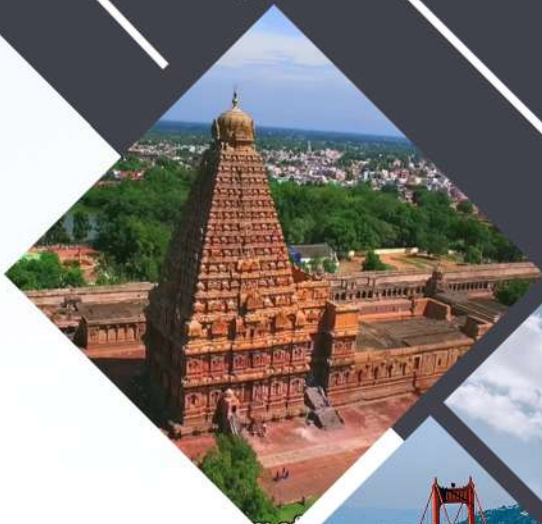
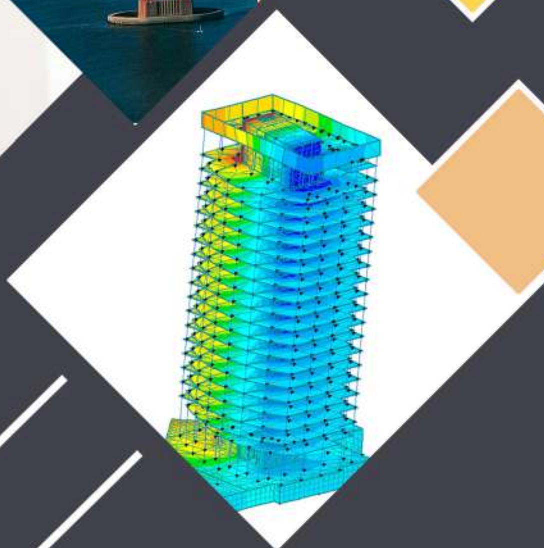
M.Tech in

STRUCTURAL ENGINEERING

(Curriculum and Syllabus)
with effect from AY 2022-2023





Department of Civil Engineering
National Institute of Technology
Tiruchirappalli - 620015

M. Tech.

IN

STRUCTURAL ENGINEERING

CURRICULUM AND SYLLABUS

(with effect from AY 2022-2023 onwards)

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015

TAMIL NADU, INDIA

VISION AND MISSION OF THE INSTITUTE

Vision of the Institute

To be a University globally trusted for technical excellence where learning and research integrate to sustain society and industry.

Mission of the Institute

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION AND MISSION OF THE DEPARTMENT

Vision of the Department

Shaping infrastructure development with societal focus.

Mission of the Department

Achieve International Recognition by:

- Developing Professional Civil Engineers
- Offering Continuing Education
- Interacting with Industry with emphasis on R&D

CURRICULUM

The total minimum credits for completing the M. Tech. Programme in Structural Engineering is 66.

SEMESTER I

Sl. No.	Course Code	Course Title	Credits
1.	MA624	Applied Mathematics	4
2.	CE651	Theory of Elasticity and Plasticity	4
3.	CE653	Structural Dynamics	3
4.		Elective 1	3
5.		Elective 2	3
6.		Elective 3	3
7.	CE659	Structural Engineering Laboratory	2
		TOTAL	**22**

SEMESTER II

Sl. No.	Course Code	Course Title	Credits
1.	CE652	Advanced Reinforced Concrete Design	3
2.	CE654	Finite Element Analysis of Structural Members	3
3.	CE656	Advanced Design of Metal Structures	3
4.		Elective 4	3
5.		Elective 5	3
6.		Elective 6	3
7.	CE660	Structural Design & Computation Laboratory	2
		TOTAL	**20**

SUMMER TERM

Sl. No.	Course Code	Course Title	Credits
1.		Practical Training/Industrial Internship (4 Weeks)	

SEMESTER III

Course Code	Course Title	Credits
CE697	Project Work Phase-I	12
	TOTAL	**12**

SEMESTER IV

Course Code	Course Title	Credits
CE698	Project Work Phase-II	12
	TOTAL	**12**

LIST OF ELECTIVES

Sl. No.	Course Code	Course Title	Credits
1.	CE661	Matrix Methods of Structural Analysis	3
2.	CE662	Stochastic Processes in Structural Mechanics	3
3.	CE663	Random Vibrations and Structural Reliability	3
4.	CE664	Fracture Mechanics	3
5.	CE665	Structural Optimization	3
6.	CE666	Failure Analysis of Structures	3
7.	CE667	Stability of Structures	3
8.	CE668	Theory of Plates and Shells	3
9.	CE669	Advanced Steel and Concrete Composite Structures	3
10.	CE670	Seismic Design of Structures	3

11.	CE671	Prefabricated Structures	3
12.	CE672	Smart Structures and Applications	3
13.	CE673	Prestressed Concrete Structures	3
14.	CE674	Analysis and Design of Tall Buildings	3
15.	CE675	Structures in Disaster Prone Areas	3
16.	CE676	Design of Boiler Structures	3
17.	CE677	Structures for Power Plants	3
18.	CE678	Forensic Engineering and Rehabilitation of Structures	3
19.	CE679	Soil Structure Interaction	3
20.	CE680	Advanced Concrete Technology	3
21.	CE681	Special Concrete	3
22.	CE682	Hydraulic Structures	3
24.	CE683	Design of Bridges	3
25.	CE684	Health, Safety and Environmental Management (HSE) Practices	3
26.	CE685	Design of Offshore Structures	3
27.	CE686	Non - Linear Analysis	3
28.	CE815	Ground Improvement Techniques	3
29.	CE816	Analysis of Deep Foundation	3
30.	HM712	Human Resource Management	3

LIST OF OPEN ELECTIVES

Sl. No.	Course Code	Course Title	Credits
1.	CE668	Theory of Plates and Shells	3
2.	CE680	Advanced Concrete Technology	3
3.	CE683	Design of Bridges	3

Course Code	:	MA624
Course Title	:	Applied Mathematics
Number of Credits	:	4
Course Type	:	Core

Course Learning Objectives

1. To develop students with knowledge in Laplace and Fourier transform.
2. To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications.
3. To expose the students to calculus of variation, conformal mappings and tensor analysis.
4. To familiarize students in the field of bilinear transformations.
5. To expose students to the concept of vector analysis.

Course Content

Vector spaces and subspaces, solution of linear systems, Linear independence, basis, and dimension, The four fundamental subspaces, Linear transformations, Orthogonal vectors and subspaces, Cosines and projections onto lines, Projections and least squares, The fast Fourier transform, Eigenvalues and eigenvectors, Diagonalization of a matrix, Difference equations and powers of matrices, Similarity transformations.

Laplace transform: Definitions, properties - Transform of error function, Bessel's function, Dirac Delta function, Unit Step functions – Convolution theorem – Inverse Laplace Transform: Complex inversion formula – Solutions to partial differential equations : Heat equation, Wave equation.

Fourier transform: Definitions, properties – Transform of elementary functions, Dirac Delta function – Convolution theorem – Parseval's identity – Solutions to partial differential equations: Heat equation, Wave equation, Laplace and Poisson's equations.

Concept of variation and its properties – Euler's equation – Functional dependent on first and higher order derivatives – Functionals dependent on functions of several independent variables – Variational problems with moving boundaries –Problems with constraints – Direct methods – Ritz and Kantorovich methods.

Introduction to conformal mappings and bilinear transformations – Schwarz Christoffel transformation– Transformation of boundaries in parametric form– Physical applications: Fluid flow and heat flow problems.

Reference Books

1. *Sankara Rao K., Introduction to Partial Differential Equations, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.*
2. *Gupta A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.*
3. *Spiegel M.R., Theory and Problems of Complex Variables and its Application (Schaum's Outline Series), McGraw Hill Book Co., Singapore,1981.*
4. *James. G, Advanced Modern Engineering Mathematics, Pearson Education, Third Edition, 2004.*
5. *Lev. D. Elsgolc, Calculus of Variations, Dover Publications, New York, 2012.*

Course outcomes

At the end of the course student will be able

1. To solve boundary value problems using Laplace and Fourier transform techniques.
2. To solve fluid flow and heat flow problems using conformal mapping.
3. To develop the mathematical methods of applied mathematics and mathematical physics with an emphasis on calculus of variation and integral transforms.
4. To apply vector calculus in linear approximations, optimization, physics and engineering.
5. To solve physical problems such as elasticity, fluid mechanics and general relativity.

Course Code	**:**	CE651
Course Title	**:**	Theory of Elasticity and Plasticity
Number of Credits	**:**	4
Course Type	**:**	Core

Course Learning Objectives

1. To make students understand the principles of elasticity and plasticity.
2. To familiarize students with basic equations of elasticity.
3. To expose students to two dimensional problems in Cartesian and polar coordinates.
4. To make students understand the principle of torsion of prismatic bars.
5. To familiarize students with the concepts of plasticity and yield criteria.

Course Content

Basic concepts of deformation of bodies – deformation gradient- Tensor notations of stress and strain in 3D field - Traction - Engineering and Cauchy stress and Green-Lagrange Strains - Cauchy form of equilibrium equation - Transformation of stress and strain in a 3D field - Equilibrium equations in 2D and 3D Cartesian coordinates

Compatibility equations - Stresses: Principal, Octahedral, Hydrostatic and deviatoric - Derivation of Constitutive law - reduction to isotropic and uniaxial case

Plane stress and plane strain problems - 2D problems in Cartesian coordinates as applied to beam bending using Airy's stress function - Problems in 2D - Polar coordinate - Equations of equilibrium and compatibility - stress concentration in holes - Circular disc subjected to diametral compressive loading - semi-infinite solid subjected to different types of loads. Thin and thick cylinders under internal pressure.

Torsion of sections - St. Venant's theory – Torsion of elliptical sections - Torsion of triangular sections - Prandtl's membrane analogy– Warping Torsion of rolled profiles - Torsion of thin-walled tubes

Plasticity – Introduction - Reasons of plasticity - slip lines - Plastic stress-strain relations - Flow rules (associated and non-associated) - Different hardening rules - Yield criteria for metals - Graphical representation of yield criteria.

Reference Books

1. *Timoshenko and Goodier, Theory of Elasticity and Plasticity, McGraw-Hill, 2006.*
2. *Mohammed Amin, Computation Elasticity, Narosa Publications, 2005.*
3. *Chen and Han, Plasticity for Structural Engineers, Springer Verlag, 1998.*
4. *K. Baskar, T.K. Varadan, Theory of Isotropic/Orthotropic Elasticity, An Introductory Primer, Anne books Pvt. Ltd., 2009.*

5. *Chakrabarty. J., Theory of Plasticity, Elsevier Butterworth-Heinmann-UK, Third Edition, 2006.*

Course outcomes

At the end of the course student will be able

1. To apply elastic analysis to study the fracture mechanics.
2. To apply linear elasticity in the design and analysis of structures such as beams, plates, shells and sandwich composites.
3. To apply hyper-elasticity to determine the response of elastomer-based objects.
4. To analyse the structural sections subjected to torsion.
5. To understand various theories of failure and concept of plasticity.

