M.Tech

IN

STRUCTURAL ENGINEERING

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

तमसो मा ज्योतिर्गमय

Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech in Structural Engineering

PEO1	Demonstrate advanced knowledge in Structural Engineering, enabling them to excel in their profession and pursue higher academic goals
PEO2	Exhibit strong communication, technical writing and interpersonal skills
PEO3	Be strongly committed to ethical practices, adherence to quality and performance standards, the society, sustainability, and self-directed life-long learning

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M.Tech in Structural Engineering

PO1	Ability to independently carry out research /investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report/document
PO3	Ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PSO 1	Ability to understand the impact of engineering solutions on the society applying ethical principles while pursuing teaching and research and be aware of the environmental aspects and sustainable issues related to infrastructure development of the country
PSO 2	Ability for life-long learning of new and innovative technologies related to Structural Engineering

CURRICULUM

Total credits for completing M.Tech in Structural Engineering is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	20
2.	Program Electives (PE)	18
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE6101E	Theory of Elasticity and Plasticity	3	0	0	6	3	PC
2.	CE6102E	Structural Dynamics	3	0	0	6	3	PC
3.	CE6103E	Advanced Theory and Design of Concrete Structures	3	0	0	6	3	PC
4.	CE6191E	Stress Analysis Lab	0	0	2	1	1	PC
5.	******E	Elective	3	0	0	6	3	PE
6.	******E	Elective	3	0	0	6	3	PE
7.	******E	Elective	3	0	0	6	3	PE
8.	******E	Institute Elective (Entrepreneurship,Research Methodology, Communicative English etc)					2	IE
		Total					**21**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE6111E	Finite Element Method	3	0	0	6	3	PC
2.	CE6112E	Theory of Plates and Shells	3	0	0	6	3	PC
3.	CE6113E	Advanced Theory and Design of Metal Structures	3	0	0	6	3	PC
4.	CE6192E	Structural Engineering Design Studio	0	0	2	1	1	PC

5.	******E	Elective	3	0	0	6	3	PE
6.	******E	Elective	3	0	0	6	3	PE
7.	******E	Elective	3	0	0	6	3	PE
8.	CE6196E	Project Phase I	0	0	0	6	2	PC
		Total					**21**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE7197E	Project Phase II	0	0	0	*	3	PC
2.	CE7198E	Project Phase III	0	0	0	45	15	PC
		Total					**18**	**--**

Note
**Decided by the organisation in which the internship is done*

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE7199E	Project Phase IV	0	0	0	45	15	PC
		Total					**15**	**--**

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	IE6001E	Entrepreneurship Development	2	0	0	4	2	IE
2	MS6174E	Technical Communication and Writing	2	1	0	3	2	IE
3	ZZ6002E	Research Methodology	2	0	0	4	2	IE

List of Program Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	CE6121E	Structural Optimisation	3	0	0	6	3
2.	CE6122E	Modelling, Simulation and Computer Applications	3	0	0	6	3
3.	CE6123E	Earthquake Analysis and Design of Structures	3	0	0	6	3
4.	CE6124E	Nonlinear Analysis of Structures	3	0	0	6	3
5.	CE6125E	Bridge Engineering	3	0	0	6	3
6.	CE6126E	Construction Project Management	3	0	0	6	3
7.	CE6127E	Forensic Engineering and Rehabilitation of Structures	3	0	0	6	3
8.	CE6128E	Analytical Dynamics	3	0	0	6	3
9.	CE6129E	Tall Structures	3	0	0	6	3
10.	CE6130E	Structural Health Monitoring	3	0	0	6	3
11.	CE6131E	Structural Reliability	3	0	0	6	3

12.	CE6132E	Concrete Shells and Folded Plates	3	0	0	6	3
13.	CE6133E	Random Vibrations	3	0	0	6	3
14.	CE6134E	Engineering Fracture Mechanics	3	0	0	6	3
15.	CE6135E	Pre-stressed Concrete Design	3	0	0	6	3
16.	CE6136E	Mechanics of Composite Structures	3	0	0	6	3
17.	CE6137E	Advanced Finite Element Analysis	3	0	0	6	3
18.	CE6138E	Theory of Plasticity	3	0	0	6	3
19.	CE6226E	Geographic Information System and Its Applications	3	0	0	6	3
20.	CE6302E	Stochastic Processes in Structural Mechanics	3	0	0	6	3
21.	CE6304E	Marine CFD	3	0	0	6	3
22.	CE6311E	Dynamics of Ocean Structures	3	0	0	6	3
23.	CE6312E	Marine Foundations	3	0	0	6	3
24.	CE6323E	Stability of Structures	3	0	0	6	3
25.	CE6421E	Advanced Design of Foundations	3	0	0	6	3

Department of Civil Engineering, National Institute of Technology Calicut

CE6101E THEORY OF ELASTICITY AND PLASTICITY

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand mathematical formulation of elasticity problem as a well-posed boundary value problem
CO2: Solve simple engineering problems with mathematical rigour. Such solutions can act as bench-mark solutions for testing computational methods and software.
CO3: Appreciate the Cartesian tensor notation; thereby understand modern technical literature well
CO4: Enable understanding of literature and advanced books on theory of plasticity

Introduction to the Mathematical Theory of Elasticity

Elasticity, stress, strain, Hooke's law, two- dimensional idealisations, plane stress and plane strain problems, equations of equilibrium, strain- displacement relations, constitutive relations, compatibility conditions, displacement and traction boundary conditions. Two-dimensional problems in rectangular coordinates: Stress function, solution by polynomials, Saint Vénant's principle, bending of a cantilever, determination of displacements.
Two-dimensional problems in polar coordinates: General equations, problems of axisymmetric stress distribution, pure bending of curved bars, effect of circular hole on stress distribution in plates, concentrated force at a point on a straight boundary.

Introduction to Cartesian Tensors

Transformation laws of cartesian tensors, special tensors and tensor operations, the Kronecker's delta, the permutation tensor, the e-δ identity, symmetry and skew- symmetry, contraction, derivatives and the comma notation, Gauss' theorem, the base vectors and some special vector operations, eigenvalue problem of a symmetric second order tensor, equations of elasticity using index notation.
Stress-strain Problems in Three Dimensions: Principal stresses, principal strains, three- dimensional problems.

Energy Theorems and Variational Principles of Elasticity

Strain energy and complementary energy, Clapeyron's theorem, virtual work and potential energy principles, principle of complementary potential energy, Betti's reciprocal theorem, principle of linear superposition, uniqueness of elasticity solution.
Torsion of straight bars: Elliptic and equilateral triangular cross-section, membrane analogy, narrow rectangular cross-section, torsion of rectangular bars, torsion of rolled profile sections, hollow shafts and thin tubes.

Introduction to Plasticity

One-dimensional elastic-plastic relations, isotropic and kinematic hardening, yield function, flow rule, hardening rule, incremental stress-strain relationship, governing equations of elastoplasticity.

References:

1. Timoshenko, S.P. and Goodier, J.N., Theory of Elasticity, Mc Graw Hill, Singapore, 1982.
2. Srinath, L.S., Advanced Mechanics of Solids, Second Edition, Tata McGraw Hill, India, 2003.
3. Ameen, M., Computational Elasticity–Theory of Elasticity, Finite and Boundary Element Methods, Narosa Publishing House, 2004.
4. Leipholz, H., Theory of Elasticity, Noordhoff International Publishing, Layden, 1974.
5. Sokolnikoff, I.S., Mathematical Theory of Elasticity, Tata Mc Graw Hill, India, 1974.
6. Xu, Z., Applied Elasticity, Wiley Eastern Ltd, India, 1992.
7. Chakrabarty, J, Theory of Plasticity, Elsevier, London, 2006.
8. Hill, R., Mathematical Theory of Plasticity, Oxford University Press, 1998.
9. Chen, W.F., and Han, D.J., Plasticity for Structural Engineers, Springer Verlag, 1998.

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CE6102E STRUCTURAL DYNAMICS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Mathematically model a structural system for dynamic analysis.
CO2: Carry out free vibration analysis of a single degree of freedom system
CO3: Analyze a single degree of freedom systems subjected to harmonic loading, periodic loading and general dynamic loadings.
CO4: Perform free vibration and forced vibration analyses of multi degree of freedom systems.
CO5: Analyze a continuous system both as a distributed parameter system and discrete parameter system.

Introduction-SDOF system fundamentals

Introduction to dynamics of structural systems: continuous systems and discretization; significance of single degree of freedom system in the dynamic analysis of structural systems. Free vibration response of Singe-Degree-of-Freedom Linear Systems: General considerations; characteristics of discrete system-components; differential equation of motion of second-order linear systems; free vibration response of undamped and damped single degree of freedom systems; logarithmic decrement; critically damped, under damped and overdamped systems.

SDOF System-Forced vibration response

Forced Response of Singe-Degree-of-Freedom Systems: Response to a harmonic excitation force, response to support motion; complex vector representation of harmonic motion; vibration isolation, vibration measuring instruments; energy dissipation and structural damping; superposition and response to periodic excitation; Fourier series; the unit impulse and impulse response; unit step function and step response; response to general dynamic loading - the convolution integral.

Multi Degree of Freedom Systems

Multi-Degree-of-Freedom Systems: Equations of motion, generalized coordinates, matrix formulation; stiffness and mass matrices; linear transformations and coupling, undamped free vibration response. the matrix eigenvalue problem; natural frequencies and mode shapes; orthogonality of modal vectors; expansion theorem; response to initial excitation; modal analysis, solution of eigenvalue problem by matrix iteration; power method; Rayleigh's coefficient; general response of discrete linear systems.

Continuous systems, Analytical Dynamics

Continuous System: Relation between discrete and continuous system, boundary value problem, free vibration, eigenvalue problem; axial vibration of rods; bending vibration of beams; orthogonality of natural modes; expansion theorem; Rayleigh's quotient; response of systems by modal analysis; introduction to approximate methods of analysis of continuous systems; Rayleigh-Ritz method; finite element method. Introduction to Analytical Dynamics: Work and energy- principle of virtual work, D' Alembert's principle, Lagrange equations of motion

References:

1. Meirovitch L, Elements of Vibration Analysis, McGraw Hill, 1986
2. Clough R.W. and Penzien J, Dynamics of structures, McGraw Hill, 2015.
3. Chopra, A.K., Dynamics of structures – Theory and Application to Earthquake Engineering, Prentice Hall, 2015.
4. Thomson W.T. and Dahleh M.D, Theory of Vibration with Applications, Pearson Education,1998.
5. Craig, Jr. R.R, Structural Dynamics, John Wiley, 1981.
6. Hurty, W.C. and Rubinstein M.F, Dynamics of Structures, Prentice Hall, 1964.
7. Jagmohan L. Humar, Dynamics of Structures 2nd Edition, Balkema Publishers, 2002.

CE6103E ADVANCED THEORY AND DESIGN OF CONCRETE STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Gain in depth knowledge in the areas of serviceability limits and stress-strain behaviour of concrete.
CO2: Get familiarized with the principles of unified concrete theory and design of RCC structures using strut and tie model concepts.
CO3: Analyze and design of shear walls
CO4: Acquire knowledge on the design of special RCC members

Stress-strain characteristics of concrete under multi- axial stresses- confined concrete- Effect of cyclic loading on concrete and reinforcing steel.
Ultimate Deformation and ductility of members with flexure- strength and deformation of members with tension -Control of deflections- immediate and long term deflections-Control of cracking – classical theory of cracking-International codal procedures on crack-width computation.

