterworth-Heinemann Ltd., 3rd Edition, 2006.
6. S. Muthukrishnan, Nonlinear Analysis of Structures, CRC Press, 1st Edition, 2017.
7. W. Lacarbonara, Nonlinear Structural Mechanics: Theory, Dynamical Phenomena and Modeling, Springer-Verlag New York Inc., 1st Edition, 2016.
8. A. H. Nayfeh and P. F. Pai, Linear and Nonlinear Structural Mechanics, Wiley-VCH, 1st Edition, 2004.

Course	CE6225 Theory of Random Vibration
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Theory of Random Vibration
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Introduce concept of probability theory and random process. 2. Understand the stochastic field simulation process. 3. Predict the responses of linear and nonlinear structures under random excitation. 4. Apply the concept of random vibration in analyses of structure under wind and earthquake loading.
Course Description	The focus of this course will be on introducing the necessary techniques that will enable the student to assess the linear and non-linear structural response under uncertain loads. To this end, different probabilistic method, random variables and random processes will be introduced. Special focus will be given to simulate stochastic field for wind and earthquake loading and the assessment of probabilistic structural responses under such random excitation.
Course Outline	Introduction: concept and classification of uncertainty in dynamic system and randomness in in excitation; Overview of probability: fundamental of probability theory and random variables, probability distribution, function of random variables, Monte Carlo simulation methods; Stochastic process: classification and description of random processes, stationarity and ergodicity, stationary and non-stationary random process, Fourier series, Fourier transform of a stochastic process, power spectral density and correlation functions, properties of power spectral density function, narrow band and broad band random processes, spectral representation methods, polynomial chaos expansions, Markov processes, stochastic field simulation; Stochastic response of structural systems: excitation response relations of linear SDOF, MDOF, and continuous system under random excitation, normal mode approach, level of crossing, peak and envelop statistics, equivalent linearization, stochastic averaging, and non-linear random vibrations SDOF, MDOF, and continuous system, application to wind and earthquake engineering.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand probability theory, random variables, and various types of random process. 2. Developed skill to perform stochastic field simulation. 3. Gain knowledge on linear and nonlinear structural analysis under stochastic dynamic loading.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. N. C. Nigam, Introduction to Random Vibrations, MIT Press, Cambridge, 1983.
2. D. E. Newland, An Introduction to Random Vibrations and Spectral Analysis, Longman Inc., New York, 2nd Edition, 1984.
3. A. Papoulis and S. Unnikrishna Pillai, Probability, Random Variables and Stochastic Processes, McGraw-Hill, New York, 4th Edition, 2017.
4. J. B. Roberts and P. D. Spanos, Random Vibration and Statistical Linearization, Dover Publications Inc., 2003.
5. A. Haldar and S. Mahadevan, Probability, Reliability, and Statistical Methods in Engineering Design, Wiley, 2000.
6. H. S. Ang and W. H. Tang, Probability Concepts in Engineering Planning and Design, John Wiley, 1975.
7. R.W. Clough and J. Penzien, Dynamics of Structures, McGraw-Hill, 1975, 2nd Edition, 1992.
8. S.S. Rao, Mechanical Vibrations, Prentice Hall, 6th Edition, 2021.

Course	CE6226 Analysis of Structural Stability
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analysis of Structural Stability
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Understand the concept of stability and buckling for different structural elements such as beam, column, frame, and plates. 2. Elastic and inelastic buckling analysis of different structures and its components under static and dynamic scenario. 3. Gain knowledge on analysis and design of structure considering the issues with stability.
Course Description	The course deals with stability of structure under static and dynamic loading. This course provides the students an exposure for bucking analysis and behaviour of different structural elements.
Course Outline	Criteria for design of structures: stability, strength, and stiffness; Classical concept of stability; Stability of discrete systems: linear and nonlinear behaviour; Stability of continuous systems: stability of columns: axial flexural buckling, lateral bracing of columns, combined axial flexural torsion buckling; Stability of frames: member buckling versus global buckling, slenderness ratio of frame members; Stability of beams: lateral torsion buckling; Stability of plates: axial flexural buckling, shear flexural buckling, buckling under combined loads; Advance topics in structural stability: introduction to inelastic buckling and dynamic stability, bifurcation and limit point instability, finite distributed instability, snap through instability, geometric imperfection and material inelasticity, stability of shells, application of software for elastic and inelastic stability analysis of structures.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Stability analysis of different structural members. 2. Elastic and inelastic buckling analysis structures. 3. Perform nonlinear analysis and design of structures accounting the aspect of stability and buckling.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Z. P. Bazant, Stability of structures: elastic, inelastic, fracture and damage theories, World Scientific Publishing Company, 2010.
2. S. P. Timoshenko and J. M. Gere, Theory of elastic stability, Dover Publications, 2nd Edition, 2009.
3. A. Kumar, Stability of structures, Allied Publishers Ltd, New Delhi, 1998.
4. M. L. Gambhir, Stability analysis and design of structures, Springer, New York, 2004.
5. I. Elishakoff, J. H. Starnes, and Y. Li, Non-classical problems in the theory of elastic stability, Cambridge University Press, 2001.

Course	CE6228 Analytical Techniques for Infrastructure Systems Analysis
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 PLOs 2, 4, and 5 and the objective for learning this course are Lecture:

	1. 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 Outline	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	At the end of the course, student would be able to Lecture: 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.

Textbooks/ Reference books:

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	CE6230 Advanced Concrete Pavement Analysis and Design
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 PLOs 1, 2, and 4 and the objective for learning this course are Lecture: 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 Lecture: 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/ Reference books:

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

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan. Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods. Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation. Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.). Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.

Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

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

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

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

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

REFERENCES:

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