Course Code	**:**	CE653
Course Title	**:**	Structural Dynamics
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives

1. To introduce the concepts of dynamic loading and to study the dynamic response of SDOF, MDOF and continuous systems subjected to different types of dynamic loads.
2. To learn free and forced vibration response of structural systems.
3. To familiarize students with mathematical models representing real time problems of discrete and continuous vibratory systems.
4. To make students understand the principle of virtual displacements.
5. To expose students to the concept of resonance.

Course Content

Introduction to Dynamic analysis - Elements of vibratory systems and simple Harmonic Motion - Mathematical models of SDOF systems - Principle of Virtual displacements - Evaluation of damping resonance.

Fourier series expression for loading - (blast or earthquake) - Duhamel's integral - Numerical methods - Expression for generalized system properties - vibration analysis - Rayleigh's method - Rayleigh-Ritz method.

Evaluation of structural property matrices - Natural vibration - Solution of the Eigen value problem - Iteration due to Holzer and Stodola.

Idealization of multi-storeyed frames - analysis to blast loading - Deterministic analysis of earthquake response - lumped SDOF system.

Differential equation of motion - Beam flexure including shear deformation and rotatory inertia - Vibration analysis using finite element method for beams and frames.

Reference Books

1. *Mario Paz, and William Leigh, Structural Dynamics, CBS, Publishers, 1987.*
2. *Roy R Craig, Jr., Structural Dynamics, John Wiley and Sons, 1981.*
3. *A. K. Chopra "Dynamics of Structures Theory and Application to Earthquake Engineering" Pearson Education, 2001.*
4. *Clough and Penzien, Dynamics of Structures, McGraw Hill, 5th Edition, 1975.*
5. *Srinivasan Chandrasekaran, Dynamic Analysis and Design of Ocean Structures, Springer, 2015.*

Course outcomes

At the end of the course student will be able

1. To analyse structures subjected to blast loading and apply finite element method.
2. To analyse structures using various methods of vibration analysis.
3. To use structural property matrices to study structural behaviour.
4. To arrive at solution to Eigen value problem and idealize multi storied frames.
5. To perform deterministic analysis for earthquake response.

Course Code	**:**	CE652
Course Title	**:**	Advanced Reinforced Concrete Design
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives

1. To provide better understanding on theoretical background of RC structural elements under axial, bending and combined forces.
2. To understand 1D and 2D structural sections.
3. To familiarize with analytical tools such as yield line theory.
4. To get exposed to behaviour of concrete and steel.
5. To understand the failure criteria of concrete.

Course Content

Analysis of rectangular and Non-rectangular cross-sections – Strain- compatibility method of analysis - Design for Serviceability Limit states - Design calculation of deflections and crack width according to IS 456-2000 - Torsion.

Behaviour of slender RCC Columns- Failure modes and Interaction Curves- Additional Moment Method-Comparison of codal provisions- calculation of design moments for braced and unbraced columns-Principles of Moment magnification method- design of slender columns – Design of Tension member.

Yield line theory of slabs - Hillerberg method of design of slabs- Design of Flat slabs and flat plates -Shear in Flat Slabs and Flat Plates. Approximate analysis and design of Grid floors.

Discontinuity regions and strut-and-tie models - Design and detailing of Deep beams – Corbels – column-walls sections.

Special Structural elements - Analysis and design of beams curved in plan – RC walls – Slender beams - Water tanks.

Reference Books

1. *Varghese P.C., "Advanced Reinforced Concrete", Prentice Hall of India, New Delhi, 2009*
2. *Krishna Raju, N., "Advanced Reinforced Concrete Design", CBS Publishers and Distributers, 2008*
3. *Unnikrishnan Pillai S and Menon D., "Reinforced concrete Design", Tata McGraw Hill Book Co., New Delhi, 2003.*
4. *James K. Wight and James G. MacGregor, "Reinforced Concrete: Mechanics and Design: Mechanics and Design", Pearson Publications, 2016*
5. *N.Subramanian, "Design of Reinforced Concrete Structures" Oxford Publishers, 2013*
6. *Park and Paulay T, "Reinforced concrete Structures", John Wiley and Sons, New York, 2009.*

Course outcomes

At the end of the course student will be able

1. To understand structural behaviour of flexural members.
2. To compute deflection of flexural members.
3. To understand redistribution of moments.
4. To design compression members.
5. To understand the concept of shear and torsion.

Course Code	:	CE654
Course Title	:	Finite Element Analysis of Structural Members
Number of Credits	:	4
Course Type	:	Core

Course Learning Objectives

1. To study the energy principles, finite element concept, stress analysis, meshing, nonlinear problems and applications.
2. To arrive at approximate solutions to finite element problems.
3. To perform finite element analysis on one dimensional and two dimensional problems.
4. To familiarize students with isoparametric element components.
5. To apply equilibrium equations, strain displacement relation, linear constitutive relation in practical problems.

Course Content

Direct stiffness method - Special characteristics of stiffness matrix - Assemblage of elements –Boundary condition and reaction - Analysis of framed Structures - 2D truss element - 2D beam element - Gauss elimination and LDLT decomposition - Basic steps in finiteelement analysis.

Differential equilibrium equations - strain displacement relation - linear constitutive relation - special cases - Principle of stationary potential energy - application to finite element methods. Some numerical techniques in finite element analysis.

Displacement models - convergence requirements. Natural coordinate systems - Shape function. Interpolation function - Linear and quadratic elements - Lagrange and Serendipity elements - Strain displacement matrix - element stiffness matrix and nodal load vector.

Two dimensional isoparametric elements - Four noded quadrilateral elements - triangular elements - Computation of stiffness matrix for isoparametric elements numerical integration (Gauss quadrature)- Convergence criteria for isoparametric elements.
Analysis of plate bending: Basic theory of plate bending - displacement functions - plate bending Elements. Plane stress and plane strain analysis: Triangular elements - Rectangular elements

Reference Books

1. *Krishnamoorthy, C. S, Finite Element Analysis - Theory and Programming, McGraw - Hill, 2011.*

2. *Singiresu S. Rao, The Finite Element Methods in Engineering, Butterworth-Heinemann, an Imprint of Elsevier, 2014.*
3. *G.R. Liu and S.S.Quek, Finite Element Method: A Practical Course, Butterworth-Heinemann; 1st edition (21 February 2003)*
4. *Chennakesava R. Alavala Finite Element Methods: Basic Concepts and Applications, Prentice Hall Inc., 2010.*
5. *J.N.Reddy, An Introduction to Finite Element Method, Tata McGraw-Hill, New Delhi, 2005*
6. *P. Seshu, Textbook of Finite Element analysis, PHI Learning Private Limited, New Delhi, 2012*

Course outcomes

At the end of the course student will be able

1. To use displacement models to solve practical problems in structural engineering.
2. To apply numerical techniques of finite element analysis to solve real time problems.
3. To make use of shape function and interpolation function to study structural behaviour.
4. To apply linear and quadratic elements in the finite element analysis of various types of structures.
5. To predict structural behaviour using strain displacement matrix and element stiffness matrix.

Course Code	**:**	CE656
Course Title	**:**	Advanced Design of Metal Structures
Number of Credits	**:**	3
Course Type	**:**	Core

Course Learning Objectives

1. To compute wind load on structures and deflection of beams.
2. To understand design of stacks.
3. To get familiarized with cold formed steel sections and different types of connections.
4. To get exposed to design of compression and tension members.
5. To design members subjected to torsion and understand plastic analysis of structures.

Course Content

Steel metallurgy – mechanical properties – section classification - limit state method of design for structural steel – plastic analysis and design

Estimation of loads – structural systems for multi-story and industrial buildings - moment resisting frame, concentrically and eccentrically braced frame – pre-engineered building systems – moment resisting connections

Composite construction – shear connector – behaviour and design of steel concrete composite slabs, beams and columns

Fatigue behaviour and design – S-N curve approach – design category classification – design for variable repeated loading - fatigue assessment

Cold formed steel design – buckling and post-buckling behaviour of members – effective width method and direct strength method for design of cold-formed steel beams, columns, beam-columns

Reference Books

1. *Subramanian N, Design of Steel Structures, Oxford University Press, New Delhi, 2008.*
2. *Bhavikatti, S.S., Design of Steel Structures, I.K. International Publishing House Pvt. Ltd., New Delhi, 2010.*
3. *Punmia B.C., Comprehensive Design of Steel Structures, Lakshmi Publications, New Delhi, 2000.*
4. *Lynn S. Beedle, Plastic Design of Steel Frames, John Wiley and Sons, 1990.*
5. *Wie Wen Yu, Design of Cold Formed Steel Structures, McGraw Hill Book Company, New York, 1996.*

Course outcomes

At the end of the course student will be able

1. To compute wind load on structures and determine deflection of beams.
2. To understand design of stacks.
3. To get familiarized with cold formed steel sections and different types of connections.
4. To get exposed to design of compression and tension members.
5. To design members subjected to torsion and understand plastic analysis of structures.

Course Code	:	CE659
Course Title	:	Structural Engineering Laboratory
Number of Credits	:	2
Course Type	:	Laboratory

Course Learning Objectives

1. To study the properties of concrete.
2. To learn the method of concrete mix design as per ACI and IS code and to get exposure to special concrete.
3. To carry out strength tests and non-destructive tests on concrete.
4. To investigate the structural behaviour of RC beams and measure strain.
5. To assess the dynamic behaviour of structural components.

Course Content

Properties of concrete ingredients – concrete mix design ACI/ IS method for M45 to M60 grade (IS), up to M80 grade (ACI), Design of Special Concrete like FRC, SCC, HPC - strength tests on concrete – Non-destructive tests on concrete. Use of various types of strain gauges - Mechanical and Electrical strain gauges – Specimen preparation and testing of R.C. beams and study of their behaviour.

Experiments on dynamic analysis - Assessment of the mode shapes and frequencies of Demo MDOF system - Assessment of the behaviour of structure under non-harmonic load - Assessment of the mode shape of cantilever beam - Assessment of the mode shape of simply supported beam.

Reference Books

1. *C. B. Kukreja, K. Kishore and Ravi Chawla, Material Testing Laboratory Manual, Standard Publishers Distributors, New Delhi.*
2. *L. S. Srinath, Experimental Stress analysis, Tata McGraw-Hill Publishing Company Limited.*
3. *Colin. D. Johnston, Fibre Reinforced Cements and Concrete, Taylor and Francis Publishers.*
4. *Geert De Schutter, Peter J. M. Bartos, Peter Domone, John Gibbs, Self Compacting Concrete, Whittles Publishing, 2008.*
5. *A. K. Chopra "Dynamics of Structures Theory and Application to Earthquake Engineering" Pearson Education, 2001.*

Course outcomes

At the end of the course student will be able

1. To arrive at concrete mix design for various types of concrete as per codal provisions.
2. To be familiar with the properties of concrete and perform non-destruction testing on concrete.
3. To cast and test structural RC elements for strength and deformation behaviour.
4. To carry out dynamic testing on structural components.
5. To assess the behaviour of structures subjected to static cyclic load testing.