Strut and Tie Models- Development- Design methodology- selecting dimensions for struts- ACI Provisions-Applications- RCC beam – column joints- classification – shear strength- design of exterior and interior joints-wide beam joints.

Strength and ductility of concrete frames- analysis of shear walls- distribution of lateral loads in uncoupled shear walls- Equivalent stiffness method- Shear wall frame interactions.
Behaviour and design of special RCC members- Design of concrete corbels- deep beams, ribbed, hollow block or voided slab- RCC walls.

References:

1. Arthur. H. Nilson, David Darwin and Charles W Dolan, Design of Concrete Structures, Tata McGraw Hill, 2004.
2. Park,R and Paulay T, Reinforced Concrete Structures, John Wiley & Sons, New York, 1975.
3. James G MacGregor,James K Wight, Reinforced Concrete- Mechanics and Design, Prentice Hall, Pearson Education South Asia Pte Ltd, 2006.
4. Macleod, I.A, Shear Wall Frame Interaction. A design aid with commentary Portland Cement Association, 1971.
5. Thomas T. C. Hsu, Unified Theory of Reinforced Concrete, CRC Press, London,1993.
6. IS 456 –2000, Indian Standard for Plain and Reinforced Concrete- Code of Practice, New Delhi
7. ACI – 318: 2014, Building Code Requirements for Structural Concrete and Commentary, ACI Michigan.

CE6191E STRESS ANALYSIS LAB

Pre-requisite: Nil

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Understand the latest methods for measuring deformations and strains.
CO2: Gain knowledge on the operation of different loading systems and force measuring devices.
CO3: Learn different Non-Destructive techniques for structural systems.
CO4: Enhance knowledge on reinforced cementitious composites.

Measurement of Strain: - Mechanical Strain Gauges- Electrical Strain gauges- Extensometers and Compressometers. Measurement of Deflection: - Dial gauges - Linear Variable Differential Transducers

Principles of operations of UTM, hydraulic loading systems, force measuring devices etc.
Study on the behaviour of structural materials and structural members- Casting and testing of simple compression, tension and flexural members.

Introduction to various Non-Destructive Testing methods for structural members.

Reinforced Cement Composites: - Introduction to Steel fiber reinforced concrete – Ferrocement – Polymer concrete - Self Compacting Concrete – High Performance Concrete.

References:

1. J,W.Dally & W.F.Riley Experimental Stress Analysis , College House Enterprises, 2005.
2. L.S.Srinath, M.R.Raghavan, K.Lingaiah, G.Gargesa, B.Pant & K.Ramachandra. Experimental Stress Analysis ,Tata McGraw Hill,1984.
3. Pundit Lab Manual

CE6111E FINITE ELEMENT METHOD

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To formulate finite element model of a physical system
CO2: To derive element stiffness matrix for a given problem
CO3: To write a computer code and analyse a structure using the finite element method
CO4: To use latest commercial FE software

Introduction: Finite element analysis, Problem classification, Modelling and discretization, interpolation, elements, nodes and D.O.F, Example applications, History of FEA.

One-Dimensional Elements: Bar element, Beam element, Bar and beam elements of arbitrary orientation, Assembly of elements, Properties of stiffness matrices, Boundary conditions, Exploiting sparsity, Mechanical loads, Thermal loads, Stresses, Structural symmetry.

Basic Elements: Interpolation and shape functions, Linear triangle, Bilinear rectangle, Rectangular solid element, Nodal loads, Stress calculation, Nature of finite element solution.

Formulation Techniques: Variational Methods: Principle of stationary potential energy, Problems having many D.O.F., Potential energy of an elastic body, Rayleigh-Ritz method, Strong and weak forms, Finite element form of Rayleigh-Ritz method, Convergence of finite element solutions.

Formulation Techniques: Galerkin and Other Weighted Residual Methods: Methods of weighted residuals, Galerkin FEM in one dimension, Integration by parts, Galerkin FEM in two dimensions.

Isoparametric Elements: Bilinear quadrilateral, Quadrature for obtaining [k] by numerical integration, Quadratic isoparametric elements, Hexahedral isoparametric elements, Stress calculation, Patch test, Validity of isoparametric elements.

Isoparametric Triangles and Tetrahedra: Reference coordinates, shape functions, analytical integration, area and volume coordinates, numerical integration.

Coordinate Transformation and Selected Topics: Displacement, strain, stress, material property and stiffness matrix transformations, Changing the direction of restraints, Connecting dissimilar elements, Structural modification, Reanalysis.

Modelling Considerations: Repetitive symmetry, Static condensation, Substructures.

References:

1. Cook, R.D., et al, Concepts and Applications of Finite Element Analysis, John Wiley, 2003.
2. Krishnamoorthy, C.S., Finite Element Analysis – Theory and Programming, Tata McGraw Hill, 1996.
3. Bathe, K.J., Finite Element Procedures, Prentice Hall of India, 1996.
4. Desai, C.S., Elementary Finite Element Method, Prentice Hall of India, 1998.
5. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vol. I and II, Mc Graw Hill, 1991.
6. Buchanan, G.R., Finite Element Analysis, Schaum's Outlines, Tata McGraw-Hill, India, 1995.
7. Rajasekaran, S., Finite Element Analysis in Engineering Design, Wheeler Pub, 1998.

CE6112E THEORY OF PLATES AND SHELLS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse different types of plates with various boundary conditions in the field of civil engineering and related fields.
CO2: Employ numerical techniques in solving special plate problems.
CO3: Address complex problems in plates and shells which require a rigorous mathematical background.
CO4: Identify different type of shells and analyse shell structures for the stress resultants leading to an optimal design.

Introduction-Plate fundamentals and basic equations

Introduction: - Assumptions in the theory of thin plates – Pure bending of Plates – Relations between bending moments and curvature - Particular cases of pure bending of rectangular plates, Cylindrical bending - immovable and simply supported edges - Synclastic bending and Anticlastic bending – Strain energy in pure bending of plates in Cartesian and polar co-ordinates – Limitations.

Rectangular Plates and Advanced Topics

Laterally Loaded Rectangular Plates: - Differential equation of plates – Boundary conditions – Navier solution for simply supported plates subjected to uniformly distributed load and point load – Levy's method of solution for plates having two opposite edges simply supported with various symmetrical boundary conditions along the other two edges loaded with u.d.l., Simply supported plates with moments distributed along the edges - Approximate Methods

Circular plates and advanced topics

Laterally Loaded Circular Plates: - Differential equation of equilibrium – Uniformly loaded circular plates with simply supported and fixed boundary conditions – Annular plate with uniform moment and shear force along the boundaries.

Effect of transverse shear deformation - plates of variable thickness – Anisotropic plates- thick plates, orthotropic plates and grids - Large Deflection Theory Plate vibration – free flexural vibration of rectangular and circular plates

Theory of shells

Deformation of Shells without Bending: - Definitions and notation, shells in the form of a surface of revolution, displacements, unsymmetrical loading, spherical shell supported at isolated points, membrane theory of cylindrical shells, the use of stress function in calculating membrane forces of shells.

General Theory of Cylindrical Shells: - A circular cylindrical shell loaded symmetrically with respect to its axis, symmetrical deformation, pressure vessels, cylindrical tanks, thermal stresses, inextensional deformation, general case of deformation, cylindrical shells with supported edges, approximate investigation of the bending of cylindrical shells, the use of a strain and stress function, stress analysis of cylindrical roof shells.

References:

1. Timoshenko, S.P., and Krieger, S.W., Theory of Plates and Shells, McGraw Hill, 1987.
2. Ventsel, E., and Krauthammer, T., Thin plates and shells, Theory, Analysis and Applications, Marcel Dekker, Inc, New York, 2001.
3. Szilard, R., Theory and Analysis of Plates – Classical Numerical Methods, Prentice Hall Inc., 1974.
4. Bairagi, N.K., Plate Analysis, Khanna Publishers, New Delhi, 1986.
5. Gould, P.L., Analysis of Shells and Plates, Springer-Verlag, New York, 1988.

CE6113E ADVANCED THEORY AND DESIGN OF METAL STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To analyze and design steel structures by plastic LRFD design concepts.
CO2: To analyze and design steel structures for fatigue and fire loads.
CO3: To analyze and design connections in steel structures.
CO4: To analyze and design light gauge steel structures.
CO5: To analyze and design steel industrial and moment resisting frames.

Plastic methods of analysis

Plastic methods of analysis and design: Plastic behavior under static and cyclic loading - Static, kinematic and uniqueness theorems - Shape factors - moment redistribution - Analysis of single and two bay portal frames.

LRFD Approach: Plastic design with LRFD concepts - LRFD with elastic analysis - Current and future design philosophies.

Fatigue in steel structures – Introduction – Design and Detail category – Fatigue strength -Fatigue assessment.

Fire loads in steel structures - Fire-resistant design – Fire resistance level – Period of Structural adequacy – Variation of Mechanical properties of steel with temperature – Limiting steel temperature – Fire protected and Unprotected steel members analysis – Fire resistance rating of steel members.

Bolted and Welded Connections

Classification (Simple, Rigid, Semi rigid) of connections and Moment rotation characteristics - Failure modes of a joint - Types of bolts - Bearing and High strength bolts- Prying force.

Beam to Column bolted connections - Design of seat angle - Unstiffened and Stiffened - Web angle & end plate connections – Moment resistant connection - Beam and column bolted splices - Design of framed beam connection – Continuous beam to beam connection.

Beam to column welded connections - Stiffened beam seat connection - Moment resistant joint - Beam and column welded splices - Tubular connections - Parameters of an in-plane joint - Hotspots - Welds in tubular joints - Curved weld length at intersection of tubes - SHS and RHS tubes - design parameters - Advance types of welded connections.

Light Gauge Structures

Design of light gauge steel structures: Introduction – Types of cross sections – Materials - Local and post buckling of thin elements - Stiffened and multiple stiffened compression elements - Tension members - Beams and deflection of beams - Combined stresses and connections.

Steel Building Frames

Design of industrial buildings: Design of members subjected to lateral loads and axial loads - Sway and non-sway frames, bracings and bents - Rigid frame joints - Knees for rectangular frames and pitched roofs - Knees with curved flanges - Valley joints - Rigid joints in multi-storey buildings - Vierendeel girders.

Special steel moment resisting frames – Basic capacity deigns approach – Beams, columns and connection panel design – P-Delta stability of moment resisting frames.

References:

1. Gaylord, Design of Steel Structures, McGraw Hill, New York.
2. Subramanian, N., Design of Steel Structures, Oxford.
3. Wie-Wen, Yu, Cold-Formed Steel Structures, McGraw Hill Book Company.
4. Chen, W.F., and Toma, S., Advanced Analysis of Steel Frames, CRC Press.
5. Bruneau,M., Uang C.M., and Sabelli, R., Ductile Design of Steel Structures, McGraw Hill, New York.

CE6192E STRUCTURAL ENGINEERING DESIGN STUDIO

Pre-requisite: Nil

L	T	P	O	C
0	0	2	1	1

Total Practical sessions: 26

Course Outcomes:

CO1: Use latest analysis and design tools and softwares.
CO2: Carry out practical design of a typical RC residential building, multi-storeyed building, overhead water tanks, and ribbed floor systems.
CO3: Perform practical design of steel industrial building, steel bridges, storage structures and steel towers.

Introduction to Engineering Software: General purpose packages in Civil Engineering.

Concrete Structures: Analysis, design and detailing of solid slabs, beams columns and foundation in a typical residential building — Typical intermediate floor of a multi-storey building — Overhead water tank and — Ribbed slab floor system — Analysis, design and detailing for seismic forces.

Metal Structures: Design and detailing of steel industrial building, steel bridges, storage structures, towers.

References:

1. Arthur. H. Nilson, David Darwin and Charles W Dolan, Design of Concrete Structures, Tata McGraw Hill, 2004.
2. Park,R and Paulay T, Reinforced Concrete Structures, John Wiley & Sons, New York, 1975.
3. Pankaj Agarwal and Manish Shrikhande, Earthquake Resistant Design of Structures, Prentice Hall of India (P) Ltd., 2008
4. IS 456 :2000, Indian Standard for Plain and Reinforced Concrete- Code of Practice, BIS, New Delhi.
5. SP:16, Design Aids for Reinforced Concrete to IS 456:2000, BIS, New Delhi.
6. SP: 34, Handbook on Concrete Reinforcement and Detailing, BIS, New Delhi.
7. IS 1893 (Part 1):2016 Indian Standard Criteria for Earthquake Resistant design of Structures, BIS, New Delhi.
8. IS 13920: 1993, Indian Standard for Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces - Code of Practice, BIS, New Delhi.
9. IS 800:2007, Indian Standard General Construction in Steel – Code of Practice, BIS, New Delhi.
10. Dayaratnam, P., Design of Steel Structures, Wheeler Pub., 2012.

CE6196E PROJECT PHASE I

Pre-requisite: Nil

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Identify a relevant problem, carry out literature review and identify the research gaps
CO2: Propose a methodology for solving the problem
CO3: Document and present the work done

The primary objective of the course 'Project Phase I' is to introduce the students to the various areas of research in Structural Engineering. The students will identify a problem, carry out a systematic and exhaustive literature review and identify the research gaps. The students will propose a methodology for solving the identified problem and will also document their work and make a presentation before the designated "Evaluation Committee".

CE7197E PROJECT PHASE II

Pre-requisite: Nil

L	T	P	O	C
0	0	0	*	3

CO1: Identify a relevant problem, carry out literature review and identify the research gaps
CO2: Propose a methodology for solving the problemessions
CO3: Document and present the work done

The student will identify a relevant problem in the broad area of Structural Engineering and work on it. The study could be experimental, analytical, or computational. The students will document their work and make a presentation before the designated "Evaluation Committee" after their internship. This applies to all students who take this up as an internship in industry/ company/ institute.

(Course outcomes may be changed depending on the actual work performed during the internship.)

CE7198E PROJECT PHASE III

Pre-requisite: Nil

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Demonstrate theoretical and research skills to become independent researchers with high ethical values
CO2: Demonstrate a degree of originality in research emphasizing the concept of sustainability
CO3: Develop professional documentation and presentation skills

The student will identify a relevant problem in the broad area of Structural Engineering and work on it. The study could be experimental, analytical, or computational. The students will also document their work and make a presentation before the designated "Evaluation Committee". This applies to all students who take this up as an internship in industry/ company/ institute.

(Course outcomes may be changed depending on the actual work performed during the internship.)

CE7199E PROJECT PHASE IV

Pre-requisite: Nil

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

Students will be able to

CO1: Develop theoretical and research skills to become independent researchers with high ethical values
CO2: Demonstrate a degree of originality in research emphasizing the concept of sustainability.
CO3: Develop professional documentation and presentation skills.

The primary objective of the course 'Project Phase IV' is to introduce the students to various sub-fields in Structural Engineering. It is aimed at exposing the students to current development and research activities in the above-mentioned fields. The students are also trained to gather in-depth information on specified areas or topics and to solve a research problem independently. The students are made proficient to make proper technical documentation on the selected topic. The course also provides training to students to make effective technical presentations.

CE6121E STRUCTURAL OPTIMISATION

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To exploit the available limited resources in a manner that maximizes output and the structural performance in a way that economises energy or minimise discomfort.
CO2: To select the best structural design from the large number of feasible designs in terms of minimum cost, minimum weight or maximum performance or combinations of these.
CO3: To analyse structures using optimisation techniques which replaces the time consuming and costly design iterations and hence reduces design development time and overall cost while improving design performance.

Introduction: Structural optimisation problem formulation with examples.
Single Variable Unconstrained Optimisation Techniques – Optimality criteria
Bracketing methods: Unrestricted search, Exhaustive search
Region elimination methods: Interval Halving methods, Dichotomous search, Fibonacci method, Golden section method.
Interpolation methods: Quadratic Interpolation method, Cubic Interpolation method.
Gradient Based methods: Newton-Raphson method, Secant method, Bisection method.

Multi Variable Unconstrained Optimisation Techniques – Optimality Criteria - Unidirectional Search Direct Search methods: Random search, Grid search, Univariate method, Hooke’s and Jeeves’ pattern search method, Powell’s conjugate direction method, Simplex method.
Gradient based methods: Cauchy’s (steepest descent) method, Conjugate gradient (Fletcher Reeves) method, Newton’s method, Variable metric (DFP) method, BFGS method.

Constrained Optimisation Techniques
Classical methods: Direct Substitution method, constrained variation method, method of Lagrange multipliers, Kuhn-Tucker conditions.
Linear programming problem: Standard form, Simplex method.
Indirect methods: Elimination of constraints, Transformation techniques, Penalty function method.
Direct methods: Zoutendijk’s method of feasible direction, Rosen’s gradient projection method.

Specialized Optimisation techniques: Dynamic programming, Geometric programming, Genetic algorithms.

References:

1. Rao S. S., Engineering Optimisation – Theory and Practice, John Wiley & Sons, Inc., New Jersey, 2009.
2. Deb, K.., Optimisation for Engineering Design – Algorithms and Examples, Second edition, PHI Learning Pvt. Ltd., New Delhi, 2012.
3. Kirsch, U., Optimum Structural Design – Concepts, Methods and Applications, McGraw-Hill, New York, 1981.
4. Arora J. S., Introduction to Optimum Design, Fourth edition, Academic Press Inc., 2016.
5. Spillers, W.R., and MacBain, K.M., Structural Optimisation, Springer, New York, 2009.
6. Christensen, P.W., and Klarbring, A., An Introduction to Structural Optimisation, Springer, New York, 2009.

CE6122E MODELLING, SIMULATION AND COMPUTER APPLICATIONS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the role of computational modeling as a solution for various applications.
CO2: Fundamentals of deterministic and probabilistic simulations.
CO3: Basics of data generation, analysis and computing.
CO4: Introduction to algorithms and coding.

Numerical Solution of Nonlinear Equations

Algebraic equations – Secant, fixed point iteration, Newton-Raphson, differential equations – initial and boundary value problems - Euler's methods, Runge-Kutta methods, predictor-corrector methods, Wilson theta, HHT-α methods, finite difference, numerical integration - trapezoidal rule, Simpson's rule, quadrature.

Matrix algebra

Matrix operations, Gaussian elimination, Gauss-Jordan elimination, matrix inversion, singular value decomposition, LU decomposition, Eigenvalues, Eigenvectors, introduction to parallel computing.

Stochastic modeling and simulation

Probability preliminaries, random variables and random processes, Monte Carlo simulations - random number generation, Gaussian and non-Gaussian random process simulation, variance reduction, statistics - sampling distributions, point estimation, hypothesis testing, maximum likelihood estimation.

Machine learning

Supervised machine learning - regression and classification, machine learning algorithms - linear and logistic regression, decision trees, support vector machines, random forest, gradient boosting techniques, neural networks - multilayer perceptron, backpropagation, convolutional neural networks, introduction to deep learning.

References:

1. Chopra, S.C., and Raymond, P.C., Numerical methods for engineers, Eighth edition, McGraw-Hill, New Delhi, 2021.
2. Strang, G., Introduction to linear algebra, Sixth edition, Wellesley-Cambridge Press, Wellesley 2023.
3. Rubinstein, R.Y., and Kroese, D.P., Simulation and the Monte Carlo method, Third edition, John Wiley & Sons, Inc., New Jersey, 2017.
4. Bishop, C.M., Pattern recognition and machine learning, Springer, New York, 2006.

CE6123E EARTHQUAKE ANALYSIS AND DESIGN OF STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To assess the need for seismic analysis for a given Civil Engineering structural system.
CO2: To perform seismic analysis of a structure.
CO3: To carry out seismic design and detailing of different types of structure as per latest IS code of practice.

Introduction to engineering seismology: Causes of earthquakes - seismic waves – body and surface waves- measurement of an earthquake – magnitude and intensity of earthquake - response of structure to earthquake motion - seismic zoning map of India - response spectrum of earthquake.

Concept of seismic design : Approach to earthquake resistant design – general principles of a seismic design – relevant IS codes – design earthquake loads - load combinations and permissible stresses - equivalent static analysis – vertical distribution of seismic forces and horizontal shears, dynamic analysis – design spectrums – seismic weights – modal combination – load combinations and permissible stresses – guidelines for earthquake resistant design – ductile detailing for seismic design - improving seismic behaviour of masonry, timber and steel buildings.

Seismic design of water tanks – elevated tower supported tanks- hydrodynamic pressure in tanks – examples - seismic design of towers – stack like structures – chimneys.

Seismic design principles of retaining walls – concept of seismic design of bridges – seismic design of bearings, seismic control of structures : base isolation- tuned mass dampers.

References:

1. Agarwal, P., and Shirkhande, M., Earthquake Resistant Design of structures, Prentice-Hall of India, 2006.
2. Duggal, S. K., Earthquake Resistant Design of structures, Oxford University Press, 2007.
3. Datta, T.K., Seismic Analysis of Structures, John Wiley and sons (Asia) Pvt Ltd, 2010.
4. Brijesh, C.,Chandasekaran, Krishna Jai, A.R., Elements of Earthquake Engineering, South Asian Publishers Pvt.Ltd, 1994.
5. Gupta, A., Response Spectrum Method in Seismic Analysis and Design of Structures, CRC press, INC, 1992.
6. Relevant latest BIS Codes (IS: 1893, IS: 4326, SP:22, IS:13920).

CE6124E NONLINEAR ANALYSIS OF STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Solve nonlinear equations encountered in structural mechanics
CO2: Perform geometric nonlinear analysis on pin-jointed and rigid jointed framed structures
CO3: Perform sectional analysis on reinforced concrete, masonry and steel elements
CO4: Perform material nonlinear analysis on pin-jointed and rigid-jointed framed structures
CO5: Perform nonlinear static and dynamic analysis of structures using state-of-the-art software packages

Fundamentals

Review of classical matrix analysis – Local and Global coordinates – Transformation matrix – Flexibility method – Stiffness method – Direct stiffness method – Shear deformation – Timoshenko beam element – Torsional Deformations – Constraint Equations – Rigid Diaphragms and Rigid Links.

Sources of Nonlinearity in Structural Analysis – Geometric nonlinearity, Material nonlinearity, Force nonlinearity and Kinetic nonlinearity – Levels of structural analysis (First order – elastic, First order - inelastic, Second order – elastic and Second order – inelastic).