Course Code	**:**	CE660
Course Title	**:**	Structural Design & Computation Laboratory
Number of Credits	**:**	2
Course Type	**:**	Laboratory

Course Learning Objectives

1. To learn the principles of computer graphics and application packages, optimization and artificial intelligence.
2. To expose students to computer aided drafting.
3. To familiarize students with 2D objects in drawing and enable them to prepare plan, elevation and sectional drawings.
4. To expose students to 3D modelling.
5. To apprise students with DBMS concepts.

Course Content

Module 1: Analysis, design and drafting with commercial software: (3 D modelling – RCC & STEEL)

(a) Modelling and analysis - applying known concepts of structural components, codal provisions for loads and dimensioning, analysis procedures etc.

(b) design using software or manual designusing spreadsheets software or Macros

(c) drafting / detailing using commercialCAD software.

(Different groups may be assigned differentbuildings/structures)

Module 2: Programming for structural engineering using MATLAB or any programming language choice of student. Exercises include, but not limited to: Solution using Newton-Raphson method, Gauss elimination, Gauss-Jordan method, Linear Regression, Curve fitting by Polynomial Regression, Eigen value extraction by power method etc.

Module 3: Finite Element software fundamentals - modelling, analysis and postprocessing of simple planar, wire and shell models – introduction to different types of meshes, elements, analysis steps etc.

Reference Books

1. *Rajaraman, V., Computer Oriented Numerical Methods, Prentice – Hall of India, 2004.*
2. *Krishnamoorthy C. S and Rajeev S., "Computer Aided Design", Narosa Publishing House, New Delhi, 1991.*
3. *Groover M. P. and Zimmers E. W. Jr.," CAD/CAM, Computer Aided Design and Manufacturing ", Prentice Hall of India Ltd, New Delhi, 1993.*
4. *Harrison H. B., "Structural Analysis and Design Vol. I and II", Pergamon Press, 1991.*

5. *Hinton E. and Owen D. R. J., Finite Element Programming, Academic Press, 1977.*

Course outcomes

At the end of the course student will be able

1. To work on spreadsheets and worksheets.
2. To understand regression and matrix inversion concepts.
3. To arrive at C programs to solve problems using numerical techniques.
4. To use computer methods of structural analysis to solve structural problems.
5. To work on finite element programming to solve real time problems.

Course Code	:	CE661
Course Title	:	Matrix Methods of Structural Analysis
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce the classical, matrix and finite element methods of structural analysis.
2. To make students understand structural behaviour.
3. To enable students to analyse determinate and indeterminate structures.
4. To familiarize students with displacement method.
5. To expose students to analysis of substructures.

Course Content

Generalized measurements - Degrees of freedom - Constrained measurements - Behavior of structures - Principle of superposition - Stiffness and flexibility matrices in single, two and n-co-ordinates - structures with constrained measurements.

Stiffness and flexibility matrices from strain energy - Betti's law and its applications- Determinate and indeterminate structures - Transformation of element matrices to system matrices - Transformation of system vectors to element vectors.

Flexibility method applied to statically determinate and indeterminate structures – Choice of redundant - Transformation of redundant - Internal forces due to thermal expansion and lack of fit.
Stiffness method - Internal forces due to thermal expansion and lack of fit - Application to symmetrical structures - Comparison between stiffness and flexibility methods.

Analysis of substructures using the stiffness method and flexibility method with tridiagonalization - Analysis by Iteration method - frames with prismatic members - non-prismatic members.

Reference Books

1. *Natarajan, C., Revathi, P., Matrix Methods of Structural Analysis-Theory and Problems, PHI Learning Private Limited, Delhi, 2014.*
2. *Moshe, F., Rubenstein, Matrix Computer Analysis of Structures, Prentice Hall, New York, 1966.*
3. *Rajasekaran S, Computational Structural Mechanics, Prentice Hall of India, New Delhi, 2001.*
4. *McGuire, W., and Gallagher, R.H., Matrix Structural Analysis, John Wiley and Sons, 1979.*
5. *John L. Meek., Matrix Structural Analysis, McGraw Hill Book Company, 1971.*

6. *Devdas Menon, Advanced Structural Analysis, Narosa Publishers in India and Alpha Science International, UK, 2009.*

Course outcomes

At the end of the course student will be able

1. To understand energy concepts in structures, characteristics of structures, transformation of information in structures.
2. To perform analysis by iteration method and determine deflection of structures using Maxwell-Betti Law of Reciprocal Deflections.
3. To understand generalized and constrained measurements.
4. To apply principle of superposition in practical problems.
5. To understand fundamental relationships for structural analysis and develop analytical models.

Course Code	**:**	CE662
Course Title	**:**	Stochastic Processes in Structural Mechanics
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the basic concept of random variables and its extension to stochastic processes.
2. To know the modelling of natural phenomena through random processes.
3. To learn probability distribution of a random variable.
4. To understand the concept of multiple random variables.
5. To familiarize students with covariance, conditional mean and variance.

Course Content

Basic Theory of Random variables - Probability distribution of a random variable, multiple random variables, main descriptors of a random variable – Moments, expectation, covariance, correlation, conditional mean and variance. Functions of random variables, moments of functions of random variables.

Basic Theory of Stochastic Processes - Introduction, Statistics of stochastic processes, Ergodic processes, Some properties of the correlation functions, Spectral analysis, Wiener-Khintchine equation.

Some Important Random Processes - Normal processes, Poisson processes, Markov processes.

Properties of Random Processes - Level crossing peaks, Fractional occupation time, Envelopes, First-Passage time, Maximum value of a Random Process in a time interval.

Some Models of Random Processes in Nature - Earthquake, Wind, Atmosphere turbulence, Random Runways, Road Roughness, Jet Noise, Ocean wave turbulence. Fourier analysis and Data Processing.

Reference Books

1. *Papoulis, A., Probability, Random Variables and Stochastic Processes, McGraw Hill.*
2. *Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill.*
3. *Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA.*
4. *Crandall, S. H. & Mark, W. D., Random Vibration in Mechanical Systems, Academic Press.*
5. *Srinivasan Chandrasekaran, Offshore Structural Engineering: Reliability and Risk Assessment, CRC Press, Florida, 2016.*

Course outcomes

At the end of the course student will be able

1. To understand basic theory of stochastic processes and its relevance in the realistic modeling of natural phenomena.
2. To understand the basic theory of random variables, multiple random variables and random processes.
3. To be familiar with probability distribution of a random variable.
4. To be familiar with covariance, conditional mean and variance.
5. To understand the concept of Fourier analysis and data processing.

Course Code	:	CE663
Course Title	:	Random Vibrations and Structural Reliability
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. Identify sources of uncertainty in solid mechanics problems.
2. Develop probabilistic models or input/system parameter uncertainty.
3. Compute the reliability index for structural systems.
4. Compute bounds on effective properties for heterogeneous materials.
5. Compute statistics of response of random dynamical systems.

Course Content

Review of probability: probability space, random variables, functions of random variables, sequence of random variables and limit theorems for sums, products and extremes. Review of random processes: stationarity, ergodictiy, power spectrum and auto covariance. Calculus of random processes. Input-output relations for linear systems. Stochastic steady state. Level crossing and first passage problems. Extreme value distributions. Reliability index based analyses: FORM and SORM. Monte Carlo simulations and variance reduction. Reliability of existing structures.

Reference Books

1. *N C Nigam, Introduction to Random Vibrations, MIT Press, Boston, 1983.*
2. *A Papoulis, Probability, Random Variables and Stochastic Processes, McGrawHill, New York, 1993.*
3. *R E Melchers, Structural Reliability Analysis and Prediction, John Wiley, Chichester, 1999.*
4. *O. Ditlevsen, H. O. Madsen, Structural Reliability Methods, Wiley, 1st Edition, 1996.*
5. *Srinivasan Chandrasekaran, Offshore Structural Engineering: Reliability and Risk Assessment, CRC Press, Florida, 2016.*

Course outcomes

At the end of the course student will be able

1. To get an understanding of the various methods of reliability assessments and its application as well as importance.
2. To apply the knowledge of the application of reliability study in various fields of structural engineering and its relevance.
3. To understand various methods and techniques as well as provisions in reliability assessment.
4. To assess partial safety factors by FORM analysis.
5. To use crude Monte-Carlo Simulation technique to solve practical problems.

Course Code	:	CE664
Course Title	:	Fracture Mechanics
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To understand the concept of fracture mechanics.
2. To get exposed to method of stress analysis.
3. To understand failure mechanisms.
4. To understand design methods.
5. To understand stress intensity factor.

Course Content

Failure theories, Fracture, Definition of stress intensity factor, Fracture toughness - Energy release rate, Critical Energy release rate - Crack mouth opening displacement, R-Curve and J integral - Basic reasons for fracture mechanics approach for concrete, Limitations of linear elastic fracture mechanics for concrete and steel. Non- linear fracture method - Fracture energy and size effect. Shrinkage and creep, shear transfer, Failure modes

Test Methods for fracture analysis, Case studies and discussions.

Reference Books

1. *David Broek, Elementary Engineering Fracture Mechanics, Sijthoff and Noordhaff, Alphen Aan Den Rijn, The Netherlands, 2001.*
2. *Analysis of Concrete Structure by Fracture Mechanics, Ed L. Elfgren and S.P. Shah, Proc of Rilem Workshop, Chapman and Hall, London, 2001.*
3. *Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw Hill, New Delhi, India, 2009.*
4. *K. Ramesh, e-Book on Engineering Fracture Mechanics, IIT Madras, 2007.*
5. *Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley, India, 5th Edition, 2014.*

Course outcomes

At the end of the course student will be able

1. To understand fracture toughness and fracture energy.
2. To be familiar with energy release rate.
3. To get exposed to the concept of crack mouth opening displacement.
4. To understand fracture mechanics of concrete.
5. To be familiar with linear and nonlinear fracture mechanics.

Course Code	:	CE665
Course Title	:	Structural Optimization
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. The objective of this course is to introduce the concepts of design optimization and review major conventional and modern optimization methods used in structural optimization applications.
2. To understand the formulation of structural optimization problems.
3. To get familiarized with the application of linear and non-linear programming to structural optimization.
4. To get exposed to unconstrained and constrained optimization.
5. To understand direct and indirect methods, direct search and gradient methods.

Course Content

Formulation of Structural Optimization problems: Design variables - Objective function - constraints. Fully stressed design. Review of Linear Algebra: Vector spaces, basis and dimension, canonical forms.

Linear Programming: Revised Simplex method, Application to structural Optimization. Nonlinear Programming: Deterministic Methods - Unconstrained and constrained Optimization - Kuhn-Tucker conditions, Direct search and gradient methods - One dimensional search methods - DFP and BFGS algorithms, constrained Optimization - Direct and Indirect methods - SLP, SQP and SUMT, Application of NLP methods to optimal structural design problems.