Solution procedures for nonlinear algebraic and transcendental equations – numerical solution of nonlinear differential equations- Explicit and Implicit methods.

Geometric Nonlinearity

Second order structural analysis – Concept of 'Instability' – P-Δ effect - Critical load for beam-columns and frames using equilibrium, energy and numerical methods – Effect of axial force on bending stiffness - Stability Functions – Matrix formulation - Geometric stiffness matrix - Effect of bending on axial stiffness – Second Order Effects in structures – Design guidelines.

Force-Displacement relationship - Tangent stiffness matrix – Solution of nonlinear equilibrium equations – Incremental single-step methods – Incremental iterative methods - Load control, Displacement control, Work control, Arc-length control – Convergence criteria.

Material Nonlinearity

Elastic versus Inelastic behaviour – Uniaxial material models – Confinement effects - Behaviour of steel, concrete and masonry under cyclic loading – History dependence – Hysteresis rules - Lumped plasticity versus Distributed plasticity modelling - Moment hinges and Shear hinges - Sectional Analysis – Moment curvature relationship – Lateral load behaviour of masonry structures and V-N interaction – P-M interaction curves– Fiber sections - Material nonlinear analysis of pin-jointed and rigid-jointed frames – Equivalent frame analysis of masonry structures - Limit analysis – Moment redistribution.

Nonlinear Static and Dynamic Analysis

Performance based analysis and design - Static Pushover Analysis – Background to Multi-modal and Adaptive pushover analysis - Nonlinear Time History Analysis – Numerical evaluation of nonlinear dynamic response – Software packages.

Hands on project implementing nonlinear static and nonlinear dynamic analysis.

References:

1. McGuire, W., Gallagher, R.H., and Ziemian, R.D., Matrix structural analysis, Wiley, 2015.
2. Kim, N.H., Introduction to nonlinear finite element analysis, Springer, 2018.
3. Chen, W.F., and Lui, E.M., Structural stability: Theory and implementation, Prentice Hall, 1993.
4. Ghali, A., and Neville, A.M., Structural analysis: A unified classical and matrix approach, CRC Press, Taylor & Francis Group, 2017.
5. Kassimali, A., Matrix analysis of structures, Cengage, 2022.
6. Menon, D., Advanced structural analysis, Alpha Science International Ltd., 2009.
7. Tomaževič, M., Earthquake resistant design of masonry buildings, Imperial College Press, 2006.
8. Majid, K.I., Nonlinear Structures, John Wiley and Sons, 1972.
9. Powell, G.H., Modeling for Structural Analysis, Computers and Structures, 2010.
10. Deierlein, G.G., Reinhorn, A.M., and Willford, M.R., Nonlinear Structural Analysis for Seismic Design (NIST GCR 10-917-5), National Institute of Standards and Technology, California; 2010.

CE6125E BRIDGE ENGINEERING

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Decide the structural form for a bridge depending on the functional requirements and site conditions. Identify various structural components of the chosen bridge form.
CO2: Design various components of bridges based on relevant IRC and Indian railway loading standards.
CO3: Understand the design principles of long span bridges.
CO4: Design bearings, piers and abutments for bridges.

Introduction

Introduction–classification and components of bridges - layout and planning - Structural forms of bridge decks - grillage analysis of slab decks, beam and slab decks, cellular decks.

Design standard for bridges

Standard specifications for bridges - IRC loadings for road bridges - standards for railway bridges - design of RC slab, skew slab and box culverts. Design of T beam bridges - balanced cantilever bridges - rigid frame bridges - Arch bridges - bow string girder bridges.

Design of plate girder bridges, peirs and abutments

Design of plate girder bridges - steel trussed bridges - Introduction to long span bridges: cable stayed bridges and suspension bridges - instability.
Forces on piers and abutments - Design of piers and abutments - types of wing walls - types of bearings - design of bearings.

References:

1. E.C. Hambly, Bridge deck behaviour, Taylor & Francis, London, 1976.
2. P. Nagarajan, Design of Concrete Bridges, Wiley Publications, 2020.
3. E.J. O'Brien and D.L. Keogh, Bridge deck analysis, E& FN Spon, New York , 1999.
4. D.Johnson Victor, Essentials of bridge engineering, Oxford & IBH publishing Co. Ltd., New Delhi, 2001.
5. N.Krishna Raju, Design of bridges, Oxford & IBH publishing Co. Ltd., New Delhi, 2009.
6. Jaikrishna and O.P Jain, Plain and reinforced concrete-vol.II, Nemchand & Bros,Roorkee, 2007.
7. Relevant IRC and IRS codes.

CE6126E CONTRUCTION PROJECT MANAGEMENT

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire knowledge in modern trends in management
CO2: Understand Network techniques like bar charts, CPM and PERT and the use of Management softwares
CO3: Apply optimisation techniques to materials management and work assignment problems
CO4: Perform budget estimation and the use of cost control techniques. Use computer aided cost estimation

Introduction to the Project Management

Project Management - Trends in Modern Management - Strategic Planning and Project Programming - Effects of Project Risks on Organization - Organization of Project Participants - Traditional Designer-Constructor Sequence - Professional Construction Management - Owner-Builder Operation - Turnkey Operation - Leadership and Motivation for the Project Team - Interpersonal Behavior in Project Organizations - Perceptions of Owners and Contractors

Quality and Safety Concerns in Construction - Organizing for Quality and Safety - Work and Material Specifications - Total Quality Control - Quality Control by Statistical Methods - Statistical Quality Control with Sampling by Attributes - Statistical Quality Control with Sampling by Variables – Safety

Network techniques

Network techniques: Bar charts – Critical path method – Programme evaluation and review technique – Time estimates- uncertainties of time - time computations – monitoring of projects – updating - Crashing and time-cost tradeoff

PERT and CPM-Software Development - Use of Management Software.

Optimisation techniques

Optimisation techniques: Resource allocation – Heuristic approach - Linear programming – Graphical and Simplex methods – Optimality Analysis - Material transportation and Work assignment problems

Materials management: planning and budgeting – inventory control – management of surplus materials - equipment control

Process control: Work study- crew size – job layout- process operation.

The Cost Control Problem

The Cost Control Problem - The Project Budget - Forecasting for Activity Cost Control - Financial Accounting Systems and Cost Accounts - Control of Project Cash Flows - Schedule Control - Schedule and Budget Updates - Relating Cost and Schedule Information.
Costs Associated with Constructed Facilities - Approaches to Cost Estimation - Type of Construction Cost Estimates - Effects of Scale on Construction Cost - Unit Cost Method of Estimation - Methods for Allocation of Joint Costs - Historical Cost Data - Cost Indices - Applications of Cost Indices to Estimating - Estimate Based on Engineer's List of Quantities - Allocation of Construction Costs Over Time - Computer Aided Cost Estimation - Estimation of Operating Costs.

References:

1. Chitkara, K.K. Construction Project Management: Planning, Scheduling and Control, Tata McGraw-Hill Publishing Company, New Delhi, 1998.
2. Feigenbaum., L., "Construction Scheduling With Primavera Project Planner", Prentice Hall Inc., 1999.
3. Halpin, D. W., Financial and Cost Concepts for Construction Management, John Wiley & Sons, New York, 1985.
4. Choudhury, S, Project Management, Tata McGraw-Hill Publishing Company, New Delhi, 1988.
5. A.K Datta, Materials Management , Prentice Hall , India, 1984.
6. Arnold, J.R Tony, Introduction to Materials Management, Prentice Hall, India, 2007
7. Joy, P.K., Total Project Management – The Indian Context, Macmillan India Ltd., New Delhi, 1992.

CE6127E FORENSIC ENGINEERING AND REHABILITATION OF STRUCTURES

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

Students will be able to
CO1: To understand the design and environmental factors leads to the failure of structures.
CO2: To assess the distress in structural members and identify the causes for the failures
CO3: To familiarize the modern techniques to repair and strengthen the structural members

Defects and failure of structures

Causes of distress in concrete structures – Design and construction errors – Durability of RCC structures – Effects due to climate, fire, chemicals, wear and erosion – Corrosion of rebars – Damage due to earthquake – Provisions in IS 1893 and IS 4326 – Types of cracks – Learning from failures – Case studies

Condition assessment and NDT methods

Diagnosis and Assessment of Distress: Preliminary inspection, planning stage, visual inspection, field and laboratory testing stage – Load test for Stability – non-destructive tests: ultrasonic pulse velocity method, rebound hammer technique, penetration resistance, pull out tests, core sampling and testing – Crack detection techniques – Chemical tests: carbonation and chloride tests – Corrosion potential assessment, cover meter survey, resistivity measurement – Identification and estimation of damage, structural integrity and soundness assessment, interpretation and evaluation of results – consideration for repair strategy – Case studies of RCC buildings subjected to distress

Repair materials and methods

Essential parameters for repair materials: Premixed cement concrete and mortars, polymer modified mortars and concrete, epoxy and epoxy systems, Rust eliminators, polymer concrete system – Repair to active and dormant cracks: grouting, routing and sealing, stitching, slurry injection, gunite, shortcrete, vacuum concrete – Repair and strengthening of various damaged structural elements (slab, beam, and columns): reinforcement replacement, plate bonding technique, ferrocement jacketing, RCC jacketing, internal and external pre-stressing, fiber wrap technique – Underwater repair – Chemical and electrochemical method of repair– Cathodic protection – Case studies

References:

1. ACI 546R-14, Guide to Concrete Repair, American Concrete Institute, 2014
2. ACI PRC-364.4-21: Determining the Load Capacity of a Structure when Structural Drawings are Unavailable – TechNote, American Concrete Institute, 2021
3. Concrete Repair and Maintenance Illustrated: Problem Analysis; Repair Strategy; Techniques by Peter. H. Emmons, Galgotia publications Pvt. Ltd., 2002.
4. Concrete Structures: Protection, Repair and Rehabilitation, R.Dodge Woodson, Elsevier, 2009.
5. Construction Failures, Jacob Feld and Kenneth L Carper, Wiley Europe, 1997
6. CPWD Handbook on Repair and Rehabilitation of RCC buildings, Jain Book Agency, 2011.
7. Design and Construction Failures, Dov Kaminetzky, Galgotia Publication, New Delhi,2001
8. Diagnosis and treatment of structures in distress by R. N. Raikar, Published by R&D Centre of Structural Designers & Consultants Pvt. Ltd., Mumbai, 1994.
9. Handbook on seismic retrofit of buildings, A. Chakrabarti et.al., Narosa Publishing House, 2008.

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CE6128E ANALYTICAL DYNAMICS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate problems of dynamics using differential equation approach and variational approach.
CO2: Solve engineering problems that can act as benchmark solutions for testing computational methods and software.
CO3: Appreciate energy theorems and variational principles of mechanics in theory and in dealing with real-life problems.
CO4: Formulate numerical solutions to mechanics problems based on variational formulations

Fundamentals of Newtonian mechanics: Newton's laws, impulse and momentum, angular momentum, work and energy, systems of particles. Fundamentals of Analytical Mechanics: Degrees of freedom, generalised coordinates, systems with constraints, stationary value of a definite integral, principle of virtual work, D'Alembert's principle, Hamilton's principle, Lagrange's equations of motion, Lagrange's equations for impulsive forces, conservation laws, Routh's method for the ignoration of coordinates, Rayleigh's dissipation function, Hamilton's equations.

Motion relative to rotating reference frames: Transformation of coordinates, rotating coordinate systems, moving references.

Rigid body dynamics: Kinematics of a rigid body, linear and angular momentum of a rigid body, translation theorem for angular momentum, kinetic energy of a rigid body, Euler's equations of motion, Euler's angles, moment-free inertially symmetric body, general case of moment-free body, symmetric top, equations of motion referred to arbitrary system of axes.

Behaviour of dynamical systems: Motion of single degree of freedom autonomous systems about equilibrium points, limit cycle, stability of linear multi-degree of freedom autonomous systems, Routh-Hurwitz criterion, Liapunov direct method, geometric interpretation, construction of Liapunov function. Introduction to Advanced Topics: Introduction to the following topics: non-autonomous systems, perturbation techniques, transformation theory, Hamilton-Jacobi equation.

References:

1. Meirovitch, L., Methods of analytical dynamics, Dover Publications, New York, 2003.
2. Goldstein, H., Poole, C.P., and Safko, J., Classical mechanics, Third edition, Pearson Education Limited, Noida, 2011.
3. Torok, J.S., Analytical mechanics with an introduction to dynamical systems, John Wiley & Sons, Inc., New York, 2000.
4. Baruh, H., Analytical dynamics, McGraw-Hill, New York, 1999.
5. Greenwood, D.T., Classical dynamics, Dover Publications, Inc., New York, 1997.

CE6129E TALL STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand design philosophy and different systems adopted for tall structures
CO2: Carry out analysis of tall structures, both by approximate and accurate methods
CO3: Understand various serviceability conditions and effect of other secondary effects like creep, shrinkage, temperature
CO4: Apply the stability aspects in the analysis and design of tall structures

Design philosophy- materials- loading- Gravity loading- Wind loading- Earthquake loading-blast loading.

Behaviour of various structural systems- factors affecting growth, height and structural form- High rise behaviour, rigid frames, braced frames, infilled frames, shear walls, coupled shear walls, wall frames, tubulars, cores, futrigger-braced and hybrid mega system.

Analysis and design :- modeling for approximate analysis, Accurate analysis and reduction techniques. Analysis of building as total structural systems considering overall integrity and major subsystem interaction, Analysis for member forces, drift and twist, computerized general three dimensional analysis- Shear wall frame interaction.
Structural elements :- Sectional shapes, properties and resisting capacity, deflection, cracking. Prestressing, design for differential movement, creep, and shrinkage effects, temperature effects and fire resistance.

Stability of tall buildings
Overall buckling analysis of frames- P- Delta analysis- Translational, torsional instability, out of plumb effects, effect of foundation rotation

References:

1. Taranath , B.S., Structural Analysis and design of Tall Building, Tata McGraw Hill., 1988.
2. Wilf gang Schuller, High Rise Building Structures, John Wiley and Sons, 1977.
3. Lynn S. Beedle, Advances in Tall Buildings, CBS Publishers and Distributers, Delhi, 1981.
4. Brayan Stafford Smith, Alexcoull, Tall Building Structures, Analysis and Design,, John Wiley and Sons, 1991

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CE6130E STRUCTURAL HEALTH MONITORING

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand systems and sensors for health monitoring of structures
CO2: Gain knowledge of the static and dynamic measurement techniques
CO3: Carry out different damage detection techniques for health monitoring of structures
CO4: Use the IoT and machine learning concepts for health monitoring of structures

Introduction to structural health monitoring (SHM)

Need for Structural Health Monitoring, Structural Health Monitoring versus Non-Destructive Evaluation, Methods of SHM, Local & Global Techniques for SHM, Short & Long-Term Monitoring, Active & Passive Monitoring, - Challenges in SHM - Remote Structural Health Monitoring – Importance and Advantages – Methodology – IoT applications in SHM – Application Machine leaning Techniques in SHM.

Sensors and instrumentation for SHM

Sensors for measurements: Electrical Resistance Strain Gages, Vibrating Wire Strain Gauges, Fiber Optic Sensors, Temperature Sensors, Accelerometers, Displacement Transducers, Load Cells, Humidity Sensors, Crack Propagation Measuring Sensors, Corrosion Monitoring Sensors, Pressure Sensors, Acoustic emission sensors, ultrasonic sensors, piezoceramic sensors and actuators, fiber optic sensors and laser shearography techniques, imaging techniques – Data Acquisition Systems – Data Transmission – Data Processing – Storage of processed data – Knowledgeable information processing

Measurement and damage detection techniques

Static measurement: Load test, concrete core trepanning, flat jack techniques, static response measurement – Dynamic measurement: vibration-based testing – ambient excitation methods, measured forced vibration – impact excitation, step relaxation test, shaker excitation method – Damage diagnostic methods based on vibrational response and wave propagation – Neural network-based classification techniques- Extraction of features from measurements, training and simulation techniques, connectionist algorithms for anomaly detection, multiple damage detection

Data processing and case studies

Review of Signals – Advanced signal processing methods – Wavelet, Hilbert-Huang transform, Practical aspects of testing large bridges for structural assessment – Optimal placement of sensors – Structural integrity and condition monitoring of aging multistorey buildings.

References:

1. Daniel Balageas, Peter Fritzen, Alfredo Guemes, Structural Health Monitoring, John Wiley & Sons, 2006.
2. Douglas E Adams, Health Monitoring of Structural Materials and Components Methods with Applications, Wiley Publishers, 2007
3. Hua-Peng Chen, Structural Health Monitoring of Large Civil Engineering Structures, Wiley Publishers, 2018
4. Ansari, F Karbhari, Structural health monitoring of civil infrastructure systems, V.M. Woodhead Publishing, 2009
5. J. P. Ou, H. Li and Z. D, “Duan Structural Health Monitoring and Intelligent Infrastructure”, Vol1, Taylor and Francis Group, London, UK, 2006.
6. Victor Giurglutiu, “Structural Health Monitoring with Wafer Active Sensors”, Academic Press Inc, 2007.

CE6131E STRUCTURAL RELIABILITY

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify deterministic and random variables associated with structures and quantify the degree of randomness
CO2: Perform reliability analysis for basic structural elements under different safety criterion
CO3: Develop reliability based design criteria of any structure and determine optimal safety factors
CO4: Perform system reliability analysis of simple structures

Concepts of structural safety
Basic Statistics:- Introduction, data reduction
Probability theory: Introduction, random events, random variables, functions of random variables, moments and expectation, common probability distributions.

Resistance distributions and parameters: - Introduction, Statistics of properties of concrete, steel and other building materials, statistics of dimensional variations, characterization of variables, allowable stresses based on specified reliability.
Probabilistic analysis of loads: gravity loads, wind loads

Basic structural reliability:- Introduction, computation of structural reliability.
Level 2 Reliability methods: Introduction, basic variables and failure surface, first order second moment methods (FOSM)
Reliability based design: Introduction, determination of partial safety factors, development of reliability based design criteria, optimal safety factors

Monte Carlo study of structural safety: -General, Monte Carlo method, applications
Reliability of Structural system: Introduction, system reliability, modelling of structural systems, bounds of system reliability, reliability analysis of frames

References:

1. R. Ranganathan., Reliability Analysis and Design of Structures, Tata McGraw Hill, 1990.
2. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. I Basic Principles, John Wiley & Sons, 1975.
3. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. II Decision, Risks and Reliability, John Wiley & Sons, 1984.
4. Jack R. Benjamin & C. Allin Cornell., Probability, Statistics and Decision for Engineers, McGraw-Hill, 2014
5. H. O. Madsen, S. Krenk& N. C. Lind, Methods of Structural Safety, Prentice-Hall, 1986.
6. R. E. Melchers. Structural Reliability - Analysis and prediction, Ellis Horwood Ltd, 1987.

CE6132E CONCRETE SHELLS AND FOLDED PLATES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design shell structures using simplified approaches.
CO2: Analyse and design special structures such as cooling towers and hyperbolic shells.
CO3: Analyse and design folded plate structures with the help of simplified methodologies
CO4: Confidently design special structures using shells and folded plates combining aesthetics and cost effectiveness.

Introduction- Classification of shells-General specification of shells- Analysis of shells- Membrane theory of cylindrical shells, perturbational stresses- bending theory, Design of cylindrical shell- Beam method- ASCE manual 31 method.

Hyperboloid of revolution-hyperbolic shells-analysis of membrane forces- design of hyperbolic cooing towers.

Hyperbolic paraboloid – general features – geometry of hyper shell-analysis of membrane forces- design of hyperbolic paraboloid roofs – pre-stressed concrete shells.

General features- types- structural behaviour of folded plates- analysis of folded plates- ASCE task committee method- Whitney’s method- Simpson’s method- iteration method- beam method- design of folded plates- pre-stressed folded plates.

Note: Each student shall submit a term project.

References:

1. Kelkar.V.S and Sewell R.T, Fundamentals of the Analysis and Design of Shell Structures, Prentice Hall, Inc., 1987.
2. Billington,D.P, Thin Shell Concrete Structures, McGraw Hill Book Co., 1982.
3. Gibson, J.E, Linear Elastic Theory of Thin Shells, Pergamon Press, 1965.
4. Hass.M, Design of Thin concrete Shells (vol.I&II). John Wiley and Sons Inc., 1962.
5. Ramaswamy,G.S, Design and Construction of Concrete Shell Roofs, Tata – McGraw Hill Book Co.Ltd., 1971.
6. Design of cylindrical Concrete Shell Roofs (ASCE manual 31), Committee on masonry and reinforced concrete of the structural division.

CE6133E RANDOM VIBRATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	0	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Distinguish deterministic and random variables associated with structural analysis and response.
CO2: Quantify the randomness or uncertainties in the variables associated with structural analysis and response.
CO3: Model different physical phenomena by appropriate stochastic processes.
CO4: Apply the various mathematical theories associated with stochastic processes representing various natural phenomena to find important properties that are useful at design stage.

Basic Theory of Stochastic Processes (A review)

Basic Theory of Stochastic Processes (A review): Introduction, statistics of stochastic processes, ergodic processes, some properties of the correlation functions, spectral analysis, Wiener-Khintchine equation.

Stochastic Response of Linear SDOF Systems

Deterministic dynamics, evaluation of impulse response function and frequency response function, impulse response function and frequency response function as Fourier Transform pairs, stochastic dynamics, response to stationary excitation, time domain analysis, frequency domain analysis, level crossing, peak, first passage time and other characteristics of the response of SDOF Systems.

Linear systems with multiple inputs and outputs

Linear systems with multiple inputs and outputs: Linear MDOF Systems, uncoupled modes of MDOF systems, stochastic response of linear MDOF Systems – time domain and frequency analysis. Stochastic response of linear continuous system.

Response of non-linear systems to random excitation

Response of non-linear systems to random excitation: Approach to problems, Fokker-Plank equation, statistical linearization, perturbation and Markov Vector Methods. Fatigue damage of structure due to random loads.