Optimality criteria based methods, Reanalysis techniques - Approximation concepts - Design sensitivity, Optimization of sections, steel and concrete structures - framed structures, bridge structures.

Stochastic Optimization Methods: Genetic Algorithms - Binary coding - Genetic Operators - Simple Genetic Algorithm (SGA) and variable length Genetic Algorithm (VGA). Simulated annealing. Applications to discrete size, Configuration and shape optimization problems.

Artificial Intelligence and Artificial Neural Networks based approaches for structural optimization problems.

Reference Books

1. *Haftka, R. T. and Gurdal, Z., Elements of Structural Optimization, Springer, 3rd Edition, 1992.*
2. *Gurdal, Z, Haftka, R. T., and Hajela, P., Design and Optimization of Composite Materials, Wiley, 1998.*
3. *K. K. Choi and N. H. Kim, Design Sensitivity Analysis for Linear and Nonlinear Structures, Springer, 2005.*
4. *Arora, J. S., Introduction to Optimum Design, Elsevier, 2nd Edition, 2004.*
5. *Rao. S. S. Optimization Theory and Applications, Wiley Eastern (P) Ltd., 1984.*

Course outcomes

At the end of the course student will be able

1. To use the optimization tools for the design of structures effectively.
2. To understand the concept of optimality criteria and reanalysis techniques.
3. To use approximation concepts and stochastic optimization methods.
4. To be familiar with genetic algorithm and simulated annealing.
5. To be able to work in artificial intelligence and artificial neural networks.

Course Code	:	CE666
Course Title	:	Failure Analysis of Structures
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To understand the causes of failure, failure modes and mechanism.
2. To know how engineering materials and components fail.
3. To understand the concept of design and manufacturing integrity.
4. To understand material selection procedure based on requirement.
5. To get exposed to legal problems in failure of structures.

Course Content

Causes of failure – Types of failure – why, what, how – durability of materials – Landmark case – Performance and shape inadequacy – statistics and reliability – life cycle assessment.

Structural failure – material and load effects – environment effect - Non-structural and structural repairs – Biocidal treatment and use of preservatives – deterioration of wood.

Macro micro level failures – component and sub-system failures - failure theories – analytical models – cases and type of problem in components – safety evaluation.

Structural systems – case studies – pin-jointed steel systems – rigid jointed frames – concrete walls - arches – reinforced concrete beams and frames – shells – repair of concrete bridge and water retaining structures.

Bridge maintenance techniques – The refurbishment of buildings, legal responsibilities – Case studies – Definition of smartness – sensors – automatic and adaptive systems – smart components.

Reference Books

1. *Rasnom, W. H., Building Failures, E&F, N. SPON Ltd., 1980.*
2. *Moskvin V, Concrete and Reinforced Structures – Deterioration and Protection, Mir Publishers, Moscow, 1980.*
3. *Kenneth and L. Carper, Forensic Engineering, CRC Press, 2nd Edition, 2001.*
4. *V K Raina, Concrete Bridge Practice Construction, Maintenance and Rehabilitation, Shroff Publishers and Distributors, 2nd Edition, August, 2010.*
5. *Srinivasan Chandrasekaran, Luciano Nunzinate, Giorgio Seriino, Federico Caranannate, Seismic Design Aids for Nonlinear analysis of Reinforced Concrete Structures, CRC Press, Florida, 2009.*

Course outcomes

At the end of the course student will be able

1. To identify the objective of study of fracture mechanics.
2. To model linear elastic fracture mechanics.
3. To simulate actual failure analysis problems in site.
4. To understand repair and maintenance of structures and product liability issues.
5. To analyse and design structures for failure prevention.

Course Code	**:**	CE667
Course Title	**:**	Stability of Structures
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. This course deals with stability problems in structural forms and systems.
2. It also takes care of special consideration for stability during design of structural elements.
3. It also aims for studying the buckling and analysis of structural elements.
4. To study the stability analysis problems in column, beam and beam-column.
5. To make students understand the phenomenon of buckling of frames and plates.

Course Content

Stability concept –bifurcation buckling – methods of stability analysis – energy method – initial imperfection – large displacement analysis

Buckling of columns –Euler column –second order and fourth order equation method – Rayleigh-Ritz and numerical methods – Axially loaded column – Eccentrically loaded column – inelastic buckling

Buckling of frames – braced and unbraced frames – slope deflection equations, matrix method – effective length – alignment charts

Torsional and flexural-torsional buckling – torsion of thin walled open cross-section – flexural-torsional buckling of columns – lateral-torsional buckling of beams and beam-columns

Buckling of plates – Differential equation of plate buckling – critical load on plates for various boundary conditions – Energy method – Finite difference method

Reference Books

1. *Timoshenko. S. P and Gere. J. M, Theory of Elastic Stability, McGraw Hill Book Company, 1981.*
2. *Alexandar Chajes, Principles of Structural Stability Theory, Prentice Hall, New Jersey, 1980.*
3. *Iyenger, N. G. R., Structural Stability of Columns and Plates, Affiliated East West Press Pvt. Ltd., 1990.*
4. *Bleich F., Buckling Strength of Metal Structures, McGraw Hill 1991.*
5. *Gambhir, Stability Analysis and Design of Structures, Springer, New York, 2004.*

Course outcomes

At the end of the course student will be able

1. To understand stability of static and dynamic equilibrium.
2. To evaluate static stability criteria using stability equations.
3. To solve stability problems by energy method and finite difference method.
4. To predict critical loads on structures.
5. To create discrete and continuous models to solve stability problems.

Course Code	:	CE668
Course Title	:	Theory of Plates and Shells
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce the concept of plate theory.
2. To study the behaviour and analysis of thin plates.
3. To study the procedure for rectangular plates and circular plates subjected to lateral loads.
4. To study the classification and behaviour of shells.
5. To study the membrane analysis of shells.

Course Content

Thin plates with small deflection; assumptions - Long plates in cylindrical bending, strain energy in rectangular plates - governing differential equations (Kirchhoff Plate) and various boundary conditions.

Simply supported rectangular plates - Navier solution with various types of loads, rectangular plates with various boundary conditions - Naviers method for patch/point loads - Levy's method, Axi- symmetric circular plates

Demonstration of numerical methods such as Rayleigh, Galerkin and Kantorovich methods.

Approximate analysis of Grids (Rankine-Grashoff) – Analysis of Folded Plates by Winter-Pei distribution

Overview on Orthotropic plates – Overview on Large deflection of plates and mid-plane stretching (Foppl- von Karman plate) – Overview on Mindlin Reissner Theory

Stability of rectangular plates fundamentals - some edge conditions- design applications such as section classification and simple postcritical method

Shells: structural behavior, classification, translational and rotational shells- hyperbolic paraboloid- elliptic paraboloid- Gaussian curvature - Overviews on Shell theories such as Higher order theories, Marguerre theory, DKJ Theory etc

Membrane theory of shells- cylindrical shells- shells of revolution including design

Reference Books

1. *Timoshenko, S. and Krieger S.W. "Theory of Plates and Shells", McGraw Hill Book Company, New York, 2003*
2. *Chandrashekahara, K. Theory of Plates, University Press (India) Ltd., Hyderabad, 2001.*
3. *Szilard, R., "Theory and Analysis of Plates - Classical and Numerical Methods", Prentice Hall Inc., 2004.*
4. *J.Raamachandran. "Thin shells; Theory and problems", Universities press.*

Course outcomes

At the end of the course student will be able

1. To assess the strength of thin plates under different types of loads.
2. To analyze thin plates using Navier's method and Levy's method.
3. Analyse circular plates under axi-symmetric deflection.
4. To classify different types of shells and study their behavior.
5. To analyze shells using membrane theory.

Course Code	**:**	CE669
Course Title	**:**	Advanced Steel And Concrete Composite Structures
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To introduce students to steel-concrete composite structures and types of shear connectors.
2. To make students understand analysis and design of composite beams and deflection of composite beams.
3. To make students be familiar with composite slabs, analysis and design of composite floor systems.
4. To get students exposed to types of composite columns.
5. To make students learn vibration of composite beams and cyclic behaviour of composite sections.

Course Content

Introduction – limit states of composite sections - shear connectors – types of shear connectors – degree of shear connection – partial and complete shear connections – strength of shear connectors – Analysis and design of composite beams without profile sheet.

Design of composite beam – propped condition – un-propped condition – deflection of composite beams – beam with profile sheeted deck slab – design of partial shear connection.

Introduction – Composite slabs – profiled sheeting – sheeting parallel to span – sheeting perpendicular to span – analysis and design of composite floor system.

Types of Composite columns – design of encased columns – design of in-filled columns – axial, uni-axial and bi-axially loaded columns.

Temperature – shrinkage and creep – vibration of composite beams – Cyclic behavior of composite section – case studies.

Reference Books

1. *Johnson R. P., "Composite Structures of Steel and Concrete"' Volume-I, Black Well Scientific Publication, U.K., 1994.*
2. *Teaching Resources for "Structural Steel Design". Vol. 2 of 3, Institute of Steel Development and Growth (INSDAG), 2000.*
3. *Narayanan R., "Composite Steel Structures – Advances, Design and Construction, Elsevier, Applied Science, U. K., 1987.*

4. *Owens, G. W & Knowels, P., Steel Designers Manual," Steel Concrete Institute (U. K), Oxford Blackwell Scientific Publication, Fifth Edition, 1992.*
5. *Oehlers D. J. and Bradford M. A., Composite Steel and Concrete Structural Members, Fundamental Behaviour, Pergamon Press, Oxford, 1995.*

Course outcomes

At the end of the course student will be able

1. To understand steel-concrete composite structures and types of shear connectors.
2. To understand analysis and design of composite beams and deflection of composite beams.
3. To be familiar with composite slabs, analysis and design of composite floor systems.
4. To get exposed to types of composite columns.
5. To learn vibration of composite beams and cyclic behaviour of composite sections.

Course Code	:	CE670
Course Title	:	Seismic Design of Structures
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce the basics of earthquake engineering and how they influence the structural design.
2. To aim at introducing engineering seismology and building characteristics.
3. To make students understand structural irregularities, do's and don'ts in earthquake engineering design, code provision on different types of structures.
4. To make students be familiar with structural modelling and lateral load resisting design.
5. To make students get exposed to strength, stiffness and ductility requirements and energy dissipation devices.

Course Content

Engineering seismology – rebound theory plate tectonics - Seismic design concepts EQ load on simple buildings – load path floor and roof diaphragms – seismic resistant building architecture – plan configuration – vertical configuration – pounding effects – mass and stiffness irregularities – torsion in structural system.

Provision of seismic code (IS1893, IS 13920)- Ductile Detailing – Building systems – frames – shear wall – braced frames – layout design of Moment Resisting Frames (MRF) – Design of Masonry structures

Cyclic loading behaviour of RCC and Steel elements (Damage Models) - base isolation – Energy dissipating devices – case studies.

Performance Based Seismic Design - Seismic performance evaluation of structural and non-structural components and systems.