References:

1. Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA, 1983.
2. Loren D Lutes & Shahram Sarkani., Stochastic Analysis of Structural and Mechanical Vibrations, Prentice Hall, NJ, 1997.
3. J Solnes, Stochastic Processes & Random Vibration, Theory and Practice, John Wiley,1997
4. Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill, 1967.
5. Bendat & Piesol., Random Data Analysis and Measurement Procedure, John Wiley, 1991.
6. Meirovitch, L., Elements of Vibration Analysis, McGraw Hill, 1986.
7. Papoulis, A., Probability, Random Variables and Stochastic Processes, McGraw Hill, 1991.
8. Ray W Clough & Joseph Penzien. Dynamics of Structures, McGraw Hill, 1993.

CE6134E ENGINEERING FRACTURE MECHANICS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Solve problems of fracture mechanics using Energy approach, SIF, J-integral approach and COD approach.
CO2: Determine fracture toughness experimentally.
CO3: Analyse problems involving fatigue.
CO4: Solve practical problems using the concepts of fracture mechanics.

Introduction

Introduction: Significance of fracture mechanics - Griffith energy balance approach - Irwin’s modification to Griffith theory - stress intensity approach - crack tip plasticity - fracture toughness -subcritical crack growth - influence of material behavior - I, II &III modes - mixed mode problems.

Linear Elastic Fracture Mechanics (LEFM): Elastic stress field approach - mode I elastic stress field equations - expressions for stresses and strains in the crack tip region - finite specimen width - superposition of stress intensity factors (SIF) - SIF solutions for well known problems such as centre cracked plate - single edge notched plate and embedded elliptical cracks.

Crack tip Plasticity: Irwin plastic zone size - Dugdale approach - shape of plastic zone - state of stress in the crack tip region - influence of stress state on fracture behavior.

Energy balance approach and Elastic Plastic fracture mechanism

Energy Balance Approach: Griffith energy balance approach – relations for practical use determination of SIF from compliance – slow stable crack growth and R-curve concept – description of crack resistance.

LEFM Testing: Plane strain and plane stress fracture toughness testing - determination of R-curves -effects of yield strength and specimen thickness on fracture toughness - practical use of fracture toughness and R-curve data.

Elastic Plastic Fracture Mechanics (EPFM): Development of EPFM, J-integral - crack opening displacement (COD) approach - COD design curve - relation between J and COD - Tearing modulus concept - Standard JICtest and COD test.

Fatigue crack growth mechanism

Fatigue Crack Growth:Description of fatigue crack growth using stress intensity factor – effects of stress ratio and crack tip plasticity – crack closure, prediction of fatigue crack growth under constant amplitude and variable amplitude loading – fatigue crack growth fromnotches – the short crack problem.

Sustained Load Fracture: Time-to-failure (TTF) tests – crack growth rate testing –experimental problems – method of predicting failure of a structural component – practical significance of sustained load fracture testing .

Practical Problems: through cracks emanating from holes – corner cracks at holes – cracks approaching holes – fracture toughness of weldments.

References:

1. Kumar, P. Elements of Fracture Mechanics, Tata McGraw Hill, 2009.
2. Maiti, S. K., Fracture Mechanics: Fundamentals and applications, Cambridge, 2015.
3. Jin, Z.H., Sun, C.T., Fracture Mechanics,Academis Press, 2005.
4. Anderson, T.L., Fracture Mechanics: Fundamentals and applications, CRC Press, 2011.
5. Broek, D. Elementary Engineering Fracture Mechanics, Sijthoff&Noordhoff International Publishers, 1982.
6. Janssen, M., Zuidema, J. and Wanhill, R., Fracture Mechanics, Spon Press, 2004.
7. Knott J.F, Fundamentals of Fracture Mechanics, Butterworth & Co, 1973.

CE6135E PRESTRESSED CONCRETE DESIGN

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse prestressed concrete structural members and estimate the losses of prestress.
CO2: Analyse and design of prestressed concrete structural elements as per IS 1343.
CO3: Design prestressed concrete flexural members, composite members and statically indeterminate structures.

Introduction

Basic principles: Introduction - need for prestressed concrete - structural behaviour of prestressed concrete member - methods of prestressing - pre-tensioning and post-tensioning - anchorage systems - types of prestressed concrete - comparison with reinforced concrete.
Materials: High tensile steel - types of prestressing steel - high strength concrete - properties of high tensile steel and high strength concrete.
Losses in prestress: Immediate losses - time dependent losses - total losses.
Analysis of sections: Analysis at serviceability limit state - combined load approach - internal couple approach - equivalent load approach - concept of load balancing - decompression moment - cracking moment.
Design for flexure: Modes of failure in flexure - ultimate moment of resistance of sections with bonded tendons - strain compatibility method - IS code procedure.

Design of shear and torsion

Design for shear and torsion: Effect of prestress in shear strength - zones for shear design - shear resistance of sections - design for shear - failure modes in torsion - design for torsion.
Design of anchorage zones: Anchorage zones in pre-tensioned members - development length - end zone reinforcement - anchorage zones in post-tensioned members - bearing stresses - bursting forces - end zone reinforcement.
Control of deflections: Deflection in type I and type II beams - short term and long term deflections - IS code procedures.

Flexural members and Indeterminate structure

Design of flexural members: Governing stress inequalities for uncracked sections - design of prestressing force - Magnel's diagram - allowable cable zone - flexural efficiency factor.
Composite members: Analysis at serviceability limit state - stresses due to differential shrinkage - ultimate moment of resistance.
Indeterminate structures: Primary and secondary moments and shears - effective cable line - linear transformation of cable profile - concordant cable - analysis of sections.

References:

1. Lin, T. Y., and Ned H. Burns, Design of Prestressed Concrete Structures, John Wiley and
2. Sons, 2004.
3. Krishna Raju, N., Prestressed concrete, Tata McGraw Hill, 2000.Kumar, P. Elements of Fracture Mechanics, Tata McGraw Hill, 2009.
4. Nagarajan, P.,Prestressed concrete Design, Pearson,2013
5. Dayaratnam, P., Prestressed Concrete, Oxford and IBH, 1982.
6. Rajagopalan, N., Prestressed Concrete, Narosa publishers, New Delhi, 2004.
7. Relevant BIS codes

CE6136E MECHANICS OF COMPOSITE STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design composite beams with shear connectors.
CO2: Analyse and design composite floors.
CO3: Design composite columns using different materials.
CO4: Analyse and design continuous beams.

Introduction

Composite beams, Elastic behaviour of composite beams, No interaction case, Full interaction case, Shear connectors, Characteristics of shear connectors, Ultimate load behavior, Serviceability limits, Basic design considerations, Design of composite beams.

Composite floors

Structural elements, Profiled sheet decking, Bending resistance, Serviceability criteria, Analysis for internal forces and moments.

Composite columns

Materials: Structural steel, Concrete, Reinforcing Steel, Composite column design, Fire resistance, Combined compression and uniaxial bending.

Continuous beams and slab Hogging moment regions of composite beams, Vertical shear and moment, Shear interaction, Global analysis of continuous beams, Design strategies.

References:

1. Johnson, R.P, Composite Structures of Steel and Concrete, Vol.1Beams, Slabs, Columns and Frames in Buildings, Oxford Blackwell Scientific Publications, London, 1986.
2. INSDAG teaching resource for structural steel design, Vol 2, INSDAG, Ispat Niketan, Calcutta, 2003.

CE6137E ADVANCED FINITE ELEMENT ANALYSIS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform finite element analysis of structures using plate and shell elements.
CO2: Perform error analysis and convergence studies within the realm of the finite element method.
CO3: Apply the finite element method to structural dynamics and vibration problems.
CO4: Develop finite element models capable of simulating the real behavior of structures with reasonable accuracy.
CO5: Solve nonlinear problems using the finite element method.

Plate Elements and Shell Elements

Plate Bending: Plate behaviour, Kirchhoff and Mindlin plate elements, boundary conditions.

Shells: Shells of revolution, general shells, three- and four-noded shell elements, curved iso-parametric elements.

Error Analysis and Imposition of Constraints

Error, Error Estimation and Convergence: Sources of error, ill-conditioning, condition number, diagonal decay test, discretisation error, multimesh extrapolation, mesh revision methods, gradient recovery and smoothing, a-posteriori error estimate, adaptive meshing.

Constraints**,** Penalty Forms, Locking and Constraint Counting: Explicit constraints, transformation equations, Lagrange multipliers, penalty functions, implicit penalty constraints and locking, constraint counting, modelling incompressible solids.

Dynamic Analysis and Structural Modeling

Finite Elements in Structural Dynamics and Vibrations: Dynamic equations, mass and damping matrices, consistent and lumped mass, natural frequencies and modes, reduction of the number of degrees of freedom, modal analysis, Ritz vectors, harmonic response, direct integration methods, explicit and implicit methods, stability and accuracy, analysis by response spectra.

Modelling Considerations and Software Use: Physical behaviour versus element behaviour, element shapes and interconnections, test cases and pilot studies, material properties, loads and reactions, connections, boundary conditions, substructures, common mistakes, checking the model, critique of computed results.

Nonlinear Finite Element Analysis

Introduction to Nonlinear Problems: Nonlinear problems and some solution methods, geometric and material nonlinearity, problems of gaps and contacts, geometric nonlinearity, modelling considerations.

Stress Stiffening and Buckling: Stress stiffness matrices for beam, bar and plate elements, a general formulation for $[k_\sigma]$, bifurcation buckling, remarks on $[k_\sigma]$ and its use for buckling analysis.

References:

1. Cook, R.D., Concepts and Applications of Finite Element Analysis, Fourth Edition, John Wiley & Sons Inc., Singapore, 2003.
2. Asghar Bhatti, M., Advanced Topics in Finite Element Analysis of Structures, Wiley, 2006.
3. Reddy, J.N., An Introduction to Nonlinear Finite Element Analysis, Oxford University Press, 2021.
4. Desai, C.S., and Kundu, T., Introductory Finite Element Method, CRC Press, London, 2001
5. Bathe, K.J., Finite Element Procedures, Prentice Hall of India, 1996.
6. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vols. I and II, Mc Graw Hill, 2000.

CE6138E THEORY OF PLASTICITY

Pre-requisite: Theory of Elasticity

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand different failure theories and plastic behaviour of materials
CO2: Carry out plastic analysis of bars under tension and flexure
CO3: Carry out limit analysis of bodies in plane stress and plane strain conditions
CO4: Carry out limit analysis of trusses and beams, apply finite elements limit analysis problem, and incremental methods of determining limit load

Fundamentals of Plasticity

Preliminaries: Basic equations of theory of elasticity: Index notation, equations of equilibrium, constitutive relations for isotropic bodies, strain-displacement relations, compatibility, displacement and traction boundary conditions, admissibility of displacement and stress fields, plane stress and plane strain problems.

Framework of Plastic Constitutive Relations: Plastic behaviour in simple tension, generalisation of results in simple tension, yield surfaces, uniqueness and stability postulates, convexity of yield surface and normality rule, limit surfaces.

Yield Surfaces

Initial Yield Surfaces for Polycrystalline Metals: Summary of general form of plastic constitutive equations, hydrostatic stress states and plastic volume change in metals, shear stress on a plane, the von Mises initial yield condition, the Tresca initial yield condition, consequences of isotropy.

Plastic Behaviour under Plane Stress Conditions: Initial and subsequent yield surfaces in tension- torsion, the isotropic hardening model, the kinematic hardening model, yield surfaces made of two or more yield functions, piecewise linear yield surfaces, elastic perfectly plastic materials.

Plastic Behaviour and Limit Analysis

Plastic Behaviour of Bar Structures: Behaviour of a three-bar truss, behaviour of a beam in pure bending, simply supported beam subjected to a central point load, fixed beams of an elastic perfectly plastic material, combined bending and axial force.

The Theorems of Limit Analysis: Introduction, theorems of limit analysis, alternative statement of the limit theorems, the specific dissipation function.

Limit Analysis in Plane Stress and Plane Strain

Limit Analysis in Plane Stress and Plane Strain: Discontinuities in stress and velocity fields, the Tresca yield condition in plane stress and plane strain, symmetrical internal and external notches in a rectangular bar, the punch problem in plane strain, remarks on friction.

Limit Analysis as a Programming Problem: Restatement of limit theorems, application to trusses and beams, use of finite elements in programming problem, incremental methods of determining limit load.

References:

1. Martin, J.B., Plasticity: Fundamentals and General Results, MIT Press, London, 1975.
2. Kachanov, L.M., Fundamentals of the Theory of Plasticity, Mir Publishers, Moscow, 1974.
3. Chakrabarty, J, Theory of Plasticity, McGraw Hill, New York, 1987.
4. Hill, R., Mathematical Theory of Plasticity, Oxford University Press, 1998.
5. Chen, W.F., and Han, D.J., Plasticity for Structural Engineers, Springer Verlag, 1988.

CE6226E GEOGRAPHIC INFORMATION SYSTEM AND ITS APPLICATIONS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the components of a GIS and the reference systems for mapping and data acquisition

CO2: Select suitable data representation tools and methods for analysis

CO3: Process the data to derive meaningful inferences for decision making

CO4: Apply the tools and techniques available in GIS for the selected practical applications

Introduction: Definitions of GIS – Components of GIS – Geographic data presentation: maps – mapping process – coordinate systems – transformations – map projections – geo-referencing – data acquisition

Geographic Data Representation, Storage, Quality and Standards: Storage - Digital representation of data – Data structures and database management systems – Raster data representation – Vector data representation – Concepts and definitions of data quality – Components of data quality – Assessment of data quality – Managing data errors – Geographic data standards

GIS Data Processing, Analysis and Modeling: Raster-based GIS data processing – Vector-based GIS data processing – Queries – Spatial analysis – Descriptive statistics – Spatial autocorrelation – Quadrant counts and nearest neighbour analysis – Network analysis – Surface modeling – DTM

GIS Applications: Applications of GIS in Environment monitoring – Natural hazard management – Natural resources management urban planning – utility management – Land information – Business development

References

1. Burrough, P.A., Principles of Geographical Information Systems, Oxford Publication, 1998.
2. Chang, K-T., Introduction to Geographic Information Systems, McGraw Hill Education, 2016.
3. Clarke, K., Getting Started with Geographic Information Systems, Prentice Hall, New Jersey, 2010.
4. DeMers, M.N., Fundamentals of Geographic Information Systems, John Wiley and Sons, New York, 2002.
5. Heywood, I., Cornelius S. and Carver S., An Introduction to Geographical Information Systems, Pearson Education Ltd, Delhi, 2006.
6. Jeffrey, S. and John E., Geographical Information System – An Introduction, Prentice-Hall, 1990.
7. Jensen J R and Jensen R R, Introductory Geographic Information Systems, Pearson Education Ltd, Delhi, 2013.
8. Lo, C.P. and Yeung A.K.W., Concepts and Techniques of Geographic Information Systems, Prentice Hall of India, New Delhi, 2006.
9. Reddy, A. M., Remote Sensing and Geographical Information Systems, B.S. Publications, Hyderabad, 2001.

CE6302E STOCHASTIC PROCESSES IN STRUCTURAL MECHANICS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Quantify the randomness or uncertainties in the variables associated with analysis and response of physical phenomena.
CO2: Understand the basic theory of stochastic processes so that the uncertainties associated with the stochastic processes are quantified.
CO3: Apply the various mathematical theories associated with stochastic processes, to determine the response of SDOF and to find important properties that are useful at design stage.
CO4: Determine the response of MDOF systems to random excitation and to understand some models of random processes occurring in nature.

Fundamentals of probability theory with applications

Probability theory: Sample space and events, probability measure, mathematics of probability, conditional probability — Random variables: Continuous and discrete random variables, probability distribution and density functions, expected values and moments, multiple random variables, marginal and conditional distributions, dependent and independent variables — Functions of random variables: expectation of a function of a random variable — Common probabilistic models: Models from simple discrete random trials, models from random occurrences, models from limiting cases, other commonly used distributions, multivariate models — Derived probability distributions and distributions of functions.

Basic theory of stochastic processes

Basic Theory of Stochastic Processes: Introduction, statistics of stochastic processes, stationary, ergodic and non-stationary processes, auto and cross correlation and co variance function, stochastic calculus and mean square limit, conditions for continuity, differentiability, integrability of a random process, spectral decomposition of a random process, power spectral density function, narrow band and broad band random process, Wiener-Khintchine equation.

Response of simple linear systems

Stochastic Response of Linear SDOF Systems: Deterministic dynamics, evaluation of impulse response function and frequency response function, stochastic dynamics, response to stationary excitation, time domain analysis, frequency domain analysis.

Properties of Random Processes: Level crossing peaks, fractional occupation time, envelopes, first- passage time, maximum value of a random process in a time interval — Fatigue failure.

Response of MDOF systems and models of stochastic processes

Stochastic Response of Linear MDOF Systems to random excitation, normal mode approach — Some models of random processes in nature: Earthquake, wind, atmosphere turbulence, random runways, road roughness, jet noise, ocean wave turbulence — Some important random processes: Normal processes, Poisson processes, Markov processes.

References:

1. Ang, A. H. S., and Tang, W. H., Probability concepts in engineering planning and design, Vol. I - basic principles, John Wiley & Sons, New York, 1975.
2. Benjamin, J.R., and Cornell, C.A., Probability, statistics and decision for engineers, Dover Publications, New York, 2014.

3. Papoulis, A., and Pillai, S.U., Probability, random variables and stochastic processes, Fourth edition, McGraw Hill Education, New Delhi, 2017.
4. Nigam N. C., Introduction to random vibrations, MIT Press, Cambridge, USA, 1983.
5. Lutes, L.D., and Sarkani, S., Stochastic analysis of structural and mechanical vibrations, Prentice Hall, New Jersey, 1996.
6. Solnes, J., Stochastic processes and random vibrations - theory and practice, John Wiley & Sons, Chichester, 1997.
7. Lin, Y. K., and Cai, G.Q., Probabilistic theory in structural dynamics, McGraw Hill, New York, 1995.
8. Meirovitch, L., Elements of vibration analysis, McGraw Hill, New York,1986.
9. Clough, R.W., and Penzien, J., Dynamics of structures, McGraw Hill Education, New Delhi, 1993.
10. Wilson, J.F., Dynamics of offshore structures, Second edition, John Wiley & Sons, Inc., New Jersey, 2003.

CE6304E MARINE CFD

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Knowledge of conservation equations, finite difference technique and its formulation.
CO2: Acquire knowledge of finite volume methods, finite element methods and solution of finite difference equations.
CO3: Knowledge of solving CFD problems using Navier-Stokes equation.
CO4: Acquire knowledge on the application of computational fluid dynamics in marine structures.

Introduction, conservation equation - mass, momentum and energy equations - convective form, classification and overview of numerical methods - boundary and initial conditions, finite difference technique – formulation of finite difference equation, treatment of boundary conditions, accuracy of finite difference method.

Finite volume methods - different types of finite volume grids, approximation of surface and volume integrals, finite element methods - Rayleigh-Ritz, Galerkin and least square methods, interpolation functions - one and two dimensional elements, methods of solution, solution of finite difference equations, stability analysis.

Numerical grid generation - transformation and mapping. Navier-Stokes equations, explicit and implicit methods, fractional step methods - turbulence modelling, Reynolds averaged Navier-Stokes equations - turbulence modelling, RANS modelling - DNS and LES.

Free surface modelling – interface tracking and interface capturing techniques, grid independence analysis, CFD in marine applications, wave pattern calculations for steady ship flow, ship resistance estimation, seakeeping and manoeuvring simulations.

References:

1. Ferziger, J. H., and Peric, M., Computational methods for fluid dynamics. Third edition, Springer-Verlag, Berlin, 2002.
2. Versteeg, H. K., and Malalasekara, W., Introduction to computational fluid dynamics: the finite volume method, Second edition, Pearson Education Ltd., Essex, 2007.
3. Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., Computational fluid mechanics and heat transfer, CRC Press, Boca Raton, 2013.
4. Anderson, J.D., Computational fluid Dynamics: the basics with applications, McGraw Hill Education, New York, 2017.
5. Fletcher, C.A.J., Computational techniques for fluid dynamics, Vol. 1: fundamental and general techniques, Second edition, Springer, New York, 2005.
6. Kumar, A., Stability of structures, Allied Publishers Limited, New Delhi, 1998.
7. lyengar, N.G.R., Structural stability of columns and plates, Ellis Horwood Limited, Chichester. 1988.
8. Simitses, G.J., Introduction to the elastic stability of structures, Prentice-Hall Inc., New Jersey, 1976.

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CE6311E DYNAMICS OF OCEAN STRUCTURS

Pre-requisite: Structural Dynamics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the parameters governing solid-fluid interaction and environmental forces acting on offshore structures.
CO2: Acquire training in the response analysis of offshore structures – single and multi-degree freedom systems, frequency, and time domain analyses.
CO3: Evaluate the stability of submerged and floating structures.
CO4: Assess the mooring line forces, wave drift and springing forces.

Beam - Columns

Dynamic characteristics and water depth capability of ocean structures - Solid fluid interaction parameters - Added mass and damping - Effect of viscosity on damping - Spring factor - Diffraction and radiation problems - Wave exciting force.

Elastic buckling of bars

Modelling of offshore structures - Single and multi-degree freedom systems - Dynamic amplification factor - Response analysis of offshore structures - Coupled and uncoupled motions - Frequency domain analysis - Time domain analysis - Newmark-Beta method - Wilson-□ method - Response analysis of fixed and compliant platforms.

Elastic buckling of simple frames

Floating and submerged bodies - Intact and dynamic stability - Stability at small and large angles - hydrodynamic analysis - Strip theory - Response analysis of floating bodies - Tension Leg Platforms - Semi submersibles - Floating vessels - Static and dynamic analysis of Mooring lines.

Torsional buckling and buckling of plates and shells

Motion analysis in random waves - Response spectrum - Low and high frequency oscillations - Wave drift forces - Springing forces - Damping at low and high frequencies.

References:

1. Bhattacharya. R., Dynamics of marine vehicles, John Wiley & Sons, Inc., New Jersey, 1978.
2. Chakrabarti, S. K, Hydrodynamics of offshore structures, WIT Press, New Forest, 2003.
3. Chakraborti, S. K., Non-linear methods in offshore engineering, Elsevier, Netherlands,1990.
4. Clauss, G., Lehmann, E., and Ostergaard, C., Offshore structures – Vol. 1: conceptual design and hydromechanics, Springer-Verlag, London, 1992.
5. Clauss, G., Lehmann, E., and Ostergaard, C., Offshore structures – Vol. 2: strength and safety for structural design, Springer-Verlag, London, 1994.
6. Hooft, J. P., Advanced dynamics of marine vehicles, John Wiley & Sons, Inc., New York, 1982.
7. Patel, M.H., and Witz, J.A., Compliant offshore structures, Butterworth Heinemann Ltd., Oxford, 2013.
8. Chandrasekaran, S., Dynamic analysis and design of ocean structures. Springer, New Delhi, 2015.
9. Wilson, J. F., Dynamics of offshore structures, John Wiley & Sons, Inc., New Jersey, 2003.