Reference Books

1. *Pankaj Agarwal and Manish ShriKhande, Earthquake Resistant Design of Structures, Prentice- Hall of India, New Delhi, 2007.*
2. *Bullen K. E., Introduction to the Theory of Seismology, Great Britain at the University Printing houses, Cambridge University Press, 1996.*
3. *S K Duggal, "Earthquake Resistant Design of Structures", Oxford University Press, 2007.*
4. *Paulay, T and Priestly, M. N. J., "A Seismic Design of Reinforced Concrete and Masonry buildings", John Wiley and Sons, 1991.*
5. *Srinivasan Chandrasekaran, Luciano Nunzinate, Giorgio Seriino, Federico Caranannate, Seismic Design Aids for Nonlinear analysis of Reinforced Concrete Structures, CRC Press, Florida (USA), 2009.*

Course outcomes

At the end of the course student will be able

1. To understand the basics of earthquake engineering and how they influence the structural design.
2. To understand engineering seismology and building characteristics.
3. To learn structural irregularities, do's and don'ts in earthquake engineering design, code provision on different types of structures.
4. To be familiar with structural modelling and lateral load resisting design.
5. To get exposed to strength, stiffness and ductility requirements and energy dissipation devices.

Course Code	:	CE671
Course Title	:	Prefabricated Structures
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce prefabrication and its types.
2. To make students know the different types of prefabrication systems.
3. To make students learn different structural connections.
4. To make students exposed to erection of RC structures.
5. To make students familiarize with designing and detailing of prefabricated units.

Course Content

Types of prefabrication, prefabrication systems and structural schemes - Disuniting of structures - Structural behavior of precast structures.

Handling and erection stresses - Application of pre-stressing of roof members; floor systems, two way load bearing slabs, Wall panels, hipped plate and shell structures.

Dimensioning and detailing of joints for different structural connections; construction and expansion joints.

Production, Transportation and erection - Shuttering and mould design - Dimensional tolerances - Erection of R.C. Structures, Total prefabricated buildings.

Designing and detailing prefabricated units for 1) industrial structures 2) Multistorey buildings and 3) Water tanks, silos bunkers etc., 4) Application of pre-stressed concrete in prefabrication.

Reference Books

1. *Hass, A. M. Precast Concrete Design and Applications, Applied Science Publishers, 1983.*
2. *Promyslolw, V Design and Erection of Reinforced Concrete Structures, MIR Publishers, Moscow 1980.*
3. *Koncz. T., Manual of Precast Concrete Construction, Vol. I, II and III, Bauverlag, GMBH, 1971.*
4. *Structural Design Manual, Precast Concrete Connection Details, Society for the Studies in the use of Precast Concrete, Netherland Betor Verlag, 1978.*
5. *B. Lewicki, Building with Large Prefabricates, Elsevier Publishing Company, Amsterdam/London/New York, 1966.*

Course outcomes

At the end of the course student will be able

1. To get introduced to prefabrication and its types.
2. To know the different types of prefabrication systems.
3. To learn different structural connections.
4. To be exposed to erection of RC structures.
5. To be familiar with designing and detailing of prefabricated units.

Course Code	:	CE672
Course Title	:	Smart Structures and Applications
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce passive and active systems.
2. To familiarize students with components of smart systems.
3. To make students exposed to different types of smart materials.
4. To make students understand control systems.
5. To introduce the methods and techniques for developing and designing multifunctional structures.

Course Content

Introduction to passive and active systems – need for active systems – smart systems – definitions and implications - active control and adaptive control systems – examples.

Components of smart systems – system features and interpretation of sensor data – pro-active and reactive systems – demo example in component level – system level complexity.

Materials used in smart systems – characteristics of sensors – different types of smart materials – characteristics and behaviour of smart materials – modelling smart materials – examples.

Control Systems – features – active systems – adaptive systems – electronic, thermal and hydraulic type actuators – characteristics of control systems – application examples.

Integration of sensors and control systems – modelling features – sensor-response integration – processing for proactive and reactive components – FE models – examples.

Reference Books

1. *Srinivasan, A. V. and Michael McFarland, D., Smart Structures: Analysis and Design, Cambridge University Press, 2000.*
2. *Yoseph Bar Cohen, Smart Structures and Materials, The International Society for Optical Engineering, 2003.*
3. *Brian Culshaw, Smart Structures and Materials , Artech House, Boston, 1996.*
4. *M. V. Gandhi and B. S. Thompson, Smart Materials and Structures, Chapman and Hall, 1992.*
5. *Afzal Suleman, Smart Structures Applications and Related Technologies, (International Centre for Mechanical Sciences, Courses and Lectures No.*

429), Springer, 2014.

Course outcomes

At the end of the course student will be able

1. To understand the concept of passive and active systems.
2. To be familiar with components of smart systems.
3. To be exposed to different types of smart materials.
4. To better understand control systems.
5. To be familiar with the methods and techniques for developing and designing multifunctional structures.

Course Code	:	CE673
Course Title	:	Prestressed Concrete Structures
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To develop an understanding of the philosophy of pre-stressing design.
2. To study the design of indeterminate pre-stressed concrete structures.
3. To have a better understanding about the connections for pre-stressed concrete elements.
4. To design pre-stressed concrete bridges.
5. To study the design of pre-stressed concrete pipes and tanks.

Contents

Introduction – Important concepts of pre-stressing – Systems for Pre-stressing – The philosophy of design - Time dependent deformation of concrete and losses of pre-stress.

Flexural design of pre-stressed concrete elements – Shear, torsion and bond – Indeterminate pre-stressed concrete structures – Camber, deflection and crack control.

Pre-stressed concrete compression and tension members – Two way pre-stressed concrete floor systems – Connections for pre-stressed concrete elements.

Design of pre-stressed concrete bridges incorporating with long-term effects like creep, shrinkage, relaxation and temperature effects.

Circular prestressing- Design of Prestressed Concrete Pipes and water tanks.

References

1. *Antonnie. E. Naaman, Prestressed Concrete Analysis and Design, Technopress, 3rd Edition, 2012.*
2. *Edward. G .Nawy, Prestressed Concrete, Prentice Hall, 5th Edition, 2010.*
3. *Arthur. H. Nilson, Design of Prestressed Concrete, John Wiley and sons, 2nd Edition, 1987.*
4. *Raja Gopalan N. Prestressed Concrete, Alpha Science International, 2nd Edition, 2005.*
5. *Krishna Raju, Prestressed Concrete, Tata McGraw Hill Publishing Co, 2000.*

Course outcomes

At the end of the course student will be able to

1. Ensure the design philosophy of prestressing
2. Design the flexural members due to shear, torsion, bond by incorporating the prestress losses.
3. Design the connections for compression and tension prestressing elements and floor systems.
4. Design the prestressed concrete girder bridges by incorporating the long-term effects
5. Design the prestressed concrete pipes and tanks

Course Code	:	CE674
Course Title	:	Analysis and Design of Tall Buildings
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce design philosophy, loading, different types of frames, types of shear walls.
2. To expose students to different lateral load resisting systems.
3. To make students understand approximate analysis, accurate analysis and reduction techniques.
4. To familiarize students with design of structural elements, buckling analysis, pdelta analysis.
5. To make students understand translational – torsional instability.

Course Content

Design philosophy – Loading - Sequential loading, materials.

High risk behavior, rigid frames, braced frames, in filled frames; shear walls, coupled shear walls, wall – frames, tubulars, cores, outrigger - braced and hybrid mega system.

Approximate Analysis, Accurate Analysis and Reduction Techniques - Analysis of building for member forces - drift and twist - Computerized general three dimensional analysis.

Structural elements - design, deflection, cracking, pre-stressing, shear flow - Design for differential movements, creep and shrinkage effects, temperature effects and fire.

Overall buckling analysis of frames, wall – frames – second order effects of gravity loading – simultaneous first order and P-delta analysis, Translational - torsional instability, out of plumb effects.

Reference Books

1. *Bryan Stafford Smith and Alex Coull, Tall Building Structures – Analysis and Design, John Wiley and Sons, 2006.*
2. *Taranath B. S., Structural Analysis and Design of Tall Buildings, McGraw Hill, 1988.*
3. *Lin T. Y and Stotes Burry D, Structural Concepts and Systems for Architects and Engineers, John Wiley, 1988.*
4. *Beedle. L. S., Advances in Tall Buildings, CBS Publishers and Distributors, Delhi, 1986.*

5. *Gupta. Y. P.,(Editor), Proceedings of National Seminar on High Rise Structures – Design and Construction Practices for Middle Level Cities, New Age International Limited, New Delhi, 1995.*

Course outcomes

At the end of the course student will be able

1. To understand the design philosophy, loading, different types of frames, types of shear walls.
2. To be exposed to different lateral load resisting systems.
3. To understand approximate analysis, accurate analysis and reduction techniques.
4. To be familiar with design of structural elements, buckling analysis, p-delta analysis.
5. To understand translational – torsional instability.

Course Code	:	CE675
Course Title	:	Structures in Disaster Prone Areas
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce earthquake resistant design, cyclone resistant design, flood resistant design, by laws.
2. To make students be familiar with traditional and modern structures, response of different structures to multi hazard, different types of foundation, ground improvement techniques.
3. To make students understand various methods of strengthening, strengthening of different structures exposed to multi hazard.
4. To make students get exposed to testing and evaluation of structures, classification of structures, qualification test, modern materials – disaster reduction.
5. To make students learn modern analysis, design and construction techniques, optimization for performance, damage survey, improve hazard resistance.

Course Content

Philosophy for design to resist Earthquake, Cyclone and flood – By-laws of urban and Semi-Urban areas - Traditional and modern structures.

Response of dams, bridges, buildings – Strengthening - Testing and evaluation – Classification of structures for safety point of view.

Methods of strengthening for different disasters – Qualification test.

Use of modern materials, their impact on disaster reduction – Use of modern analysis, design and construction techniques, optimization for performance.

Damage surveys – Maintenance and modifications to improve hazard resistance – Different types of foundation and its impact on safety – Ground improvement techniques.

Reference Books

1. *Allen, R. T. and Edwards, S. C., Repair of Concrete Structures, Blakie and Sons, 1980.*
2. *Moskvin V, Concrete and Reinforced Structures – Deterioration and Protection, Mir Publishers, Moscow, 1980.*
3. *A K Jain, Practical Guide to Disaster Management, Pragun Publication, 2008.*
4. *Denison Campbell, Allen and Harold Roper, Concrete Structures, Materials, Maintenance and Repair, Longman Scientific and Technical, UK, 1991.*

5. *Srinivasan Chandrasekaran, Luciano Nunzinate, Giorgio Seriino, Federico Caranannate, Seismic Design Aids for Nonlinear analysis of Reinforced Concrete Structures, CRC Press, Florida (USA), 2009.*

Course outcomes

At the end of the course student will be able

1. To understand earthquake resistant design, cyclone resistant design, flood resistant design, by laws.
2. To be familiar with traditional and modern structures, response of different structures to multi hazard, different types of foundation, ground improvement techniques.
3. To understand various methods of strengthening, strengthening of different structures exposed to multi hazard.
4. To be exposed to testing and evaluation of structures, classification of structures, qualification test, modern materials for disaster reduction.
5. To get to learn modern analysis, design and construction techniques, optimization for performance, damage survey, improve hazard resistance.