CE6312E MARINE FOUNDATIONS

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

On completion of the course, the students will be able to :

CO1. Introduce the students to the relevance of marine geotechnical engineering and study different types of marine sediments and their properties
CO2. Study the behaviour of marine deposits under static and cyclic loading conditions
CO3. Know the different methods/techniques adopted for offshore soil investigations
CO4. To understand the typical foundations for the different type of offshore structures
CO5. To expose the students to partial design of typical offshore foundation components

Introduction to Marine Geotechnical Engineering
Scope of marine geotechnical engineering- Marine and submarine soils- Classification of marine soils- Relative distribution of marine soils in the different marine regions- General characteristics of marine deposits in some specific locations and in theIndian subcontinent.

Sedimentological characteristics of marine soils
Structure of marine soils- Cementation bonding-
Morphology and genesis of marine and submarine sediments- Post-depositional changes- Effect of calcium carbonate in marine deposits.

Engineering behaviour of marine soils
Fine and coarse-grained deposits- Strength and deformation
behaviour of fine and coarse-grained marine deposits- Effect of cementation- Strength and deformation behaviour under static and cyclic loading.

Offshore Soil Investigation
General characteristics of offshore soil exploration - Sampling using free corer, gravity corer, tethered systems and manned submersibles - Deep penetration sampling using wire line techniques - In-situ determination of strength of submarine soils - Penetrometer, piezocone, vane and pressure meter techniques - General reconnaissance procedure for installation of fixed structures (gravity and piled type), floating structures, sea bed anchors and submarine pipelines.

Foundations for Gravity Structures
Types of gravity structures- Installation techniques- Movement of gravity structures- Settlement of soil beneath gravity structures- Stress distribution beneath gravity structures- Stability of gravity structures under static and cyclic loads- Foundations for jacket type structures: Types- Installation techniques- Design considerations- Axial and lateral load capacity of piles- Lateral load deformation behaviour of piles- Calculation of bearing capacity of piles- Design of piles subjected to lateral loads- Reese-Matlock method & p-y curves method.

Foundations for jack up platforms
Foundations for jack up platforms: Types of jack up platforms- Piles and mat supported- Spud cans-Different types- Techniques for installation and removal of jack up- Stability of jack up platforms-Determination of penetration of supports- Stability under lateral loads- Stability under static and cyclic load effects. Sea bed anchors, submarine pipe lines: General introduction to sea bed anchors, moorings, submarine pipe line etc.-General design considerations (brief outline only)- geotechnical aspects in the design and installation of sea bed anchors, moorings, submarine pipelines etc

References:

1. Chaney, F. Marine Geotechnology and nearshore/offshore structures, ASTM, STP-, 1986.
2. Chaney, R. C andDemars, K. R., Strength Testing of Marine Sediments - Laboratory and In-situMeasurements, ASTM, STP -883, 1985.
3. Poulos, H. G and Davis, E. H., Pile Foundation Analysis and Design, John Wiley, 1980.
4. Numerical Methods in offshore Piling, Proc. Conf. Inst. of Civil Engineers, London, 1980.
5. Le Tirant, Sea Bed Reconnaissance and Offshore Soil Mechanics for the Installation of Petroleum Structures, Gulf Publ. Co., 1979.
6. George, P and Wood, D, Offshore Soil Mechanics, Cambridge University Press, 1976

CE6323E STABILITY OF STRUCTURES

Pre-requisite: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand basic concepts of stability and perform stability analysis of beam-columns.
CO2: Perform stability analysis of bars/columns by different methods.
CO3: Carryout stability analysis of simple frames and determine safe load.
CO4: Perform stability analysis of thin walled sections, beams undergoing lateral buckling, plated and shell structure.

Beam - Columns

Introduction: Concept of stability, Static, dynamic and energy criterion of stability — Beam Columns: Differential equation of equilibrium of beam-columns, concentrated loads, continuous uniformly distributed lateral loads, different end conditions, effect of initial curvature on deflections — Interaction formula.

Elastic buckling of bars

Elastic buckling of bars: Review of Euler column theory for different end conditions, evaluation of critical loads of column using determinant, approximate methods of evaluation of critical loads of columns, energy method, Rayleigh Ritz method, finite difference method, Newmark's deflection comparison method, buckling of bars with changes in cross section using the approximate methods such as successive approximations, effect of shear force on the critical load, buckling of built up columns — Various empirical formulae for column design.

Elastic buckling of simple frames

Stability of rigid bars having linear or rotational springs: Stability of system of rigid bars using equilibrium and principle of stationary potential energy — Bulking of frames: Portal, rectangular and L-shaped frames under non-sway conditions, matrix approach and stability functions.

Torsional buckling and buckling of plates and shells

Pure torsion of thin walled bars of open cross-section: Torsional Buckling, determination for warping displacement for a thin walled channel section, examples of section with thin elements in which there is no warping — Lateral buckling of beams in pure bending: Lateral buckling of simply supported I-beams — Introduction to stability of plates and shells: Buckling of plates, buckling of shells.

References:

1. Timoshenko, S.P., and Gere, J.M., Theory of elastic stability, McGraw Hill, Singapore, 1963.
2. Chajes, A., Principles of structural stability theory, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1974.
3. Brush, D.O., and Almorth, B.O., Buckling of bars, plates and shells, McGraw Hill, 1975.
4. M L Gambhir, Stability analysis and design of structures, Springer, 2010.
5. Chai H Yoo and Sung Lee, Stability of structures – Principles and applications, Elsevier, 2011
6. Kumar, A., Stability of structures, Allied Publishers Limited, 1998.
7. lyengar, N.G.R., Structural stability of columns and plates, East West Press, 1986.
8. Simitses, G.J., Introduction to the elastic stability of structures, Prentice Hall Inc., New Jersey, 1976.

CE6403E ADVANCED DESIGN OF FOUNDATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze and interpret soil properties for foundation design.
CO2: Utilize advanced geotechnical analysis methods for complex foundation systems.
CO3: Evaluate and analyze bearing capacity and immediate settlement of foundations.
CO4: Understand design considerations for retaining walls and earth retaining structures

Ground Exploration and Shallow Foundation
Introduction, soil exploration (SPT, CPT, PLT) − analysis and interpretation of soil exploration data − estimation of soil parameters for foundation design.
Bearing capacity theories − Methods for bearing capacity estimation − total and differential settlements of footing and raft, code provisions − Design of individual footings, strip footing, combined footing, rigid and flexible mat, buoyancy raft, basement raft, underpinning.

Pile and Well Foundations
Estimation load carrying capacity of single and pile group under various loading conditions − Pile load testing (static, dynamic methods and data interpretation) − settlement of pile foundation, code provisions, design of single pile and pile groups, and pile caps.
Well or Caisson foundation types, components, construction methods, design methods (Terzaghi, IS and IRC approaches), check for stability, base pressure, side pressure and deflection.

Retaining Walls and Reinforced Earth
Types (types of flexible and rigid earth retention systems: counter fort, gravity, diaphragm walls, sheet pile walls, soldier piles and lagging) − Support systems for flexible retaining walls (struts, anchoring), construction methods, stability calculations − design of flexible and rigid retaining walls, design of cantilever and anchored sheet pile walls.
Geotechnical properties of reinforced soil − shallow foundation on soil with reinforcement, retaining walls with reinforcements, design considerations.

Soil Foundation Interaction
Idealized soil, foundation and interface behavior − Elastic models of soil behavior; Elastic-plastic and time dependent behavior of soil − Beams and plates on elastic foundation; numerical analysis of beams and plates resting on elastic foundation.

References:

1. A.P.S. Selvadurai, "Elastic Analysis of Soil-Foundation Interaction", Elsevier Scientific Publishing Company.
2. B. M. Das, "Principles of Foundation Engineering", PWS Publishing Company.
3. J. Bowles, "Foundation Analysis and Design", McGraw-Hill Book Company.
4. V.N.S. Murthy, "Advanced Foundation Engineering", CBS Publishers and Distributors.
5. S. Saran, "Analysis and Design of Substructures", 2nd Edition, Oxford & IBH Publishing Company Pvt. Ltd., 2009.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management. .

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V. (Indian Adoption) (2022). *Patterns of entrepreneurship management.* John Wiley & Sons.
2. Kuratko, D. F. (2016). *Entrepreneurship: Theory, process, and practic*e. Cengage learning.
3. Barringer, B. R. (2015). *Entrepreneurship: Successfully launching new ventures*. Pearson Education India
4. Rajiv Shah, Zhijie Gao, Harini Mittal, I*nnovation, Entrepreneurship, and the Economy in the US, China, and India*, 2014, Academic Press
5. Sundar,K.(2022). *Entrepreneurship Developmen*t, 2nd Ed , Vijaya Nichkol Imprints, Chennai
6. E. Gordon,Dr. K. Natarajan., (2017).*Entrepreneurship Development*, 6th Ed, Himalya Publishers,Delhi
7. Debasish Biswas, Chanchal Dey,*Entrepreneurship Development in India*, 2021, Taylor & Francis.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D. (2018). *Longman advanced learner's grammar, a self-study reference & practice book with answers*. Pearson Education Limited.
2. Gerson, S. J., & Gerson, S. M. (2009). *Technical writing: Process and product*. Pearson.
3. Kirkwood, H. M. A., & M., M. C. M. I. (2013). *Hallidays introduction to functional grammar* (4th ed.). Hodder Education.
4. Markel, M. (2012). *Technical Communication* (10th ed.). Palgrave Macmillan.
5. Tuhovsky, I. (2019). *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills.* Rupa Publications India.
6. Williams, R. (2014). *The Non-designer's Design Boo*k. Peachpit Press.

ZZ6002E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes

CO1: Explain the basic concepts and types of research.

CO2: Develop research design and techniques of data analysis

CO3: Present research to the scientific community

CO4: Develop an understanding of the ethical dimensions of conducting research.

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis

Literature review :Tools and Techniques, Collection and presentation of data, processing and analysis of data, Descriptive statistics and inferential statistics, Measures of central tendency, dispersion, skewness, asymmetry, Probability distributions, Single population and two population hypothesis testing, Parametric and non-parametric tests, Design and analysis of experiments: Analysis of Variance (ANOVA), completely randomized design, Measures of relationship: Correlation and regression, simple regression analysis, multiple regression, interpretation of results, Heuristics and simulation.

Research writing and Ethics

Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.

The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey.

References:

1. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., *Management Research Methodology, Pearson* Education, 2006
2. Leedy, P, D., *Practical Research: Planning and Design* (12 e) Pearson., 2018
3. Kothari, C.R., Research Methodology – Methods and Techniques, New Age International Publishers, 2004
4. Mike Martin, Roland Schinzinger., *Ethics in Engineering*, Mc Graw Hill Education, 2004
5. Vinod V Sople, *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd., 2014