Course Code	**:**	CE676
Course Title	**:**	Design of Boiler Structures
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To introduce boiler structures, types of boilers.
2. To make students learn structural components of boilers, design and construction of boilers.
3. To make students understand safety monitoring and operation, drum lifting structure.
4. To familiarize students with design loads, foundation analysis.
5. To expose students to platform structure.

Course Content

Type of boilers: Top supported - Utility boilers - Tower type - Two pass system - Once through boiler - Bottom supported - Industrial boilers - Bi drum Layout configuration - Front mill layout - Rear mill layout - Side mill layout - column configuration for 210MW-250MW-500MW and lower capacity boilers.

Boiler Structure - Structural components – Columns – beams - vertical bracings - ceiling structure including ceiling girders - girder pin connection - horizontal truss work-platforms - weather protection structure - stair ways - mid landing plat forms handrails - floor grills - post and hangers - inter connection platforms - lift structure mill maintenance plat form structure - duct supports - furnace guide supports - Eco coil handling structure - ID system structure - Fan handling structure.

Drum lifting Structure: pressure parts – ducts – fuel pipe – platform - critical pipe - lining and insulation – silencer - weather protection roof - side cladding - cable tray and pipe rack.

Dead loads - Live load - wind load - seismic load - guide load - temperature load customer load - handling loads - contingency load etc. - Foundation analysis Foundation materials - main columns - auxiliary columns - horizontal beams - vertical bracings - MBL concept - horizontal truss work – girder - pin connection - ceiling main girders - cross girders - pressure parts support beams - ceiling truss work - drum floor – stairs - mid landing plat forms - hand rails - floor grills - fasteners.

Platform Structure: Access platforms required for ducts, equipment and furnace etc. Air heater supports - Fuel pipe support - Duct support - Primary and Secondary air ducts - Bus duct – SCAPH - Flue gas duct supports. Buck stay beams - key channel- leveller guides - vertical buckstay - furnace guide - corner connections - link ties hanger tie rods

- hanger spring - hopper truss work - goose neck truss work - wind box truss work - expansion measurement instrument.

Reference Books

1. *Subramanian N, Design of Steel Structures, Oxford University Press, New Delhi, 2008.*
2. *Bhavikatti, S. S., Design of Steel Structures, I. K. International Publishing House Pvt. Ltd., New Delhi, 2010.*
3. *Punmia B. C., Comprehensive Design of Steel Structures, Lakshmi Publications, New Delhi, 2000.*
4. *Vasant Matsagar, Advances in Structural Engineering: Materials, Volume Three, Springer, 2015.*
5. *Brad Buecker, Basics of Boiler and HRSG Design, 2002.*

Course outcomes

At the end of the course student will be able

1. To understand boiler structures, types of boilers.
2. To learn structural components of boilers, design and construction of boilers.
3. To understand safety monitoring and operation, drum lifting structure.
4. To be familiar with design loads, foundation analysis.
5. To be exposed to platform structure.

Course Code	:	CE677
Course Title	:	Structures for Power Plants
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce power plant structure, different types of power plants.
2. To make students understand planning, analysis and design of power plants.
3. To make students be familiar with analysis and design of chimneys, cooling towers.
4. To make students exposed to analysis and design of turbo generator foundation.
5. To make students understand the components of intake towers, storage structures.

Course Content

Planning, Analysis and design of different types of power plants - Chimneys, Induced draught and Natural draught cooling towers, Turbo generator Foundation, Material handling structures, Intake towers, storage structures and other supporting structures for equipment.

Reference Books

1. *Kam W. Li and A. Paul Priddy., Power Plant System Design by John and Willey Sons Inc.*
2. *E. E. Khalil., Power Plant Design An abacus book Energy and Engineering Science Series, Abacus Press, 1990.*
3. *P. C. Sharma., Power Plant Engineering, S. K. Kataria and Sons, 2009.*
4. *Krishna Raju, Advanced Reinforced Concrete Design (IS: 456-2000), CBS Publishers and Distributors, 2008.*
5. *Srinivasulu P and Vaidyanathan. C, Handbook of Machine Foundations, Tata McGraw Hill, 1976.*

Course outcomes

At the end of the course student will be able

1. To understand power plant structure, different types of power plants.
2. To understand planning, analysis and design of power plants.
3. To be familiar with the analysis and design of chimneys, cooling towers.
4. To be exposed to analysis and design of turbo generator foundation.
5. To understand the components of intake towers, storage structures.

Course Code	**:**	CE678
Course Title	**:**	Forensic Engineering and Rehabilitation of Structures
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the causes of failure of structures.
2. To enable students to diagnose distress of structures.
3. To make students understand various environmental problems and natural hazards.
4. To expose students to modern techniques of retrofitting.
5. To familiarize students with case studies.

Course Content

Failure of Structures: Review of the construction theory – performance problems – responsibility and accountability – case studies – learning from failures – causes of distress in structural members – design and material deficiencies – over loading.

Diagnosis and Assessment of Distress: Visual inspection – non-destructive tests – ultrasonic pulse velocity method – rebound hammer technique – ASTM classifications – pullout tests – Bremor test – Windsor probe test – crack detection techniques – case studies – single and multistorey buildings – Fibre optic method for prediction of structural weakness.

Environmental Problems and Natural Hazards: Effect of corrosive, chemical and marine environment – pollution and carbonation problems – durability of RCC structures – damage due to earthquakes and flood - strengthening of buildings – provisions of BIS 1893 and 4326.

Modern Techniques of Retrofitting: Structural first aid after a disaster – guniting - jacketing – use of chemicals in repair – application of polymers – ferrocement and fiber concretes as rehabilitation materials – rust eliminators and polymer coating for rebars - foamed concrete - mortar repair for cracks - shoring and underpinning strengthening by pre-stressing.
Case studies – buildings - heritage buildings - high rise buildings - water tanks – bridges and other structures.

Reference Books

1. *Raikar, R. N., Learning from Failures – Deficiencies in Design, Construction and Service R&D Centre (SDCPL), Raikar Bhavan, 1987.*
2. *Dovkaminetzky, Design and Construction Failures, Galgotia Publication, New Delhi, 2001.*

3. *Shen-En Chen, R. Janardhanam, C. Natarajan, Ryan Schmidt, Ino-U.S. Forensic Practices - Investigation Techniques and Technology, ASCE, U.S.A., 2010.*
4. *C. Natarajan, R. Janardhanam, Shen-En Chen, Ryan Schmidt, Ino-U.S. Forensic Practices - Investigation Techniques and Technology, NIT, Tiruchirappalli, 2010.*
5. *Gary L. Lewis, Guidelines for Forensic Engineering Practice, ASCE, U.S.A., 2003.*

Course outcomes

At the end of the course student will be able

1. To understand the causes of failure of structures.
2. To diagnose distress of structures.
3. To understand various environmental problems and natural hazards.
4. To be exposed to modern techniques of retrofitting.
5. To be familiar with case studies.

Course Code	**:**	CE679
Course Title	**:**	Soil Structure Interaction
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To make students understand soil foundation interaction and its importance.
2. To familiarize students with model analysis, Winkler model for soil structure interaction analysis.
3. To expose students to beams and plates on elastic foundation.
4. To enable students to carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction.
5. To make students understand the concepts of laterally loaded pile.

Course Content

Soil-Foundation Interaction: Introduction to soil-foundation interaction problems, Soil behavior, Foundation behavior, Interface behavior, Scope of soil foundation interaction analysis, soil response models, Winkler, Elastic continuum, two parameter elastic models, Elastic plastic behavior and Time dependent behavior.

Beam on Elastic Foundation - Soil Models: Infinite beam, two parameters, Isotropic elastic half space, Analysis of beams of finite length, Classification of finite beams in relation to their stiffness.
Plate on Elastic Medium: Thin and thick plates, Analysis of finite plates, Numerical analysis of finite plates, simple solutions.

Elastic Analysis of Pile: Elastic analysis of single pile, Theoretical solutions for settlement and load distributions, Analysis of pile group, Interaction analysis, Load distribution in groups with rigid cap.

Laterally Loaded Pile: Load deflection prediction for laterally loaded piles, Subgrade reaction and elastic analysis, Interaction analysis, Pile-raft system, Solutions through influence charts. An introduction to soil-foundation interaction under dynamic loads.

Reference Books

1. *Selva Durai, A. P. S, Elastic Analysis of Soil-Foundation Interaction, Elsevier, 1979.*
2. *Poulos, H. G., and Davis, E. H., Pile Foundation Analysis and Design, John Wiley, 1980.*
3. *J. E. Bowles, "Foundation Analysis and Design", McGraw Hill, 1996.*
4. *J. W. Bull, Soil-Structure Interaction: Numerical Analysis and Modelling, CRC Press, 1st Edition, 1994.*

5. *Chandrakant S. Desai, Musharraf Zaman, Advanced Geotechnical Engineering: Soil-Structure Interaction using Computer and Material Models, CRC Press, 2013.*

Course outcomes

At the end of the course student will be able

1. To understand soil foundation interaction and its importance.
2. To be familiar with model analysis, Winkler model for soil structure interaction analysis.
3. To be exposed to beams and plates on elastic foundation.
4. To carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction.
5. To better understand the concepts of laterally loaded pile.

Course Code	:	CE680
Course Title	:	Advanced Concrete Technology
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To make students understand concrete admixtures, non-destructive testing, semi-destructive testing, special concrete.
2. To familiarize students with structure of hydrated cement paste, types of cement, cement production quality control.
3. To make students learn transition zone in concrete, measurement of workability, properties of concrete, concrete mix design.
4. To expose students to strength porosity relationship, failure modes in concrete, elastic behaviour in concrete.
5. To make students understand causes of concrete deterioration, permeability of concrete, durability of concrete, alkali aggregation reaction.

Course Content

Introduction to concrete – Mineral and chemical admixtures – Structure of hydrated cement paste – Calcium Aluminate Cement – Cement Production quality control Transition zone in concrete – measurement of workability by quantitative empirical methods – concrete properties: setting and hardening.

Concrete Design mix for higher grades.

Strength-Porosity relationship – Failure modes in concrete – plastic and thermal cracking – maturity concept to estimate curing duration - Elastic behavior in concrete-Creep, shrinkage and thermal properties of concrete.

Classification of causes of concrete deterioration – Permeability of concrete – durability concept: pore structure and transport process - Alkali-aggregate reactivity.

Non-Destructive testing methods - Semi-destructive testing methods. Concreting under special circumstances – Special materials in construction – Concreting machinery and equipment – Sustainability in concrete - Future trends in concrete technology.

Reference Books

1. *P. Kumar Metha and Paulo J. M. Monteiro., Concrete: Microstructure, Properties and Materials, Mc Graw Hill, Fourth Edition, 2014.*
2. *John Newman and Ban Seng Choo, Advanced Concrete Technology Part 1 to 4, Butterworth-Heinemann, First Edition, 2003.*

3. *Adam. M. Nevillie., Properties of Concrete, Wiley Publications, Fourth and Final Edition, 1996.*
4. *A. R. Santhakumar, Concrete Technology" Oxford University Press, 2006.*
5. *P. C. Aitcin, High Performance Concrete, E & FN SPON, 1998.*

Course outcomes

At the end of the course student will be able

1. To understand concrete technology, admixtures, non-destructive testing, semi destructive testing, special concrete.
2. To be familiar with structure of hydrated cement paste, types of cement, cement production quality control.
3. To learn transition zone in concrete, measurement of workability, properties of concrete, rheological behaviour of concrete, economic concrete mix design.
4. To be exposed to strength-porosity relationship, failure modes in concrete, elastic behaviour in concrete, ageing properties and long term behaviour.
5. To better understand the causes of concrete deterioration, permeability of concrete, durability of concrete, alkali aggregation reaction.

Course Code	:	CE681
Course Title	:	Special Concrete
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To understand High Performance Concrete (HPC), fresh and hardened properties of HPC, mix design of HPC.
2. To understand the properties of Ultra HPC, Special HPC.
3. To familiarize students in reactive powder concrete, bio-concrete and geopolymer concrete.
4. To understand the concept of Self Compacting Concrete (SCC), mix design of SCC and properties of SCC.
5. To expose students to better understanding of durability and serviceability conditions of HPC and SCC.

Course Content

High Performance Concrete (HPC) - Introduction – Principles of HPC – Ingredients used for HPC – Production of HPC – Curing of HPC – Mechanism of HPC – Properties of HPC during the fresh and hardened state.

Durability of HPC - Acid Attack – Permeability – Scaling resistance – Chloride penetration – Resistance to sea water – sulfate attack – Alkali-aggregate reaction – Fire resistance – Mix design methods of HPC.

Ultra High Performance Concrete - Air-entrained HPC – Light-weight HPC – Heavy weight HPC – Fiber reinforced HPC – Confined HPC – Roller Compacted HPC – Ultra High Performance Concrete – Reactive powder Concrete - Bio concrete - Geopolymer concrete.

Self-Compacting Concrete - Introduction – Principles of SCC – Ingredients used for SCC – Mix design methods – Production and curing of SCC – Behavior of SCC under fresh and hardened state. Various Case Histories on HPC and SCC.

Reference Books

1. *P. C. Aitcin, High Performance Concrete, E & FN SPON, 1998.*
2. *E. G. Nawy, Fundamentals of High Performance Concrete, John Wiley and Sons., 2nd Edition, 2000.*
3. *High Performance Concrete Structural Designers Guide published by FHWA, USA, 2005.*
4. *Geert De Schutter, Peter J. M. Bartos, Peter Domone, John Gibbs, Self- Compacting Concrete, Whittles Publishing, 2008.*

5. *Shetty M. S., Concrete Technology, S. Chand and Company Ltd. Delhi, 2003.*

Course outcomes

At the end of the course student will be able

1. To select an apt concrete for specialized construction viz. in high-rise buildings, arches, shells, long-span bridges, containment structures etc.
2. To get a thorough knowledge in the sequence of concreting techniques under different conditions.
3. To understand High Performance Concrete (HPC), fresh and hardened properties of HPC, mix design of HPC, properties of Ultra HPC, Special HPC.
4. To be familiar in reactive powder concrete, bio-concrete and geo-polymer concrete.
5. To understand the concept of Self Compacting Concrete (SCC), mix design of SCC and properties of SCC, durability and serviceability conditions of HPC and SCC.

Course Code	**:**	CE682
Course Title	**:**	Hydraulic Structures
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand preliminary investigations for hydraulic structures.
2. To understand geological and hydrological investigations for hydraulic structures.
3. To get exposed to analysis and design of dams.
4. To familiarize students with construction of dams and foundation for dams.
5. To learn design of weirs on permeable foundation.

Course Content

Investigation and Planning - Preliminary investigations and preparation of reports, Layout of projects, Geological and hydrological investigations.

Analysis and Design of Dams - Earthen Dam and Gravity Dam.

Analysis and Design of Arch Dam, Infiltration Gallery, Collector wells.

Construction of Dams - Masonry, Concrete and Earthen Dams, Foundation for Dams– Principles of Foundation treatment, grouting methods.

Design of Weirs on Permeable foundation - Creep theory, Potential theory, Flownets, design of weirs - Khosla's theory.

Reference Books

1. *Creager, W. P. Justin D, and Hinds, J., Engineering for Dams Vol. I, II and III.*
2. *Kushalani, K. B., Irrigation (Practice and Design) Vol. III and IV.*
3. *P. Novak , A. I. B. Moffat , C. Nalluri , R. Narayanan , Hydraulic Structures, CRC Press, 4th Edition, 2007.*
4. *Ken Weaver and Donald Bruce, Dam Foundation Grouting, American Society of Civil Engineers, Rev Exp Edition, 2007.*
5. *Santhosh Kumar Garg, Irrigation Engineering and Hydraulic Structures, Khanna Publishers, 1997.*

Course outcomes

At the end of the course student will be able

1. To carry out investigation and planning of hydraulic structures.
2. To analyse and design different types of dams.
3. To understand construction of different types of dams.
4. To be familiar with foundation treatment for dams.
5. To design weirs on permeable foundation.

Course Code	**:**	CE683
Course Title	**:**	Design of Bridges
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To learn the components of bridges, classification of bridges, importance of bridges.
2. To understand the investigation for bridges, subsoil exploration, choice of bridge type.
3. To study the specification of road bridges, loads to be considered.
4. To familiarize students with various types of bridges such as slab-bridge, Tbeam bridge, pre-stressed concrete bridge, continuous bridge, arch bridge, box girder bridge decks.
5. To get exposure to evaluation of sub structures, type of foundations, importance of bearings, lessons from bridge failures.

Course Content

Components of Bridges – Classification – Importance of Bridges – Investigation for Bridges – Selection of Bridge site – Economical span – Location of piers and abutments – Subsoil exploration – Scour depth – Traffic projection – Choice of bridge type.

Specification of road bridges – width of carriageway – loads to be considered - dead load – IRC standard live load – Impact effect.

General design considerations –- Slab Bridge – Design of T-beam bridge – Prestressed concrete bridge – continuous bridge – Arch Bridge – Box girder bridge decks.

Evaluation of sub structures – Pier and abutments caps – Design of pier – Abutments – Type of foundations.

Importance of Bearings – Bearings for slab bridges – Bearings for girder bridges – Electrometric bearing – Joints – Expansion joints. Construction and Maintenance of bridges – Lessons from bridge failures.

Reference Books

1. *Ponnuswamy, S., Bridge Engineering, Tata McGraw – Hill, New Delhi, 1997.*
2. *Victor, D. J., Essentials of Bridge Engineering, Oxford and IBH Publishers Co., New Delhi, 1980.*
3. *N. Rajagopalan, Bridge Superstructure, Narosa Publishing House, New Delhi, 2006.*
4. *Jagadeesh. T. R. and Jayaram. M. A., Design of Bridge Structures, Prentice Hall of India Pvt. Ltd., 2004.*

5. *Raina. V. K., Concrete Bridge Practice, Tata McGraw Hill Publishing Company, New Delhi, 1991.*

Course outcomes

At the end of the course student will be able

1. To be familiar with the components of bridges, classification of bridges, importance of bridges.
2. To understand the investigation for bridges, subsoil exploration, choice of bridge type.
3. To understand the specification of road bridges, loads to be considered.
4. To be familiar with various types of bridges such as slab-bridge, T-beam bridge, pre-stressed concrete bridge, continuous bridge, arch bridge, box girder bridge decks.
5. To get exposed to evaluation of sub structures, type of foundations, importance of bearings, lessons from bridge failures.

Course Code	:	CE684
Course Title	:	Health, Safety and Environmental Management (HSE) Practices
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To understand safety, health and environmental management.
2. To be familiar with hazard classification and assessment, hazard evaluation and hazard control, environmental issues and management.
3. To get exposed to accidents modeling, accident investigation and reporting, concepts of HAZOP and PHA.
4. To be familiar with safety measures in design and process operations.
5. To get exposed to risk assessment and management, principles and methods.

Course Content

Introduction to safety, health and environmental management - Basic terms and their definitions - Importance of safety - safety assurance and assessment - safety in design and operation - organizing for safety.

Hazard classification and assessment - hazard evaluation and hazard control.

Environmental issues and Management - atmospheric pollution - flaring and fugitive release - water pollution - Environmental monitoring - environmental management.

Accidents modeling - release modeling - fire and explosion modeling - toxic release and dispersion modeling - accident investigation and reporting - concepts of HAZOP and PHA.

Safety measures in design and process operations - inerting, explosion, fire prevention, sprinkler systems.

Risk assessment and management - Risk picture - definition and characteristics - risk acceptance criteria - quantified risk assessment - hazard assessment - fatality risk assessment - risk management principles and methods.

Reference Books

1. *Skelton. B, Process Safety Analysis, Gulf Publishing Company, Houston, 210pp., 1997.*
2. *Terje Aven and Jan Erik Vinnem, Risk Management with Applications from Offshore Petroleum Industry, Springer, 200pp., 2007.*

3. *Jorg Schneider, Introduction to Safety and Reliability of Structures, Structural Engineering Documents Vol. 5, International Association for Bridge and Structural Engineering (IABSE), 138pp., 1997.*
4. *Roger L. Brauer, Safety and Health for Engineers, John Wiley and Sons Inc. pp. 645-663, 2006.*
5. *Srinivasan Chandrasekaran, Health, Safety and Environmental Management in Offshore and Petroleum Engineering, John Wiley and Sons, 2016.*

Course outcomes

At the end of the course student will be able

1. To understand safety, health and environmental management.
2. To be familiar with hazard classification and assessment, hazard evaluation and hazard control, environmental issues and management.
3. To get exposed to accidents modelling, accident investigation and reporting, concepts of HAZOP and PHA.
4. To be familiar with safety measures in design and process operations.
5. To get exposed to risk assessment and management, principles and methods.

Course Code	:	CE685
Course Title	:	Design of Offshore Structures
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To understand the demand for coastal and offshore structures, overview of different types of ocean structures.
2. To get exposed to structural geometry, analysis methods, design techniques, construction practice, different types of material, guidelines associated with selection of materials for marine environment.
3. To learn various types of structural systems/forms, brief overview of various environmental loads.
4. To be familiar with the problems associated with the material behavior in marine environment and various protection methods.
5. To understand the inspection and testing methods, repair and rehabilitation processes.

Course content

Wave generation process, small, finite amplitude and nonlinear wave theories.

Wind forces, wave forces on small bodies and large bodies - current forces - Morison equation.

Different types of offshore structures, foundation modelling, fixed jacket platform structural modelling.

Static method of analysis, foundation analysis and dynamics of offshore structures.

Design of platforms, helipads, Jacket tower, analysis and design of mooring cables and pipelines.

Reference Books

1. *API RP 2A-WSD, Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design - API Publishing Services, 2005*
2. *James F. Wilson, Dynamics of Offshore Structures, John Wiley and Sons, Inc, 2003.*
3. *Reddy, D. V. and Arockiasamy, M., Offshore Structures, Vol. 1 and Vol. 2, Krieger Publishing Company, 1991.*
4. *Turgut Sarpkaya, Wave Forces on Offshore Structures, Cambridge University Press, 2010.*
5. *Reddy. D. V and Swamidas A. S. J., Essential of Offshore Structures, CRC Press, 2013.*

Course outcomes

At the end of the course student will be able

1. To understand different types of ocean structures, different structural systems of ocean structures and types of environmental loads.
2. To be familiar with structural action of ocean structures, planning guidelines and design principles and regulations and codes of practice.
3. To understand the concepts of foundation of ocean structures, sea bed anchors, dredging methods and equipment.
4. To get exposed to materials for marine applications, deterioration of materials, inspection and testing of marine structures.
5. To be familiar with non-destructive techniques, repair and rehabilitation of marine structures and structural health monitoring of marine structures.

Course Code	**:**	CE686
Course Title	**:**	Non-Linear Analysis
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To provide an understanding of the nonlinear behaviour of structures
2. To study the methods for analysing nonlinear response of framed structures
3. To study the Basic equations for continuum; Beams, plates and shells
4. To study the Analytical and discrete numerical solution techniques
5. To learn the Applications of finite element method

Course content

Geometrical and material non-linear problems; Basic equations for continuum; Beams, plates and shells, Analytical and discrete numerical solution techniques; Applications of finite element method.

Reference Books

1. *Steel Structures: Design and Behavior, fourth edition, Salmon, C.G., and Johnson, J.E., Harper Collins College Publishers, New York, 1996.*
2. *Steel Framed Structures: Stability and Strength, edited by R. Narayanan, Elsevier Applied Science Publishers, New York, 1985.*
3. *Elastic Instability Phenomena, Thompson, J.M.T., and Hunt, G.W., John Wiley and Sons, New York, 1984.*
4. *Beams and Beam-Columns: Stability and Strength, edited by R. Narayanan, Elsevier Applied Science Publishers, New York, 1983.*
5. *Nonlinear Structures, Majid, K.I., John Wiley and Sons, Inc., New York, 1972.*
6. *Theory of Elastic Stability, Timoshenko, S.P., and Gere, J.M., 2nd ed., McGraw-Hill Book Co., Inc., New York, 1961.*

Course outcomes

At the end of the course, student will be able to

1. Analyse the Frames including the Material nonlinearity
2. Analyse the Frames including the Geometry nonlinearity
3. Analyse frames using the elastic-plastic approach
4. Analyse frames using numerical solution techniques
5. Apply the Finite element method to solve nonlinear problems

Course Code	**:**	CE815
Course Title	**:**	Ground Improvement Techniques
Number of Credits	**:**	3
Course Type	**:**	Elective

Course Learning Objectives

1. To understand the engineering properties of soil and problems associated with weak deposit.
2. To understand the need for ground improvements.
3. To study the concept of soil stabilization.
4. To familiarize students in recent ground improvement techniques.
5. To get exposure to soil reinforcement techniques and geo-synthetics.

Course Content

Introduction - Engineering properties of soft–weak and compressible deposits – problems associated with weak deposit – Requirements of ground improvements – introduction to engineering ground modification, need and objectives.

Soil Stabilization - Science of soil stabilization – Mechanical modification – Hydraulic modification – Dewatering systems – Chemical modification – Modification by admixtures like lime, Cement, Bitumen etc – Grouting – Deep jet mixing methods.

Recent Ground improvement techniques - stabilization using industrial waste – modification by inclusion and confinement – soil nailing – stone column – compaction piles – dynamic compaction – prefabricated vertical drains – preloading – electroosmosis – soil freezing vacuum consolidation – deep explosion – dry powdered polymers – enzymes.

Soil reinforcement - Historical background, RCC – Vidalean concept of reinforced earth – Mechanisms – Types of reinforcements – Soil–Reinforcement – Interaction studies – Internal and External stability criteria – Design Principles of steep reinforced soil slopes – pavements – Embankments on soft soils.

Geo-Synthetics - Geo-synthetic clay liner – Construction details – Geo Synthetic Materials – Functions – Property characterization – Testing Methods for GeoSynthetics – Recent research and Developments. Control of Improvement – Field Instrumentation – design and analysis for bearing capacity and settlement of improved deposits.

Reference Books

1. *Hausmann, M. R., Engineering Principles of Ground Modification, McGraw – Hill International Editions, 1990.*
2. *Purushotham Raj, Ground Improvement Techniques, Laxmi Publications, New Delhi.*
3. *Sharma. S. K., Principles, Practice and Design of Highway Engineering, S. Chand and Co. New Delhi, 1985.*
4. *Jones C. J. F. P, Earth Reinforcement and Soil Structures, Butterworths, London.*
5. *Moseley M. P., Ground Improvement, Blockie Academic and Professional, Chapman and Hall, Glassgow, 1993.*

Course outcomes

At the end of the course student will be able

1. To understand the engineering properties of soil and problems associated with weak deposit.
2. To understand the need for ground improvements.
3. To be familiar with the concept of soil stabilization.
4. To be familiar in recent ground improvement techniques.
5. To be exposed to soil reinforcement techniques and geo-synthetics.

Course Code	:	CE816
Course Title	:	Analysis of Deep Foundation
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To gain familiarity with different types of foundation, deep foundation and its importance, design of deep foundations.
2. To explain how pile classification is done based on its functions and how to estimate pile capacity based on static and dynamic approach as per codes.
3. To explain how to select soil design parameters for pile capacity analysis and role of geotechnical investigation in the pile capacity analysis.
4. To explain pile group failures under varies conditions and the importance of group action in pile group capacity.
5. To explain how lateral pile capacity analysis is done under various pile failure mode.

Course Content

Functions and requisites of a foundation - Different types - Choice of foundation type – Types of deep foundation – Types of pile foundations - Factor governing choice of type of pile – Choice of pile materials.

Load carrying capacity of piles by static formulae - Introduction: IS code method - API method - Piles in cohesive and cohesionless soils – Piles in layered cohesive and cohesionless soils – Settlement of single pile – Piles bearing on rock – Piles in fill and Negative skin friction.

Load carrying capacity of piles by dynamic formulae: Introduction - Pile driving formulae - selection of pile hammers - Determination of temporary elastic compression - Driving stresses in piles - Field measurement - Wave equation analysis.

Group action in piled foundations: Introduction - Minimum spacing of piles - group efficiency - Estimation of group bearing capacity - Effect of pile arrangement - Effect on pile groups of installation methods - precaution against heave effect in pile groupSettlement of pile group - Reduce differential settlement in pile group.

Pile subjected to lateral load: Introduction - Lateral resistance of single pile - IS 2911 method for lateral resistance of pile - Broms charts for lateral load analysis - Elastic analysis - p-y curves, use of p-y curves - improving lateral resistance of piles - field test on piles.

Reference Books

1. *J. E. Bowles, "Foundation Analysis and Design", McGraw Hill, 1996.*
2. *M. J. Tomlinson, "Pile Design and Construction Practice", E & FN Spon, 1987.*
3. *Braja M. Das., "Principles of Foundation Engineering", Thomson Asia Pvt Ltd, 1987.*
4. *P. C. Varghese, "Foundation Engineering", Prentice-Hall of India, New Delhi, 2005.*
5. *Swamy Saran, Analysis and Design of Substructures, Oxford and IBH Publishing Co. Pvt. Ltd., 2006.*

Course outcomes

At the end of the course student will be able

1. To select appropriate foundation type based on available soil conditions.
2. To determine the load carrying capacity of pile foundation.
3. To gain thorough knowledge about the design of pile foundations.
4. To understand the importance of deep foundation in civil engineering construction field and they could able to select appropriate pile system based on the site conditions.
5. To do pile capacity (static, dynamic, lateral and group capacity) analysis as per code and they will understand the complete physics of pile and pile group failure mode under various circumstances.

Course Code	:	HM712
Course Title	:	Human Resource Management
Number of Credits	:	3
Course Type	:	Elective

Course Learning Objectives

1. To introduce human resource management and its importance.
2. To understand human relations concepts and human resources accounting.
3. To understand the efficiency and effectiveness of the human resources in an industrial organization.
4. To get exposure to job design and performance appraisal methods.
5. To familiarize students in human resource planning and industrial relations.

Course Content

Human Resource Management – Definition – Features – Importance – Objective of Human Resource Management – Concepts – Commodity, Production, Goodwill, Humanitarian, Human Relations Concepts – Approaches to the Study of Human Resource Management – Systems, Situational, Role, Process approaches – Human Resources Accounting – Case Studies.

Job Design – Approach to Job Design – Engineering, Human, The Job characteristics, Approaches – Job Design Process – Job Design Methods; Job Rotation, Job Enlargement – Job Enrichment – Job Evaluation – Methods of Job Evaluation – Performance Appraisal Methods – Case Studies.

Human Resource Planning – Benefits – Problems – Retention Plan – Organizing Human Resource Planning – Recruitment Policy – Sources of Recruitment – Selection – Meaning – Definition – Need for Scientific Selection Systems – Selection Process – Types of Psychological Tests – Placement – Introduction – Employee Training – objectives, Training Process – Methods of Training – Case studies.

Contemporary Problems of HRM – Quality of Work Life – Specific Issues in Quality Work Life (QWL) – QWL and Productivity – Barriers to Quality of Work Life – Strategies for Improvement in QWL – Quality Circles – Definition – Objectives – Processes – Techniques – Organization Structure – Worker's participation in Management – Methods of Worker's participation in Management – Morale and Productivity – Case Studies.

Industrial Relations – Concepts, Structures and Functions – Trade Unions – Unionization – Law and Environment – Collective Bargaining – Concept – Process – Trends and Conclusions – Employee Grievances – Approaches – Procedures – Industrial Conflict – Nature of Conflict – Statutory, Non-Statutory and other Statutory Measures – Case Studies.

Reference Books

1. *Rao V. S. P, Rao Subbha P, Personnel/Human Resource Management Texts, Cases and Games - Konark Publishers Pvt. Ltd, 2008.*
2. *Decenzo A. David, Robbins P. Stephen, Personnel/Human Resource Management – PHI - 2012.*
3. *Monappa Arun, Nambudiri Ranjeet, Patturaja Selvaraj, Industrial Relations and Labour Laws, TMH - 2012.*
4. *Srivastava S. C., Industrial Relations and Labour Laws, Vikash Publishing House Pvt. Ltd. - 2012.*
5. *Pareek Udai, Rao T. V., Designing and Managing Human Resource Systems, Oxford and IBH - 2005.*

Course outcomes

At the end of the course student will be able

1. To understand human resource management and its importance.
2. To understand human relations concepts and human resources accounting.
3. To understand the efficiency and effectiveness of the human resources in an industrial organization.
4. To get exposure to job design and performance appraisal methods.
5. To be familiar in human resource planning and industrial relations.